Mullion Island basalt, forms the projecting headland at the south end of the Great Perhaver Beach, north of Gorran Haven.[1]

These localities mark out almost precisely the same horizon as the radiolarian cherts of Mr. Howard Fox. The curve followed by this pillow-lava is also fairly parallel to that of the well-known quartzite of the Meneage and Gorran districts, to the slate containing limestone lenticles with Upper Silurian fossils, and to that of the conglomerate placed by Mr. Upfield Green at the base of the Gedinnian. Fragments of an altered basalt very similiar to the Mullion Island rock were found in this conglomerate along Gillan Creek, at Flushing and Lestowder Beaches.

NOTICES OF MEMOIRS, ETC.

I.—British Association for the Advancement of Science. Cambridge Meeting, 1904.

Address to the Geological Section by Aubrey Strahan, M.A., F.R.S., F.G.S., President of the Section.

IT is forty-two years since the British Association last met in Cambridge, and we may turn with no little interest to the record of what was taking place at a date when the science of geology was still in its infancy, and in a University where its promise of development was first recognised. Dr. John Woodward, the founder of the Woodwardian Chair, had been dead 176 years, but his bequest to the University had not long begun to bear fruit, for the determination to house suitably the collection of fossils and to provide for the reading of a systematic course of lectures was not arrived at until 1818. In that year Adam Sedgwick, on his appointment to the Woodwardian Chair, began a series of investigations into the geology of this country, which made one of the most memorable epochs in the history of British geology. At the Cambridge meeting of 1862 he had therefore held the Professorship for forty-four years, a period sufficient to spread his reputation throughout the civilised world as one of the pioneers of geological science.

Towards the close of his life Sedgwick gave expression to the objects which he had had in view when he accepted a Professorship in a science to which he had not hitherto specially devoted his attention. "There were three prominent hopes," he writes, "which possessed my heart in the earliest days of my Professorship. First, that I might be enabled to bring together a collection worthy of the University, and illustrative of all the departments of the science it was my duty to study and to teach. Secondly, that a geological

[1] Igneous rocks occur at the top of Greeb Head and at Little Perhaver Beach, but they are of more acid trachytic type than the Mullion Island rock, and show large porphyritic crystals of oligoclase in a fine-grained felspathic base with little or no development of ferromagnesian minerals. Fragments of somewhat similar trachytic rocks, but containing shreds of opacite suggestive of altered soda-pyroxenes or amphiboles, were found in a crushed breccia of grit and slate on the north-east of Porthluney Cove.

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museum might be built by the University, amply capable of containing its future collections; and lastly, that I might bring together a class of students who would listen to my teaching, support me by their sympathy, and help me by the labour of their hands."

We, visiting the scene of his labours more than thirty years after he wrote these words, witness the realisation of Sedgwick's hopes. The collection is not only worthy of the University, but has become one of the finest in the kingdom. It is housed in this magnificent memorial to the name of Sedgwick, on the completion of which I offer for myself, and I trust I may do so on behalf of this Section also, hearty congratulations to the Woodwardian Professor and his staff. Finally, I may remind you that at this moment the Directorship of the Geological Survey and the Presidential Chair of the Geological Society are held by Cambridge men; that the sister University has not disdained to borrow from the same source; and lastly, that it is upon Cambridge chiefly that we have learned to depend for recruiting the ranks of the Geological Survey, as proofs that Cambridge has maintained her place among the foremost of the British schools of geology.

Though he had taken a leading part at former meetings of the Association, Sedgwick's advanced age in 1862 necessitated rest, and this Section was deprived to a great extent of the charm of his presence. It benefited, however, in the fact that the Presidential Chair was occupied by one of his most distinguished pupils. Jukes was one of those men the extent of whose knowledge is not readily fathomed. It has been my experience, and probably that of many others in this room, to find that some conclusion, formed after prolonged labour and perhaps fondly imagined to be new, has been arrived at years before by one of the old geologists. Such will be the experience of the man who follows Jukes' footsteps. Turning to his Address given to this Section in 1862, we find much of what is now written about earth-movement and earth-sculpture forestalled by him, with this difference, however, that whereas the custom is growing of using a phraseology which may sometimes be useful, but is generally far from euphonious, and not always intelligible, he states his arguments in plain, forcible English.

It may raise a smile to find that Jukes thought it necessary in 1862 to combat the view that deep and narrow valleys had originated as fissures in the crust of the earth, and that the Straits of Dover must have been formed in this way, because the strata correspond on its two sides. But we shall do well to remember that the smile will be at the public opinion of that day, and not at Jukes himself. In no branch of geology have our views changed more than in the recognition of the potency of the agents of denudation. In 1862 it was necessary to present preliminary arguments and to draw inferences which in 1904 may be taken as granted.

The evidences of the prodigious movements to which strata have been subjected, and of the extent to which denudation has ensued, cannot fail to strike the most superficial observer. Both mountain and plain present in varying degree proof that sheets of sedimentary material originally horizontal are now folded and fractured. But after a momentary interest aroused by some example more striking than usual, glimpsed, it may be, from a train-window, the subject is probably dismissed with an impression that such phenomena are due to cataclysms of a past geological age and have little concern for the present inhabitants of the globe. These stupendous disturbances, it might be argued, can only have taken place under conditions different from those which prevail now. We are familiar with mountain-ranges in which their effects are conspicuous; we have carried railways over or through them and have been troubled by no cataclysmic movements of the strata. Apparently the rocks have been fixed in their plicated condition, and are liable to no further disturbance. Parts of the world, it is true, are subject to earthquakes accompanied by fissuring and slight displacement of the crust, but not even in earthquake regions can we point to an example of such thrusting and folding of the strata being actually in progress as have taken place in the past. Nor, again, can volcanic activity be appealed to, for some of the most highly disturbed regions are devoid of igneous rocks. Volcanic eruptions are more probably the effect than the cause of the disturbances of the crust. Nowhere in the world therefore, it will be said, can we see strata undergoing such violent treatment as they have experienced in the past. How, then, can we dispute the inference that the forces by which the folding was produced have ceased to operate?

