PROCEEDINGS

OF THE

GEOLOGICAL AND POLYTECHNIC

SOCIETY

OF THE

WEST RIDING OF YORKSHIRE,

1871—1877.

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PAPERS

READ BEFORE THE

Geological and Polytechnic Society

OF THE

WEST RIDING OF YORKSHIRE

AND

MINUTES OF THE PROCEEDINGS

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Of the West Riding of Yorkshire.

1871–72.

ON FURTHER DISCOVERIES OF FLINT TOOLS IN HERTFORDSHIRE AND SUSSEX. BY JOHN FFOOKS.

[PUBLICATION DEFERRED.]

ON CONTORTION OF ROCKS. BY L. C. MIALL, CURATOR OF THE LEEDS PHILOSOPHICAL AND LITERARY SOCIETY.

IN a previous communication to this Society I endeavoured to describe the remarkable anticlinals of Skipton and Draughton, which are perhaps the most striking features of the geology of South Craven. The geological relations of these disturbed tracts were discussed on that occasion, and I do not propose to refer to them now. But the most interesting problem connected with these contorted rocks is the circumstance that they are bent so sharply without fracture. On this subject I formerly offered a few remarks, and cited some incomplete experiments. During the last three years these experiments have been continued, and the most important results are here presented.

The photographs now exhibited shew the contorted limestone beds in Draughton quarry. You will see that solid layers of rock, a foot or two in thickness, have been bent into the figure of an inverted W. The angles are sharp, but unbroken. You may easily test this on the ground by passing a finger over the apex of one of the bends. There is neither crack nor vein.

I propose now to consider how this phenomenon can have been produced, and under what conditions rocks once hard and horizontally laid can be bent to an acute angle without fracture.

Forty years ago it would have seemed natural to invoke a volcanic eruption acting upon plastic matter—to regard such folds and contortions as due to the formation or elevation of a kind of blister upon the earth's surface. But thanks to a few experimental inquirers, such as Sorby, Hodgkinson and Tyndall, a number of plausible suppositions have been swept away as fallacies. In 1867 the geologist looked rather to lateral pressure (due possibly to contraction of the figure of the earth) as most probably the force concerned, and he did not find it necessary to suppose that the distorted rocks had ever been plastic. It is true that Sir James Hall assumed that the rocks of Berwickshire were ductile when contorted, and Dr. Edward Hitchcock, a well-known American geologist, had recently maintained that some contorted pebbles in a conglomerate at Newport, Rhode Island, must have been as plastic as moist clay when they were bent and twisted. But this gratuitous assumption was soon disposed of. There were a few fossils in the Draughton limestone, and these were distorted like the rest of the rock.

This seemed to prove that plasticity was not a necessary condition of contortion. The shells and corals had surely not been plastic. Indeed the matrix itself may well have been compact rock from the time of its deposition, growing by the addition of hard lumps and shells and films of stony calcareous matter.

A rigid body compressed without fracture into the figure of W—was this possible? There is, as I afterwards discovered, a source of error in the word "rigid"—a latent hypothesis which turns out to be erroneous. "Rigid" is purely a relative term. Stone is rigid in comparison with clay, but plastic in comparison with cast steel. Absolute rigidity is an unknown property of matter. Let us select a few examples of what are commonly regarded as rigid bodies. Rock crystal, glass, calc spar, steel and limestone, are surely fair specimens. Yet Tyndall gives instances of quartz crystals altered in shape by pressure, some of them having yielded along transverse planes as if one half had slidden over the other, but subsequently strongly cemented together by mere apposition and pressure. He regards the action of strongly compressed glass upon polarized light as proof of an alteration in its molecular arrangement. Mr. Sorby has cited examples of distorted crystals of calc spar in cleaved limestones. M. Tresca, in his paper on the "Flow of Solids," read before the Institution of Mechanical Engineers at Paris in 1867, gives the results of experiments made upon lead, iron, and even steel, and shows that these metals behave like liquids when subjected to adequate pressures. As to limestones and other rocks, I can say from my own experiments that they are both elastic and plastic, yielding more or less to forces of short duration, but recovering their original figure; while when subjected to long-continued pressures or strains of low intensity, they are capable of setting permanently in a new shape.

It is curious to observe how speculation has been misled by the notion of absolutely rigid bodies, by the assumption that hard rock can exhibit neither an appreciable elasticity nor any ductile properties. Sir James Hall, of Dunglass, whom Professor Geikie has lately styled "the founder of Experimental Geology, since it was he who first brought geological speculation to the test of actual physical experiment," investigated the subject of contortion with much care. The curved strata of the Berwickshire coast had engaged his attention since the year 1788. In 1814 appeared his remarks on "The Convolutions of Strata and their meeting with Granite."* In this interesting paper he describes the local phenomena with some minuteness, and then gives the "rude experiment" contrived to imitate the conditions which he supposed to have obtained in nature:—

"Several pieces of cloth, some linen, some woollen, were spread upon a table, one above the other, each piece representing a single stratum; a door (which happened to be off the hinges) was then laid above the mass, and being loaded with weights, confined it under a considerable pressure. Two boards being next applied vertically to the two ends of the stratified mass, were forced towards each other by repeated blows of a mallet applied horizontally. The consequence was, that the extremities were brought nearer to each other, the heavy door was gradually raised, and the strata were constrained to assume folds, bent up and down, which very much resembled the convoluted beds of killas, as exhibited in the crags of Fast Castle, and illustrated the theory of their formation.

"I now exhibit to the Society a machine by which a set of pliable beds of clay are pressed together, so as to produce the same general effect; and I trust that the forms thus obtained, will be found, by gentlemen accustomed to see such rocks, to bear a tolerable resemblance to those of nature."

The positions which we may now consider to have been established by Sir James Hall's experiments and reflections are these: That strata originally horizontal have been curved and folded; and that the disturbing force has acted in a horizontal direction. His further decision that the force

* "Transactions Royal Society Edinburgh," vol. vii. pt. 1.

concerned is necessarily volcanic may be questioned. The absence of superficial traces of volcanic agency over large areas of contorted strata—the limestone district of Craven, for example—is not easily reconciled with the views derived by Hall from his instructor, Hutton. We must also emphatically dissent from his tacit assumption that the contorted rocks must have been "in a soft but tough and ductile state." Distorted fossils, crystals and pebbles cannot well have been soft when they were pinched and bent out of shape. Nor need we assume such a condition during the formation of ordinary curved strata. The mechanical properties of limestones and other rocks, dry and at ordinary temperatures, are such as in themselves satisfy the conditions of the problem.

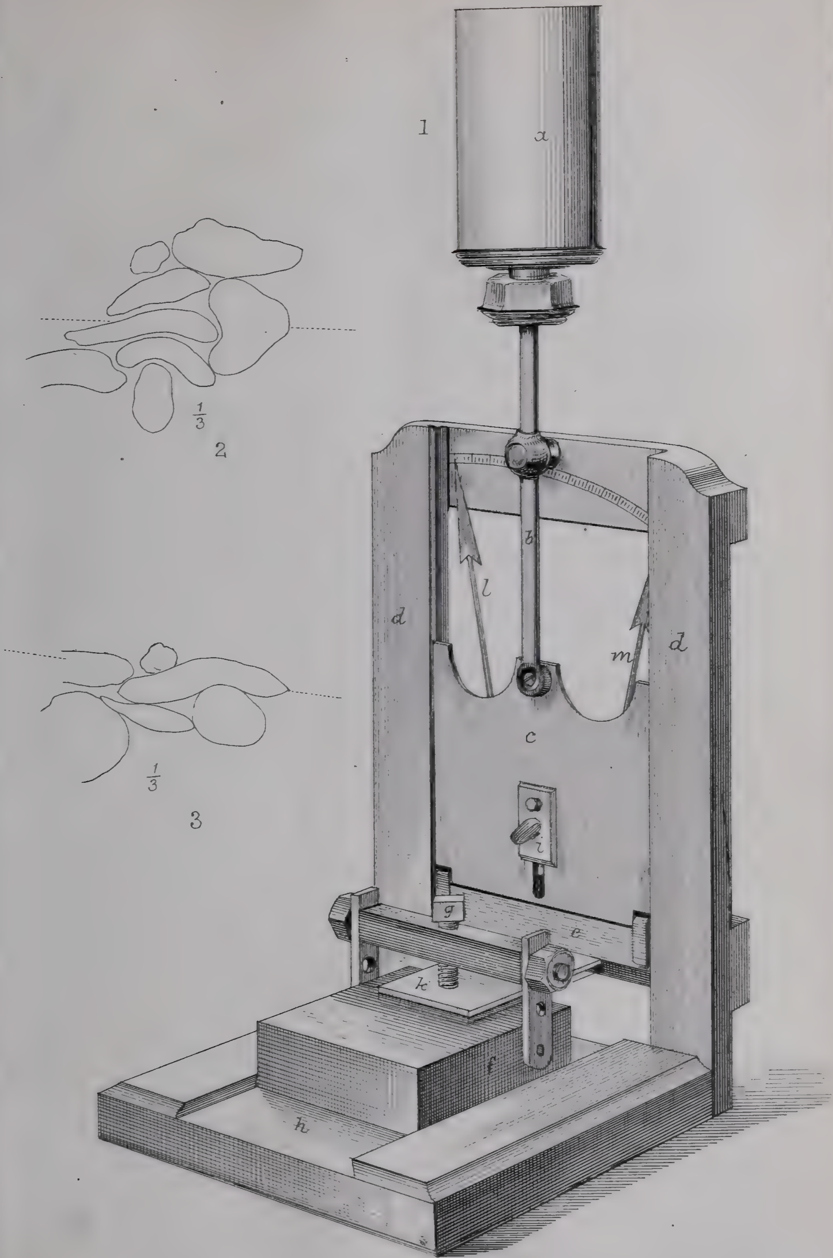
In 1866 I began some simple experiments, taking up the points that had been disregarded by Hall. First of all, I took a thin slab of marble and placed it on the edge of a mantelpiece, so that the end projected. A few books kept the slab in its place, and then I placed a letter weight of one ounce on the free end and left it for some weeks. On testing it by a straight edge it was found to be deflected to a trifling extent. Other plates of different materials, two or three inches long and as thin as possible, were next procured and subjected to the same treatment. But no accurate results were obtained, and the form of the experiment was inconvenient.

Subsequently I tried an improved plan. Two wooden slabs, ten inches by four, were fitted together by a hinge so that they could be set at any angle from 0° to 180°, just as you might open a book, keeping the letterpress always downwards. One slab was screwed to the table, the other could be adjusted at pleasure. The angle made by the two surfaces was indicated by a graduated semicircle. Upon the ridge various thin plates of stone were placed and attached at one end to the fixed slab by heavy weights. The other end of the plate of rock, projecting over, but not at first in contact with the moveable slab of wood, was lightly weighted and allowed time for bending. The angle of sudden fracture could be obtained by setting the machine at a low angle and forcibly bending down the lamina of rock until it touched both surfaces. If it yielded thus far, the angle was slightly increased and the experiment was repeated.

This apparatus had some advantages but many defects. The most serious was that the pressure exerted at any time was difficult to estimate. A weight placed upon a surface of gradually increasing inclination exerts a diminishing pressure which changes appreciably even at angles of 3° or 4°. It was difficult to read the small deflections obtained with any accuracy, and the apparatus was liable to disturbance and accident.

At length I tried the machine represented in the Plate.* Here a thin plate of limestone or other rock is screwed down to a block *f* travelling in a horizontal groove *h*. Upon this descends a vertical plate *c*, terminating in a hinged knife-edge *e*. We get in this way pressure applied always to the same line upon the lamina of rock, for when deflection begins the knife-edge inclines forwards out of the perpendicular at its lower edge without sliding over the rock specimen. By pushing the block *f* along the groove *h* perpendicularity is restored. An index *m* connected with *e* makes any deviation more apparent. When a piece of rock is to be tested, shot is poured into the cylinder *a*, which is in direct communication with the vertical plate *c*, and the pressure is taken by a steelyard or balance. The index *l* is set at zero by the screw *i*, and its motion along the graduated scale enables the observer to record with precision a deflection of less than

* For the construction of this machine, and for many useful suggestions, I am indebted to Mr. Thomas Prince, of Bradford.



Apparatus for shewing Rock contortion.

·01 in. If in adjusting the knife-edge the index is displaced, it can be restored by this screw independently of other parts of the machine.

