19. *On ADDITIONAL EVIDENCE of the OCCURRENCE of GLACIAL CONDITIONS in the PALÆOZOIC ERA, and on the GEOLOGICAL AGE of the BEDS containing PLANTS of MESOZOIC TYPE in INDIA and AUSTRALIA.*
By W. T. BLANFORD, Esq., LL.D., F.R.S., Sec. G.S. (Read March 24, 1886.)

THE two subjects mentioned in the title of this paper are accidentally connected, the evidence of contemporaneous origin in certain Indian and Australian beds that contain plants of Mesozoic types being strongly supported by peculiar physical characters believed to be due to the action of ice. The last number of the 'Records of the Geological Survey of India,' contains several contributions to the history of the question, and these appear to me to form an addition to our knowledge of general stratigraphical geology of importance sufficient to justify my calling the attention of the Society to them. The subject is one to which I have given much attention in past years, and which I have discussed at various times, and this will, I trust, serve to excuse my writing upon it, although I have no new observations of my own to produce.

The principal papers to which I wish to call attention are, first, one by Mr. Richard Oldham entitled "Memorandum on the Correlation of the Indian and Australian Coal-bearing Beds," chiefly giving the results of a visit to Australia by a geologist who had had the advantage of seeing some of the Indian Gondwana beds; and, secondly, one by Dr. W. Waagen, with the title of "Note on some Palæozoic Fossils recently collected by Dr. H. Warth in the Olive Group of the Salt Range." A paper by Mr. Griesbach on rocks near Herat, and a recent observation of Mr. R. Oldham's in Northern Rajpūtāna, furnish some additional facts of value.

Before proceeding to notice the new data contained in these papers, it will be useful to point out as briefly as possible the previous state of our knowledge. As is well known, three great groups of beds, chiefly of freshwater origin, in three countries bordering on the Indian Ocean—namely, the Karoo formation of South Africa, the Gondwana system of the Indian peninsula, and the Coal-measures and associated beds of Australia—present remarkable points of resemblance in mineral character, fossil contents, and the rarity or absence of bands containing marine fossils. Roughly, these various great groups are thus classed, minor subdivisions being omitted:—

SOUTH AFRICA.	INDIA.	AUSTRALIA.
Stormberg.	Upper Gondwana. { Cutch and Jabalpur. Kota-Maleri. Rajmahal.	Upper plant-beds of Queensland, &c.
Beaufort.	Panchet.	Wianamata.
Konap.	Damuda.	Hawkesbury (glacial).
	Karharbari.	Newcastle.
		Upper marine beds (glacial).
Ecca (glacial).	Talchir (glacial).	Stony-Creek beds.
		Lower Marine beds (glacial).

With the higher of these beds we are not at present concerned: some of them in India and Australia are proved to be of Jurassic age by the association of marine fossiliferous strata, and I have elsewhere* shown what an extraordinary resemblance exists between the geological features of the South-African and Indian formations. Turning to the lower series, the first noteworthy point of similarity is the presence in all of coal-seams with a flora containing closely allied or identical species, the nearest allies of which are found, in Europe, in rocks of Mesozoic and, for the most part, of Jurassic age. The next feature to be noticed is the occurrence in all these regions of boulders supposed to have been transported by ice †.

In Australia alone marine fossiliferous formations are intercalated towards the base of the plant-beds. Species of *Orthoceras*, *Spirifer*, *Comularia*, *Fenestella*, and other fossils of typically Carboniferous affinities are found both above and below certain coal-beds, known as the Stony-Creek beds. Dr. Feistmantel, to whom we are indebted for the best and most recent description of the Australian fossil flora ‡, records from the Stony-Creek beds one species of *Neggerathiopsis* (a cycad), four of *Glossopteris* (a fern), one of *Annularia* and one of *Phyllothea* (Equisetaceæ). All of these genera, except *Annularia*, are found in the overlying Newcastle beds, and also in the Damuda series of India; and most of the species are either identical with Newcastle forms or very closely allied.

This intercalation, though clearly proved by the publication of sections from coal-pits by the Rev. W. B. Clarke § in 1865, and though supported by the evidence of every geologist who has visited the beds (and the number is considerable), has been doubted or rejected by many palæo-botanists. It is scarcely necessary to say that it is fully confirmed by Mr. Oldham. Merely because of the singular unwillingness on the part of some of the best writers on fossil botany to admit the force of evidence that has long since convinced geologists, it may be useful to quote Mr. Oldham's words. After referring to the doubts that had been thrown upon the observations of the Rev. W. B. Clarke and other geologists, and to the suggestion by their opponents that the apparent superposition of Carboniferous marine beds upon strata containing *Glossopteris* &c. must be due to inversion or faulting, he proceeds thus:—

“Such a conclusion, however, could not be allowed by any one who had seen the ground where these beds are exposed. The section is fortunately easily accessible by the Great Northern Railway starting from Newcastle, and the beds are well exposed in the frequent cuttings. There are two exposures of these lower Coal-measures on opposite sides of an anticlinal, one at Stony Creek, two miles west of Braxnton, and the other at Greta, ten miles further

* Rept. Brit. Assoc. 1884, p. 705.