Before accepting a conclusion which would amount to admitting that the globe is moribund and that the forces by which land has been differentiated from sea have ceased to act, we shall do well to look more closely into the history of the earth-movements to which any particular region has been subjected. The investigation is one which calls for the most intimate knowledge of the geological structure, and, as time will admit of my dealing with a small area only, I shall confine my observations to England and Wales, selecting such facts as have been established beyond dispute.

At the outset of the investigation we find reason to conclude that the movements, so far as any one region is concerned, have been intermittent. Evidence of this fact is furnished wherever any considerable part of the geological column is laid open to view. Sheets of sediment, aggregating perhaps thousands of feet in thickness, have been laid down in conformable sequence, all bearing evidence of having been deposited in shallow seas. The inference is inevitable that that period of sedimentation was a period of uninterrupted subsidence. But sooner or later every such period came to an end. Compression and upheaval took the place of subsidence, and the strata lately deposited were plicated and brought within the reach of denudation. Illustrations of the recurrence of these movements abound, and I need dwell no further upon them than to remark that movements of subsidence and upheaval may be seen to have alternated wherever opportunity is afforded for observation.

On extending our observations we are led to infer that the movements of the crust were developed regionally, not universally. The areas of subsidence, for example, evidenced by the marine formations had their limits, though those limits did not coincide with the shores of existing seas, nor has reason been found to believe that the proportion of land to sea has varied greatly in past times. The limits of the area affected by any one movement of upheaval are more difficult to determine, but the effects were manifested in the crumpling up of comparatively narrow belts of country, and are easy of recognition.

Further than this, we ascertain that the movements of one region were not necessarily contemporaneous with those of adjoining regions. The forces operating upon the crust of the earth came into activity in different places at different times, and, while some Continental tracts have been but little disturbed from early geological times, there are parts of the globe which have been the scene, so to speak, of almost ceaseless strife. Among the latter we may include the British Isles.

These are commonplaces of geology, and I mention them merely to emphasise the fact that the geological structure of these islands is the result of movement superimposed upon movement. Obviously, therefore, in order to gain a comprehensive view of the operations which were in progress in any one region during any one epoch, we have to find some means of distinguishing the movements of that epoch and of eliminating all which preceded or followed it. This, briefly, is the problem which has engaged the attention of geologists for many years past, and upon which I propose to touch.

The determination of the age of a disturbance is seldom easy, and among the older Palæozoic rocks is often impossible; but at the close of the Carboniferous period, during the great Continental epoch which led to and followed upon the deposition of the Coal-measures, there came into action a set of movements of elevation and compression, which generally can be distinguished both from those which preceded them and from those which have been superimposed upon them. The distinction depends upon the determination of the age of the rocks affected by the movements. For example, a movement by which the latest Carboniferous rocks have been tilted from their original horizontal position is obviously post-Carboniferous. On the other hand, if Permian rocks lie undisturbed upon those tilted Carboniferous rocks, it is equally obvious that the movement was pre-Permian. Now it happens that earth-movements of the date alluded to were particularly active in the British Isles, and played an important part in shaping the platform on which the Permian and later rocks were laid down. Though they have been more completely explored than others in the working of coal, their further investigation is of the greatest economic importance. I have attempted, therefore, briefly to sketch out the principal lines along which earth-movements of that age came into operation in England, premising, however, that by Permian I mean the Magnesian Limestone series, and not the "Permian of Salopian type," which is now known to be partly of Triassic but principally of Carboniferous age. In the course of the investigation we shall find reason to conclude that several at least of the movements followed old axes of disturbance, lines of weakness dating from an early period in the history of the habitable globe; and, again, that some of the latest disturbances of which we have cognisance were but renewals of movement along the same general lines.

One of the most clearly proved examples of pre-Permian faulting in the Carboniferous rocks occurs in the Whitehaven Coalfield. The fault forms the south-eastern limit of the Coal-measures, and has been precisely located for a distance of six miles. In its course towards the south-west it passes under five outliers of Permian rocks, and finally is lost to sight under the Permian and Trias of St. Bees. The dislocation in the Carboniferous rocks amounts to about 400 yards, but the Permian rocks have not been even cracked; though broken and displaced by numerous faults of later date, they pass undisturbed over this great dislocation, the movement along it obviously having ceased before they were deposited. This fault forms part of the upheaval which brought the older rocks of Cumberland and Westmoreland to the surface, and in that sense it may be said to form the north-western frontier of the Lake District.

On the north-eastern side also of the Lake District the Permian rocks rest upon uptilted Carboniferous strata, but the axis of upheaval runs in a north-north-westerly direction and defines what we may regard as the north-eastern frontier. Along this frontier much movement has taken place in post-Permian times, but the unconformable relations of the Permian and Carboniferous rocks enable us to distinguish that part of the tilting which intervened between the two periods. On the south-eastern frontier also the Carboniferous rocks had been upheaved and denuded before the Permian sandstones were laid down. A huge fault, along which Carboniferous rocks have been jammed from the east in a multitude of plications against Silurian, runs from Kirkby Stephen by Dent to Kirkby Lonsdale, and thence trends south-eastwards by Settle. It is highly probable, though it has not been proved, that this fault is of pre-Permian age. That the Pendle axis which upheaves the Lower Carboniferous rocks between Settle and Burnley is pre-Permian is placed beyond doubt by the fact that an outlier of Permian rests upon the denuded crest of the anticline near Clitheroe.

