hoped that the terms of reference to the Committee, when established, will be sufficiently wide and elastic, so as to permit an exhaustive enquiry being undertaken. Those who have actually done research on fish and fisheries in India are few, and we have no doubt that the wealth of knowledge and experience accumulated by individual scientists will be found invaluable in conducting the enquiry by the Committee. We confidently hope that sufficient room will be found for experts on this proposed Committee whose proceedings will be followed with earnestness by the public, whose interest in the development of the food resources of the country is manifestly increasing.

Some Recent Advances in Indian Geology.*

By W. D. West,
Geological Survey of India.

3. The Geology of the Himalaya.

DURING the past ten years or so considerable progress has been made in our knowledge of the geology of the Himalaya, *which has only served to show how complicated is the geology of this great range and how great is our ignorance of its real structure.* During this period work by the Geological Survey of India has mainly been concentrated in two areas, the North-West Himalaya in Hazara and Kashmir, and the Simla hills around Simla and Chakrata; while in addition there have been several foreign expeditions to the Karakoram and neighbouring tracts beyond the Himalaya which have added something to our knowledge of the geology of those parts. Thus in spite of large blanks still existing on the geological map of the Himalaya, largely accounted for by the inaccessibility of Nepal, the accumulating results of steady mapping are gradually providing a sure foundation on which may ultimately be built a complete synthesis of Himalayan geology. Theories of mountain structure based on our present incomplete knowledge of even one section of the Himalaya must necessarily be largely speculative. They arrive almost by every mail, and are frequently advanced by those whose acquaintance with Himalayan geology is by no means extensive. Perhaps of no part of Indian geology can one more truly say that the more one knows of it the more one realises how little one knows. The present policy of the Geological Survey is to concentrate its small available resources on two sections of the Himalaya, as stated above, in the belief that a sustained attack on these two selected areas will yield more valuable knowledge of the geological structure of the Himalaya as a whole than a larger number of smaller investigations spread over a wider area. The summary that follows, therefore, deals mostly with these two areas. In compiling it the writer is indebted to his colleague Mr. J. B. Auden for many fruitful discussions on the problems raised therein.

THE NORTH-WEST HIMALAYA.

The most striking feature in the orogeny of the North-West Himalaya is the way the strike of the mountains, after following an arcuate S.E.—N.W. direction for over 1,200 miles from Assam to Kashmir, makes a great bend in Hazara, rapidly curving round through an E.—W. to a N.—S. direction, and producing thereby a great re-entrant angle in the alignment of the mountains between Abbottabad on the South-West and the Kashmir valley on the North-East. This bend is seen not only in the frontal ranges bordering the Indo-Gangetic alluvium, but is repeated in each successive range northwards, culminating in the Pamir massif. Even this great mass shows the same trend lines, which are south-west on the west, equatorial through the Pamirs, and south-east on the east side, as first determined by D. L. Ivanow and subsequently confirmed by Sir Henry Hayden.[1] As regards the origin of this feature, it had previously been supposed by E. Suess in his great work 'Das Antlitz der Erde' that the rapid change in the strike of the mountains was due to the meeting at an oblique angle of two mountain systems, the Himalaya and the Hindu Kush.[2] For this line of meeting

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* Published with the permission of the Director, Geological Survey of India.

[1] *Rec. Geol. Surv. Ind.*, 1916, **45**, 271.

[2] *The Face of the Earth*, 1904, **1**, 422.

Suess used the term 'schaarung', which was translated by Sollas as 'syntaxis'. The following quotation from the English edition gives his conclusions:

"Like two shallow streams of lava, or two flows of slag running side by side, the waves of which as they cool come into syntaxis against a long line, now fusing completely together, now encroaching on one another, so the chains of the Himalaya meet those of the Hindu Kush."