With this apparatus I began a long series of observations on limestone. Thin plates of various thickness from ·1 to ·05 in. were subjected to low but protracted pressures. Experience taught the best form of plate and the time required to produce a given result. I succeeded in one case in bending a plate ·07 in. in thickness to an angle (reckoned as rectilinear) of 12°. This took three months to accomplish. On removal from the machine the plate cracked near the apex of the angle of deflection in three days, or I should have operated upon it again. The pressure was applied so gently and uniformly that sudden fracture seldom occurred except when intentionally produced. The bent slabs were, however, very fragile, and could seldom be kept many days after released from strain, cracks slowly extending themselves transversely across the part where the deflection was greatest. From this circumstance, which caused much annoyance at the time, some useful lessons were learned. Details of the experiments with limestone have already appeared.* It will now suffice to say that thin plates of mountain limestone (especially a certain bituminous kind, occurring in thin beds with partings of shale) proved indefinitely plastic. The elasticity of the rock was greater than I had expected, but the set or permanent deflection produced by long-continued pressures of inconsiderable amount far exceeded what I had hoped to find. It may be doubted whether there is any limit to the bending which a careful and patient observer can produce. I found that magnesian limestones, while usually much more elastic than specimens of pure carbonate of lime, were slightly more plastic. The two properties are not connected in any direct or inverse ratio that I can discover. Some of the

* "British Association Report," 1869; "Geological Magazine," November, 1869.

"flexible limestones" are very difficult to bend permanently. One specimen exhibited for many years in a public museum, with the two ends supported and the centre slightly depressed to show its flexibility, does not present any visible deflection when placed on its edge.

Thin natural laminæ of flagstone from the coal measures were also tried. Various specimens were selected according to their texture and mineralogical character, but none yielded important results. It will be seen further on from other evidence that considerable deflection has been unintentionally produced in these flagstones, but as yet I have never succeeded in bending thin plates more than 8′. Slates of various kinds have also proved very intractable, an interesting and not unexpected result. No material has yet done so well in my hands as carefully cut slabs of mountain limestone 4 in. × 3 in. and ·07 in thickness.

The frequent destruction by spontaneous fracture of bent plates when removed from the machine seems to imply that an indefinitely protracted and uniformly contorting force is needed to produce unbroken curvature, such as that on the coast of Berwickshire. The experiments next to be related tend to show that resistance on all sides diminishes the risk of fracture. While designed to answer other purposes, the precautions described and the result attained serve to strengthen the opinion that unbroken anticlinals and synclinals are only formed under a considerable weight of superjacent strata.

Anxious to imitate the natural condition of lateral pressure more closely, and at the same time to preserve well-contorted specimens for reference, I tried another method, which ultimately yielded interesting results. My object was to apply pressure to the edges of a slab of stone and overcome the tendency to fracture by embedding it in a matrix of some tenacious substance. The precaution was especially necessary in this second series of experiments. It is easy to see that when deflection begins the bending force is increased in a high ratio. We have the pressure acting upon the slab, not as a force transmitted through its plane, but concentrated upon the centre, the two halves acting as levers. As the contortion proceeds the strain increases rapidly, and in practice it is found that no graduated pressure can be contrived sufficiently delicate to avoid sudden fracture.

To overcome such difficulties as these I imbedded thin slabs of limestone in pitch and fitted them into a cast-iron box, the two sides of which were removed. One end was cut to allow a screw to travel through it, and within was a plate of iron which could be moved along by the pressure of the screw so as to tighten the slab within the box. By this means pressure was applied to the edges of the plates of rock, and after a few failures the pitch did its work sufficiently well. I regard the matrix of pitch as almost indispensable to success when the experiment of lateral pressure is performed.

By the process just described slabs 9 in. long have been bent until they rose $\frac{2}{3}$ in. in the centre. More conspicuous results may be expected hereafter. The operations required for the production of apparently inconsiderable deflection are tedious and slow, but patience rather than fresh methods seems to be needed. The contortions which we would imitate were not made in a day. Nature is as superior to us in resources of time as of power. Completer and more varied experiments than these are to be desired. Larger specimens of rock should be tested, and the exposure should be longer than thin plates require. With appropriate apparatus a series of observations as detailed and exact as those instituted by Fairbairn in the case of iron and steel might be carried out, greatly to the advantage of geologists, physicists, and engineers.

While occupied with this subject of the mechanical properties of rocks a number of examples of unintentional or natural contortion have come under my notice.

Not long ago I saw some small casts of the Elgin marbles prepared in the form of long strips of plaster of Paris $2\frac{1}{4}$ in. broad. These casts had been laid aside for some years and had warped visibly. In one case the deflection (estimated as a rectilinear angle) amounted to 6°. This led to some experiments on plaster of Paris. On submitting dry plates $\frac{1}{4}$ of an inch in thickness to the knife-edge machine a deflection of 8° was obtained in six weeks, and I soon found that this material is indefinitely plastic if the strain be gradually applied. It would probably be easier to bend a flat plate of plaster of Paris into a cylinder than a plank of deal.

Walking one rainy day past the burying-ground attached to a country chapel, I found some gravestones supported horizontally upon corner pedestals. The flagstone of which the monuments were constructed had yielded towards the unsupported centres, and there were pools of water standing in the hollows. The sculpturing of the inscriptions was too sharp to admit the supposition of extensive weathering. The stones were quite smooth, and the method of rubbing down the surface must have rendered them quite level before erection.

Shortly afterwards, I saw a flagstaff in a public park resting upon a broad flagstone $2\frac{1}{2}$ inches in thickness and supported in an upright position by iron ties fixed in the ground at a short distance. The weight of the mast I guessed to be about two tons. The flagstone at its base was visibly curved, as if it had bent beneath the weight of the pole. That this was actually the case appeared from the raising of the free edges of the slab above the surrounding pavement, which was elsewhere fairly level. But all doubt on this point was removed by subsequent measurement. A year and five months later the centre of the slab had sunk $\frac{7}{16}$ of an inch more, relatively to the ends.

Again, a friend communicated to me the experience of slaters, who find that when by yielding of the timbers the surface of an old roof has become bowed, the tiles are distorted to such an extent that they will not lie flat upon a new roof. Old stone tiles (I do not know whether the same is true of slates and brick tiles) are often rendered perfectly useless in this way, however sound they may be. It is perhaps unnecessary to cite other similar cases. Every observant architect and engineer can give from his own experience facts of interest in reference to the influence of long-continued pressure upon an unsupported edge of stone.

The magnificent instances of contortion sometimes displayed in coast sections are certainly more impressive, but perhaps less wonderful in reality, than the cases on record of distorted pebbles. The unlimited effects of long pressure are nowhere so clearly demonstrated as in the bending of round or oval masses of small size. Instances of pebbles elongated in the direction of planes of cleavage occur at Llyn Padarn, near Llanberis, in the Lake District, and elsewhere. But the most remarkable cases of alteration of figure effected by pressure are those described by Dr. Hitchcock, Mr. G. L. Vose and others, as occurring in New England. In Vermont, Maine, Massachusetts and Rhode Island are found conglomerates where sometimes for hundreds of square feet every pebble, whether of granite, sandstone, schist or quartz, has been flattened. Occasionally one pebble has been driven into another, so as to indent it or squeeze it into a semicircular form, yet without fracture. Some of the examples figured resemble soft cakes jammed together into one mass with unyielding stones, so freely do they curve round in layers and adapt their shape to the various lines of force. Yet plasticity in any ordinary sense of the word is out of the question. These very pebbles are water-worn and some of them cleaved. Not a few are rolled fragments of plutonic rock. (See Plate, Figs. 2, 3.)

The connection between contorting and cleaving force is not quite clear. It would seem that when a certain freedom of extension is allowed even the most intractable substances yield and change their form. But if the compressed mass be wedged up so tightly that change of figure is impossible, the individual particles seem to revolve upon their axes, and arrange themselves as coins would do, with their principal planes transverse to the line of pressure. If the conditions exclude even such change as this, the indestructible force may develope itself in other ways still less intelligible to us, and reappear as heat, chemical action, or segregation. Into these inquiries we need not now enter. Our W of limestone is explained—that is, brought into an intelligible relation with other observed phenomena.

It would be interesting, though hardly profitable, to pursue this subject yet further into the field of molecular philosophy. Many attempts have been made to resolve various physical states into combinations of certain hypothetical atomic forces. These speculations are sure to recur, and molecular or atomic theory will some day be the basis of all physical science. Newton, as he says, strongly suspected that all the phenomena of cohesion and aggregation, all the phenomena of chemistry and physiology, resulted from the agency of forces varying with the distance of the particles. Boscovitch endeavoured to establish a general theory of cohesion upon the properties of unextended atoms endowed with powers of attraction and repulsion varying, not only in degree but in kind, with the distance, and to such elementary forces he expected ultimately to reduce the peculiar manifestations of chemical and vital change. In our day Sir William Thomson, expanding a suggestion made by Helmholz, has sought to show that all material phenomena may be due to motions created in an incompressible, frictionless, universal fluid—that the ultimate analysis of matter will hereafter give not particles, but vortices. As yet these doctrines remain mere unverified conjectures; the atomic history of the universe is yet to be constructed. We do not accurately know what takes place when a piece of india-rubber is bent or a piece of moist clay is squeezed into a new shape. Still we are in the way of progress when we collect and sift facts, arrange them into classes under general propositions, and test those propositions by applying them to fresh cases. Hereafter it will be possible to apply one principle to explain at once the fluidity of water and the contortion of rocks. Even now we can group together the past and the present, the great and the small. We can show that the forces which arched the Silurian rocks of Wales are still operative, and that the same forces can be displayed and recognised in the laboratory of the student.

EXPLANATION OF PLATE.

Fig. 1. Contortion apparatus.

a. Cylinder containing shot.
b. Rod connecting *a* with the vertical plate *c*.
d, d. Frame in which the plate *c* slides.
e. Knife-edge, hinged on *c*.
f. Iron block, sliding in groove *h*, to which the lamina *k* is fixed by the screw *g*.
i. Apparatus for setting the index *l* at zero in any position of the vertical plate.
l. Index moving over a graduated arc.
m. Index moving backwards and forwards to show the deviation of *e* from the perpendicular.

Scale nearly $\frac{1}{7}$ of the actual machine.

All the parts are iron or steel, except the cylinder *a*, the rod *b*, the indices and the scale, which are brass.

Figs. 2, 3. Examples of distorted pebbles in conglomerate at Newport, Rhode Island, reduced from Memoirs of the Boston Society of Natural History, vol. i. pl. 17, 18.

The Plate was prepared to illustrate an article on the Contortion of Rocks, which appeared in the Popular Science Review, for January, 1872. We are enabled to reproduce it here by the courtesy of the Publisher of the Review.

ON THE GEOLOGY OF CRAVEN. BY W. H. DALTON, OF H. M. GEOLOGICAL SURVEY.

(COMMUNICATED BY PERMISSION OF THE DIRECTOR.)

The title of this Paper would have been given more correctly as the Geology of Airedale, for I do not propose to bestow more than a passing notice on any rocks not occurring within the basin of the Aire. I must state that, as the Memoirs of the Survey will contain full descriptions of all the phenomena connected with the geological structure of the districts which they illustrate, the regulations prohibit any forestalment of the Memoirs, unless some very important fact is discovered, the withholding of which till the publication of the Memoirs would be detrimental to the progress of science. As nothing very new or startling has been discovered in Airedale, my remarks must of necessity be limited to such general observations as will not lessen the value of the forthcoming Memoirs on the district.

The basin of the Aire consists of three districts of distinct lithological, and consequently physical, aspects. From the source of the Aire in Malham Tarn to the lofty precipice of Malham Cove, extends a plateau of limestone, falling gently to the north, and intersected by several deep rugged gorges. The surface of the southern part consists chiefly of bare rock, whilst in the Silurian area to the north extensive deposits of coarse boulder-gravel, almost entirely composed of limestone, form large pastures of coarse grass, through which the larger boulders protrude.

South of Malham we have a depressed area of undulating ground, consisting of limestone, with numerous intercalations of calcareous shale, the whole being extremely contorted, denuded and obscured by drift. Above the general level of this tract rise three hills, capped with Millstone Grit, viz., Rye Loaf Hill, between Malham and Settle; The Weets, east of Malham; and Flasby Fell, near Skipton. The outline of the latter, as seen from the south-east, presents a striking, but I need scarcely say, purely superficial resemblance to that of a volcano with ancient crater and modern cone.

At Skipton commences the third area, composed of Millstone Grit and Lower Coal Measures. The country thence to beyond Leeds presents the characteristic scenery of these formations, with rugged scarps where the coarse grits occur, bold, wooded banks for the finer-grained, but still massive sandstones, gentler undulations for the softer flagstones, and irregular hummocks of shale.

The lower part of Airedale is occupied by Permian and Triassic rocks and tidal warps: not having seen these, I can say nothing about them.

I will now briefly describe the lithological characters of the rocks of the district, and indicate the most instructive sections in each.