The south-western frontier is defined by a still more marked unconformable overlap by the Permian strata, which here pass over the edges of the lowest members of the Carboniferous series and come to rest upon the Lake District rocks.

We have thus defined the sides of an oblong tract which was upheaved in the period we are considering. The older rocks forming the northern part of that tract had already had imposed upon them a dominant north-easterly strike by a pre-Carboniferous movement of great energy. As a result also of that and other movements they had been subjected to vast denudation, not only

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in the Lake District, but throughout the north-west of England generally. But while it is doubtful whether any of the physical features then produced have survived, it seems to be beyond dispute that it was in consequence of the pre-Permian movements that the older rocks of the Lake District were freed from their Carboniferous covering, and that to this extent the district may be said to have been blocked out in pre-Permian times. The detailed sculpturing resulted from later movements, with which we are not now concerned.

During this same period there rose into relief that part of the Pennine axis which runs between Lancashire and Yorkshire. The doming up of the Lower Carboniferous rocks and the wildness of the moorlands which characterise their outcrops have impressed all who have had occasion to cross from the one populous coalfield to the other, and have gained the name of the 'backbone of England' for this anticlinal axis. Whether, however, it can be regarded as one axis or as the result of several movements is doubtful, but not material for our present purpose. Regarded as a geological structure it is not continuous with that part of the Pennine axis which runs along the north-eastern frontier of the Lake District.

Passing westwards from the Pennine axis, we cross the deep and broad Triassic basin of Cheshire, which may be regarded as the complement of the dome of elevation of Derbyshire. To the west of this, again, we reach a part of North Wales which was more or less shaped out by the earth-movements which came into action between the Carboniferous and Permian periods. Two leading faults traverse the district. The one runs in a north-north-westerly direction across Denbighshire and introduces that little bit of "Cheshire in Wales" known as the Vale of Clwyd. Though there has been some later movement along this fault, it was in the main pre-Triassic, which statement, in view of the perfect conformity between the Permian and Trias, amounts to saying that it was pre-Permian. The other passes across Wales in a north-easterly direction along the Dee Valley at Bala, and reaches the Triassic basin between Chester and Wrexham. The date of this fault has not been worked out in detail, but the fact that it is associated with a pre-Triassic anticline, where it reaches the Triassic margin, proves that it is in part at least of pre-Triassic age. In Anglesey also there has been strong post-Caboniferous folding in the same north-east to south-west direction.

It is to be noticed, further, that the Carboniferous rocks maintain their characters to their margins on the flanks of the Clwydian Hills and other ranges of Silurian rocks in North Wales. Both along the coast, and even in a little outlier preserved near Corwen by an accident of faulting, they show a persistence of type and of detail in sequence which could hardly have been maintained had the Silurian uplands existed in Carboniferous times. The inference that the uplands of Denbighshire and Flintshire are the result of post-Carboniferous upheaval is strengthened by the fact that the Carboniferous rocks reposing on their flanks are tilted at an angle which would carry them over their tops. This part of North Wales, therefore, presents a history corresponding in its main events with that of the Lake District. It had undergone elevation and denudation in pre-Carboniferous times on a scale so vast that rocks showing slaty cleavage and other indications of deep-seated metamorphism had been laid bare. But in both cases it was in consequence of the post-Carboniferous movements that the leading physical features as they exist to-day began to take shape.

In both these regions pre-Carboniferous movements had been extremely active. For example, an axis of compression and upheaval ranges from north-east to south-west, involving the Lake District, the Isle of Man, and Anglesey. It belongs to the Caledonian system of disturbances which is developed on a large scale further north, and which sufficed here to cause slaty cleavage and presumably the extrusion of the Shap granite. I mention this pre-Carboniferous axis to point out that it offers an explanation of the direction taken by the post-Carboniferous disturbances of Whitehaven, Pendle, Anglesey, and possibly Bala. With the exception of the last-named they lie well within the region affected, and alone among the post-Carboniferous axes take that particular direction.

The Pennine axis ends as a particular feature in South Derbyshire and North Staffordshire on the margin of a deep channel filled with Triassic marl, which extends westwards from Nottingham into Shropshire. In this part of England there springs into existence a remarkable series of disturbances tending to radiate southwards. The westernmost of these is the great fault which forms the western boundary of the North Staffordshire Coalfield. Recent work by Mr. W. Gibson has shown that the vertical displacement of the Coal-measures amounts to no less than 900 yards, but that it is far less, though recognisable, in the Trias, proving that the disturbance was in the main pre-Triassic. The fault ranges from Macclesfield in a south-south-westerly direction, is lost to view under the Trias near Market Drayton, but is recognisable further on in the great dislocation which passes along the western side of the Wrekin, and thence through Central Shropshire by Church Stretton to Presteign in Radnorshire, and thence into Brecknock.

The second is the Apedale Fault of the North Staffordshire Coalfield. In working the coal this disturbance has been found to possess the structure of a broken monocline, a fold with fracture such as may be regarded as an early stage in the formation of an overthrust from the east. It runs through the coalfield in a direction slightly east of south, and then passing under the Trias of Stafford ranges for Wolverhampton and Stourbridge. This fault is mainly pre-Triassic, but what Mr. Gibson believes to be a continuation of it, following the same direction as far south as Hanbury, certainly effects a great movement in the Trias.

