if θ has a greater value than $22\frac{1}{2}°$) (Fig. 3).

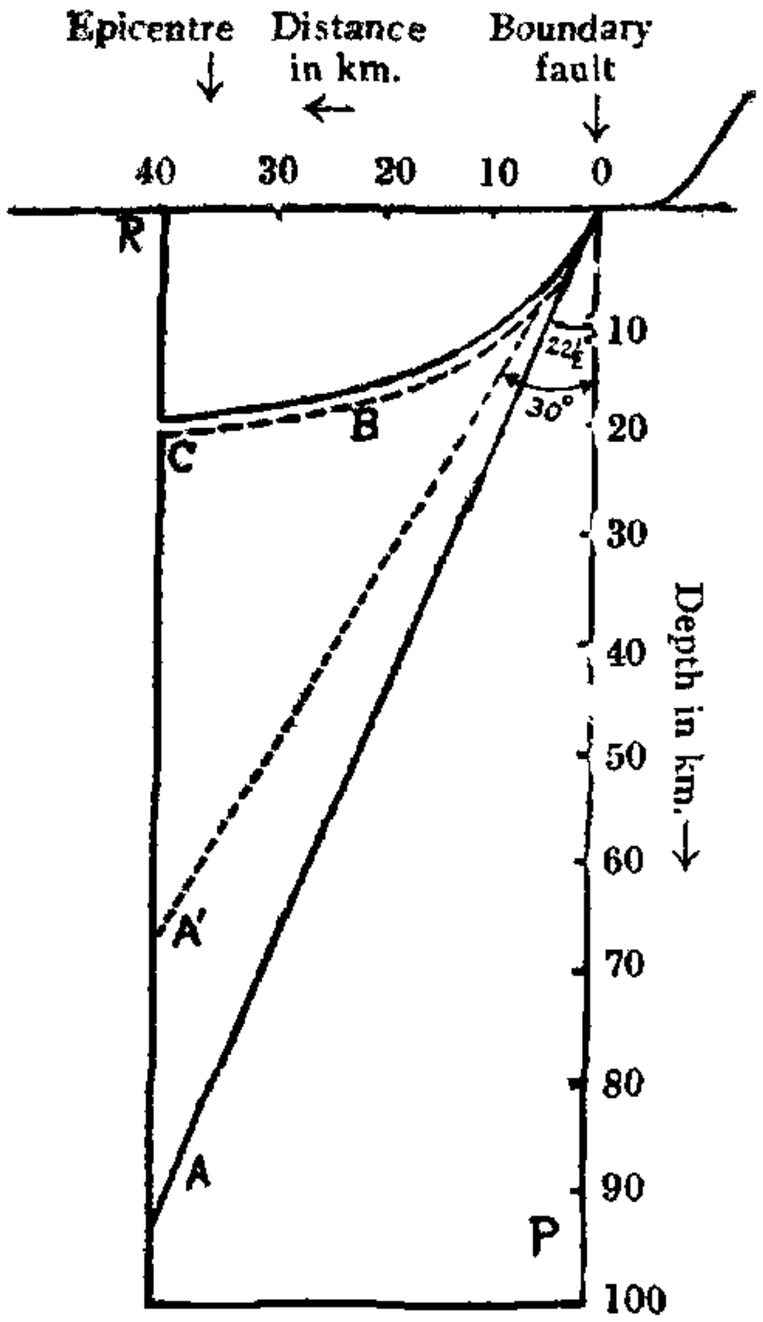


Fig. 3.

Vertical Section through epicentre and nearest point of boundary fault.

For, observations as well as theory of fractures[7] produced by loading always indicate that they lie along a curve such as OBC. The depth of the faults below the observed epicentral tract will therefore be about 20 km., and if an elongated rock of dimensions 150 km. × 100 km. and thickness 10 km. (rectangular, elliptical or other shape) was lying across the fault at this depth and was strained, it could by fracture give the energy required for the production of the earthquake. The two subsidiary epicentral tracts near Khatmandu and Monghyr were probably induced by a major crack of this kind.