The oldest rocks occurring in the basin of the Aire are the Silurian slates already mentioned as present at the source of the river, where however they are completely hidden by the drift. On the north, their denuded edges are covered by the Carboniferous rocks, and on the south they are bounded by the great North Craven fault. The strip of land thus enclosed varies in width from a few dozen yards on the western watershed to nearly a mile at the Tarn, eastwards from which the base of the Carboniferous series rapidly approaches the fault, reaching it just beyond the Gordale Beck, in which it and the subjacent slates are seen in section. In Ribblesdale this series is largely exposed, and, besides running far up the valleys to the bases of Ingleboro' and Penyghent, it extends quite across Ribblesdale to Clapham, a distance of eleven miles from Gordale. The exact position of these beds in the typical Silurian series is, I believe, not yet fully determined, but such as occur in Airedale are certainly newer than the Bala limestone, on which they rest, apparently unconformably, at Horton in Ribblesdale, and Southwaite near Austwick. The Airedale sections are too limited to be of any value, except as indications of the course of the fault; they occur only at Gordale and at Capon Hall, where on the watershed the slates contain beds of tough blue crystalline sandstone. The general dip is S.S.W., so that the lowest beds occur under the Tarn, and the highest on the watershed near Capon Hall. The direction of the cleavage is the same, but the angle is rarely that of the dip. I may remark here that this extension of the Silurian area of Ribblesdale as far east as Gordale Beck is not shown in any geological map yet published.

The base of the Carboniferous series consists generally of limestone, crowded with pebbles, mostly of Silurian rocks, and varying according to the nature of the strata immediately underlying them. Occasionally we find, beneath this limestone-conglomerate, a mass of sandstone, some parts of which are also full of Silurian pebbles, often softer from decomposition than the calcareous sandstone which forms the matrix. This latter deposit is well seen at Capon Hall, nearly fifteen feet in thickness, underlying the pebbly limestone conformably. (In this locality I found the cast of an Encrinite-stem, about half-an-inch long, encrusted with calc-spar.) Similar sandstone also occurs in Gordale Beck, and again in a gorge about a mile and a quarter east of Gordale.

The typical Carboniferous, or Scar Limestone, is too well known to require much description. It is a mass of pure, or very nearly pure, limestone, from 600 to 1,000 feet in thickness, composed entirely of organic débris. This is its character both at Settle and in Derbyshire, but as if to show the value of the artificial divisions of the Carboniferous system which scientific men have adopted, it is represented in the north of Ireland and in Scotland by sandstones, shales, and thick coal-seams, with occasionally a thin band of limestone. If we trace the upper boundary of it from Wharfedale to Wensleydale, we find the thin ends of several wedges of sedimentary strata splitting up the higher part of the limestone, and this subdivision continues till, as I have said, the limestones are nearly extinct. Between Settle and Derbyshire we have only the South Craven district to furnish us with any evidence of the changes occurring in the Carboniferous Limestone. From Malham to Bell Busk and Gargrave we have a thick mass of impure laminated limestone, with frequent bands of calcareous shale. To the west, this is reversed, and we have a thick mass of shale, with occasionally bands of impure limestone. Then, at Skipton, we find a mass of thin bedded limestone, overlaid by three or four good thick limestones, separated by equally thick beds of calcareous shale, the whole being overlaid by thick shales, calcareous only at their base. Similar shales with thin limestones occur in the Calder Valley, near Todmorden.

We now come to the Millstone Grits, which, for the sake of distinction we subdivide into four groups, corresponding to the five which occur in Derbyshire, the second (in descending order) having died out or merged with the first. The lowest of these groups consists of sandstones (sometimes calcareous) and shales. It is the "Yoredale Grit" of Derbyshire, but we have dropped that name, as this group appears to be wanting in the Yore Valley. Next we have a thick mass of coarse grits and shales, with finer sandstones towards the top. This is the equivalent of the Kinder Scout Grit, of Derbyshire. Near Skipton it is coarser than any conglomerate of Carboniferous age that I have seen elsewhere. I found one pebble of vein-quartz weighing over two ounces, and measuring three inches by one and a quarter by one inch. This was in contact with others, averaging a spherical inch, the interstices being filled with smaller pebbles and coarse sand. I also found a pebble of sandstone, the grains of which are of a peculiarly translucent quartz. These were from the ridge behind High Bradley.

Next we have another great series of fine-grained sandstones and shales, forming the body of the hills surrounding Keighley under their outlying caps of Rough Rock. In this vast thickness of strata, any bed which can be identified, wherever it occurs, by its physical characters, is like a landmark to the home-bound sailor—it tells us where we are in the series, no matter how many cross-gales in the shape of faults we may have encountered in traversing a district. Such a bed we have for instance in the grit forming the fine escarpment of Otley Chevin, and extending with sundry shiftings of small faults, to the Aire at Hawk Cliff, whence it continues westward, overhanging the Glusburn Valley. Without such a landmark, it is evident that after crossing a line of fault, we should at once be out of our reckoning, though, unlike the mariner, we can always put back into port and start again by another route, so as to avoid faults.

The Rough Rock is the highest group of the Millstone Grit series. Its upper part is always a coarse grit or conglomerate, whilst the lower part, as at Haworth and Cullingworth, is fine grained and flaggy. The Cross Roads quarries are good sections of the lower part. Sometimes the entire mass is coarse conglomerate, as the Druid's Altar escarpment between Keighley and Bingley.. From one of the blocks near the Altar I got a slightly rolled pebble of felspar, not in the least degree decomposed, though protruding from a weathered surface. I also found felspar pebbles in the deep gully behind Harden, and in Hog Holes Delf. Some of them were so little worn as to show that the crystals of which they were formed were the usual square and rhomboidal prisms. In Hog Holes

Delf fragments of black chert or hornstone occurred sparingly. The Rough Rock caps all the hills between the Wharfe and the Aire, and forms outliers above Keighley on both sides of the Worth. To the south-east it dips gently under the lower Coal Measures, of which a few outliers stud its surface. Only three or four of these outliers contain workable coals, as at Yeadon, Baildon, and near Denholme.

Of the Lower Coal Measures I have so little knowledge from personal examination, that it will not be well for me to hazard any remarks on the subject.

Few collections, whether private or public, have not a well-arranged suite of fossils from the Carboniferous Limestone, but the Millstone-Grit group rarely affords good specimens. We often have traces of Stigmaria and Lepidodendron, and I have seen a very respectable fern from the Morton Banks Colliery. The shales frequently have traces of Goniatites, Aviculopecten, &c., but I have seen none worth keeping. In the bottom grit, near Skipton, I found a very obscure cast of Edmondia sulcata, an estuarine mollusc, also found on the same horizon in the Calder Valley. The Coal Measures are, I believe, more prolific, and perhaps if excavated and very carefully examined, some of the Millstone Grit shales would prove to be the same. Generally, however, the shales are sandy, and more or less porous, and the coarse sandstones, like modern gravel beaches and sand flats, are void of organisms, which would, if they ever existed, have been long since removed by the percolation of water.

Near Malham extensive mines were formerly worked in the rich deposits of calamine and galena occurring in the limestone near the Middle Craven fault.* In the débris I found quartz crystals, calcite, heavy spar, galena coated by oxidation with lead-sulphate, calamine, earthy and botryoidal,

* New workings have been commenced in these mines since the reading of this paper.

and traces of blue and green copper-carbonate. A good vein of galena is worked near Cononley in a fault. It is accompanied by barytes, and the cheeks are grit. Fluor spar occurs near Skipton, but I have not found it elsewhere in Airedale. The value of the limestone for burning and road metal, and of the grits for various building purposes, is well known. Some of the siliceous ganisters of the grit series might be quarried with advantage for use, in combination with the "core" of burnt lime, as road metal.

I have said nothing about the contortions and tiltings of the beds, partly because I have neither liberty nor time for details, chiefly because any one can see them, and seeing is about the most that anyone can do. The beds in the south limestone district, from Malham to Bolton Abbey, are often vertical, and, as a friend of mine would say, tied into knots. If a book were put through a turnip-cutting machine, and subsequently daubed with mud, the task of determining the page and line of every visible and invisible fragment would be little more perplexing than has been the deciphering of the contorted and broken limestones of South Craven.

Very little drift occurs in Airedale, but what there is, is of two sorts at least—a boulder clay, full of scratched limestone blocks, and a superjacent deposit of sand and gravel. Of the chronological relation of these deposits with other glacial beds we have very little evidence, and I decline to pronounce an opinion.

ON THE FORMATION OF ANTHRACITE. BY L. C. MIALL.

[ABSTRACT.]

The physical and chemical properties of the chief varieties of coal were briefly described. Reference was then made to the various forces to which the production of Anthracite has been assigned, such as internal heat of the earth *(Hull's Coal-fields of Great Britain, pp.* 67 *and* 68, and many other writers); strongly heated vapour escaping through crevices in the coal, which are due to undulations of the strata (*Rogers' Pennsylvania II., ii, p.* 809); evaporation through faults, with or without heat (*Lyell's Travels in North America, vol. ii.*)

The mode of occurrence of Anthracite in South Wales and Pennsylvania was described. The gradual debitumenization of the coal westward in South Wales and south-eastward in Pennsylvania was discussed with reference to the great lines of disturbance.

Cases of coal altered in texture, cleavage, and proportion of volatile matter by approach to open faults were cited. Details were given of one case in the Black Bed Coal at Cleckheaton, where the coal lost its cubical fracture completely, and from 8 to 14 per cent. of its volatile matter on approaching an imperfectly sealed fault.

Experiments, suggested by this circumstance, had been instituted by the author, and various kinds of coal powdered and exposed to the air were found to lose from 4 to 17 per cent. of their volatile constituents in two months' time. The highest proportion resulted from an experiment on Low Moor Better Bed coal.

The quantity of volatile matter in coal covered by a sandstone roof is usually much diminished. This was attributed by the author to evaporation through a comparatively porous rock. Many cases of great accumulations of coal-gas in fissures or cavities in the coal were then cited.

The recent experiments of Grundmann of Tarnowitz and Varrentrapp of Brunswick were quoted, but the author had been unable to reproduce their experiments. The temperature employed by them is not stated; perhaps it was higher than the ordinary temperature to which the powdered coal was exposed in the author's experiments (Mean of two months, June and July = 61°).

It was next shewn that coal altered by contact with igneous rocks does not form Anthracite, but *cinder coal* or *soot coal.* The phenomena observed at the contact of coal-seams with the dyke at Cockfell and the basalt of the Rowley Hills were minutely described with reference to this point.

Our almost complete ignorance of pressure as a metamorphic force renders it unsafe to speculate upon its possible influence in this case. Some features of the Anthracites of the Alps and of the Basse-Loire suggest that decomposition of so unstable and complex a substance as coal may be facilitated by pressure.

Summary. 1. That coal loses its volatile constituents by simple evaporation at ordinary temperatures.

2. In this process it loses its cubical fracture.

3. This process of evaporation is facilitated by disturbance of the strata.

4. There is no evidence to shew that a seam of Anthracite has ever resulted from contact with heated rock.

ON THE STRUCTURE OF GANOID FISHES, INTRODUCTORY TO AN ACCOUNT OF THE GANOID FISHES OF THE YORKSHIRE COAL-FIELD. BY L. C. MIALL.

Almost all that is really known about Ganoid Fishes is of modern discovery. The year 1844 is the era of sound knowledge, the commencement of true progress so far as this branch of zoology is concerned. Nothing but descriptions of no physiological value, and generalisations attractive in manner but devoid of substantial accuracy, can be derived from the previous literature of the subject. Even the magnificent "Poissons Fossiles" of Agassiz does not suffice to qualify this statement. We shall see hereafter how sharp a line is to be drawn between the already obsolete discussions of thirty years ago and the permanently valuable discoveries, which have, as we would hope, only proved without exhausting the fertility of the subject.

The ichthyology of Cuvier is of no great value, at least so far as its general method is concerned, nor was its supremacy of long duration. Twenty-seven years its influence extended (1817-1844*) and then it fell as in a day. It may justly rank as an improvement upon what went before, but like too many artificial and facile systems it impeded further advance long before it was superseded. The best proof of its want of sure physiological foundation lies in the unnatural divisions and alliances which it made. For our purpose it is only necessary to remark that the order Ganoidei was broken up into two widely separated sections. The Sturgeons and Polyodons went among the Chondropterygian or Cartilaginous Fishes; *Lepidosteus* and *Polypterus* ranked side by side with the Salmons and Herrings among the Malacopterygii Abdominales. Had *Calamoichthys* been known to Cuvier it would have gone among the Eels as one of the Malacopterygii Apodes.

This unfortunate separation of a singularly homogeneous group is the more remarkable that Cuvier had already noted the external points of resemblance between the fossil Ganoid *Palæoniscus* of the Zechstein, and both the groups into which he divided its living allies. His decision was, that having such striking resemblances to both, it could belong to neither.†

It was in some respects a step forward when Agassiz announced his views on the method of classifying fossil fishes. He rescued the Ganoid order as a whole, placing the cartilaginous Sturgeons side by side with the osseous *Polypterus* and *Lepidosteus.* But the grounds on which this was done were most unsatisfactory. It is perhaps almost need-

* The date of the scheme as published in the *Règne Animal.* It was, however, anticipated by a sketch published in 1815 in the *Mémoires du Muséum*, vol. i.