He especially emphasised, however, the essential unity of the movements, and the unity of structure of the whole. Quite recently D. N. Wadia's work in the more southern portion of this syntaxial area has shown that both from a structural as well as from a stratigraphical point of view there is a complete continuity of Himalayan geology around this re-entrant, at any rate on its southern border, the structure and stratigraphy on the Hazara side of the syntaxis being the mirror image of the structure and stratigraphy on the Kashmir side, as originally pointed out by Middlemiss.[3] Instead, therefore, of two directions of mountain movement having converged upon Hazara, the Hindu Kush from the north-west and the Himalaya from the north-east, as envisaged by Suess, Wadia concludes that there has been a single Himalayan movement from the north which has come up against some underground obstacle around which it has been forced to diverge. It is suggested by him that a tongue of the ancient and stable peninsular rocks extends upto the north-west beneath a covering of Kainozoic rocks, and that this has formed the obstacle to the folding movement coming from the north, so that the original north and south direction of movement has been resolved into a N.E.—S.W. direction in Kashmir, and a N.W.—S.E. direction in Hazara. There still, however, remains the difficulty of explaining how the W.S.W. to E.N.E. direction of overthrust which is found on the south-west side of the syntaxis, in the neighbourhood of Garhi Habibulla, can have originated in a movement coming from the north. This latter problem was discussed briefly by J. W. Gregory, who suggested that the older supposed 'Altaid' mass of the Safed Koh in the country west of Peshawar may have been responsible for this backward movement.[4] Recently D. Muschketoff has suggested that this 'Jhelum wedge', as he calls the underground obstacle, has been a tectonic feature of importance since Caledonian times, and has been responsible for a number of abnormalities such as the N.N.W.—S.S.E. direction of the Ferghana range, which although of Kainozoic age runs at right angles to the main Himalayan trend lines on either side.[5] A complete understanding of the origin of this great orogenic feature will probably have to await further information concerning the structure of the Hindu Kush, the Karakoram, the Pamirs, and the country north of the Pamirs.

In that part of the syntaxial area investigated by Wadia, three structural elements are defined: (1) a 'foreland' consisting of a great thickness of moderately folded Murree (Miocene) rocks, overlying the supposed tongue of Peninsular India; (2) a belt of autochthonous rocks thrust (the Murree thrust) against the foreland of Murrees, comprising rocks ranging in age from Carboniferous to Eocene, but consisting essentially of a recumbent fold of Eocene rocks, with a core of Panjal trap; and (3) a 'nappe' zone of central Himalayan rocks, which has travelled far along a nearly horizontal thrust plane (the Panjal thrust), so as to lie with marked discordance sometimes upon the rocks of the autochthonous zone and sometimes directly on the rocks of the foreland. This Kashmir 'nappe', as Wadia calls it, is composed, in the syntaxial area, mostly of Dogra (=Attock) slates and the Salkhala series (=Jutogh series of the Simla hills). The former are thought to be lowest Cambrian or older, and the latter Archæan (see table below), the whole 'nappe' being the oldest part of the Himalayan geosyncline which has been overfolded and travelled along a thrust plane many miles from its original place of deposition. To the east of the syntaxial area, and lying upon the top of the 'nappe' in the form of a synclinal basin, and forming the Shamsh Abari mountains, there occurs a thick sequence of Palæozoic rocks, including Lower Palæozoic, Devonian (Muth quartzite), Panjal volcanic rocks and Trias. The well-known Kashmir basin of sedimentary rocks occupies a very similar position further east. In his most recent paper Wadia has described the sequence in this north-west part of Kashmir

[3] *Rec. Geol. Surv. Ind.*, 1931, **65**, 189 and *op. cit.*, 1911, **41**, 136–7.

[4] *The Structure of Asia*, 1929, 12.

[5] *Sixteenth Internat. Geol. Congr. Wash.*, Abstract of Papers, 1933.

State.[6] It differs from the sequence worked out by Middlemiss in south-east Kashmir in two ways: (1) it shows a full development of the Cambrian with a good trilobite fauna; (2) it includes an extensive mid-Palæozoic unconformity, there being a gap between the top of the Silurian and the middle of the Carboniferous, which is not found in the rest of Kashmir or in Spiti. This new work is also of interest in showing a passage from the unfossiliferous slate series up into beds bearing annelids and other organic remains, and of these up into beds containing trilobites and brachiopods of Middle Cambrian affinities. According to F. R. C. Reed, "nearly all the species are new, while there is little resemblance to the faunas of corresponding age in the Central Himalaya or northern China. . . . The Cambrian of the Salt range has quite a different assemblage of fossils." It seems likely, therefore, that the Dogra Slates, which underlie these beds, are lower Cambrian or Purana in age. But until fossils have been found in actual Attock, Dogra, or Simla Slates, the age of these rocks must remain in doubt.