The third disturbance runs on the east of the Forest of Wyre Coalfield in a direction a little west of south. Here, as I learn from Mr. T. C. Cantrill, the thrust from the east is obvious, for Old Red Sandstone has been pushed from that direction against and even over Coal-measures, while the strata have been forced up into a vertical position for some miles. In South Staffordshire all the Carboniferous rocks, including the "Salopian Permian," are involved in this and the previously mentioned movement, proving that both disturbances were of post-Carboniferous date.

Traced southwards this disturbed belt leads to Abberley, and there connects itself with the well-known Malvernian axis. The broken belt known by that name runs north and south, and may be followed almost continuously from Worcestershire to Bristol. It presents evidence of having been a line of weakness through a large part of the world's history, as shown by Professor Groom, and of having yielded repeatedly to earth-stresses; but there is seldom difficulty in distinguishing the movements which were effected during the period under consideration. For example, near and south of Abberley the Coal-measures are clearly involved in a thrust from the east, which was sufficiently energetic to turn over a great belt of Old Red Sandstone and other rocks beyond verticality for some miles. Further south, again, among repeated proofs of the ridging up of the old axis in several pre-Carboniferous periods, we find evidence of post-Carboniferous elevation along the same general line. Throughout this same region there has been also post-Triassic dislocation, which, however, is on a comparatively small scale. That the Carboniferous rocks were greatly disturbed before the Trias was laid down is proved by the great unconformity between the two formations.

The Malvernian axis continues southward by Newent, but perhaps with diminishing intensity. On its west side a broad syncline rolls in the tract of Carboniferous rocks which underlies the Forest of Dean. The syncline trends north and south, and is shown to be of pre-Triassic age by the fact that the Triassic strata on the banks of the Severn do not share in the synclinal structure. Here we must leave the Malvernian axis for the present.

The fourth disturbance ranges along the Lickey Hills, which, diminutive as they are, tell a story of great geological significance, They range in a south-south-easterly direction, and in the fact that they are formed of extremely ancient rocks furnish evidence of immense upheaval. From the relations of these ancient formations to one another we may gather also that the upheaval was due to a recurrence of movement along the same axis at more than one geological date, but at the same time we find no difficulty in distinguishing that part of the movement which took place between Carboniferous and Triassic times, for the Coal-measures are tilted up on end along the flanks of the axis, while the Trias passes horizontally over all the tilted rocks. A clue to the southward extension of the axis under the Secondary rocks is furnished by some faulting as far as Redditch, here also there having been a renewal of movement on a small scale in post-Triassic times.

The fifth disturbance runs through Warwickshire, and includes the low ridge of ancient rocks which ranges through Atherstone and Nuneaton in a south-easterly direction. About fifteen miles to the north-east Archæan rocks form the parallel ridge or series

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of ridges of Charnwood Forest, while the intervening space is overspread by Trias, resting partly on Carboniferous and partly on older strata. The structure of the Carboniferous and older strata is dominated by what is known as the Charnian movement, which includes disturbances of several ages ranging in a south-easterly direction. That part of the movement which was post-Carboniferous is identifiable by the fact that Coal-measures are tilted on either side of the ridges of old rocks. They once overspread both ridges, but were removed by denudation as a consequence of upheaval before the Trias was deposited. It has been found also in working the coal, as I am informed by Mr. Strangways, that there are large faults having the south-eastward or Charnian direction which shift the Coal-measures, but do not break through the overlying Trias. The evidence, therefore, of a great Charnian movement having taken place during the period under consideration is conclusive. The disturbance ranges as a whole in the direction of Northampton, where, in fact, borings have reached the Charnwood rocks at no great depth.

The five great disturbances which I have briefly indicated tend to converge northwards, but their exact connection with the Pennine axis is not known. What may be only a part of that axis trends for Charnwood through a tract of Lower Carboniferous rocks exposed at Melbourne, between the Yorkshire and Leicestershire Coalfields, but the Triassic channel I have already mentioned intervenes, and the structure of the rocks underlying the red marl is unknown. The channel itself appears to be of Triassic age, for not only is the depth of marl in it suggestive of its having been a strait in the Triassic waters, but its northern margin has been found by Mr. Gibson to coincide with, and perhaps to have been determined by, faults known to be mainly of pre-Triassic age. One of these, with a downthrow of 400 yards to the south, runs from Trentham through Longton, and south of Cheadle, while another ranges from near Nottingham to the north of Derby.

We come now to the south-west of England, where we find striking proofs of a still more energetic movement than any yet mentioned having intervened between the Carboniferous and Triassic periods. The central part of the Armorican axis, as it has been called, after the ancient name of Brittany, trends nearly east and west, and keeps to the south of our South Coast; but we have opportunities in Devon and Cornwall of seeing some of the stupendous effects produced along its northern side. A belt of country measuring some 130 miles in width has been completely buckled up. Slaty cleavage was superimposed upon the intricate folds into which the strata were being thrown, while after or towards the close of these phenomena granite was extruded at several points along the belt of disturbance, a little north, however, of the line along which the oldest rocks were brought up to the surface. In Devon the Culm-measures are fully involved in the movement, but on the other hand the Permian strata, while containing fragments of the cleaved and metamorphosed rocks, are themselves wholly free from such structures. The age of the folding, cleavage, and extrusion of the granite is thus definitely fixed as having been subsequent to the deposition of the Culm-measures, but previous to that of the Permian rocks.