The earthquake occurred on a new moon day, and on such a day we get a body tide due to the elastic yielding of the solid material of the earth, such that the height of the oceans, as measured by the rise and fall of the sea, relative to the land is reduced to about $\frac{2}{3}$ of the true equilibrium height (if the rigidity of earth be assumed to be the same as that of steel). On that day also an atmospheric disturbance was passing over Northern India and Darwin has shown that if the difference of barometric pressure between consecutive regions of "high" and "low" pressures be 5 cm. of mercury and if the centres of "high" and "low" be 1,500 miles apart, then as a consequence of the yielding of the ground, it will be 9 cm. higher under the barometric depression than under the elevation. These causes could, therefore, conceivably have served to produce a kind of trigger action.

[7] Banerji, *Bulletin Cal. Math. Soc.*, 1921, **12**, 93.

Some Recent Advances in Indian Geology.*

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

5. The Geology of Salt Range.

THIS comparatively small range of mountains in the northern Punjab has long been regarded as the show locality of Indian geology. Its fairly complete geological record, its abundant fossils and its complicated structure have combined to make it a place of great attraction to geologists. Bound up with the correct interpretation of its structure is the question of the age of the Saline series, concerning which almost every geologist who has visited the Salt Range seems to have propounded a theory. The problem, it will be recollected, lies in the fact that while in the Salt Range the Saline series underlies rocks of Cambrian (or possibly pre-Cambrian) age, in the Kohat district, only 17 miles away, it underlies rocks of Upper Nummulitic (Middle Eocene) age. And since in the latter place it was considered by D. N. Wadia and L. M. Davies to be of lower Eocene age,[1] a view subsequently corroborated by E. R. Gee,[2] its stratigraphical position in the Salt Range was difficult to understand.

There is no need to summarise the early stages of this controversy. Suffice it to say that Sir Edwin Pascoe, as a result of his

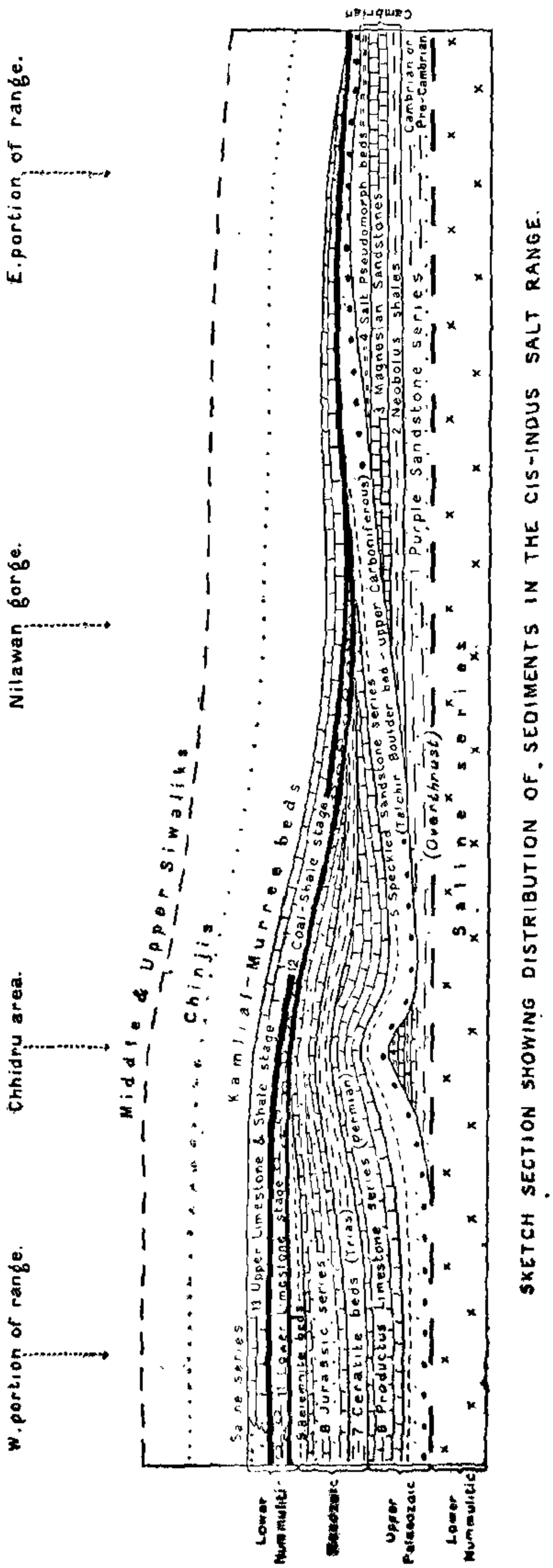
* Published with the permission of the Director, Geological Survey of India.