Before leaving this area mention must be made of the finding by Wadia of scratched boulders in the Tanakki conglomerate near Abbottabad, where it underlies the Infra-Trias limestone.[7] This find, together with his further observation that the Infra-Trias limestone is interbedded with the Agglomeratic Slate in North Hazara, adds further strength to the contention, first made by R. D. Oldham, that this conglomerate or boulder bed is homotaxial with the Talchir glacial boulder bed, and therefore Upper Carboniferous in age.[8]

An important paper recently published on the geology of Kashmir deals with the researches of C. S. Middlemiss and H. S. Bion on the Agglomeratic Slate series and the Panjal Trap, work that was in progress at the time of the outbreak of the Great War.[9] The Agglomeratic Slate series occurs lying immediately below the great series of bedded basic lavas known as the Panjal Trap, up into which it appears to pass by interbedding. These two series, over most of the area, keep to an horizon between the Middle Carboniferous and the Permian, that is to say at the junction of the Dravidian and Aryan groups, a datum line of great importance in Indian geology, though these limits do not hold good everywhere. Previously found to be destitute of organic remains, the Agglomeratic Slate has been found by these two investigators to be fossiliferous in a few places. To quote from their memoir:

> "This temporarily overlooked fauna is of much intrinsic interest, some of it being new to Himalayan geology and helping to bridge the gap between the middle part of the Carboniferous (as represented by the Fenestella shales) and the Permian which immediately overlies the Panjal volcanics at most points—a gap that had been assumed previously to have been wholly given over to vulcanicity in this region."

As regards the mode of origin of this series, Middlemiss suggested that either it was the product of explosive volcanic action, preparatory to the outpouring of the Panjal Traps, or it was due to ice action, the beds thus being homotaxial with the Talchir beds of peninsular India. He was inclined to favour the first hypothesis. Another peculiar point which puzzled Middlemiss and Bion is clearly brought out by them in this paper, namely, that the Agglomeratic Slate and the Panjal Trap together exhibit in certain areas a very inconstant horizon. Thus the lowest horizon at which the Agglomeratic Slate appears in different sections is very variable, ranging from Middle Carboniferous (Moscovian) to the top of the Uralian. The top of the Panjal Trap shows an even greater variability, ranging from just below the Gangomopteris beds up to the base of the Upper Trias. Thus the total length of time during which vulcanicity occurred in one place or another was from the Middle Carboniferous to the close of the Middle Trias, an immense period of time, queerly contrasted with certain areas where it was restricted to the limits of the Permian only. Further peculiarities noted by these workers included two thick lenticular bands of Triassic limestone interbedded with the Panjal Trap, one of which was surrounded on all sides by trap. The total of these observations led Middlemiss to consider whether the Panjal Traps were not lava flows but intrusive sills, and therefore later in age than the base of the Upper Trias. He even suggests the possibility of their being contemporaneous with the great outpouring of similar basic lavas in peninsular India known as the Deccan Trap, which commenced at the close of the Mesozoic. More recent work by D. N. Wadia on the Pir Panjal range, which borders Kashmir on the

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6 *Rec. Geol. Surv. Ind.*, 1929, **62**, 121.
7 *Op. cit.*, 1929, **62**, 153.
8 *Op. cit.*, 1930, **63**, 130.
9 *Pal. Ind.*, N.S., 1928, **12**.

south, has shown that the Agglomeratic Slate series is undeniably volcanic in origin, as is clear from the presence of unaltered as well as devitrified glass in one or two specimens, in which are embedded phenocrysts of orthoclase, plagioclase and quartz.[10] That the greater part of the Panjal Trap consists of sub-ærial lava flows is also concluded by Wadia; and the problems indicated by Middlemiss and Bion, referred to above, do not appear to affect the main conclusions, and may be of only local significance, though they still require solution. As regards its composition, the Panjal Trap is shown by Wadia to consist of abundant flows of basalt, which are generally epidotised to give the familiar bright green colour of these rocks. In places their total thickness is over 5,000 feet. Recently it has been pointed out by K. K. Mathur and S. N. Wakhaloo that volcanic rocks of a more acid type, approaching to rhyolites, are also to be found in this series, being abundant in the vicinity of Srinagar.[11]

While referring to this part of the Himalaya it is convenient to record here that Lydekker's view that the axis of the Pir Panjal is composed of granite has been shown by Middlemiss and Wadia to be incorrect.[12] The greater part of the summit zone is composed either of Panjal Trap or the Agglomeratic Slate series, with small outcrops of Gondwanas.