But we may fix the age still more closely. A broad syncline of Carboniferous rocks traverses Mid-Devon, and is succeeded northwards by an anticline and by an extrusion of granite at Lundy Island, the age of which, however, has not yet been definitely ascertained. Still further north in a series of folds and overthrusts which traverse the southern margin of South Wales we can recognise the last effects of the great Devonshire movement at a distance of not less than 130 miles from the central axis, the ground-swell, so to speak, subsiding as it receded from the distant storm-area. Here the higher Carboniferous rocks are involved, and thus prove that this part at least of the Armorican disturbance was of post-Carboniferous age.

In Dorset, Somerset, and Gloucestershire the Palæozoic rocks pass eastwards under Secondary formations, and are seen no more in the south of England. That the disturbance continues, however, is inferred from the fact that it has been traced across a large part of the continent of Europe in the one direction and across the south of Ireland in the other. The determination of its position therefore, and especially of the effects of its intersection with the Midland disturbances, is of the greatest importance in view of the possible occurrence of concealed coalfields under the Secondary rocks. One such intersection is open to observation.

The Malvern and Devonshire disturbances intersect in Somerset. On investigating their behaviour as they approach we may notice in the first place that the subsidiary axes which form the northernmost part of the Devonshire disturbance in South Wales die away one after the other towards the east. Thus an east and west disturbance at Llanelly runs a few miles and disappears. The more important Pontypridd anticline, which traverses the centre of the coalfield, fades away near Caerphilly, while the coalfield itself terminates a little further east, its place on the same line of latitude being taken by the Usk anticline, which trends southwards and south-westwards. So far it might be inferred that the east and west folds die away on approaching the north and south Malvernian axis. But the Cardiff anticline, which lies south of and was more energetic than those mentioned, crosses the Bristol Channel and, emerging on the other side in a complicated region near Clevedon and Portishead, passes to the north of Bristol and holds its course right across the coalfield at Mangotsfield. The coalfield, however, lies in what is part of the Malvernian disturbance, for it occupies a syncline running north and south along the west side of the main axis of the upheaval. Though the interruption is local and the strata recover their north and south strike to the south of it, yet the east and west axis obviously holds its course right through the Malvernian structure.

Still further south, in the direction in which the east and west movements gradually increase in energy, a series of sharp folds is

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well displayed in the coast of South Wales and in an island in the Bristol Channel, ranging for that part of the east and west disturbance which is known as the Mendip axis. This name has been applied to a series of short anticlines which are arranged *en échelon* along a line ranging east-south-east, but each of which runs east and west. Among them we may distinguish the Blackdown anticline, the Priddy anticline, the Penhill anticline, north of Wells, and the Downhead anticline, north of Shepton Mallet. With one exception they all die out eastwards after a course of two to ten miles, but the Downhead anticline holds its course into the Malvernian disturbance, the two engaging in a prodigious *mêlée* south of Radstock. From that much shattered region the Downhead anticline emerges, but the Malvernian axis is seen no more, and, so far as can be judged under the blanket of Secondary rocks, comes to an end.

Mention has been made of the fact that many of the subsidiary east and west folds die away on approaching the Malvernian axis. In a general way we may attribute their disappearance to the influence of the north and south movement, for it is commonly to be observed in these great belts of disturbance that they are composed of a number of parallel anticlines or elongated domes of upheaval, constantly replacing one another; it is a common feature also that these subsidiary folds replace one another not exactly in the direction in which they point, but that they lie *en échelon* along a line slightly oblique to it. The behaviour of the South Wales and Mendip folds is in accordance with these observations, and may be taken to indicate that the effects of the east and west disturbance reached further north in South Wales than they did in Somerset, or, in other words, that they failed to penetrate as far into the region where north and south movements were in progress as in the region where there were no movements in that direction.

The fact that the east and west folds keep their course across the north and south wherever the two actually meet comes out prominently, and supports the inference that they dominate the structure of the Palæozoic rocks which lie hidden beneath the Secondary rocks of the south and south-east of England. Somewhere under this blanket of later formations the east and west axis presumably intersects the other disturbances which traverse the Midlands. To ascertain where and how the intersections takes place will be going far towards locating any concealed coalfields which may exist; but the knowledge can be obtained only by boring, and the number of such explorations as yet made is wholly insufficient. The majority have been made in search of water, and have been stopped as soon as a supply was secured. Near Northampton the older rocks were reached at a small depth on what is believed to be the underground continuation of the Charnian axis, and a boring at Bletchley traversed what is thought to have been a great boulder of Charnian rock, suggesting that the axis is not far off; but with these exceptions the counties of Oxford, Buckingham, Bedford, Huntingdon, Cambridge, and Norfolk are unknown ground. Yet under these counties the axes must run

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if they keep their course. Where exposed at the surface each post-Carboniferous syncline between two axes contains a coalfield. It remains to future exploration to ascertain whether similar conditions hold good under the Oolitic and Cretaceous areas of Central England.