[1] *Trans. Min. Geol. Inst. Ind.*, 1929, **24**, 202.

[2] *Rec. Geol. Surv. Ind.*, 1931, **65**, 20; and *Curr. Sci.*, 1934, **2**, 461.

studies of the oil-bearing strata of north-western India, suggested a Tertiary age for the salt deposits of both the Salt Range and the Kohat area. This view necessitated the introduction of an overthrust between the Saline series of the Salt Range and the overlying Cambrian beds.[3] The chief objection to this view was that no Salt Marl had been found in the Tertiary rocks of the higher parts of the Salt Range. Subsequently C. S. Fox, as a result of a visit to parts of the range, gave reasons for reverting to the Cambrian age of the salt,[4] a view which also received some support from the fact that salt deposits were found in Persia associated with Cambrian rocks.[5] More recently, G. de P. Cotter, after first accepting a Cambrian age as probable on the balance of evidence,[6] has now supported the view that the Saline series is of Ranikot age, suggesting that its place of original deposition was in the Soan geosyncline to the north of the Salt Range, and that during folding movements associated with the final uplift of the range and of the Kala Chitta hills some of the salt marl was intruded southwards into its present position beneath the Cambrian beds.[7] It has to be admitted, however, that owing to the thick covering of upper Tertiary rocks in the Soan geosyncline of the Potwar, the Saline series is nowhere seen *in situ* in its supposed original position beneath the Laki beds.

In the midst of so much speculation it is refreshing to know that during the past six years a careful re-survey of the Salt Range has been carried out by E. R. Gee whose mapping has been continued westwards across the Indus to link up with the *trans*-Indus ranges and with the Kohat salt region to the north. A summary of the conclusions that have resulted from this survey has, in so far as the Saline series is concerned, already been published in *Current Science*.[8] In this Gee maintains that the Saline series of the Salt Range area is essentially *in situ*, and that the deposit is homotaxial with that of the Kohat salt region and with the Nummulitic limestone and shale deposits of Lower



SKETCH SECTION SHOWING DISTRIBUTION OF SEDIMENTS IN THE CIS-INDUS SALT RANGE.

(The red line represents the Lower Eocene ferruginous pisolite).

By E.R. Gee.

Eocene age which cover wide areas in north-western India.

[3] *Mem. Geol. Surv. Ind.*, 1920, **40**, 358-371.
[4] *Rec. Geol. Surv. Ind.*, 1928, **61**, 147.
[5] *The Structure of Asia*, 1929, 3.
[6] *Proc. Eighteenth Ind. Sci. Congr.*, 1931, 295.
[7] *Mem. Geol. Surv. Ind.*, 1933, **55**, 149-156.
[8] *Curr. Sci.*, 1934, **2**, 460-463.