The Great Himalaya range is generally regarded by geographers, and rightly so, as ending at the Indus, where the great mass of Nanga Parbat dominates everything. Further north-west, beyond the Indus, there are no great heights to suggest its continuation in that direction. Geologically speaking, however, it is continued round the hairpin bend of the Punjab re-entrant into North-East Hazara, as shown by Wadia, and it is probably correct to regard it as terminating, in a geological sense, near Garhi Habibulla, north-east of Abbottabad, where the last of the Salkhala series, belonging to the Central Himalayan zone, are seen. The geology of Nanga Parbat and the adjoining country has recently been described by D. N. Wadia, who shows it to consist of four main elements.[13] These are: (1) para-gneisses, greatly intruded by gneissose granite ('central gneiss' type); (2) the Pre-Cambrian Salkhala series; (3) a mixed zone situated between (1) and (2), consisting of Salkhala series penetrated by gneiss; and (4) great masses of intrusive dolerite and epidiorite. Nanga Parbat itself consists of (1). Wadia was naturally unable to examine the rocks of the main peak itself. But from the evidence of boulders in moraines he thought *it was probably composed of gneissose* granite. But Dr. P. Misch, who accompanied this year's expedition to Nanga Parbat, states that the mountain is composed entirely of group (1) as given above. The dolerites and epidiorites are regarded by Wadia as genetically connected with the Panjal Trap lava flows, of which they are the hypabyssal phase. In addition to the gneissose granite or 'central gneiss' of Stoliczka, there is a younger hornblende-granite which is post-Panjal Trap in age.

ASSOCIATED RANGES TO THE NORTH.

Coming now to that region of the Himalaya and beyond which has of late been investigated by a number of foreign expeditions, the facts at our disposal are very much fewer, and it is difficult to be certain of the age and mutual relations of some of these ranges. This, added to the fact that geographers and geologists seem to take a different view of what is meant by a range, makes the correct interpretation of a number of isolated observations a matter of some difficulty. Moreover, the country covered by these expeditions does not strictly come within the Himalayan area. Certain points, however, may be referred to, which are of interest to the student of the Himalaya. As has already been pointed out, the Pamirs are to be regarded as the culmination northwards of the great Punjab re-entrant. And since both it and the associated ranges on either side, and the Hindu Kush and the Karakoram further south, conform to the trend lines of this re-entrant, it is natural to expect these mountain ranges to be of Himalayan origin, at least in part. North of the Pamirs the same trend lines are no longer evident. But until a great deal more is known of these mountains, and any older structures which they may show differentiated from their later Himalayan

[10] *Mem. Geol. Surv. Ind.*, 1928, **51**, 238–212.

[11] *Curr. Sci.*, 1933, **2**, 126. Since writing the above Mr. Wadia has informed me that in his opinion these rocks are in the main ordinary Panjal Trap which has been silicified, and not true acid volcanic rocks.

[12] *Rec. Geol. Surv. Ind.*, 1911, **41**, 134; and *Mem. Geol. Surv. Ind.*, 1928, **51**, 223.

[13] *Rec. Geol. Surv. Ind.*, 1932, **66**, 212.