In speaking of the north and south disturbances I have in more than one case stated that the post-Carboniferous movement was but a renewal of activity along an old line of disturbance. The fact is proved by the unconformities visible among the pre-Carboniferous rocks, and it is important for the reason that the geography of this part of the globe at the commencement of the Carboniferous period had been determined by these movements. It has long been known, for example, that the parts of the counties of Stafford, Warwick, and Leicester traversed by the axes of upheaval were not submerged till late in the Carboniferous period. On the other hand, some of the area lying immediately west of the Malvernian axis was submerged at an earlier date, as is shown by the existence of Carboniferous Limestone at Cleobury Mortimer and, in greater development, in the Forest of Dean. The borings near Northampton also proved the presence of Carboniferous Limestone, a fact which is in favour of the occurrence of concealed coalfields, in so far as it indicates that the whole Carboniferous series may have once existed there. It is remarkable that none of the borings in the south and east of England have touched Carboniferous Limestone, all having passed into older or newer rocks. The existence of that formation is neither proved nor disproved.

The determination of the age of these disturbances and a discussion of the pre-Carboniferous geography may seem at first sight to be only of scientific interest, but that problems of great economic importance are involved has been shown recently. It has long been known that the principal coal-seam of South Staffordshire deteriorates westwards as it approaches the pre-Carboniferous ridge evidenced in the neighbourhood of Wyre Forest. There seemed, however, to be no theoretical reasons why it should not keep its characters on either side of the fault which forms the western boundary of the South Staffordshire Coalfield, inasmuch as that fault came into existence after the deposition of the Coal-measures. A shaft recently sunk has proved the correctness of the inference. The seam has been found to be well developed to the west of the fault, and a considerable addition has been made to our productive coalfields.

So much has been written about the range of the Devonshire disturbance under the south of England that I shall add no more than a brief comment on some of the evidence on which reliance has been placed. We have seen that there has been some post-Triassic movement along old lines of disturbance in North Wales and the Midlands and along the Malvern axis. It is suggestive, therefore, to find that in the region which we believe to be underlain by the east and west disturbance east and west folding forms the dominant structure of the Secondary and Tertiary rocks.

The anticlines of the Vales of Pewsey and Wardour, the London syncline, the Wealden anticline, the Hampshire syncline, and the

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anticline of the Isles of Wight and Purbeck, not only lie in the range of the axis, but show an increasing intensity southwards, towards what we may suppose to have been the most active part of that axis. A similar structure prevails in the Oolitic rocks also. They too had been thrown into east and west folds before the Cretaceous period, and this earlier set of movements also grew in intensity towards the south. It would seem, then, at first sight that the structure of the later rocks gives an easy clue to the structure of the older rocks buried beneath them. This is by no means the case. That the movements manifested in the Oolitic and Cretaceous rocks followed the same general line as the older movement admits of little doubt, but that the later structures correspond in detail with the earlier is improbable.

A brief examination of the region where the Carboniferous rocks disappear under the Secondary formations will give the grounds for this statement. There we find that the Trias passes over the complicated flexures of the Mendip axis in undulations so gentle as to prove that those flexures had been completed before it was deposited. Nor, again, do the members of the Oolitic group of the rocks cropping out in succession further east show any such folds as those visible in the Carboniferous, and it is not till we have passed over a considerable tract of Secondary rocks in which there are no signs of east and west folding that we reach the anticlines of the Vales of Pewsey and Wardour. Nor can we then fit these folds in the Cretaceous formation on to any visible axes in the Carboniferous rocks. Under these circumstances it would be unjust to suppose that such synclines and anticlines as those of the London and Hampshire basins, or of the Weald, coincide with previously formed synclines and anticlines in the older rocks. They give a clue to the position of the old axis, but not necessarily to the details of its structure. Yet it is upon the determination of the position of the older anticlines and synclines, and of their intersection with the north and south disturbances, that we must depend for locating concealed coalfields. So far but little has been done in the forty-eight years since the question was first mooted by Godwin-Austen. The existence of a coalfield in Kent has been proved, and what appears to be a prolongation of a disturbance from the Pas de Calais along the south-western side of it. The other borings which have reached the Palæozoic floor round London and at Harwich have thrown but little light on the details of its structure. By far the greater part of the ground remains yet to be explored.

In this brief review of the earth-movements of one period, as manifested in one small part of the globe, we have found reason to conclude that they were the result of compression and upheaval; that the crust yielded to the compression by overthrusting and buckling along certain belts; that these belts in the north of England and the Midlands ran for the most part north and south, diverging, however, to the south-west and to the south-east, while in the south of England they took an east and west direction and concentrated themselves along a belt of country which presents the phenomena of crushing on a stupendous scale. We have touched in two cases the flanks of a mountain-range, the Caledonian, which was built and ruined before the Carboniferous period; the Armorican, which was built after that period, and which, though it has stirred so recently as the late Tertiary period, and so energetically as to initiate the physical features and river-system of the south of England, yet expended the greater part of its energy before the Permian period. Lastly, we have found evidence, in the majority of cases, that the disturbances were but renewals of movement along lines of weakness long before established, and that in several cases there has been further renewal along the same lines during successive periods later than the one we have considered. With such a history before us, and with the knowledge that mountain-ranges have been built in other parts of the world by the upheaval of strata of almost recent date, we have more cause to wonder that the internal forces have left this quarter of the globe alone for so long, than reason to believe that they have ceased to exist. Changes of level, however, have taken place in comparatively recent times, and are now in progress. Though almost imperceptibly slow, they serve to remind us that a giant lies sleeping under our feet who has stretched his limbs in the past, and will stretch them again in the future. Nor in view of the fact that the structures I have described have only been revealed by the denudation of vast masses of strata does it seem unreasonable to suppose that they are deep-seated phenomena. The slow changes of level may be the outward manifestation of more complicated movements being in progress at a depth.