To make clear the latest views on the stratigraphy of the Salt Range, a diagrammatic section showing the general geological sequence is given, for the construction of which I am much indebted to Mr. Gee. In this simplified section, taken roughly along the length of the range, the lateral variations in the sequence are indicated. Two marked unconformities are shown. One separates the Lower Palæozoic from the Upper. Along this line the Talchir boulder bed (Upper Carboniferous) overlaps successively westwards across the Salt Pseudomorph beds, the Magnesian Sandstone and the Neobolus Shales on to the Purple Sandstone strata, and finally, as a result of overthrusting, comes to rest directly on the Saline series of the western part of the range. This unconformity with overlap has been discussed by R. D. Oldham and C. S. Middlemiss.[9] That the overlap is less regular than was previously supposed has recently been pointed out by Gee, local exposures of the fossiliferous Cambrian beds cropping up around Chhidru in the western half of the range.[10]

The second large unconformity, first recognised by A. B. Wynne, occurs beneath the Eocene nummulitic rocks. It is marked by a thin irregular bed of ferruginous shale, often pisolitic, which evidently represents an old land-surface. In the extreme east this ferruginous pisolite rests on Talchir shales, in the middle portion of the range it overlies the Productus Limestone, while in the western half it lies on various horizons of the Mesozoic rocks. The nummulitic rocks above the unconformity were, until recently, regarded by most observers to be Laki in age. It has now been discovered that at least the lower portion of the sequence is Ranikot in age.[11]

A third unconformity, less marked in the field than those above-mentioned, but none the less important, is represented by the junction of the Murree Kamlial beds with the underlying Nummulitic Limestone.[12] This unconformity was thought by earlier workers to represent the whole of the Oligocene; recent work by Pilgrim, Cotter and Lahiri has enabled its limits to be more clearly defined.[13]

Regarding the exact age and correlation of the various rock groups, much palæontological work still remains to be done. Recent fieldwork by Gee, however, has shown the close relationship in age between the Neobolus Shales, the Magnesian Sandstone and the Salt Pseudomorph beds, all of which are probably Cambrian.[14] As regards the underlying Purple Sandstones, Fox has stated that they are conformably overlain by the Neobolus Shales, and he places both in the Middle Cambrian.[15] Gee has found in places that the Neobolus Shales rest with a thin basal conglomerate on the Purple Sandstones, and he regards the latter as Cambrian or pre-Cambrian. No fossils have so far been found in them.

Coming now to the Upper Palæozoic rocks, plant remains of lower Gondwana type have been found by Gee in shales overlying the Talchir boulder bed,[16] whilst higher in the sequence, in similar carbonaceous shales among the lower half of the Productus Limestone, Cotter had previously discovered Gangamopteris and Glossopteris.[17] The Warcha section of the Productus Limestone has been described by Cowper Reed, Cotter and Lahiri.[18] In the Jurassic beds, which include a thick sequence in the western part of the Salt Range and which are also well represented in the *trans*-Indus ranges, an Upper Gondwana flora has recently been found by Gee.[19]

It will be remembered that the Nummulitic series (of which only the lower half is represented in the Salt Range) includes the Salt Range coal seam in the eastern half of the range, where the seam occurs not far above the ferruginous pisolite. Traced westwards, however, thick nodular foraminiferal limestones come in below the coal, while the latter passes into a carbonaceous shale, as originally described by Wynne. In the western part of the Salt Range, however, near Daud Khel, exposures showing the lateral passage of the upper limestone (above

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[9] *Rec. Geol. Surv. Ind.*, 1886, **19**, 127-131; and *op. cit.*, 1891, **24**, 21-24.

[10] *Op. cit.*, 1234, **68**, 115-120.

[11] Director's Annual Report for 1934 (in the press).

[12] *Mem. Geol. Surv. Ind.*, 1933, **55**, 101-104.

[13] *Rec. Geol. Surv. Ind.*, 1910, **40**, 185; and *op. cit.*, 1933, **43**, 264, and reference 12 above.

[14] *Op. cit.*, 1934, **68**, 115.

[15] *Rec. Geol. Surv. Ind.*, 1928, **61**, 147.

[16] *Op. cit.*, 1933, **67**, 22.

[17] *Op. cit.*, 1930, **62**, 443.

[18] Reference 16, 412-443.