† For details and references see ‘Manual of the Geology of India,’ chapter v.; Feistmantel, ‘Palæontologia Indica,’ ser. ii., xi., xii., Rec. G. S. I. 1880, p. 250; Oldham, J. A. S. B. liii. p. 187.

‡ Palæontographica, 1878–79; Pal. u. mes. Flora im östl. Australien.

§ Trans. Roy. Soc. Victoria, vol. vi. p. 27, pl. 2.

west. At both places the dip is moderate and steady, to east-south-east at Stony Creek, to west-north-west at Greta; at both places the section is practically continuous, and the marine beds may be traced dipping under the coal-seams, and a short way above them again reappearing. The reappearance of the seam on the opposite side of the anticlinal and the absence of any duplication of the seam are conclusive against any theory that the appearances are due to inversion or strike-faults; while, if further proof were necessary, it would be found in the fact that both at Stony Creek and Greta shafts have been sunk through the marine beds into the Coal, and at the former place through it into more marine beds, thus clearly showing that the Coal-measures are interbedded with the marine beds."

It is unnecessary to enter into the question of the relationship between the fossil floras of India, Australia, and South Africa. Full details will be found in the papers already quoted. A brief history of the glacial evidence may, however, be useful.

The boulder-beds of Talchir were first distinguished in Orissa by my brother and myself in 1856. The suggestion was then made that these beds afforded evidence of ice-action*, because boulders of large size (several have been measured exceeding 6 feet in diameter) occur very often in fine silt, and water in sufficiently rapid action to move the boulders would have swept away the silt instead of depositing it. The boulders in the Talchirs are almost always rounded, probably by torrents, and as the beds are entirely destitute of marine remains, there is every probability that the transporting agent was river-ice.

For many years the theory remained without confirmation, and the boulder-bed, everywhere occupying the same position as the base of what had, in course of time, come to be generally known by Mr. H. B. Medlicott's name of the Gondwána system, was traced throughout a wide area in Bengal and the Central Provinces. At last, in 1872, Mr. F. Fedden† had the good fortune, west of Chánda, to come upon polished and striated surfaces, both on the boulders themselves and on the underlying rock. The late Dr. Oldham, who was in the neighbourhood, immediately on hearing of the discovery, visited the spot and extracted a well-striated boulder‡.

At the base of the Karoo beds in South Africa a boulder-conglomerate has also been found, and its glacial origin pointed out by Dr. Sutherland§ and others. From the description this formation is wonderfully similar to the Talchir bed, but the boulders are not rounded. Dr. Sutherland suggested that this Ecca bed might have been contemporaneous with the Permian breccias of England, described by Sir A. Ramsay||. My brother, Mr. H. F. Blanford¶, in

* Mem. G. S. I. vol. i. p. 49.

† Rec. G. S. I. 1875, p. 16.

‡ Mem. G. S. I. vol. ix. p. 324. This boulder has just been sent to the Indian and Colonial Exhibition to be opened in May at South Kensington.

§ Q. J. G. S. vol. xxvi. p. 514.

|| Q. J. G. S. vol. xi. p. 185.

¶ Q. J. G. S. vol. xxxi. pp. 529, 530.

1874, pointed out that the Talchirs were probably contemporaneous with the Ecce beds.

In 1861 the late Dr. T. Oldham noticed the resemblance between specimens from the lower marine beds of Australia and the Talchir beds of India. He pointed out that not only are both bluish-green silty beds, but that they further resemble each other in the presence of pebbles and large rolled masses in fine silt. This point of resemblance was noticed by my brother, Mr. H. F. Blanford*, but has not generally been alluded to in the discussion of late years†, probably because it had never been confirmed by any one who examined the beds *in situ* until Mr. R. Oldham did so.

In 1866 Dr. A. R. C. Selwyn and the late Sir R. Daintree‡ found a bed containing boulders of considerable dimensions at a spot called Bacchus Marsh in South Australia. The bed yielded some fossil plants allied to *Glossopteris*, and described by Prof. McCoy as *Gangamopteris*, a genus found also in the Australian Newcastle beds and in the Talchir and Damuda series of India.

In 1878 Mr. C. S. Wilkinson§ discovered large transported boulders in the Hawkesbury series. Dr. Feistmantel|| classed this and the Bacchus-Marsh beds as contemporaneous with each other, and also with the Indian Talchir and the South-African Ecce beds.

I believe the above are the most important links that had so far been forged in the chain of evidence, and I now proceed to the additional information just obtained.