† Ossemens Fossiles.

less to describe the arrangement of Agassiz. In geological text-books it still holds a respected place, though banished from zoology. We have four groups based upon tegumentary organs, *ganoid*, with (usually) rhomboidal or polygonal scales; *placoid*, with shagreen or prickly tubercles; *ctenoid*, with membranous scales jagged on the hinder edge; *cycloid*, with rounded scales destitute of enamel.

Agassiz further called attention to the distinction between *heterocercal* fishes (such as have the superior lobe of the tail larger, and containing a prolongation of the vertebral column), and *homocercal* (such as have a symmetrical tail). He believed that all fishes anterior to the chalk were heterocercal. It is not unusual to see the two terms used as if they designated two groups or orders of fishes, but no such systematic value is assigned by Agassiz to the distinction, although he exaggerated its importance, and misconstrued its anatomical significance.

A few words will show how superficial and destitute of classificatory importance is the distinction of heterocercal and homocercal tails. Many years ago Von Baer and Vogt shewed that the tail is unsymmetrical in the embryonic state of the Carp, and also of *Coregonus*, a genus of *Salmonidæ*. This curious fact was regarded by Agassiz as reconcileable with the homocercal character of the *Salmonidæ*. He seems for a time to have believed that all fishes are heterocercal in an early stage of development, but that the true *homocerci* become symmetrical in the adult state, whereas the plagiostomous fishes and others never pass beyond the embryonic stage. Looking upon the geological distribution of the two types of structure, the *heterocerci* being supposed to include all known palæozoic fishes, Agassiz maintained that there was a parallel between the development of the individual and the development of the class. Just as the Salmon or Carp is first heterocercal and grows gradually homocercal, so it seemed possible to affirm that the class Pisces slowly changed from its palæozoic or embryonic to its modern and adult structure. At a time when it was imagined that the older fishes and reptiles and Crustacea were in all respects larval or embryonic, the supposition was at least plausible. But the doctrine of Progressive Development, consistent as it doubtless appears with those views of modification of species which the writer holds in common with so many naturalists of our day, derives no support from palæontology. Silurian Crustacea, Devonian Fishes, Carboniferous Amphibia, Jurassic Mammals are in no sense embryonic. What animals of highly general structure may have inhabited the seas and plains of the pre-Cambrian world we know not. So far as the accessible stratified rocks and their revelations are concerned, the forms both of animal and of vegetable life are differentiated and complex from the first.

Later research has in no way confirmed the hypothesis of Agassiz. Vogt has since (1845) shewn that the adult salmon is not only heterocercal like the young, but heterocercal to a much greater degree. Huxley has demonstrated a different kind of asymmetry in the Stickleback and Eel. Here the *chorda dorsalis* (the aggregation of cells corresponding to the vertebral centra) is prolonged beyond the extremity of the vertebral column, and enclosed within a hollow styloid bone (the *urostyle*). Kölliker has detected so many fresh cases of extremely heterocercal tails under the guise of homocercity, that he even doubts whether a single instance is to be found of a truly symmetrical termination of the vertebral column in fishes.

The process of growth which ends in this singular transformation is as follows:—A young salmon just emerged from the egg is already slightly heterocercal. The *chorda dorsalis* has an upward turn which becomes from day to day more pronounced. The hæmal arches or lower processes of the caudal vertebræ are alone developed, and ultimately give rise to the "hypural" plates which constitute the bony framework of the tail. The upper or neural arches are nearly suppressed, and thus the *chorda dorsalis* is directed towards the upper angle of the tail fin, where it may be detected in the adult fish, though partly concealed by a short cartilaginous sheath.

The fishes ordinarily reckoned as homocercal are therefore excessively heterocercal, the upper lobe of the tail being suppressed. This recent discovery need not in itself destroy the classificatory value of Agassiz' distinction, could it be still maintained that the external outline of the tail is a safe guide to affinity. In a shark the upper lobe is predominant, in a salmon the lower. Though both are heterocercal or unsymmetrically developed, the resulting contours are quite unlike. Had there ever been much substantial truth in the distinction of homocercal and heterocercal as a clue to the discovery of real affinity, a change of phrase would have set all right. But tail characters are not available for the identification of any of the great groups of fishes. At most they are of generic value. Within the order Ganoidei we have a great variety of structure in this respect. *Polypterus* and many fossil genera are "diphycercal," the nearest approach to true symmetry found among fishes; *Lepidosteus* and the sturgeons, besides many fossil forms, are visibly heterocercal. *Calamoichthys* has an urostyle developed on one side only of the caudal fin. No appeal to analogy would completely decide whether such a fish, for example as *Holoptychius*, whose caudal fin is not accurately known, had a symmetrical or unsymmetrical tail, nor would analogy suffice to show how the vertebral column terminated in such a fish.

Just as a classification based upon tail characters would break up the well-defined order of Ganoid Fishes, so also the application of the test of texture or form of scales would remove true Ganoids from the group, and introduce alien genera having no real affinity with the order. *Amia,* with its cycloid scales, the two species of *Polyodon,* with their nearly naked skin, would go in spite of the ganoid character of their heart, intestine and optic nerves. *Balistes, Loricaria,* and a number of plectognathous fishes would enter the order, entitled to do so solely by their osseous scutes. The zoologist would not tolerate for a day the consequences of any principle of division which involves such anomalies as these.

Müller has pointed out how destitute of value is any classification of teleostean fishes based upon scale characters. Well-defined and natural families contain both cycloid and ctenoid genera. Genera can be named with both cycloid and ctenoid species. *Atherina* (the Sand Smelt), and *Mugil* (the common Mullet), both belong to one family, the *Mugilidæ,* yet the first is cycloid and the second ctenoid. The families *Percidæ, Clupeidæ, Gobidæ,* and many others include both forms. In short, scale-characters, like characters taken from the caudal fin, tell us nothing unless the affinities of the fish in question are beforehand nearly determined.

In 1844 appeared the celebrated Memoir of Müller, "Ueber den Bau und die Grenzen der Ganoiden,"* to which we have already referred as a work which marks the era of sound general principles of definition and classification of Ganoid Fishes.

Müller gives first a historical resumé of the work done by his predecessors in this field of inquiry, Rafinesque, De Blainville, Cuvier, and Agassiz. The views of the last only of these receive a full discussion, for he alone had recognized the ties which connect the Ganoids together. Briefly, but with irresistible weight of argument, Müller disposes of the

* Abhandlungen der Akademie der Wissenschaften zu Berlin, 1844.

arrangement based upon scale-characters. He points out the many fatal anomalies which result from the definitions of orders according to Agassiz, and shatters the delusive hope of establishing a natural history of value upon such superficial distinctions. The essential peculiarities of the Ganoids are shewn to lie, not in scales, fins, or tails, but in the heart, brain, and intestine.

The anatomical research of this paper gives it a permanent value which the labours of no mere systematist can confer. The structure of *Polypterus* and *Lepidosteus* in particular is given with a fullness and completeness which more recent investigation has hardly modified. In the reconstruction of the order certain of the Siluroids, Scleroderms, Gymnodonts, and Lophobranchs admitted by Agassiz as armour-plated fishes, are removed entirely from the order Ganoidei. The remaining recent genera are enumerated by Müller thus:—*Polypterus, Lepidosteus, Accipenser, Scaphirhynchus,* and *Spatularia (Polydon).*

Since 1844 the list of genera has been modified as follows: —The Ganoid structure of *Amia,* discovered by Vogt, is announced in a postscript to Müller's paper. The *Amia* (Bowfin or Mud-fish of the United States) is a Ganoid, disguised as a herring or sprat. Ganoid in its heart, optic nerves, and intestines, it has soft cycloid scales, a fact which in itself suffices to vitiate the systematic value of scale characters. *Calamoichthys,* first described in 1865, and *Ceratodus,* added to the list of living genera in 1870, were unknown to Müller. *Lepidosiren,* ranked by Agassiz as a Ganoid in his later monograph, but excluded by Müller, it is now proposed to readmit. The conspicuous differences of their structure from that of the typical Ganoids have been bridged over by the discovery of *Ceratodus,* as will shortly appear. In other respects Müller's restricted order is co-extensive with that of the ichthyologist of 1872, and the ordinal definition (with the exception of one character noted by Müller himself as provisional) stands unshaken.

That definition comprehends the following differentiæ of Ganoid Fishes.

A Teleostean fish has a two-chambered heart from which ascends the aorta, dilated a little at its origin, but not contractile, and separated from the ventricle by a pair of opposite valves. In a Ganoid fish a far more complex structure appears. The dilated origin of the aorta is strengthened by numerous additional muscular fibres, which almost entitle it to rank as a third chamber of the heart; it is besides rhythmically contractile. On slitting open this part of the aortic tube (the *bulbus arteriosus*) rows of valves appear, generally attached to the inner arterial wall transversely, but ranged in longitudinal rows. *Polypterus* has three principal vertical series, each including nine valves. Alternating with these are three incomplete series, each containing five to nine valves of less size. In *Lepidosteus osseus* we usually find five vertical rows, comprehending forty valves similar to each other, and uniformly situated. *Amia* has five to six vertical series with two valves in each. The number, arrangement, and relative size of these valves is not uniform for the same species. The valves are generally connected together by delicate tendinous chords, each to the one above it in the same vertical row.

No such structure is known among Teleostean fishes. The Sharks (especially *Lamna cornubica*, the Porbeagle) display a comparable series of valves, though less numerous and arranged in three vertical rows. Other Plagiostomi recede further from the Ganoid type, though the *bulbus arteriosus* and some trace of the three series of valves is always to be found. *Lepidosiren* and *Protopterus* exhibit the *bulbus arteriosus* with two longitudinal valves.

The presence of a contractile *bulbus arteriosus* furnished internally with valves is thus seen to be a valuable character, separating the Ganoids sharply from the Teleostei, Cyclostomata (Lampreys) and Leptocardii (*Amphioxus*), though not distinguishing them from *Lepidosiren*, *Chimæra*, the Sharks or Rays.

A second differential character of Müller's restricted order *Ganoidei* is to be found in the arrangement of the fibres composing the optic nerves. In the Lampreys and the Hags the optic nerve proceeds direct to its orbit from the *thalamus opticus* of the same side. In a Teleostean fish the nerves decussate, all the fibres from one side of the brain crossing over to the retina of the other side. Higher Vertebrata than fishes possess a still more complex arrangement, a redistribution at the point of decussation of the fibres in their passage forward to the orbit. In the human optic nerve, for example, there is thus formed a true *chiasma* (χ): some of the fibres are continued across direct to the retina of the same side; others pass to the retina of the opposite side; a few connect together the optic tracts, *i. e.*, that part of the nerve intermediate between the brain and the chiasma; lastly, some connect together the retinæ or the optic nerves beyond the chiasma. The physiological bearing of these differences of structure is not unimportant, but we are here concerned only with their systematic value. The Ganoid Fishes have not the simple decussation of the Teleostei, but they agree with *Lepidosiren*, the Sharks, Rays and *Chimæra*, in having a commissure or chiasma. The arrangement of the fibres is less complicated than in the higher vertebrates; most of the fibres pass to the retina of the same side.

Müller includes free gills and the presence of a gill-cover as a third distinctive feature of Ganoids. In the *Chimæra* Sharks and Rays (hence termed *Elasmobranchii* by Bonaparte) the gills adhere to the outer skin or wall of the gill-cavity, and are thus comparatively fixed, being attached at each end to the wall of the chamber. Water enters the respiratory chamber by five to seven lateral openings in the case of the Plagiostomi, by a single aperture in *Chimæra.* It will be convenient to contrast this with the Teleostean branchial apparatus. Here we have gills supported on branchial arches, but not attached to each other or to the sides of the gill-cavity. The outer wall of the respiratory chamber is formed by a moveable plate, the *operculum* or gill-cover. We see that Ganoids with their free gills and gill-cover resemble the Teleostei and recede from the Elasmobranchii so far as their respiratory apparatus is concerned. There are, however, variations and anomalies which may induce us to hesitate before attaching much classificatory weight to these resemblances and differences. *Polypterus* and *Calamoichthys,* with their single rudimentary spiracle on each side of the head remind us strongly of *Chimæra,* and *Ceratodus,* besides the spiracle, has each of its four gills attached externally to the wall of the gill-cavity.

Lastly, Müller gives the abdominal position of the ventral fins as an easy external mark of the Ganoid order. This is plainly not of great importance; it is the characteristic of one of Cuvier's sections of Teleostei or Osseous fishes, the Malacopterygii Abdominales. Moreover, since 1844, *Calamoichthys* has been brought to light, a Ganoid with no ventral fins at all. Müller seems to have contemplated such a contingency, as we see from the words—"Den Character von den abdominalen Bauchflossen halte ich bloss zeitweilig für bindend."

Such are the never-failing and absolute characters of the Ganoids known to Müller. Besides these, there are other features which require attention.