It is interesting to speculate on what appearance the globe would have presented had it not been enveloped in an atmosphere and covered for the most part with water. Owing to those circumstances it possesses the power of healing old wounds and burying old scars. In their absence we may suppose that the belts of crushing and buckling would have given rise to ridges growing in size at every renewal of movement, for they would have been neither levelled by denudation nor smoothed over by sedimentation. This globe, we may suppose, would have appeared to the inhabitants of another planet as being encompassed in a network, and we are prompted to ask whether our astronomers can distinguish in any other planet markings that may be attributable to this cause. I must remind you, however, how much more remains to be done than I have been able to touch upon to-day. The map (exhibited) represents one episode only in a long series of events, and a series of such maps would be required to illustrate the first appearance of lines of weakness in the earth's crust, the subsequent renewals of movement along those lines, and the formation of new lines in successive geological periods. With the case thus set out we shall be justified in appealing to the physicists for an explanation of the restlessness of this globe.

II.—Short Notices.

1. South African Geology.—Dr. F. H. Hatch extends our knowledge of the geology of the Transvaal by describing in Trans. Geol. Soc. South Africa (vii, 1904) the Marico district. This is stated to be a great syncline formed by the Pretoria beds, the Dolomite and Black Reef Formations, and the underlying Ventersdorp beds. Dr. Hatch describes the interesting igneous complex to which reference has been made by Molengraaff under the name of the "Plutonic Series of the Bush Veld." In this complex the great development of pyroxenite with associated peridotites would appear to constitute an outer ultra-basic zone. For, as one travels eastwards, one traverses successively zones of a more and more acid type, until rocks are reached in which quartz plays the predominant *rôle*. A rough map attached to the paper explains this succession.

Dr. Corstorphine, in dealing with the Central South African Coalfield (Trans. Geol. Soc. South Africa, vi), considers that the coal of Vereeniging and that of the Orange River Colony, as well as that of the Eastern Transvaal and the neighbouring portion of Natal, is of Ecca Age. Molengraaff (ibid.) concludes that the remarkable tectonics of the Vredefort mountain-land have been caused by the intrusion of a huge granite boss, the Vredefort granite, which phenomenon took place after the deposition of the rocks of the Cape System (Black Reef series, Dolomite series, and Pretoria, or Gatsrand, series), and before the deposition of the strata of the Karroo System; and in the discussion which followed, Hatch said he agreed, and that Molengraaff was also probably correct with regard to the overtilting of the Witwatersrand beds.

J. P. Johnson has described (ibid.) some implement-bearing gravels in the neighbourhood of Johannesburg. These show facies of true Eoliths, Palæoliths, and Neoliths, as compared with European examples, and the author comes to the conclusion that the Bezuidenhont Valley drift must be much newer than the hill-drift of Rordekop, and that the close of the Neogene era in South Africa saw much the same evolution in the culture of its stone-age as did that of the Thames basin and the rest of Britain and Western Europe, and that such progress must have taken an approximately equal length of time.

J. Kuntz (ibid.) gives an interesting example of the pseudomorphosis of quartz pebbles into calcite. T. N. Leslie, in reviewing the fossil flora of Vereeniging, carefully points out the many errors that have occurred in recording various plants from these beds, and gives Seward's final list of plants as showing the Permo-Carboniferous age of these plants as compared with those of India and South America.

The Annual Reports for 1901 and 1902 of the Geological Commission of the Cape of Good Hope provide much matter of special interest. Messrs. Rogers and Schwarz report on a journey from Swellendam to Mount Bay, on a general survey of the rocks in the southern part of the Transkei and Pondoland, including a description of the Cretaceous rock of Eastern Pondoland, and on a geological survey of the Kentani division. The shells and bones in the Cretaceous appear to be rolled and rounded in the lowest beds. The bones include those of Chelonia, and a lower jaw resembling that of *Mosasaurus*, while sharks' teeth also occur. Further reports by the same authors deal with the Matatiele division, with an account of the petrography of the volcanic rocks, and on the divisions of Beaufort West, Prince Albert, and Sutherland. The authors propose a slightly different classification of the Karroo System, in that they separate the Dwyka series from the Ecca.

2. CEYLON.—The Report of the Director of the Mineralogical Survey of Ceylon Administration Reports, 1903, pt. iv (Miscellaneous), has just reached us. The Mineralogical Survey was established in the latter part of 1902 for three years, the objects being an examination of the occurrence of economic minerals in the island with a view to their further development and the preparation of a report descriptive of the mineral resources, as well as the arrangement of the geological collections in the Museum and the accumulation of further specimens, a duplicate series being reserved for exhibition at the Imperial Institute. A separate guide to the geological collections is to be ultimately prepared.

The staff consists of a Director, A. K. Coomáraswámy, an assistant director, James Parsons, an office peon, two overseers, a 'collector' (*sic*), and eight coolies. The staff is sanguine enough to suggest that 1,000 square miles can be superficially surveyed in the course of a year. Perhaps we under-estimate the capacity of the peon.

The greater part of Ceylon consists of ancient crystalline rocks, granulites, or, in a wide sense, gneisses, which belong to the Charnockite series. Mica seems to be the most important economic mineral in the area reported upon, and includes muscovite, biotite, and phlogopite, of which the latter is of chief commercial importance. Graphite, the most important of all the mineral resources of the island, is chiefly distributed in areas outside the range of this report, but sketches of several mines are given. Working, however, depends on the price of the graphite, which is at present low. Iron is the only metal treated of. The precious stones mentioned are Corundum, Moonstone and Garnet, and the other mineral mentioned is Pitchblende (Uraninite), but a footnote states that the materials from Bambarbotuwa and Gampola are probably not Uraninite but a new mineral, whose detailed composition is not yet certain. Mr. Coomáraswámy does not believe in the reported discoveries of Cinnabar, he thinks Sindurankanda was 'salted,' and that there is no geological probability of there being ore of mercury at Kotte.