In Mr. R. Oldham's recent visit to Australia, he has ascertained that striated pebbles and boulders occur in the Carboniferous marine beds both above and below the Stony-Creek beds. He says:—"Blocks of slate, quartzite, and crystalline rocks, for the most part subangular, are found scattered through a matrix of fine sand or shale, and these latter beds contain delicate *Fenestella* and bivalve shells with the valves still united, showing that they had lived, died, and been tranquilly preserved where they are now found, and proving, as conclusively as the matrix in which they are preserved, that they could never have been exposed to any current of sufficient force and rapidity to transport the blocks now found lying side by side with them. These included fragments of rock are of all sizes from a few inches to several feet in diameter." Mr. Wilkinson had seen in these same beds boulders of slate &c., the dimensions of which might

* *L. c.* p. 534.

† Mr. Oldham appears surprised at my not having mentioned this observation of his father in my reply to Dr. Feistmantel (*Rec. G. S. I.* 1878, p. 104). I was well acquainted with the observation, but I felt and still feel doubtful whether similarity in mineral character can be used as evidence of age, and I do not attach much importance to deductions as to physical characters unless made from examination of the beds in the field. It must be remembered also that no evidence of glacial action in the beds of New South Wales was then available.

‡ Report on the Geology of the District of Ballan, Melbourne, 1866, p. 10. I take from Mr. Oldham's paper this and the next reference to Australian literature.

§ *Trans. Roy. Soc. N. S. W.* vol. xiii. p. 105.

|| *Rec. G. S. I.* 1880, p. 250.

be measured in yards. Mr. Oldham found fragments well smoothed and striated as if by a glacier, and he is inclined to believe that the fragments of rock were derived from icebergs.

Nor are these boulder-beds confined to the locality mentioned north of Sydney. Similar deposits are shown by Mr. Oldham to occur at Wollongong to the south and in the Blue Mountains to the west, and again far to the northward in Queensland. Mr. Oldham also thinks, and I thoroughly agree with him, that the Stony-Creek beds, and not the much later Hawkesbury, are the equivalents in time of the Bacchus-Marsh beds of Victoria. The evidence of ice-action in the Hawkesbury beds is fully accepted by Mr. Oldham, though not regarded as evidence of glaciation so extensive as that which affected the underlying series*.

Thus throughout Eastern Australia, from Queensland to Victoria, there is found evidence of ice-transport in beds belonging to the Carboniferous period. The Australian marine Carboniferous beds have usually been considered of Mountain-Limestone age; but I learn from Dr. Waagen, who has made a special study of the Carboniferous fauna in connexion with his description of that found in the Salt Range of the Punjab, that the Australian marine Carboniferous fossils are of somewhat later date, corresponding approximately to the Coal-measures of Western Europe and to the *Fusulina*-limestones and their associated beds in Russia.

It is very remarkable that, at the very time when Mr. Oldham was engaged in obtaining evidence of glacial action in Carboniferous times in Australia, Dr. Waagen's attention was called to similar evidence in Northern India. The two lines of research were absolutely independent of each other, neither writer being aware of the other's studies, and therefore the circumstance that both, from widely different data, come to the same conclusion as to the age of the Lower Gondwanas is one of those extraordinary coincidences which rarely occur except when a real scientific discovery is made. As already mentioned, both papers appear in the same number of the Indian Geological Survey Records.

In the Salt Range surveyed by Mr. Wynne and described by him in the fourteenth volume of the Memoirs of the Geological Survey of India, and in the continuation of the range to the westward beyond the Indus, described by the same geologist in vol. xvii., boulder-beds have been found in several places and are described in the works mentioned. One of the most important occurrences is in the eastern part of the range, near the Khewra salt-mines. Here the bed consists of dark shales filled with large boulders of granite, syenite, porphyrite, quartzite, and other hard rocks of unknown derivation. Mr. Wynne, when he surveyed the Salt Range, had very little if any acquaintance with the Lower Gondwana; but Mr. Theobald, who had a good knowledge of the Talchir beds, at once recognized the

* In the Hawkesbury series angular boulders of shale, of a kind also interbedded, are found in the sandstone. They occur of all sizes up to 20 feet in diameter, with their stratification at all angles to the dip of the sandstone.

similarity of the boulder-formation in the Salt Range, and he obtained from it a roughly rounded fragment of red granite*, polished and striated on three sides, the direction of the striation being different in each case. This boulder is now in Calcutta.

The bed just mentioned has hitherto been considered part of the "Olive Group" of Wynne, and classed as Cretaceous. The relations of the beds may be illustrated by the accompanying section, copied from Mr. Wynne's sketch of Karángli Hill†, the locality from which Mr. Theobald obtained the boulder just mentioned.

Section through Karángli Hill. [From the 'Memoirs of the Geological Survey of India,' vol. xiv. pl. xv. fig. 19.]

1. Salt Marl; 2. Purple sandstone; 3. Dark shales with *Obolus*; 4. Magnesian Sandstone; 5. Olive Group; 6. Nummulitic Limestone; 7. Tertiary Sandstone.