structure, it is best not to be too dogmatic. As regards the relations between the Himalaya and its associated ranges up to the Karakoram on the one hand, and the Kun Lun, the Tian Shan and other ranges to the north on the other hand, it has generally been accepted by geologists, following Suess, that the former group are Kainozoic in age, belonging to Suess's 'Alpides', and the latter of Hercynian age, belonging to his 'Altaids'. E. Argand, however, in his attempted synthesis of Asiatic tectonics, regards the whole as essentially Alpine, any pre-existing 'Altaid' structures having in his view been destroyed in the great Alpine paroxysm.[14] Argand, however, has been proved to be wrong in so many of his conclusions, as for example in Persia, that we may well hesitate before accepting his ideas. According to the more recent field work of E. Trinkler and H. de Terra in the Karakoram and the West Kun Lun, the Karakoram ranges are regarded as Hercynian in age, while their present Himalayan features are attributed to later epeirogenic movements accompanied by extensive faulting.[15] They would therefore group the Karakoram with the Kun Lun in being structurally Palæozoic mountains. In writing of the granite core of the Karakoram, de Terra remarks on the fact that it is underlain everywhere by crystalline rocks, and suggests that the granite has been thrust by mountain making processes over different formations. In this it closely resembles the behaviour of much of the central Himalayan gneissose-granite and its associated crystalline rocks, which appear in so many places to be thrust over the underlying rocks, a problem which is referred to again below. The old controversy as to the course of the Karakoram east of longitude 78° seems to be settling itself as our knowledge of the geography and geology of these areas progresses, and there can now be little doubt that the Karakoram extend E.S.E. and E. right on into the Tibetan plateau.

THE HIMALAYAN ARC.

In all these discussions it is generally assumed that Gondwanaland played a passive rôle, and that it was the southward move of the rest of Asia against Gondwanaland which buckled up the soft marine deposits of the Tethys, and caused them to be thrust over the edge of Gondwanaland, which to some extent broke along its northern border. But it is of course equally conceivable that it was Gondwanaland which moved against Asia, crumpling up the rocks of the Tethys, and underthrusting itself beneath them. The writer has always failed to understand how one can expect to decide whether Asia moved south and over Gondwanaland, or whether Gondwanaland moved north and under Asia, by observing the structure of the country along the line of thrusting, though others appear to think it possible.[16] There is, however, one line of reasoning which seems to throw light on this problem, and that involves a consideration of the position of Asia with respect to the rest of the world before and after the movement. This point of view has been developed by P. Lake, who, in a paper on island arcs and mountain building, has drawn attention to the fact that the well-known arcs off the Pacific coast of Asia, the East Indian arc through Sumatra and Java, the Himalayan arc, and the Iranian arc of Persia, which are all of Kainozoic age, all have their convex side facing away from Asia, the Pacific arcs facing east, and the others facing south or south-west.[17] We are thus required to explain how a single Asiatic mass can have moved along its eastern border towards the Pacific and at the same time along its southern border towards the Indian Ocean. As Lake points out, a movement of the mass as a whole in both directions does not seem possible, but underthrusting of the ocean-floor from both sides is conceivable, and is, in fact, a necessary consequence of the contraction theory or of Joly's theory. This view receives additional support from a consideration of the central Asian mass itself. Had the earth's crust spread outwards radially from central Asia, we should expect to find a deficiency of matter at the centre of the continent, as Burrard has pointed out.[18] But in fact the reverse is the case, and there is an excess of mass protruding above the spheroidal surface which has nothing to equal it elsewhere on the globe. Consequently the alternative hypothesis, that there has been a general pressure acting

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[14] *La Tectonique de L'Asie*, 1924.

[15] *Geologische Forschungen im Westlichen Kun Lun und Karakoram-Himalaya*, 1932.