The arrangement of the Museum goes on slowly but surely, and the Director asks for a special grant to enable him to secure and exhibit a representative collection of gems.

3. *EUCERATHERIUM.*—This is a singular quaternary ungulate found by W. J. Sinclair and E. L. Furlong in the caves of the Shasta country, California. Its affinities are not clear. It may be placed in the Ovinæ, but cannot be regarded as intimately related to any existing North American member of that group. The cranium is larger than in the big-horn sheep, while the horn-cores are smaller, are situated much further behind the orbits, and differ greatly in form and curvature. Although there is a resemblance to *Ovibos* in dental structure, the horn-cores are of an entirely different type. A relationship with the cattle is excluded by fundamental differences in dental structure. It is separated from the goats by the presence of a lachrymal pit. This character serves to distinguish *Euceratherium* from *Haplocerus*, from which it differs also in greater size, in the shape and position of the horn-cores, and in the exclusion of the parietal from the cranial roof. The description and plates appear in Bull. Geol. Univ. California Publications, iii, 1904.

4. GEOLOGY UNDER THE PLANETESIMAL HYPOTHESIS OF EARTH-ORIGIN.—In the Bull. Geol. Soc. Amer. (xv, 1904) H. L. Fairchild discusses the bearings on several problems in geology of the new hypothesis of earth-origin recently formulated by T. C. Chamberlin. This hypothesis will shortly be printed in full in a new text-book by T. C. Chamberlin and R. D. Salisbury. Its comparison with the nebular theory is thus given by Fairchild: "The old hypothesis assumes the existence of a mass of incandescent vapour, with or without a nucleus, which by condensation and rotation was differentiated into successive rings, the latter being eventually gathered into the planets while still retaining intense heat. From this postulate there necessarily follows the conception of a cooling earth, and hypogeic geology has been founded on the idea of crustal solidification on a molten globe. The new hypothesis holds that the disseminated planet-forming matter had lost its heat while yet existing in the loose form, as rings or wisps of the parent nebula, and that the globular planets were formed by the slow accretion or infalling of cold discrete bodies or particles ('planetesimals').

"The old hypothesis assumes an originally hot globe with shrinking on account of cooling. The new regards the globe as originally and always cold at the surface, and the interior heat as the product of gravitational condensation. The old view requires continuous cooling of the globe, while the new allows the conception of increasing internal heat. The old hypothesis makes the earth of largest size at birth and of constantly diminishing volume. The new regards the earth as beginning with a small nucleus and slowly growing by surface accretion, but with large reduction of volume by compression during and subsequent to the accretionary process. The old hypothesis involves the recognition of a primal heated atmosphere and ocean consisting of the more volatile substances of the earth's mass. The new derives the present fluid envelopes from the earth's interior by a slow process of expulsion due to pressure and heat."

Having thus distinguished the new theory from the old, Fairchild discusses on the new basis the following points:—Origin of the atmosphere and ocean; earliest sedimentary rocks; volcanic phenomena; source of the hydrocarbons; genesis of metalliferous deposits; origin of gypsum and salt; climates; glaciation; diastrophic movements; irregularities of the earth's figure; and life on the earth.

5. The Frank Landslip.—The Department of the Interior of the Dominion of Canada, in their Annual Report for 1903, has issued a report on the disastrous landslide at Frank, by Messrs. R. G. McConnell and R. W. Brock. Turtle Mountain, the eastern face of which gave way on 29th April, 1903, consists of Devonian Limestones resting on Cretaceous shales and sandstones. The Devonian beds dip to the west at an average angle of 50°. The fall occurred about 4.10 a.m., and consisted of a mass of rock half a mile square, and 400 to 500 feet thick. The mass broke across the bedding planes almost at right angles, and therefore the slide falls under Balzer's heading of 'Bergstürtz,' of which it is a typical example. The mass appears to have been shattered into fragments during its descent, and the material seems to have travelled by a succession of great leaps, or ricochets, rather than by a true slide. The bulk of the fallen mass is calculated at nearly 36,000,000 cubic yards, equal in weight to some 80,000,000 tons. The primary cause of the breaking away of the mass from Turtle Mountain is to be found in the structure and condition of the mountain itself. It was ripe for a slide. The steep slopes, the shattered and fractured nature of the rocks, particularly of the basal beds of the limestone series, overlying a thrust-fault, coupled with unusually heavy precipitation, are causes which in themselves are quite sufficient to have produced the slide, and, unaided, the loosened masses would sooner or later have fallen. The report points out the probability of further slides in the same area, and advises the inhabitants of Frank to move up the valley.

REVIEWS.

I. — On some Additional Fossils from the Vancouver Cretaceous, with a Revised List of the Species therefrom. By J. F. Whiteaves, LL.D., F.G.S., etc. Geological Survey of Canada, part v, pp. 309–416, pls. 40–51. (Ottawa, August, 1903.)

THIS is the concluding part of the first volume of illustrated reports upon the Cretaceous fossils from the Queen Charlotte and Vancouver Islands, the first part of which appeared in 1876. It deals more particularly with the fossils which have been obtained from Vancouver and the adjacent islands since 1879. The rocks containing these fossils were named the Nanaimo group by the late Dr. Dawson, and, as now understood, this group appears to be the equivalent, not only of the Chico group of California, but also