Nummulitic Limestone occurs at the top, resting upon the Olive Group, the uppermost portion of which is fossiliferous, and contains locally, amongst other fossils, *Cardita Beaumonti*, a characteristic fossil, in Sind‡, of a stage that is certainly older than any recognized Tertiary horizon, and must probably be classed as very high Cretaceous. Beneath this fossiliferous band there is a considerable thickness of sandstone, containing no fossils except some ill-marked bivalves, and then comes the boulder-bed. The *Cardita-Beaumonti* beds, Olive sandstone, and boulder-bed form the "Olive Group" of Mr. Wynne.

Beneath the boulder-bed there is, in places, a band of thin-bedded sandstones and bright red clays, known as the Pseudomorphic Salt-Crystal Zone, on account of the pseudomorphs of cubical salt-crystals found on the surface of the sandstone. This bed is unfossiliferous and may be neglected. The next in descending order, the "Magnesian Sandstone," is equally unfossiliferous, but it is much more important. It is unquestionably Palæozoic; for, further to the westward, it passes beneath another unfossiliferous bed, the "Speckled Sandstone," which there underlies the Carboniferous *Productus*-limestone. Both Speckled Sandstone and Carboniferous Limestone, it must be understood, thin out to the eastward§. Thus it is mani-

* Rec. G. S. I. 1877, p. 224.

† Mem. G. S. I. vol. xiv. pl. xv.

‡ Mem. G. S. I. vol. xvii. p. 34; also Pal. Ind. ser. xiv. pt. 2, p. 16, pt. 3, p. 7.

§ See the diagram given by Mr. Wynne, *l. c.*, opposite p. 69.

fest that either the beds between the *Cardita-Beaumonti* zone and the Magnesian Sandstone represent all the geological sequence from Lower Carboniferous or even older to Upper Cretaceous, or else that one or more breaks, representing vast lapses of time, occur in the sequence.

Here, as elsewhere in the Salt Range, we are assured by all observers, there is the most marked parallelism and apparent conformity in all the beds*. In the absence of fossils, the only clue to subdivisions of the sequence is in changes of mineral character. There is thus no *a priori* reason, so far as the description leads us, why a break should not exist in the middle of the Olive Group; and, according to Waagen's view, a great break does occur here.

This, however, is not the only instance of boulder-beds occurring in the Salt Range. Two other instances, at least, occur. One of these is in the "Speckled Sandstone" just mentioned as occurring at the base of the *Productus*-limestone; the other, apparently the most important of all, is to the west of the Indus, in beds immediately beneath the *Productus*-limestone. These two are evidently on nearly the same horizon, and were, I believe, regarded by Mr. Wynne† as identical. Polished and striated blocks were observed by him‡ in the bed west of the Indus.

Before proceeding further, it is essential to mention that the *Productus*-limestone of the Salt Range is divided by Dr. Waagen into three stages, the two upper of which he classes as representing the Permian, and the third as the equivalent of the upper part of the European Coal-measures§, and that, in his introduction to his work on the *Productus*-limestone fossils||, he includes the Magnesian Sandstone (and of course the Speckled Sandstone overlying the Magnesian Sandstone) in the *Productus*-limestone system. Indeed, he especially insists on the close connexion of the Speckled Sandstone with the lower beds of the *Productus*-limestone¶.

In the neighbourhood of Choya Saidan Shah (near Karāngli and the Khewra salt-mines) Dr. H. Warth, a mining-engineer in the service of the Government of India, found, about the beginning of last year, a marine fossil in what he then supposed to be a pebble of the boulder-bed. The fossil was a *Conularia*, and the nodule in which it occurred was at first supposed to have been brought from a distance. But Dr. Warth subsequently obtained numerous additional specimens in similar nodules, and ascertained that these nodules were confined to a thin layer at the top of the boulder-bed, and this layer he traced over an area exceeding ten square miles. This discovery, and also the circumstance that all the nodules are of about the same size and of an oval form, led to the conclusion (which,

* This is very remarkable, as it appears to show that throughout all geological time from the date of the Salt Marls (older Palæozoic) to Eocene and perhaps later, there was a complete absence of disturbance in this area. Yet for a considerable portion of the time the tract appears to have been on or near a coast-line.

† Mem. G. S. I. vol. xvii. p. (236) 26.

§ Rec. G. S. I. 1886, p. 32.

¶ Rec. G. S. I. 1886, p. 32.

‡ Ibid. p. (239) 29.

|| Pal. Ind. ser. xiii. p. 8.

however, is disputed*) that the nodules were not pebbles, but concretions.

Dr. Waagen, to whom the fossils were sent for examination, found 10 recognizable species amongst them. Of these, 2 *Serpulæ* and a Lamellibranchiate mollusk, referred with some doubt to *Atomodesma* (*Mytilidæ*), are new. A *Nucula* and a *Discina* also occur, but not sufficiently well preserved for accurate specific determination. The more important identifications are:—

Bucania, cf. *kattaensis*, Waagen.