Like *Lepidosiren* and the Elasmobranchii the Ganoids have a spiral valve in the intestine. This structure, the function of which is imperfectly known, may be described as an open spiral riband or ridge, very variable in its proportions, which lines the lower part of the intestinal tube, and in many cases its whole length. Müller speaks of it as not known in all Ganoids, *Lepidosteus* being an exception so far as he knew. Subsequent dissections have demonstrated the presence of a rudimentary but strictly homologous structure in this genus also, so that we may now regard the spiral valve as a fresh character of Ganoids, distinguishing them from all Teleostei, associating them more closely with Elamobranchii and *Lepidosiren*.

Some of the inconstant features of the Ganoids are available for subdivision of the order. *Amia*, *Polypterus*, and *Lepidosteus* are covered with scales and have a bony skeleton; the Sturgeons, *Scaphirhynchus* and *Polyodon* are naked or only partially covered with osseous scutes, while their endoskeleton is incompletely ossified, especially in the skull. These points of difference define the two sections—the *Holostei* and the *Chondrostei* of Müller. As subsidiary and merely generic characters the varying structure of scales and fins has value. *Amia* is cycloid; *Polypterus* and *Lepidosteus* ganoid in the sense of Agassiz. *Lepidosteus* and the Chondrostei have *fulcra*, or spines attached to the edge of the fins; *Polypterus* and *Calamoichthys* have fins without fulcra. Most of the Ganoids have abdominal ventral fins; *Calamoichthys* has no ventral fins at all.

Müller's discoveries were sufficient to define the Ganoid order, to subdivide it into two natural sections, and to arrange under these with just and precise definitions all the then known forms. It now remains to narrate briefly the progress of discovery since 1844, and to discuss the position of the Ganoids in the class Pisces as disclosed to us by the more complete knowledge which further investigation has furnished.

Before entering upon this narrative of later research, let us turn back for a moment to the discovery in 1839 of the real structure and zoological significance of *Lepidosiren*.

Iu 1837 an undescribed fish was sent to the Vienna Museum from the river Amazons. It was examined by Fitzinger, who named it *Lepidosiren paradoxa,* placing it, as we now see, erroneously, in the class of Reptiles, but calling attention at the same time to its piscine affinities. It completely resembled a fish in external form, except that attenuated processes, cylindrical and pointed, occupied the position of the pectoral and ventral fins. It further possessed true gills, blind nasal sacs, a spiral valve in the intestine, besides a vertebral column and an organ of hearing comparable only to those of a fish. But it was found to be furnished with a true paired lung, which communicated with the œsophagus by an airduct closed with a glottis, and received venous blood from the heart, returning it as arterial. This last hint as to its affinity was regarded for a time as decisive. The presence of a functional lung was then held to be the one test sufficient to separate the class Reptilia (= Reptilia + Amphibia of modern naturalists) from the class Pisces. *Lepidosiren* possessed a functional lung, and was reckoned as a reptile, or as what we should now more distinctively term a Perennibranchiate Amphibian.

Within two years from the publication of Fitzinger's new species *Lepidosiren paradoxa,* another nearly allied animal from Senegambia was submitted to Professor Owen for examination. He was at first disposed to regard it as a new genus, and in the manuscript catalogue of the Museum of the College of Surgeons, he assigned to it the name of *Protopterus,* but the perusal of Natterer's account of *Lepidosiren paradoxa* afterwards led him to believe the two species to be generically identical. Ultimately the points of difference appeared to be of generic importance, and the name of *Protopterus* was revived for what was first named in print *Lepidosiren annectens.* Meanwhile Peters* had pro-

* Monatsbericht der Akademie der Wissenschaften zu Berlin, 1844, p. 414.

posed the name of *Rhinocryptis,* which is thus a third synonym in use.

Owen seems to have come at once to the conclusion that *Lepidosiren* was not an amphibian, but a fish. His views provoked a long controversy, in which every part of the structure of each species was minutely scrutinized. The reptilian determination was supported by Natterer, Bischoff, Milne-Edwards, and Gray. Owen at first opposed them almost alone, but ultimately gained over to his side all zoologists of influence. The old discussion is extinct, and opinion is now divided only as to the position of the genus among fishes.

The *Lepidosiren* or *Protopterus* of Tropical Africa is now known to frequent the river Gambia, the Rokelle, the Zambesi, and the Nile. All these streams are more or less intermittent. When the waters retreat the *Protopteri* which may be left upon the bank bury themselves in the mud, leaving however a small aperture for communication with the air. As the mud dries and cracks in the sun, the fishes become enveloped in earthy cases lined by a thick mucous secretion. In this state they remain until the return of the rainy season enables them to escape and swim about again. The more obvious peculiarities of these curious fishes seem to depend largely upon their exceptional vital conditions. During the torpid state respiration is carried on by the swim-bladders, which temporarily discharge the function of lungs, receiving imperfectly venous, and returning arterial blood. When the rising of the water permits the fish to resume aquatic habits, the gills oxygenate the blood, and the swim-bladder receives arterial blood from the branchial arteries for nutrition only. The *Lepidosiren paradoxa* of the Amazons is similarly adapted for both atmospheric and aquatic respiration.

The characters common to the two genera of *Protopteri* are these:—The skeleton is imperfectly ossified and the vertebral column notochordal. The limbs are filiform fins, supported by jointed, cartilaginous rods. Both jaws are armed with corresponding dental plates, which are provided with cusps and cutting ridges. The intestine has a spiral valve. There is a double air-bladder, communicating by means of a duct and glottis with the hæmal side of the œsophagus. The gills are free. The *bulbus arteriosus* has two longitudinal valves, and there is a second (left) auricle, receiving blood from the air-bladder, and incompletely separated from the right auricle by a reticulate septum. There are two blind nasal sacs, each with two openings. The optic nerves are united by a commissure. The oviducts are distinct, and the ventral fins abdominal. The body is eel-shaped, and covered with cycloid scales.

The African genus (*Protopterus*) differs from its ally *Lepidosiren*, the Mud-fish of the Amazons, in the following particulars:—The fins have a marginal fringe of numerous minute rays. Rudimentary external gills are present in the adult. There are six branchial arches, instead of five, as in *Lepidosiren*.

To all except those who may choose to suppose that *Protopterus* and the river Gambia were made simultaneously, each for the other, it will be apparent that the peculiarities of the respiratory organs of these fishes depend upon the peculiarities of their environment. *Lepidosiren* and *Protopterus* must, on any other hypothesis, be fishes of other than the existing dipnous type, which have been specially modified to suit their external conditions. It may seem hazardous to conjecture what the primæval type may have been, but it is important to notice that most of the organs not immediately related to respiration conform to Müller's definition of Ganoids. The optic nerves form the same kind of commissure, the intestine has a spiral valve, the branchiæ are free, the ventral fins are abdominal. The only notable differences relate to the heart. The Ganoids have rows of transverse valves in the *bulbus arteriosus*, and but one auricle: the *Protopteri* have two longitudinal valves in the *bulbus arteriosus*, and two auricles. The presence of an auricular septum will not appear of too great importance to those who reflect upon the variations of both auricular and ventricular septa presented by nearly allied vertebrata of other classes, or even by the same species in different stages of growth; moreover this partition is perforated even in *Protopterus*. The Dipnous type is practically separated from the Ganoid type only by the difference in the aortic valves; for the organs directly related to habitat give scanty information as to affinity, and the remaining organs agree, or vary only within the limits of variation of undoubted Ganoids.

The discovery of *Lepidosiren* and its African ally *Protopterus* has been in every way most important. The homology of the swim-bladder of the fish with the lung of the reptile, maintained long before by Harvey and Hunter, became clear enough now that the important connecting link was supplied of a fish's swim-bladder receiving venous and returning arterial blood. The definition of the class Pisces became more comprehensive, and their affinities to the higher vertebrata more apparent. From this time zoologists began to remark the many points of resemblance between fishes and Amphibia (which had hitherto been invariably placed among Reptiles). Hitherto the appearance of lungs in the adult had marked in the systems of naturalists the passage from the lower to the higher division of cold-blooded vertebrates. The absence of gills in all stages was henceforth the distinctive character of the higher groups, and zoologists began to associate the Fishes with the Amphibia, and the Reptiles with the Birds; a distribution which has since been fortified by many arguments drawn from osteology and development.

The peculiarities of *Lepidosiren* and *Protopterus* were so striking that when their place among fishes was conceded they ranked as a separate order (Dipnoi of Müller)*. Attempts were made to connect them with other orders of Fishes with various success. Some systematists were perplexed by the affinities of *Lepidosiren* with several types of piscine structure, as well as with the higher class of Amphibia. Professor Owen appears to have seen fully their relationship to the Ganoids. The following sagacious and comprehensive sentence illustrates his views better than any part of his systematic arrangement.

"It is extremely interesting to find the Ganoid *Polypterus*, which of all osseous fishes most closely resembles the *Lepidosiren* in its spiral intestinal valve, in the bipartition of the long air-bladder, the origin of the arteries of that part, and the place and laryngeal mode of communication of the short and wide air-duct or windpipe, also presenting the closest agreement with the *Lepidosiren* in the important character of the form of the brain."†

Not only was the general affinity of the Dipnoi to Ganoidei thus clearly anticipated, but not unsuccessful attempts were made to indicate their nearest allies in that order. In 1839 Professor Owen‡ described the teeth of *Protopterus* as resembling "in their paucity, relative size, and mode of fixation to the maxillæ, those of the *Chimæra* and some of the extinct cartilaginous fishes, as *Cochliodus* and *Ceratodus*." In 1861 Professor Huxley,§ while discussing the classification of Devonian fishes, was led to notice the resemblance between the fins of the Crossopterygian Ganoids and those of *Lepidosiren*. One passage of considerable historical interest is here cited.

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* Abhandlungen der Akademie der Wissenschaften zu Berlin, 1844.

† Comp. Anatomy of Vertebrates, I, 499.

‡ Linnean Transactions, vol. XVIII, pt. 2.

§ Decades of the Geological Survey, X, p. 26.

"Without wishing to lay too much stress upon the fact, I may draw attention to the many and singular relations which obtain between that wonderful and apparently isolated fish, *Lepidosiren,* sole member of its order, and the cycloid *Glyptodipterine, Ctenododipterine, Phaneropleurine* and *Cœlacanth Crossopterygidæ. Lepidosiren* is, in fact, the only living fish whose pectoral and ventral members have a structure analogous to that of the acutely lobate paired fins of *Holoptychius,* of *Dipterus,* or of *Phaneropleuron,* though the fin rays and surface scales are still less developed in the modern than in the ancient fish. The endo-skeleton of *Lepidosiren,* again, is, as nearly as possible, in the same condition as that of *Phaneropleuron,* and is more nearly similar to the skeleton of the Cœlacanths than that of any other recent fish; while, perhaps, it not stretching the search for analogies too far to discover in the stiff-walled lungs of *Lepidosiren,* a structure more nearly representing the ossified air-bladder of the Cœlacanths than any with which we are at present acquainted, among recent or fossil fishes. Furthermore, *Lepidosiren* is the only fish whose teeth are comparable in form and arrangement to those of *Dipterus.* Though *Lepidosiren* may not be included among the Crossopterygidæ, nor even in the order of Ganoidei, the relations just pointed out are not the less distinct; and, perhaps, they gain in interest when we reflect, that while *Polypterus,* the modern representative of the rhombiferous Crossopterygidæ, is that fish which has the most completely lung-like of all air-bladders, *Lepidosiren,* which has just been shown to be, if not the modern representative of the cycliferous Crossopterygidæ, yet their 'next of kin,' is the only fish provided with true lungs. These are unquestionable facts. I leave their bearing upon the great problems of zoological theory to be developed by every one for himself."

In addition to these cautious anticipations, bold speculations were not wanting. We may read a lesson in the failure, now so apparent, of the most ambitious of all. Haeckel* in one of his singular "Stammbäume," where the elaborate complexity of the table disguises the scantiness of the data, places the Protopteri (= Dipnoi), Ichthyosauri and Amphibia in one line of descent, and traces out successively the Plagiostomi, the Ganoidei, and the Teleostei in another. It will be seen immediately how far from the mark the whole pedigree has proved to be. Professor Rolleston well observes:† "Whether the general theory" (of evolution) "be accepted as a whole or not, it must be allowed that in the face, on the one hand, of our knowledge of the greatness of the unlikeness, which may be compatible with specific identity; and, on the other, of our ignorance of the entirety of the geological record, special 'Phylogenies', or hypothetical genealogical pedigrees, reaching far out of modern periods, are likely to remain in the very highest degree arbitary and problematical."

