Discussion on Mr. W. D. West's paper

The President, in inviting discussion on Mr. West's paper, said that this was a paper of great importance. All geologists were familiar with the modern idea of *nappes* in which, during mountain-forming operations, masses of rock were thrust horizontally many miles. Mr. West had been fortunate in being given two fields of work, in each of which he spent a portion of the year, namely the Simla Himalayas and the Central Provinces In the Simla Himalayas he had already demonstrated the presence of *nappe* structures similar to those detected in the Alps, and armed with this experience he had been able to detect what appeared to be a *nappe* amongst the old rocks of the Central Provinces. Some years ago the late Mr. Burton, working in the Balaghat district, thought he had detected a *nappe* structure amongst these old rocks, but his death in the war prevented his work from being carried to completion.

The President then invited discussion on Mr. West's paper.

Prof. A. C. Banerji: In the *nappe* formation of Alpine rocks the folds are from south to north and the horizontal thrust is from south to north, whereas in the *nappe* formation of the Himalayas in the neighbourhood of Simla the folds are from north to south and the thrust is also from north to south. Is there any geological or physical reason why the folds should be in opposite directions ?

Mr. W. D. West: Though the movements in the main have probably been from south to north in the Alps and from north to south in the Himalaya, the matter is not so simple in detail. No satisfactory answer can at present be given. The late Prof. J. W. Gregory was of opinion that this contrary movement was responsible for the rift valleys of the Dead Sea, the Red Sea and the African lakes, the rift being formed at the meeting of the two directions of movement.

Prof. M. N. Saha: (1) I would like to know what is the order of dimension of the horizontal displacement which causes rocks of older formation to creep over those of newer age. In how many years have these displacements been accomplished, i.e. what are the velocities of these movements ? (2) What are the origins of the forces causing these displacements ? (3) Has any positive result been obtained as a result of the international longitude work, proving that the continents are drifting away from each other ?

Mr. W. D. West: (1) The horizontal movement, according to the advocates of *nappe* formation in the Alps, may be of the order of 100 miles in extreme cases. The time during which this took place may be of the order of 10 million years or less. (2) No doubt the chief cause is the contraction of the earth and the crumpling of the surface skin as it accommodates itself

to a shrinking interior. Most geologists, however, are of opinion that the total contraction which can have occurred since the earth's crust solidified is insufficient to explain the amount of folding. Appeal to Wegener's hypothesis of the horizontal migration of continents, and the folding of mountain ranges in the front of the advancing continents, meets with the difficulty that there is no known force which is capable of causing this movement. The various tidal forces to which Wegener attributes the movement are about one millionth part of the force required. (3) Accurate observations of the longitude of places by wireless signals have not yet been carried out for a sufficiently long time to yield any definite results.

Mr. D. S. Bhattacharji: Mr. West has adduced two main lines of evidence in favour of *nappe* structure, (1) difference in composition of the rocks of the *nappe* and of the adjacent country; (2) discordance between the *nappe* and the surrounding rocks. Arguments against the *nappe* structure are (1) that it occurs in very ancient rocks which have been immensely distorted and re-crystallized. The distortion has been so intense that even the molecular structure of the minerals have been disturbed. *Nappe* structure can be intact only in younger rocks. (2) Impurities in composition may be explained by lateral change in the type of sediment (provided the rocks were of sedimentary origin). (3) Discordance of structure may be explained by three systems of faults generally parallel to the eastern, central and western boundaries of the Deolapar *nappe*. In support of the statement about the discordance of the whole *nappe* there are several other points to be settled. For instance there is the possibility of the formation of structural troughs or crests by transverse folds as noted about Garari Hurki about 10 miles to the south of Deolapar. Such structures are found in all grades of magnitude from the size of a hand specimen to that of mappable size. When this is possible, and when such a thing as passive upheaval and subsidence is possible, and when there is no evidence of the root of the *nappe*, the structure deduced by Mr. West is not convincing.

Mr. W. D. West: (1) *Nappes* are well-known areas of crystalline schists, e.g., in the Scottish Highlands, where the rocks have also been greatly folded and metamorphosed. This is itself no argument against *nappe* structure. (2) This is just possible, and has been discussed in the paper. The change near Deolapar, however, is so sudden, and occurs just where the discordance is found, that it seems unlikely that it was due to a lateral change in the type of sedimentation. (3) The upward pitching of the *nappe* both to the west and to the east shows the structure of the under surface of the *nappe* and shows that it is synclinal in character. It is definitely not a sunken faulted tract. The fact also that the *nappe* has the structure of a recumbent fold (not referred to in the reading of the paper through lack of time), suggests horizontal rather than vertical movement. There is no evidence of three systems of faults. That the roots of the *nappe* are not seen may be due to the fact that to the north the whole area becomes covered up by the overlying

Deccan trap, while to the south the alluvium obscures everything. If the *nappe* structure which has been deduced is unconvincing, the structure suggested by Mr. Bhattacharji is even less convincing.

The President enquired from Dr. Heron if he had met with similar structures in the Aravallis. Dr. Heron replied that in the Aravallis we have cases of the deeper seated wedge-faulting to which Mr. West had referred as occurring in the north-west of the Alps and in the north-west Highlands of Scotland.

Mr. B. C. Gupta enquired from Dr. Heron if there was any trace in Rajputana of the structures which Mr. Bhattacharji had demonstrated as an alternative explanation of Mr. West's *nappe*. Dr. Heron replied that there was no evidence to that effect, and also explained that rock wedge-faults did not lead to any such great horizontal translations as in the case of *nappes*.

Mr. Auden remarked that the *nappe* structure described by Mr. West in the Central Provinces were in rocks of a high grade of metamorphism, and that it was clear that such structures were not confined only to the superficial layers of the crust as suggested by Mr. Bhattacharji. This in fact was the case in the Pennine zone of the Alps and in the crystalline schists of the South-West Highlands of Scotland.

The President asked Mr. Sondhi if he had come across any *nappe* structures in the Southern Shan States. Mr. Sondhi replied that in the course of his work in the Shan Plateau he had observed a few instances along the western edge of the plateau where the sequence of beds is inverted, especially in the region west of Kalaw where Coal Measures apparently dip under the older rock formations of the Plateau Limestones. Some of these structures may possibly turn out to be true *nappe* structures, but, although thrust-faults on a minor scale have also been observed in the region, our mapping of the Southern Shan States has not yet proceeded so far as to reveal definite evidence of severe lateral movements operating in the Plateau on the scale illustrated by Mr. West.

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