Conularia lævigata, Morris, common.

C. tenuistriata, McCoy.

C. cf. irregularis, Kon.

Aviculopecten, cf. *limæformis* (Morris).

Conularia lævigata, *C. tenuistriata*, and *Aviculopecten limæformis* are found in the Carboniferous beds of Australia, *Conularia irregularis* in the Mountain-Limestone of Belgium, *Bucania* (a genus allied to *Bellerophon*) *kattaensis* in the lower stage of the *Productus*-limestone of the Salt Range. There can be no question of the fauna being Carboniferous, whilst the fact that only one species, and that not identified with certainty, is known from the Salt-Range *Productus*-limestone, renders it probable that these fossils indicate a slightly different age from that of any of the fossiliferous beds previously known in the locality. This age cannot be newer (for it is absurd to suppose the fauna to be supra-Permian), so it must be rather older. This is the view taken by Dr. Waagen, and he shows how the appearance of a Carboniferous bed, rather older than the known *Productus*-limestone, beneath the *Cardita-Beaumonti* beds at this spot may be accounted for. In starting from the west the *Cardita-Beaumonti* beds are found resting, first on Jurassic beds, then on Triassic, then on the *Fusulina*-beds of the lower *Productus*-limestone, and finally on the *Conularia*-band of the boulder-bed. This last is precisely where the Speckled Sandstone should crop out. Dr. Waagen concludes that this boulder-bed of the eastern Salt Range is the same as that in the Speckled Sandstone of the western portion and as that west of the Indus, and that all are approximately of Coal-measure age, that is, contemporaneous with the boulder-beds shown by Mr. R. Oldham to be so extensively developed in Eastern Australia.

There is, however, a difficulty to be overcome. Mr. Wynne, who surveyed the Salt Range in detail, and is consequently entitled to speak with much authority on the geology, in a recent paper not yet published, but of which a summary is given in the 'Geological Magazine' for March 1886, and also in letters that I have received from him, questions the concretionary nature of the nodules, and states that he has evidence of their being transported†. He particularly

* I will refer to this presently.

† Specimens which Mr. Wynne was so good as to send to me for exhibition at the meeting bear out this view. One unmistakable pebble contains a *Conularia*, the shell of which is intersected by the worn surface of the pebble. But

mentions that a rolled specimen of *Comularia* was sent to him by Dr. Warth, who, if I understand rightly, now considers the nodules to be transported pebbles. Mr. Wynne is also of opinion that the east Salt-Range boulder-bed is on a different horizon from that to the westward.

I am in hopes that this difficulty will be cleared up very shortly, and that the locality will be examined by Mr. Oldham or some other officer of the Indian Geological Survey. Meantime, I think it will be well to await further information. The evidence as to the boulder-beds in the western Salt Range is unaffected by the position of that in the eastern; and if the latter be of later age there will be evidence of two glacial epochs in Northern India, instead of one; though it is difficult to avoid a suspicion that all these evidences of a low temperature are on the same general horizon.

The reason why no one has hitherto been induced to connect these Salt-Range boulder-beds with the Talchirs is, I think, first, because there was no connecting link known, and the distance at which they occurred from each other, between 700 and 800 miles, rendered any attempt to connect them by means of physical characters rather wild speculation; and, secondly, because whilst the age of the western Salt-Range boulder-beds was generally understood to be infra-Carboniferous, that of the Talchirs was scarcely admitted to be so old as Permian. In fact I was almost alone in contending for its Palæozoic age, Dr. Feistmantel having classed it as Triassic. The light now thrown upon the age of the Salt-Range boulder-beds, however, is supplemented by another discovery of Mr. Oldham's, who has corrected a faulty observation of my own.

The most north-western occurrence of the typical Talchir beds with which I am acquainted is in the Nerbudda valley, near Hoshungabad. Far to the westward of the main Gondwána area in Central India some representatives of the Upper Gondwána are found in Cutch, associated with marine Jurassic strata. The base of the system is not seen, the lowest beds, which are of Bathonian age, being on the verge of a great alluvial tract which conceals all inferior strata. Scattered outcrops, both of the marine and plant-bearing beds, are found emerging here and there from the sands of the Indian deserts north of Cutch, as far north, at all events, as Jesalmir.

In a hurried traverse that I made of the desert in 1876 I found near Pokaran, between Jodhpur and Jesalmir, a well-developed boulder-bed, resting in one place on a grooved and striated surface of the Archæan rocks. It was impossible to determine the position of this boulder-bed without further exploration: the only associated formations were the Archæan Maláni felsites, porphyries, syenites, &c., clearly inferior, and some red sandstones, which I suspected—correctly, as has since been found—to be Vindhyan (probably very old Palæozoic). It appeared to me, however, as if the sandstones

other specimens do not look rolled; the surface is irregular, as if weathered, and amongst these weathered specimens is that which Dr. Warth regards as rolled.

were higher in the series than the boulder-beds; but naturally my hurried observations, made in marching rapidly through a country where only here and there a patch of rock emerges from beneath the blown sand and alluvium, were neither satisfactory nor conclusive. I am not surprised to hear that Mr. Oldham has now ascertained that the boulder-bed is above the Vindhyan, that it is extensively developed, that it forms the basement-bed of these western representatives of the Gondwānas, and, in short, that it is shown by its character and position to be a representative of the Talchir beds.