In the early part of 1870, Mr. Krefft, of Sydney, announced the discovery of a new dipnous fish, and added that the teeth resembled in a remarkable manner those of *Ceratodus,* a well-known fossil of the lower secondary formations. The fish was obtained from several rivers in Queensland, where it occurs in both fresh and brackish waters. Specimens have since reached Europe, and Dr. Günther's account of the dissection has now been presented to the Royal Society.‡ From his description the following account is abridged:—

The *Ceratodus (Barramunda* of the natives) is a large fish, attaining a length of six feet. It is stated to be capable of sustaining prolonged exposure to the air. In figure it is

* Schöpfungsgeschichte, 2nd edition, 1870, p. 517.

† Forms of Animal Life, p. xxv.

‡ Proceedings R. S., vol. xix. p. 377. See also Nature, Sep. 21, 1871.

eel-shaped, but somewhat thick and clumsy. The body is covered with large cycloid scales. Dr. Günther considers that the specimens examined by him indicate two species, viz., *Ceratodus Forsteri* with fewer and larger, and *C. miolepeis* with smaller and more numerous scales.

Skeleton.—The vertebral column is notochordal, and its processes more or less cartilaginous. The brain-case is unossified, but protected by thin bony plates as in the Sturgeons. The fore and hind paddles (pectoral and ventral fins) are supported by a jointed cartilaginous rod, as in *Lepidosiren*, but unlike the paddles of *Lepidosiren*, each joint bears a pair of three, two, or one-jointed branches.

Limbs.—The fore and hind paddles have scaly centres surrounded by a rayed fringe, as in the fishes which compose Huxley's sub-order Crossopterygii of Ganoid Fishes.

Teeth.—The palate is armed with two large dental plates, punctated on the surface, and undulating in such a way that the projections and depressions fit exactly into the depressions and projections of two similar dental plates in the lower jaw. Five or six sharp prongs project on the outer side of the dental plates. Two small incisors are situated upon the palatal surface of the vomer. In all respects the teeth resemble those of the fossil *Ceratodus*, and less closely with those of *Lepidosiren*. Professor Owen long ago remarked the resemblance between the teeth of the two genera, *Ceratodus* and *Lepidosiren*.* The exact correspondence in dental structure and arrangement of the *Barramunda* and the fossil *Ceratodus* has satisfied Dr. Günther of their generic identity.

Intestine.—A spiral valve is present, as in Ganoids and Elasmobranchii.

Respiratory Organs.—A narrow slit on the side of the head opens to the gills, which are four in number on each

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* Odontography. Comp. Anatomy of Vertebrates, I, 369.

side. They are free from each other, but attached to the outer walls of the branchial cavity. The lung is single (not paired as in *Lepidosiren* and *Polypterus*) but divided internally into two symmetrical halves, each with about thirty compartments. A *ductus pneumaticus* communicates with two nasal openings within the mouth. The lung is probably inactive, and supplied with arterial blood so long as the fish is provided with abundance of pure water. When the water becomes thick and muddy by evaporation, it is likely that the animal fills its lung by swallowing air, and the lung then receives venous blood, returning it oxygenated to the heart by a separate pulmonary vein.

Heart.—Instead of the two longitudinal valves which are contained within the *bulbus arteriosus* of *Lepidosiren*, *Ceratodus* has two or three transverse series, only one of which is fully developed.

Without enlarging upon the many points of interest suggested by the description of *Ceratodus*, we must briefly point out its importance with reference to the definition of the order Ganoidei.

Excepting only the presence of a true functional lung, all the characters of *Lepidosiren* and *Protopterus* assimilate them to the class Pisces. In that class evidence of their special relationship to the Ganoids, Sharks, and Rays is afforded by their muscular and contractile *bulbus arteriosus*, the valves in its interior, and the spiral valve of the intestine. It has already been seen how close is the agreement between *Lepidosiren* and the Ganoid *Polypterus*. They are indeed referred to different orders of fishes only on account of the different function of the lungs, and the different position of the valves of the *bulbus arteriosus*. *Ceratodus* now comes in to bridge the interval. It has the functional lung of *Lepidosiren*, the transverse arterial valves of *Polypterus*.

Rearrangement of the whole group is thus rendered necessary. The Dipnoi henceforth form a part of the Ganoid order, whose definition is extended to include fishes having longitudinal valves in the *bulbus arteriosus.* The effect of the inclusion of the Dipnoi upon the subdivision of the Ganoid fishes will be discussed in a subsequent communication.

Dr. Günther proposes a further step—to unite the reconstituted order Ganoidei with the Elasmobranchii, so as to form a new sub-class—*Palæichthyes.* Solid reasons are adduced for this step, but its discussion is not needful in this place. The Ganoidei and Dipnoi must in any case be united, and their place is plainly next the Elasmobranchii. That the relations of the three groups are close will not be disputed by any zoologist.

Dr. Günther supplies us with the following list of living Ganoids:—One species of *Amia,* from North America; three species of *Lepidosteus* from the same region, but extending southwards into Central America and Cuba; two species of *Polypterus (Calamoichthys)* from the tropical parts of Africa; two species of *Polyodon,* from the Mississippi and the Yangsekiang; about twenty-five Sturgeons, from the temperate and subarctic regions of the Northern Hemisphere; two species of *Ceratodus* from tropical Australia; one species of *Lepidosiren* from the Amazon river; and one of *Protopterus* from tropical Africa.

From this list alone it would almost be possible to reconstruct the general history of the Ganoid order. This group, anciently marine as well as fluviatile, is now restricted to fresh waters, for even the Sturgeons are essentially river-fishes. The wide distribution of the existing Ganoids shews their extensive development in past ages; their scattered habitat, as well as the extraordinary richness in types of an order numerically so scanty, shew that we are contemplating, not the members of a recent colony, but the dispersed relics of a race which once occupied every river and sea. We may attribute their diminution to the introduction and ultimate predominance of more favoured forms. In the open seas the Ganoids can no longer hold their own, but a few species, representing, as if by accident, diverse types of structure, linger on in isolated river-basins, protected from extermination by the mountains and seas which now enclose them, and at the same time limit the area within which destructive competitors may arise.

MINUTES

OF THE

GEOLOGICAL AND POLYTECHNIC SOCIETY

Of the West Riding of Yorkshire.

1871–72.

THE SEVENTY-SEVENTH meeting was held at the Philosophical Hall, Leeds, on Wednesday, July 26th, 1871, at noon.

THOMAS WILSON, Esq., M.A., occupied the chair.

The following resolution was put and carried :—

"That the following gentlemen, with power to add to their number, be requested to prepare a report on the position and prospects of the Society, with suggestions for increasing its numbers and efficiency :—Messrs. T. Wilson, W. Sykes Ward, T. W. Embleton, E. Filliter, R. Reynolds, L. C. Miall."

A paper on "Further Discoveries of Flint Tools in Hertfordshire and Sussex," by JOHN FFOOKS, Esq., was read to the meeting.

A paper on "Contortion of Rocks," illustrated by photographs of contorted limestone in the neighbourhood of Skipton, was read by Mr. L. C. Miall. (See page 3.)

The CHAIRMAN quoted further examples of contorted flagstones; in particular, a section to be seen at the Morley railway station, near Leeds.

Mr. EDWARD FILLITER, C.E., referred to some interesting contortions exposed by the excavations for the puddle-trench at Lindley Wood, in the valley of the Washburn, and added some remarks on the apparent facility with which beds of limestone or other rock embedded in shale may be bent to sharp angles without fracture.

The Rev. W. HUNT PAINTER exhibited some nodules containing fish-remains, which he had lately discovered in the roof of the Halifax Hard Bed at Rawden. One well-preserved specimen was assigned to the genus *Acrolepis* of Agassiz.

The SEVENTY-EIGHTH meeting was held in the Mechanics' Institute, Keighley, on Wednesday, January 24th, 1872, at noon.

JOHN BRIGG, Esq., J.P., occupied the chair.

The minutes of the last meeting were read and confirmed.

The following Report, prepared at the request of the previous meeting, was read and adopted :—

"The Committee appointed at the last General Meeting of the West Riding Geological Society, on July 26th, to prepare a report on the position and prospects of the Society, with suggestions for increasing its numbers and efficiency, beg to submit the following statement:—

"They have investigated the present position of the Society and find the number of members on the books to be 121. The arrears of subscription for 1871 amount to £63 1s. 0d., and those for the previous year to £28 14s. 0d. The annual income of the Society at present is estimated at £78 13s. 0d., and its necessary expenditure at £73 0s. 0d. The Committee consider it possible to add largely to the number of members by an active canvass.

"The Committee consider it a matter of great importance to support and strengthen an institution which has rendered good service to local geology for thirty-four years, and they are of opinion that the Society has an extensive field of work open to it for the future. The geological features of this Riding are still most imperfectly understood. So varied are they, and so full of scientific interest, as well as of economic importance, that the materials for sound and useful contributions can never fail us.

"The Committee have considered the various ways in which a Society of this kind may be most useful, and they beg to offer the following suggestions for its future management :—

1. That the proceedings of the Society should be more exclusively confined to Geology and Technology, the two branches of science which were contemplated as the appropriate field of the Society at its first institution. The department of local Archæology is now occupied by a Yorkshire Society which is labouring with energy and success to discharge those duties which this Society, inconsistently, perhaps, with its title, but still usefully, had taken upon itself.

2. That a small Committee of Revision, composed of five persons, of whom three shall be a quorum, be appointed to examine all papers read at the Society's meetings, and to select such only as are specially suited to publication. That it be a standing instruction to this Committee to recommend only those papers which contain valuable original matter on some of the subjects which are taken into consideration by the Society, or which have special reference to the Geology or Industries of the West Riding.

3. That photographs of interesting geological phenomena within the Riding be issued periodically to the members, accompanied by descriptive letterpress. The photographs should be on a good scale,

and if possible, rendered permanent by some of the processes now in use. The Committee have made enquiries as to the probable cost of such photographs, and they are of opinion that one or two plates 14 ins. by 9 ins. may be issued annually without incurring too heavy an expense.

4. That a summary of Geological Literature relating to the West Riding, published within the preceding year, be inserted in the Annual Report of Proceedings. The Committee also recommend that a list of titles of papers on West Riding Geology contained in the transactions and journals for past years of the various geological societies, as well as of separate publications on the same subject, be issued in an early report.

"Mr. L. C. Miall having offered to undertake for one year, without salary, the duties of Assistant Secretary, the Committee recommend that this arrangement be sanctioned by the Society.

"The Committee consider it highly desirable to retain a collection of local fossils in some central part of the West Riding. They would urge the necessity of increasing and improving the collection of the Society, under such regulations as may add to its usefulness as a means of public instruction."

The following gentlemen were requested to act as a Committee of Publication and Revision:—Messrs. Wilson, Reynolds, Ward, Filliter, and Miall.

The Chairman then made the following remarks on the Geology of the neighbourhood of Keighley:—"Before making the remarks which I have to offer on the geology of this district, allow me to say, on behalf of the inhabitants of this town and the officers and members of the institution under whose roof we meet to-day, that we are glad to have the honour of your presence amongst us. I believe I am right in saying that this is the first time that any society whose objects are purely scientific has ever held a meeting here; and we are disposed to look upon your Society with more than ordinary interest, as we consider you to be a direct lineal descendant of the agitation in scientific matters which took place some thirty-five years ago, when Mechanics' Institutes were first formed. We find in our old cupboards and cabinets instruments and fossils that were purchased and collected at that time, but which have served little purpose since. Few persons now living remember the story of that rising of scientific light which was dimmed, if not extinguished, for want of a larger supply of ordinary education. We are now, however, in hopes that in the Elementary Education Act of 1870, and other agencies, a firm basis has been laid for the higher education of the people. It has been suggested that as I am chairman of your gathering here to-day, the least that I can do is to tell you where you are. I dare not in this matter go very fully into the geological details, as I should possibly be very soon called to account by the gentlemen of the Geological Survey who have just gone over the district. Until the maps are published and the memoirs written, however, there is scope for profane opinions, and I avail myself of the opportunity. A glimpse at the physical geography of this part of Yorkshire, as the result of geological phenomena, may not be uninteresting to some who are here, although well known to others, who must excuse my rude generalizations.

Running north and south, immediately to the west of our present position, is a ridge of high land which extends with but few breaks, from the Newcastle coal field across the great Craven fault above Skipton, to the rising of the limestone in Derbyshire. This ridge divides the water shed of this part of England, and the foot placed in a gutter on the top of the moors may direct the flowing water either into the German Ocean or the Irish Sea. Falling from this high land on both sides, but principally on this, the east side, are a number of rivers which run in almost parallel lines, and on this side the slope meet one another in the estuary of the Humber. We are here situated on the second of these rivers, the Aire; the Calder to the south, and the Wharfe, the Nidd, the Ure and the Swale to the north, similarly work out their respective valleys, leaving their intervening ridges to stand like ribs attached to the central ridge, which is sometimes spoken of as the back-bone of England. The rivers to the west of the ridge do not form such a well marked system, the distance to the sea being shorter, and the general inclination of the strata not so regular.