[19] *Op. cit.*, 1929, **62**, 103.

the coal-shale stage) into massive gypsum have recently been discovered by Gee, together with evidence indicating the passage of the underlying coal-shale stage into salt-bearing marl.[20] Both the gypsum and the marl belong to the Saline series. It is concluded, therefore, that the Saline series of the Salt Range (and of Kohat) represent local saliferous facies of Lower Nummulitic (Lower Eocene) sedimentation. This critical section, which appears to have been overlooked by previous observers, apparently provides decisive evidence regarding the age of the Saline series.*

Above the Nummulitic series of the Salt Range the middle and upper Tertiary freshwater strata cover wide areas northwards across the Potwar plateau and the Kohat area, and to the west. These sediments, the vertebrate fauna of which has been studied by G. E. Pilgrim, have recently been studied in detail by R. van V. Anderson and by Cotter and Lahiri.[21]

Regarding the structure of the Salt Range, opposing views have been put forward. Some geologists have interpreted the observed relations of the rocks as being due to overthrusting.[22] C. S. Fox, on the other hand, has endeavoured to explain these structures without the assistance of dynamic forces, attributing them to isostatic movements which have resulted from a relatively plastic salt marl having underlain the higher strata of the Salt Range.[23] Gee, however, appears to be convinced that at least the larger folds, overfolds and thrusts are definitely of tectonic origin.[24] In order to explain the presence of the Saline series beneath the Lower Palæozoic rocks of the range, he postulates an immense regular thrust along which the rocks have moved towards the south in the Salt Range and towards the east in the *trans*-Indus ranges in post-Nummulitic and pre-Siwalik times (*i.e.*, late Eocene and Oligocene), involving a movement of not less than 20 miles. The *nappe* involved in this primary thrust included the Nummulitic and underlying rocks of the Potwar, Kohat and Bannu areas, and continued further afield to link up stratigraphically with the rocks of what are now the Himalaya and Sulaiman ranges. He thinks that a second period of acute tectonic movement commenced in the late Tertiary and continued into sub-Recent times, the forces coming from the same northerly and westerly directions. Owing to the fact that the Salt Range and *trans*-Indus rocks had already, at the time of this second period of earth-movement, approached closely to the Archæan *massif* to the south, of which remnants are now exposed in the Kirana hills, further movement towards the south was impeded, and the forces were spent in causing the acute folding and duplication by overfolding and shearing of the Salt Range strata. During this second period of earth-movement the Saline series was lying beneath the beds of the primary *nappe* and was therefore folded and sheared along with the latter as though it were a portion of a normal stratigraphical sequence. It is in this way that he explains the intimate *relationship of the Saline series and the* Palæozoic rocks of the Salt Range. A fuller account of these conclusions regarding the age of the Saline series has already appeared in *Current Science* for June, 1934.

6. Epilogue.

In bringing to a close this series of short articles outlining the main lines along which recent work in Indian geology has been developing, I may refer very briefly to certain researches which for various reasons I have omitted to discuss. Chief among these is the recent work which has been carried out on the geology of the Gondwana system. This has been done in the main by C. S. Fox and H. Crookshank, who have added considerably to our knowledge of this important period of Indian geology. For a general account of the geology of these rocks the reader is referred to Fox's recent memoir on the Gondwana system,[25] which forms a part of this great work on the coalfields of India; while the Gondwana rocks of part of the Satpura hills in the Central Provinces have been described by Crookshank in a memoir which is now in the press.[26] Perhaps the most interesting

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[20] *Curr. Sci.*, 1934, **2**, 460-461.

* In a paper read by Messrs. P. Evans and M.A. Majeed, of the Burma Oil Co., Ltd., at the recent meeting of the Indian Science Congress, further evidence, based on the examination of heavy mineral residues, was brought forward in support of the Tertiary age of the Saline series of the Salt Range.

[21] *Bull. Geol. Soc. Amer.*, 1928, **38**, 665; and *Mem. Geol. Surv. Ind.*, 1923, **55**, 99.