A glance at the map of India will show that the locality in North Rajputāna is nearly equidistant from Hoshungabad in the Nerbudda valley and the Salt Range of the Punjab, and not far to the westward of a straight line between the two.

Still another observation remains to be added. Mr. Griesbach, who is attached as geologist to the mission engaged in laying down the Russian and Afghan boundary, found*, more than a year ago, in the neighbourhood of Herat, greenish sandstones and shales with boulders at the base of a great plant-bearing system containing, he says, *Vertebraria*, a typical Damuda (lower Gondwāna) plant. The boulder-bed he recognized at once as Talchir, and he insists on its resemblance to the Ecca beds of South Africa, a similarity due partly to the association of basaltic rock in both cases.

In a subsequent paper he gives further details, and states† that the boulder-bed rests conformably on marine Carboniferous beds. I cannot find any clear evidence as to the position of these beds in the Carboniferous; amongst the fossils are said to be *Productus semireticulatus*, *Athyris Royssii*, *Fenestella*, &c., but both the Brachiopoda have a wide range, and of course the determinations are made without means of accurate comparison; indeed Mr. Griesbach especially states that his notes are merely rough descriptions. Dr. Waagen speaks of the marine beds as Lower Carboniferous; and very probably they are of that age, like the limestones further west in the Elburz. If this be the case, the geological position of the boulder-bed may probably be identical with that in the western Salt Range. But I think it will be well to await further details before coming to any decided conclusion.

The importance of the observation lies chiefly in the fact that if the beds at Herat are really equivalents of the Indian Gondwānas, a great step has been made towards the connexion of the Indian beds, the position of which has so long been problematical, with the typical geological sequence in Europe. As Mr. Griesbach points out, the Herat plant-bearing beds probably represent those of Russian Turkestan and those of the Elburz and Armenia.

Although it was impossible to overlook the remarkable evidence of ice-action previously recorded from South Africa, India, and Australia, I have feared hitherto to attach too much weight to it

* Rec. G. S. I. 1885, p. 62.

† Ibid. 1886, p. 54.

as evidence of synchronism, and in one case, in the supposed proof that the Bacchus-Marsh and Hawkesbury beds were contemporaneous, reasoning from glacial evidence certainly led to a false conclusion. I must say I always felt doubtful about this particular case, and it was partly this which in the last note I wrote on the subject led me to remark, with reference to the supposed synchronism of all the various beds, that it would be very unwise to insist too much on the coincidence. The great addition made to the area over which boulder-beds have now been traced, tends very strongly indeed to support the view that all are really contemporaneous or nearly so, and that the Ecca beds of South Africa and the Talehir beds of India are of the same geological age as the Carboniferous strata of Eastern Australia, and approximately equivalent to the Coal-measures of Western Europe*. At the same time there is no improbability in a recurrence of glacial conditions during at least a considerable portion of the Carboniferous period; and to such recurrences may perhaps be attributed the glacial evidence observed in the Hawkesbury beds of Australia and the Permians of England and Germany. This, however, only overcomes part of the difficulty that arises. One of the great puzzles is to explain why, at a time when the cold, in winter at all events, in 16° north latitude, was sufficiently intense to admit of boulders being carried by ice into large river-valleys or lakes, a much richer vegetation appears to have flourished in far higher latitudes in Europe†.

Mr. R. Oldham, in a recent paper, written, however, before he visited Australia, and before much of the evidence now procured was available, suggested a great alteration in the position of the earth's axis; but I am doubtful whether the position suggested by him for the pole in Central Africa would dispose of the difficulty, and I am inclined to think it better to await more information before attempting to map out the area affected. The idea of glacial action in past times, apart from the subrecent glacial epoch, is novel to geologists in general, and it is very possible that information will accumulate when attention has been more generally drawn to the facts recently ascertained.

There is, however, one point to which attention should for a moment be called, and that is the connexion between the occurrence of a great glacial epoch at the close of the Palæozoic era and the

* I do not employ the terms Upper and Middle Carboniferous, because it is by no means certain what such terms imply. In my own opinion, it is a mistake to divorce the Permian from the Carboniferous, of which, when all are represented by marine beds, the Permian forms the upper series; but in this matter the interests of science are in competition with local convenience.