So much for the physical geography. The next step is to seek an answer to the natural inquiry, how does it happen that these six large rivers appear to be running towards the south-east, and in parallel lines? Geology must try to answer this. A reference to the geological map of England will show you the general dip of the various systems. A man walking from London in a line to the Lakes crosses, in succession, the whole of the beds between the London Clay and the Silurian. This general line of strike from south-west to north-east roughly prevails over the largest part of England, and the form of the tongues of land which form our coast line also roughly gives the same indication of S.W. and N.E. One of the most marked disturbances of this general dip is caused by the ridge of land which we have spoken of as the back-bone of England, which leads on to the Silurian district of the lakes. The part of the ridge with which we have to deal is the Millstone Grit tract of Derbyshire and Yorkshire, and thrown off on each side of it are the coalfields of Yorkshire and Lancashire; outside again come the New Red Sandstone tracts of Cheshire and the vale of York.

Looking at the position of the rivers it will now be seen that they run at right angles to the strike of these beds, which are inclined against the Millstone Grit ridge, and that they cut through the upturned edges of the different strata. The theories that have been started to account for this apparent anomaly of the water taking the most difficult route to the sea are various. The probable reason is, at any rate for this district, that the faults have presented weak lines to the action of denudation. The lines marked on the large map have been kindly indicated to me by the gentlemen of the Geological Survey as representing some of the faults which will be seen to run N.W. and S.E. The way in which denudation has *not* been affected by faults is, however, a noticeable feature in some of the minor valleys. Referring to the large map of the valley of the Aire, kindly lent by your Secretary, it will be seen that the features of the locality are principally, if not altogether, due to the action of denudation, the Rough Rock immediately underlying the coal being found at the top of all the hills in the neighbourhood.

Contrary to the views of many good geologists I am disposed to think that in this district at least, in order to account for the great denudation, there has been a time when there was a much larger rainfall than at present. Two points may be taken as some indication that this was the case; first, an examination of a section of a valley that has been cut through near Ponden, the rough sketch of which has been kindly given me by Mr. Dalton and Mr. Ellis. The sandstone rock has been cut through and the shale much worn down : at present drift covers the shale to some sixty feet, and there is little or no alteration in the cultivation or drainage higher up the streams. Another point of interest is that there are traces all over the highest parts of the moors, at depths of six or eight feet down in the peat, of tree roots, where no trees have been known to have existed in recent times. Lower down also we have traces of hazel copses, &c., where none have been known within the memory of man. It seems probable that the whole of this high land, comprising many thousands of acres, was at one time forest, and so it is possible that the rainfall may have been formerly much greater.

There are traces of glacial action on the rocks of the hill sides, which show that other agencies were at work also in assisting in the process of valley making. Without disparagement to the powers of the Geological Survey, I may say the mapping of this district has not been a very easy task. The vast sheets of glacial and other drift lying high among the hills have given them much trouble, concealing faults of great dimensions, while the abrupt upheaval of the Limestone at Skipton throwing off the whole Yordale series or their representatives, and the Kinder-Scout Grit within a few hundred yards, was more than was to be expected after the peaceable behaviour of the beds for more than twenty miles previously. The springing up of water so far charged with lime as to encrust the surrounding vegetation at elevations higher than the nearest Limestone tract, and amidst drift lying close to the bottom of the Coal series, is a question the Survey are not called upon to account for, nor are they bound to show us why lime-kilns should be built in localities where there is no lime rock to burn. The solution appears to be that the drift contains a sufficient quantity of limestone boulders to affect the water passing through it; which boulders, when exposed by the action of running streams, were gathered together and burnt in order to put on the land. Near Bingley we find that the drift in the valley has been ransacked to find out the limestone boulders.

Mr. Dalton's paper, which may tell us of faults miles in extent, and of rocks a mile in thickness, planed away and distributed through and over the surrounding country, will possibly throw some light on the condition of our immediate neighbourhood. To make my remarks very local I must ask you to imagine yourselves standing a little distance beyond the railway station on the Bradford road and looking down the valley. If by some magical power the whole of the loose soil and drift could be cleared away from the surrounding hills, we should see that all the sloping hill sides were cut into huge steps or terraces, and that these terraces had a slight regular inclination downwards; as we pass towards Bingley, the inclination of these ridges may be easily followed. A little out-crop of sandstone which comes out at Threaproyd, and which the road passes over before arriving at the cemetery, may be traced on through Utley, where it is quarried. It rises gently until it forms a step in the outline of the hill some 200 feet higher than Hawkcliffe rocks. The Hawkcliffe rocks again, and their counterpart in Holden Wood, may also be traced as rising regularly from the valley near Utley, and running round with some little variation as far as Wainman's Pinnacle above Cowling on the one hand, and round to the top of Addingham Moor on the other. These terraces are made up of alternating beds of sandstone and shales. The sandstone varies much in quality; the highest in the series, that is, the one which follows under the lowest workable coal seam, being very rough-grained and coarse, while the lowest bed or the one immediately overlying the Limestone is often coarse and full of white quartz pebbles, sometimes an inch in diameter; between these beds may be found almost all variety of sandstone, sometimes fine hard grained blue-grey flags, sometimes roofing slates, and sometimes large masses of stone without any distinct bedding. Nearly all the stone is good for building purposes; but the top and bottom beds appear to stand weathering best. If you see a well-marked nab or hill point anywhere between Bradford and Skipton, you may safely presume that it is either the Rough Rock or the Kinder Grit you are looking at. The beds of shale vary much in hardness, but appear moderately uniform in fineness or quality. In some places they appear to have a quantity of iron in them, which fits them for a good road metal; while in other places they are but little removed from soft clay. These shales are worked to some extent for bricks; but the glacial drift clays are more easily attainable for that purpose, and are largely mixed with the true shale clay. Remembering our position in the valley, and still looking south-east, the highest points of the valley in front of us are crowned with the Halifax coal seam, which having passed at inconvenient depths under Pontefract, Knottingley, Castleford and Leeds, comes to the surface in a long line stretching from Yeadon to Eccleshill, Thornton, Denholme, and Halifax, and appears in a patch on Baildon Hill. It may for aught we know have extended over the valley where we now are at a height of some 800 feet above our heads. Behind us, and appearing near Bradley before coming to Skipton, we have Limestone showing at the surface. These beds do not emerge from beneath the Millstone Grit rocks with the regularity which we might expect, for there is a line of fault which cuts off the grit beds in a very short distance, and gives them a much steeper dip than they have lower down the valley.

A more interesting geological scene can scarcely be witnessed anywhere than may be studied on the road from Skipton to Bolton Bridge. Vast sheets of hard limestone lie tilted against one another in the centre of the valley, the softer shales and limestones occupying the slopes of the hills on each side, and the edges of the hills on both sides being crowned with hard sandstones. Confining ourselves to the series of the Millstone Grit proper, it appears from the researches of the Geological Survey that there is so much irregularity in the various middle beds, some of them occasionally thinning out in short distances, and others changing their texture entirely, that it is almost impossible to form any general plan for their classification. The series in Derbyshire shows quite a different set of beds from what is found here, and these again differ entirely from the Lancashire series. There is not much to be said for the fossils of the Millstone Grit. Notwithstanding the publication of a list of some 500 species by a gentleman in the Bristol district, we find nothing but what is much better represented either in the Coal Measures proper, or else in the Mountain Limestone. In fact, the fossils are preserved as one might expect they would be if the refuse of a tropical forest were to be imbedded in the sand of a sea shore—a leaf here, a branch there. Occasionally we find a fragment that has apparently been washed down from the coal forests, carried across the sands of the shore, and then, transported far out to sea, has sunk down amidst the calcareous mud which we now call Limestone. The remains of life, such as they are, are, however, not unfrequent. There are few quarries of sandstone where you cannot see black marks representing vegetable matter ; often there are worm tracks and ripple marks in the bedding of flagstones and in the shales. *Goniatites* and *Pecten papyraceus* may be often found, though generally bruised and broken. We have thin seams of coal in different horizons of the strata, which were worked within the last twenty years, but they do not supply us with good fossils. They are now neglected on account of the cheap railway carriage from the coal fields proper, but they may at some time be found valuable if the price of coal continues to increase as it bids fair to do. I had hoped to have microscopic sections of these low coals for your examination to-day, and to have proved as I suspect, that these beds were patches of vegetation that had been some time floating in water before they settled to their present position. It seems very possible that many minute marine or estuarine animal remains may be found lodged in this coal, which are not found in coals higher up in the series.

I have thus placed before you briefly, and I am afraid but roughly, the features of the district. There are other circumstances of local interest upon which I have not touched, but which are well worthy of attention, and which, if not coming within the scope of that part of your society which is geological, may safely be included in the part called polytechnic. I refer to the share which ancient geological changes have had in introducing manufactures by providing water power ; the peculiar combination of circumstances which was the means of establishing blast furnaces for smelting iron on the tops of our hills ; the effect of our large valleys in retaining the peculiarities and dialect of their inhabitants, and the relationship in appearance and language, which may be found among people in these secluded localities, to certain North-German races ; the change of climate, as evidenced by an altered vegetation ; and other changes in trade and society, which come within the range of history. These may become subjects of interest to local students, and are better worth their attention than many of the things which now occupy their leisure time.

Mr. W. Pengelly, F.R.S., who was present by invitation, then offered, at the request of the meeting, remarks on some of the questions relating to denudation, which had been raised by the Chairman's Address.

A paper on "The Formation of Anthracite" was then read by Mr. L. C. Miall. (See page 22.)

The CHAIRMAN observed that deterioration in the quality of coal exposed to the air had long been observed by those who had the charge of engine-boilers.

Mr. WALTER ROWLEY called attention to the difference in volatile matter between the "hard" and "soft" divisions of the Barnsley Thick Seam.

In the absence of the author, a paper on "The Geology of Craven," by Mr. W. H. DALTON, of the Geological Survey, was read by Mr. C. CALLAWAY, M.A. (See page 16.)

Mr. L. C. MIALL called attention to the many points of interest presented by this paper. The announcement of Silurian slates in Gordale was doubtless novel to all present.* A few remarks on the increasing simplicity of the Lower Carboniferous Series as we go southwards from the North Riding to South Craven were added.

Specimens illustrative of various parts of the paper were then exhibited by Mr. MILLER.

A paper on "The Structure of Ganoid Fishes, introductory to an Account of the Ganoid Fishes of the Yorkshire Coal-Field," was then read by Mr. L. C. MIALL. (See page 24.)

Mr. W. PENGELLY, F.R.S., made a few observations, after which the Society adjourned.

At three o'clock a luncheon, kindly provided by Mr. JOHN BRIGG, the chairman of the meeting, was served in the exhibition-room.

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* A minute isolated patch of Silurian Rocks in the neighbourhood of Gordale is shewn in Prof. Phillips' coloured Geological Map of Yorkshire.

*** With this part of the Proceedings of the West-Riding Geological and Polytechnic Society is issued a photograph of a limestone quarry at Draughton, near Skipton. It is intended to send out one or more such photographs yearly, and the series will ultimately illustrate many of the most remarkable features of Yorkshire Geology.

Some account of the contorted limestone of Draughton will be found in the Proceedings for 1867 (vol. iv. p. 577). See also pp. 3 *et seqq.* in the current part. The rock in question belongs, apparently, to the top of the Carboniferous Limestone, which is here almost undivided.

The following photographic plates will be issued in future years, and others may be added as opportunity offers:—

1. Section of the Craven Fault at Ingleton.
2. Junction of Limestone and Slates on Moughton Fell.
3. Junction of Slates, Conglomerate and Limestone, at Thornton Force.
4. Contorted Limestone at Thornton-in-Craven.

All these are situated within the West-Riding.

The photographs will be sent to all members whose subscriptions are not in arrear.

L. C. MIALL,
Assistant Secretary.

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OF THE

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PAPERS

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ON THE RED BEDS AT THE BASE OF THE CARBONIFEROUS LIMESTONE IN THE N.W. OF ENGLAND. BY CHARLES BIRD, B.A.; SCIENCE MASTER IN THE BRADFORD GRAMMAR SCHOOL; HONORARY SECRETARY TO THE BRADFORD PHILOSOPHICAL SOCIETY. (PLATES II. AND III.)

Between the silurian and the carboniferous systems there occurs a great thickness of red and yellow sandstones and conglomerates, to which the name of old red sandstone has been given. These beds appear to have been deposited in shallow, brackish, or fresh waters, caused by the gradual shallowing and contracting of the silurian sea. The fossils of the upper silurian beds become fewer in number and dwarfed in form as they pass upwards and finally disappear, and all traces of marine shells die out, while land plants and fresh water fishes become the characteristic forms.

The old red sandstone of Shropshire, Hereford, and Wales lies regularly and conformably upon the upper Ludlow rocks, and after attaining a thickness of 10,000 feet, passes upwards conformably and without any break into the carboniferous limestone.