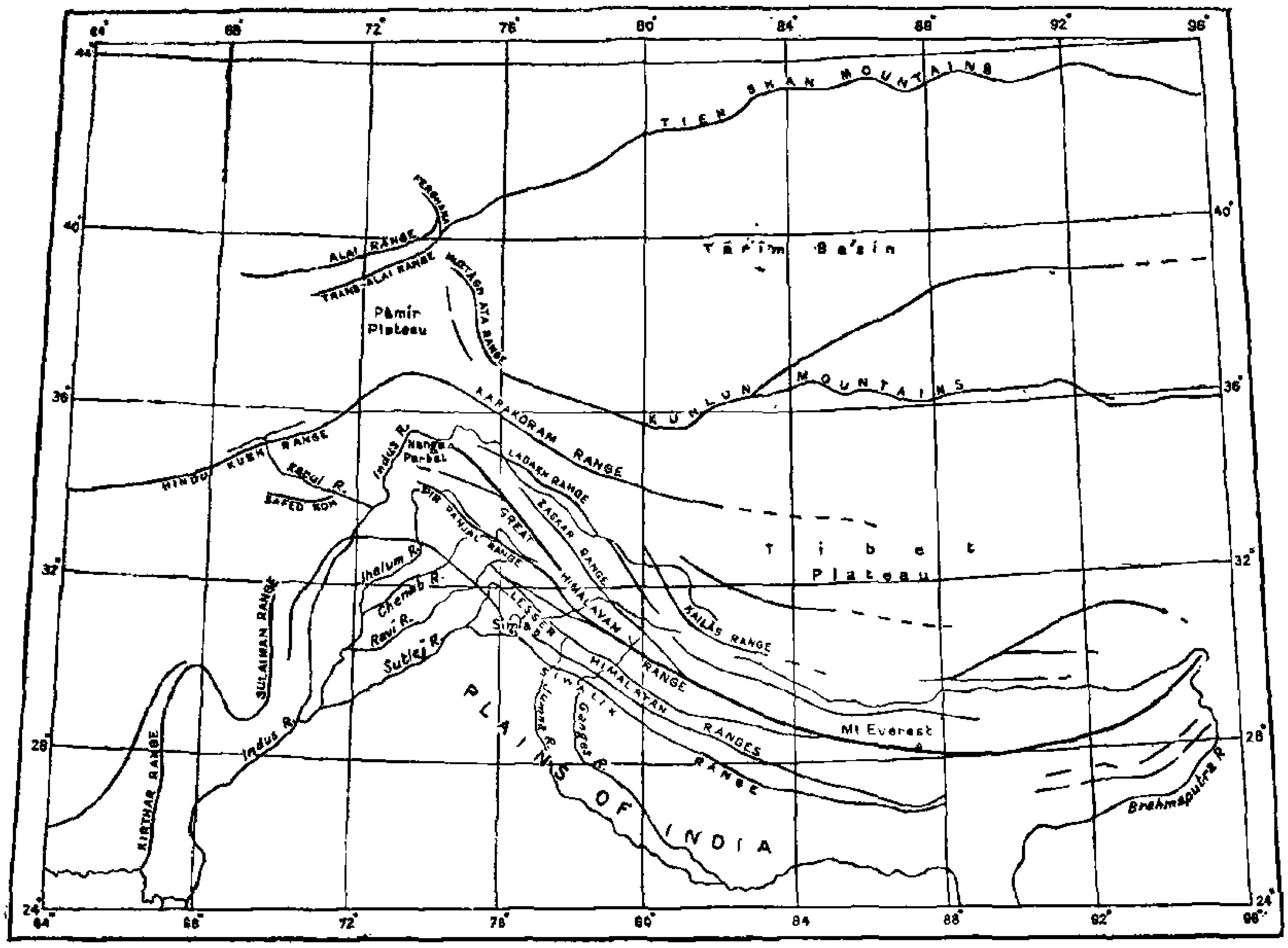
[16] N. E. Odell, *Geogr. Journ.*, 1931, **78**, 159.

[17] *Loc. cit.*, 140.

[18] *A Sketch of the Geography and Geology of the Himalaya Mountains and Tibet*, 2nd Edn., 1934, 77.

towards central Asia, seems to be the more acceptable.

The further suggestion developed by Lake in this same paper, that all mountain arcs which have the shape of an arc of a circle, have been formed by movement of a slice of the earth's crust along a single basal thrust plane, and in particular its application to the Himalaya, is one which, in spite of (or because of) its simplicity, is not in accord with the observed facts. Although the Himalayan arc can be shown to be part of a circle, with its pole in Central Asia, it must be remembered that, geologically shown by Wadia in the Punjab re-entrant, there is a continuity of geological structure around this feature which forbids one to bring the Himalaya (geologically considered) to an end at Nanga Parbat, the point at which Lake has to end his Himalayan arc. Moreover, as recently pointed out by Auden, our increasing knowledge of the structure of the Himalaya shows that not only are there a number of thrust planes of paramount importance within the Himalaya, but also that the angle of these thrusts is extremely variable and does not conform to the low angle required by Lake's hypothesis. As he



Trend Lines of the Mountain Ranges of the Himalaya and Tibet.
(Mainly after Burrard).