† The coal-plants found so abundantly in Bear Island, Spitzbergen, and Grinnell Land are chiefly from the Ursa beds, which are much older than the European Coal-measures, though one stage in Spitzbergen is said to be equivalent to the uppermost Coal-measures. No Arctic coal-plants are known, so far as I am aware, of the same date as that now assigned to the boulder-beds of India, Australia, and South Africa. Also it should not be forgotten that identity of fossil plant-remains does not prove beds to be of contemporaneous origin. At the same time the absence of glacial evidence in past times amongst Arctic lands must not be forgotten.

enormous change that took place in all life, vertebrate and invertebrate, animals and plants, in the interval between Upper Palæozoic and Lower Mesozoic times. Despite all the discoveries of Palæozoic types in the Trias, and of Mesozoic genera in Upper Carboniferous or Permian, that have taken place in the last forty years, the fact remains as distinct as it was when it formed the subject of Prof. E. Forbes's Presidential Address to the Society in 1854, that a greater change in forms of life takes place between Permian and Trias than between any other two consecutive systems in the whole of geological time. If the views above expressed be correct, and if during part of the Carboniferous period an excessively low temperature prevailed, some explanation of the change may be found. The alteration in marine life at the close of the Palæozoic period appears to have been enormously greater than anything produced by the last glacial epoch, the effects of which, indeed, may be said scarcely to have influenced the tropical seas, although in places, as in India, the modification of the land-fauna and flora has in all probability been extensive. The circumstance that the temperature towards the end of the Palæozoic era must have been lower than in the Pleistocene epoch, may account for the occurrence of boulder-beds of the former date in tropical and subtropical countries.

Under the impression that the Indian Damudas were of later date than the Newcastle beds of Australia, the idea has been suggested by several writers* that the European Mesozoic flora originated in Australia in Palæozoic times, was driven to the equator by the increasing cold in the Permian epoch, and thence spread again to the northward in Mesozoic times as the temperature improved. This may be partially the fact, but it is not necessary to invoke the aid of migration to the same extent. It is at least equally probable that a considerable tract of Southern Asia† in Carboniferous times formed part of a continuous land area extending to Australia on one side and to South Africa on the other, that this land area was absolutely severed from all the countries in which the Coal-measure flora existed at the time, and was subjected to a much colder climate. It is unnecessary to remark that the Coal-measure flora was long since proved not to have required a tropical climate for its development. The distinction between the two floras is in all probability due to long isolation—to a difference, in short, of geographical areas with a distinct biological history, or of what are generally known as botanical regions.

DISCUSSION.

The PRESIDENT remarked upon the wide range of the paper. In the case of some communications hardly more than two or three Fellows could be expected to take part in the discussion; but in the

* Manual Geol. India, Introduction, p. xxxvi; Oldham, J. A. S. B. vol. liii. pt. 2, p. 195; Waagen, Rec. G. S. I. 1886, p. 37.

† Gondwana plants, mixed up in an extraordinary manner with each other and with European Rhætic types, have been found in Tonquin. Zeller, Bull. Soc. Géol. France, sér. 3, vol. xi. p. 456.

present case, with a paper dealing with India, South Africa, and Australia, and which raised such questions as the value of fossil plants as evidence of geological age, and of the recurrence of glacial conditions, it was to be expected that the discussion would be wide, lively, and possibly warm.

Dr. SELWYN said that conglomerate beds similar to those referred to at Bacchus Marsh were very largely developed in Gipps Land, where they formed mountains 3000–4000 feet high. *Lepidodendron* and some other indistinct fossil plants were found in the associated strata, but none of the Bacchus-Marsh forms. He thought it possible the conglomerates were of the same age, though on the evidence of the plants they had been considered different. Glacial action may have operated in their formation, though he had not observed any evidence of it.

The much discussed Stony Creek section is paralleled in British Columbia, where a Tertiary flora is interbedded with a Mesozoic marine fauna.

Mr. CARRUTHERS remarked that this was not a question of stratigraphy, but as to the value of botanical and zoological data in determining the age of strata. It appeared to him that the remains of plants might indicate the age even more than those of animals. It was not a question of the replacement of the Carboniferous flora of Europe by a flora of the same age but of a different facies, for, though the *Lepidodendra* of Australia were Devonian, there was a Carboniferous flora of the same type as that of Europe in South Africa (Karoo beds), consisting of *Lepidodendra*, *Sigillaria*, *Calamites*, and Ferns; and in addition there was present this later *Glossopteris*-flora with a Mesozoic facies. In South Africa, India, and Australia this flora is placed, on zoological evidence, at a lower level than it ought to occupy.

Mr. LYDEKKER wished to call attention to two points bearing on the present paper. In the Kashmir Himalaya the Kuling series seems to represent the Lower *Productus*-limestone, and beneath it there is a considerable thickness of traps underlain by the Blaini conglomerate, which closely resembles a glacial boulder-bed. This boulder-bed appears to be the equivalent of that in the Salt Range; and other boulder-beds lower down in the series point to the prevalence of still earlier glacial conditions. Mr. Lydekker also called attention to the homotaxy of the groups of the Gondwanas, and showed a perfect agreement between the age indicated from the consideration of the vertebrate fossils and that arrived at upon other grounds by Dr. Waagen and Mr. Oldham. The sequence thus obtained indicates representative groups from the age of the Lower Jura (Kota) to that of the Carboniferous (Talchir). In South Africa, also, we get a complete series from the Jura to the Palæozoic.