[22] *Mem. Geol. Surv. Ind.*, 1920, **40**, 358-371.

[23] Reference 15.

[24] Reference 8.

[25] *Mem. Geol. Surv. Ind.*, 1931, **63**.

[26] *Op. cit.*, **66**, Part 2 (in the press).

discovery in Gondwana geology has been the find by K. P. Sinor near Umaria in Central India of a marine fauna in rocks which had hitherto been regarded as wholly continental in origin.[27] These rocks were subsequently mapped by E. R. Gee,[28] and the fossils found in them described by F. R. Cowper Reed.[29] Reference should also be made to Sir Thomas Holland's presidential address to the Geological Society of London in 1933, wherein he discusses comprehensively the evidence bearing on the age of the glacial phase at the beginning of the Gondwana period.[30] Finally a general discussion from the palæontological standpoint of the question of land bridges in Gondwana times has been given by C. Schuchert[31]; while A. L. du Toit, a supporter of the hypothesis of continental drift, has discussed the classification of the sediments of Gondwana times and the question of the boundary between the Carboniferous and the Permian.[32]

I have in these articles made little reference to recent work on the general structure of India, except indirectly in the sections dealing with the Himalaya. Attention, however, may be drawn to two papers which are of importance. The first contains a discussion by Dr. L. L. Fermor on the origin of the Aravalli range.[33] In this it is concluded that there was an original fold-range in pre-Vindhyan times which was largely eroded before the deposition of the Vindhyans (? Cambrian), and that this range was subsequently rejuvenated as a horst bounded by faults in post-Vindhyan times. Thus its present aspect as a mountain range is regarded by Dr. Fermor as younger than had hitherto been thought and not directly connected with the original folding. The second paper is by E. A. Glennie, and deals with the data provided by the geodetic investigations of the Survey of India.[34] This is an illuminating paper, for it marshals the geodetic evidence in such a way as to throw light from a new angle on many problems of Indian geology. And though it seems that there is still a long way to go before the observed facts of geology and the geodetic evidence can be satisfactorily correlated, the paper is one which should be read by everyone taking an intelligent interest in the broader aspects of Indian geology and in general problems of earth history.

In conclusion, it can, I think, be claimed that the advances which have been made in our knowledge of the geology of India during the past decade, which I have attempted to outline in the preceding articles, have been very considerable. If any general conclusion can be drawn from a survey of this work, it is perhaps that recent work has for the most part demonstrated the soundness of the foundations which were laid 60 and 70 years ago by the pioneers of Indian geology, chief among whom were H. B. Medlicott and W. T. Blanford. Much of this early work had a significance which extended beyond the boundaries of India. Whether the same can be said for the more recent work time alone can tell.

Finally, I express my thanks to Dr. Fermor for reading through the whole of these articles, and for offering a number of valuable suggestions.

The man who makes no mistakes does not usually make anything."—EDWARD J. PHELPS.

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[27] *Rec. Geol. Surv. Ind.*, 1922, **54**, 14, *Bull No.* 2, *Geol. Dept., Rewah State*, 'Rewah State Coalfields' 1923, 1-22.

[28] *Rec. Geol. Surv. Ind.*, 1928, **60**, 399.

[29] *Op. cit.*, 367.

[30] *Quart. Journ. Geol. Soc.*, 1933, **89**, 64.

[31] *Bull. Geol. Soc. Amer.*, 1932, **43**, 875.

[32] *Rept. XVI Intern. Geol. Congr. Washington*, 1933.

[33] *Rec. Geol. Surv. Ind.*, 1930, **62**, 391.

[34] Survey of India, Professional Paper No. 27, 1932.

Obituary.

WE regret to announce the sudden death of Dr. Ganes Prasad, M.A., D.Sc., Hardinge Professor of Higher Mathematics, Calcutta University, on the 9th inst. Dr. Prasad was a prominent educationist, a well-known mathematician and one of the founders of the Agra University.