Fig. 1.

considered, the Himalaya are but a part of a much more extensive mountain system, which continues to the south-west through Baluchistan and Persia, and to the south-east through Burma. And since they have been formed on the site of a long geosyncline by the crushing of its deposits through the movement of Eurasia and Gondwanaland towards one another, the shape of the mountain system so produced must be determined partly by the original disposition of the geosyncline, and partly by the shape of the two impinging masses. Further, as says, it would appear impossible to regard any single dislocation or nappe as having borne the whole burden of the advance upon the foreland.[19]

On the other hand, Burrard, as a geographer, considers that there is no Himalayan arc at all; for in his opinion the Himalaya cannot be considered independently of the mountains further north, including the Kun Lun, the Tien Shan, the Karakoram and the Hindu Kush, ranges

[19] *Rec. Geol. Surv. Ind.*, 1934, **67**, 448.

which either show no curvature at all, or curve northwards.[20] But this view ignores the important geological fact that while the Himalaya and its immediately associated mountain ranges are, at any rate mainly, of Kainozoic age, the Kun Lun, the Tien Shan, and possibly the others also, are much older having been formed most probably at the end of the Palæozoic (Hercynian). It does, however, contain a germ of truth. It is a well-established principle that older structures frequently play an important part in influencing the formation of later structures. And although the great Himalayan arc is no doubt to be regarded as essentially Kainozoic in origin, it is yet a moot point as to the extent to which an older 'grain' may still be preserved within the main Kainozoic superstructure. The point is referred to again below.

To make clear the foregoing remarks, the main trend lines are shown in Fig. 1, which is mainly copied from the frontispiece of Burrard and Heron's *A Sketch of the Geography and Geology of the Himalaya Mountains and Tibet*, with certain additions and simplification.

(To be continued.)

[20] Reference 18, p. 75.

Progress of Algological Studies in India.

By K. Biswas, M.A.,

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THE study of Botany dates as far back as somewhere 2,500 years ago. But apart from its mainly applied side not much attempt was made to investigate the Indian plants from purely scientific aspect. The first impetus to the systematic study of Indian Botany was given by the Governor of Malabar by the publication of the memorable volume entitled *Hortus Malabaricus* during the last decade of the 17th century. But the critical study of Indian plants along the modern lines was systematically taken up by Dr. William Roxburgh, 'the father of Indian Botany', since his appointment as the first Superintendent of the Royal Botanic Garden, Calcutta, the then East India Company's garden, in 1793, although Dr. Roxburgh for many years prior to his transfer to the Royal Botanic Garden had been engaged in studying the then little known flora of the Northern Circars in the Madras Presidency.

Very little attempt was, however, made to investigate the lower plants of this vast country. Bryophyta and algæ were left untouched till very late years, although study of these branches of Botany was started in Europe earlier than 1753—from the time of Linnaeus onwards.

Dr. Alexander Braun and Dr. W. H. Hervey mentioned about Belanger's and Wight's collection of Chara and seaweeds as early as 1826-28. Collection and study of algæ can thus be traced from the period of 1798 onward, when var. *Ceylonica* of *Chara polyphylla* A. Braun, was first detected in Ceylon by Lebeck in 1798 (according to Klein in *Herb. Willd*), and afterwards collected near Tranquebar. Robert Wight, M.D., F.R.S., the distinguished Indian Botanist, and a member of the Honorable Company's Madras establishment, published the Icones Plantarum Indiæ Orientalis. He issued, in collaboration with Dr. Walker Arnott, the first volume of Prodromus Floræ Orientalis, an admirable work which unfortunately was never completed. Iyengar's* reference to Wight's algal work in this volume cannot be traced. As far as could be found from the literature available at my disposal Belanger was the first to admire the treasures of the Indian Sea. In 1836, as Director of the Botanic Gardens in Pondicherry, he collected seaweeds along the coasts of Cape Comorin and its neighbourhood in South India. Jaimes Forbes Royle, Late of the medical staff of the Bengal Army, added a short note on Algæ in his monumental work on the "Illustrations of the Botany and other branches of the Natural History of the Himalayan Mountains and of the Flora of Cashmere," 1839, Vol. I, pp. 441-442. In this note Royle suggests that "the Dictyoteæ

* Iyengar, M. O. P., Presidential Address (Section of Botany), Fifteenth Indian Science Congress, 1929.