Prof. T. R. JONES remarked that in the case of the Stormberg he regarded the presence of *Lepidodendron* as a myth. The Karoo beds contain vertebrate remains, including highly organized Reptiles, and it seemed to him that these furnished better evidence than a flora. He referred to the evidence adduced by the late Mr. Stow

of glacial action in the lower part of the Karoo beds, which buried glaciated surfaces on rocks probably of Archæan age.

Prof. DUNCAN said that it was very satisfactory to know that the recent discoveries strengthened Mr. Blanford's original opinions regarding the Palæozoic age of the Lower Gondwānas. Having had the advantage of studying the rocks and fossils of the Gondwāna series in the Museum of the Royal Indian Engineering College, he (Prof. Duncan) was impressed with the necessity of approaching the study of the age of the Lower Gondwāna series from above, for there were no fossiliferous deposits beneath them. There were Purbeck-Wealdens in Kachh, and also beds containing a Jurassic flora placed between marine strata, and the Mollusca were often identical specifically with those of the European type. Then the Rajmahal beds must be lower than the Oolitic and the facies of the plants was Liassic. The succession below was through a great depth of sedimentary rock with thick plant-beds, and the Upper and Lower Damudas had a different flora from the Rajmahal above and the Karharhari beds of the Talchirs below. The flora was Mesozoic in facies, but there were such forms as *Neuropteris valida* and many Equisetaceæ, which gave a kind of European Palæozoic appearance. He considered that the animal remains must be considered of greater classificatory value than the floras. With regard to the glacial question, he considered that the Talchir boulders were the remains of the moraines on the flanks of mountains which had sunken.

Rev. E. HILL remarked that when people change the axis of the earth, they do not change its shape. Hence, for glacial conditions to thus arise in the southern localities alluded to, one pole of the earth must have been somewhere about the middle of the Indian Ocean, and the equator about where England now is. Dr. Croll claimed that there was a Glacial period in the Carboniferous epoch.

Prof. SEELEY thought it was an exceedingly doubtful proceeding to attempt correlation of beds on the ground of traces of glaciation. It seemed to him desirable that we should get fuller evidence that the glaciation referred to in the paper had really existed. A few scratches appeared to be doubtful evidence. The pebbles and boulders described by the author were in some cases several feet in diameter and rounded; and in how many cases were there those smoothed surfaces with striæ which furnished unmistakable evidence of glacial conditions? He referred to other causes of such phenomena, and even of scratches, quite independent of glaciation.

As regarded the question of fossils as indicating the age of deposits, he thought that we are not justified in taking such a plant as *Glossopteris* as characteristic of a particular geological period. He referred to the case of *Trigonia* as indicating the mistakes into which we may easily be led by attaching too much importance in this respect to particular types, and maintained that, however good such a mode of settling the age of deposits may have been in past time, with our present knowledge it is liable to lead to a delusion. From the reptiles found in the Indian rocks referred to, no one would have any reason for regarding them as referable to a sharply

defined epoch. The time has not yet come for the correlation of rocks by means of their fossil contents; and this is especially the case with deposits which seem to hold a position intermediate between the Palæozoic and Mesozoic series.

Mr. DE RANCE admitted the important testimony adduced in support of the notion of the occurrence of Glacial epochs in Palæozoic times. But he wished to ask the author how he proposed to explain the presence, throughout the extreme northern regions, of Silurian, Devonian, and Carboniferous rocks, containing fossils identical with those obtained in similar rocks in Europe. At the time of the deposition of the Carboniferous Limestone, the Lias, and Oolites, there seems to have been a continuous sea over the North Pole, There was no evidence in these rocks of difference of temperature: the conditions seem to have been the same until we arrive at the Cretaceous epoch, in which indications of climate first appear.

The AUTHOR, in reply, admitted that some of his points were fairly open to question, but he begged to say that upon these he had by no means pretended to speak decidedly. With regard to the change of position of the earth's axis, he had remarked only that this explanation had been suggested. He was quite prepared to join issue with Mr. Carruthers on the question whether plants or marine animals should decide as to the age of the deposits referred to. Prof. McCoy, who thought the plants Mesozoic, was convinced as to the Carboniferous age of the marine fossil animals in Australia; so also were Prof. Morris and Prof. De Koninck. He maintained that there is no known instance in which marine animals referred to a certain age in one place are found differently arranged elsewhere, whereas with plants the case is quite otherwise. With regard to the doubts raised as to the pebbles and boulders being transported by glacial action, he said that such masses, sometimes measuring six feet in diameter, occurred scattered through a very fine silt, and he knew of no other agency than that of ice by which boulders of that size could have been so deposited.