In Scotland there are two old red districts, one south, and the other north, of the Grampians. The beds of the southern region are divided into three groups. The lower lies conformably upon the upper silurian, the middle lies unconformably upon the lower, while the upper lies unconformably upon the middle, but passes upwards conformably into the carboniferous rocks. In the northern region also three divisions are recognisable, but there is no unconformability between them. The lower rests unconformably upon lower silurian rocks, and the carboniferous rocks are absent.

In the South of Ireland, the beds which intervene between the silurian and carboniferous systems are naturally divided into two sets; the Dingle beds, consisting of coloured grits, slates and conglomerates, apparently resting conformably upon and passing gradually downwards into the representatives of the Ludlow rocks; and a set of red sandstones and conglomerates resting unconformably upon the Dingle beds, and passing insensibly upwards into the base of the carboniferous rocks, which here consists of a vast series of grits and slates, known as the "carboniferous slates."

In Devonshire, the series of beds which occupies a position corresponding to the preceding, differs entirely from it both in mineral character and in fossils. It is a marine formation—slates, limestones, and marbles; and contains abundance of shells and corals. It was first recognised as contemporaneous with the old red sandstone of the north by Lonsdale, Murchison, and Sedgwick, in 1836, after the recognition of the anthracitic shales and sandstones of North Devon as carboniferous. In 1866, Mr. Jukes read a paper before the Geological Society, in which he maintained that the beds which underlie the anthracitic beds of North Devon were not of old red sandstone age, but were contemporaneous with the carboniferous slates of the South of Ireland. Palæontological evidence, however, is in favour of the former view.

Thus we see that in the South of England, in Wales, in Scotland, and in Ireland, the carboniferous rocks are separated from the silurian by a great thickness of strata, and wherever the junction can be seen, the lower beds of these intervening strata are found to graduate downwards into the upper silurian, and the upper to pass upwards, without any break, into the carboniferous. In Cumberland, there is another silurian district, and around it are carboniferous rocks, but here the enormous thickness of red strata is nearly absent. The carboniferous limestone dips in all directions from the silurian lake district as a centre, and only in isolated patches is there anything which can by any means be compared with the old red sandstone of Wales and Scotland, the limestone, for the most part, lying unconformably upon the contorted, metamorphosed, and denuded silurian rocks. It is the same in the Isle of Man; the carboniferous limestone, the most recent formation not tertiary in the island, is separated from the silurian schists by a few comparatively thin red beds. It is these isolated patches of red, which in these localities intervene between the silurian rocks and the carboniferous limestone, which are more especially the subject of this paper.

First, as to their character and mode of occurrence. They form almost always a coarse conglomerate. The included stones vary much in size, and some are very large. They are angular or subangular, rarely well rounded. In mineral character they are the same as the underlying silurian rocks, and appear to have been always derived from the immediate neighbourhood. The matrix is generally red, but is sometimes of a light grey or green, and sometimes a deep purple, and it contains a large quantity of iron. The conglomerate presents a rough stratification, and often contains thin, irregular, false-bedded, and ripple-marked beds of sand or sandy clay. No fossils have been found in it, except silurian fossils in the included fragments. The fossils mentioned by Dr. Nicholson* were found, not in conglomerate, but in beds above it, which Professor Harkness and the geological surveyors place in the carboniferous series.†

The limestone is not generally found superimposed directly upon this mass of conglomerate, but beds of an intermediate texture and composition intervene, as will be hereafter shown, so that, supposing this conglomerate to be of old red sandstone age, it is difficult to determine where the line between the two systems shall be drawn.

I will now proceed to describe briefly the various localities where these conglomerates are met with.

1. *Kirkby Lonsdale and Barbon.*—Here the conglomerate rests unconformably upon silurian grits and shales—the Kirkby Moor flags, the equivalents of the upper Ludlow. It is well seen on the banks of the Lune, near Kirkby Lonsdale church, where it appears as a very coarse, thick-bedded conglomerate, apparently dipping in the same direction as the carboniferous limestone (S.E.) which may be seen a little lower down the river. The conglomerate is, however, bounded on all sides by faults and cannot be actually traced upwards into the limestone.

About two miles further N. it is exposed on the banks of a small brook which flows W. into the Lune. It is here, in many places, decomposed on the surface, and might be easily mistaken for recent drift.

It can also be examined in Barbon Beck, near the railway station, where the fault which throws down the limestone to the E. can be well seen. This Barbon conglomerate is, like the preceding, bounded by faults.

2. *Sedbergh.*—Here a mass of conglomerate, two or three miles in length, occupies the valley of the Rawthy. Two

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* Essay on the Geology of Cumberland and Westmoreland, 1868.

† Memoirs of the Geological Survey. Sheet xcviii.

miles above Sedbergh, a good section may be seen, where it occupies the whole of a cliff 50 or 60 feet high, and it can be examined in many other places. It is a coarse red conglomerate throughout. It rests unconformably upon the Coniston grits—the equivalents of the Wenlock—and does not, in this locality, pass into the carboniferous limestone.

3. *Kendal.*—Near Kendal there are several patches, once, in all probability, continuous, resting unconformably upon the Bannisdale slates (Lower Ludlow and Wenlock shale). The conglomerate is interstratified with red sandstones, and is well seen in the river Mint, about two miles N.E. of Kendal. Lying conformably above it, and separated from it by thin shales and sandy limestones, are thick-bedded, grey carboniferous limestones.

4. *Tebay and Shap.*—This is perhaps the most instructive region for studying these conglomerates in their connection with the overlying limestone. The series may be seen in ascending order by proceeding N. up the Birk Beck. The lowest beds consist of red conglomerate dipping N.E. resting unconformably upon the Bannisdale slates. Further N. the conglomerate becomes somewhat finer, has a light grey matrix, and is interstratified with coarse, false-bedded thin sandstones. Above these are fine whitish sandstones, marked with dark spots. Dr. Nicholson, who calls nearly all the beds below the limestone "upper old red," classes all the above as "lower" division. Above the light coloured sandstone occur beds of red sandstone, and red sandy shale, which the same author calls "middle." These are followed by beds of conglomerate and sandstone, which he classes as "upper," and in which he has found the remains of coal plants. They are succeeded conformably by the "Dun limestone." Professor Harkness has estimated the thickness of these Birk Beck beds at 270 feet. Further N. they are much thinner, and the whole series may be seen in section in the railway

cutting near the Shap granite works. The lower beds here consist of very coarse angular conglomerate or breccia, resting unconformably upon the green slates and porphyries (lower silurian). They are succeeded by beds of red sandstone and finer conglomerate, which make up the bulk of the section. Above them are beds of variously coloured clays and thin bands of impure nodular limestone, and on the top, thicker beds of light yellow, sandy limestone ("Dun limestone"). A very similar section is exhibited near Shap Abbey, but the lower coarse conglomerate is absent, perhaps overlapped. It can be well seen, however, in a small brook running W. into the Birk Beck, where it rests on the Coniston grits, and is succeeded by thick beds of red sandstone. Near Shap Fell the conglomerate contains crystals of orthoclase from the Shap granite.

5. *Penrith.*—The red conglomerate attains its greatest thickness in the district which extends three or four miles W. from Pooley Bridge, at the W. extremity of Lake Ulleswater. It is here almost entirely thick-bedded conglomerate, without sandstones, and forms several hills, including Great and Little Mell Fell, 1,760 and 1,650 feet high respectively. Its thickness has been estimated at 2,500 feet, but taking into consideration the fact that it has an average easterly dip of 7° or 8°, it seems to me that it may be considerably less. It can be examined in the river Eamont and Dacre Becks and on the N. and N.W. shores of Ulleswater. East of Ulleswater, the limestone rests directly upon the green slate and porphyries. Tracking the conglomerate upwards towards Penrith, we find resting upon it a thickness of several hundred feet of limestone, followed by alternations of limestones, red sandstones, and shales, and then by the main mass of the carboniferous limestone.

6. *Kirkby Stephen, &c.*—These beds are again exposed to view on the E. of the Pennine Fault, near Kirkby Stephen

and Brough. Mr. Goodchild* gives the following sequence at Ash Fell:—

a. Main mass of the carboniferous limestone. (1,000 ft.)

b. Soft red sandstones, often conglomeratic, with traces of coal plants, alternating with thin shales and limestones. (500 feet.)

c. Limestone, rather impure, but not split up by sandstones and shales. (500 or 600 feet.)

d. Shales and thin impure limestones passing downwards, through calcareous beds of a more decidedly conglomeratic character, into a series of apple-green conglomerates and chocolate and grey shales.

e. Drift-like series of red conglomerates, sandstones, and shales of variable thickness. These are the beds which in various localities are seen resting unconformably upon the silurian rocks. They pass upwards into *d* without any clear line of demarcation.

A series, similar to *a*, *b*, *c* of the above, but less calcareous, is found near Brough, in the escarpment.

Thus we see that there is in several localities a mass of coarse conglomerate which passes upwards through a series of fine conglomerates, red sandstones, shales, and limestones, more or less pure, into the main mass of the carboniferous limestone.

7. *Isle of Man.*—In the Isle of Man there are two districts in which we find red beds resting on an irregular and denuded surface of silurian schists. The carboniferous limestone occurs in the S.E. of the island, and in various points showing from under it we have a thick-bedded red conglomerate, very similar to that in Cumberland. It is best seen in the small peninsula of Langness, opposite Castletown,

* "On the Carboniferous Conglomerates of the Basin of the Eden," Quart. Journ., Geol. Soc., Nov., 1874.

between high and low water mark, where it is about 50 feet thick, and perfectly conformable to the limestone. (Plate III. B.) Its junction with the silurian can be seen in many places; perhaps the most striking is a natural arch, the lower part of which is silurian and the upper conglomerate, the conglomerate being intersected by a dyke.* (Plate III. C.)

At Peel, the red beds are, almost entirely, the fine-grained thick-bedded sandstone of which the town is built. They form the cliffs for a distance of about two miles N. from Peel. The Rev. J. G. Cumming† has estimated its thickness at 300 feet, and has pointed out the fact that although there is no limestone on it now, beds of limestone, probably carboniferous, were removed from it some years ago for burning, and the shore is strewn with limestone blocks, probably washed up by the sea from beds still existing.

Having now touched upon the various localities in which these red beds are found, it remains to consider the mode of their formation, and their position in the geological series.

They are unconformable to the upper silurian, and pass upwards into the carboniferous limestone. They are, therefore, certainly not older than the upper old red. They are composed of coarse materials, and bear other evidences of rapid accumulation, and in many places pass by regular gradations of colour and mineral character into the carboniferous limestone.

Again, they rest upon an irregularly denuded surface of silurian rocks of all ages. Near Shap Fell they lie nearly horizontally upon the upturned edges of the elevated rocks,

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* The dyke is the cause of the arch. Being more readily decomposed than either the schist or the conglomerate, the sea washed through, and then enlarged the hole to its present dimensions. On the other side of Langness, the decomposition of trap dykes which intersect the schists, has caused many long narrow inlets of the sea to be formed.

† "On the Geology of the Isle of Man." Quart. Journ., 1846.

and fragments from the granite are found in them. These facts tell of a long period during which these old silurian rocks were exposed to denudation and igneous action, and during which the country received the great general features of hill and valley which it now presents. Judging by the work done, this must have been a period of very long duration. In the southern silurian district, on the other hand, 10,000 feet of strata were deposited conformably upon the upper silurian. These periods of denudation and deposition must have been contemporaneous. By far the greater part of the materials removed from the Cumbrian region would be carried out into the Devonian sea and form new rocks elsewhere, but some would remain, choking up the valleys, and when the land began to sink the first thing done by the encroaching sea would be the sorting out and rearranging of these valley deposits. The work would be done with more or less thoroughness, according to the amount and nature of the deposit and its position with reference to the advancing waters. In some cases, as at Shap, it was sorted and spread out along the valley; in others, as at Ulleswater, it was left piled up as a great bank. Then, as the land still continued to sink, overlapping deposits of sand and mud were thrown upon and against the coarser deposits, becoming more and more interstratified with limestone as the water deepened, sometimes the sandy and muddy deposits predominating, and sometimes the limestone, till finally the latter prevailed over the former, and the carboniferous limestone was deposited in thick masses round the sinking land.

There can be little doubt that the conglomerates, sandstones, and shales, represent a part of the waste of this old silurian region. This material would be brought down into the valleys either by water or ice. Everyone must be struck on first seeing the conglomerate, both in the Isle of Man and in the Lake District, with its resemblance to "till," especially where it is somewhat decomposed. Its large angular and subangular stones, its position in isolated patches, and in the valleys, suggest its glacial origin. But the subsequent action of water is also indicated by the following facts :—

(1) Scratched stones, so common in the till, are at least rare.*

(2) There is less matrix than in more recent till, and it is more sandy.

(3) Although many of the stones stand on end, yet, on the whole, they seem to lie more horizontally than would be expected had they been left undisturbed.

Finally, we have the question, Are these beds to be considered as old red sandstone or carboniferous? The materials which compose the beds were removed from the silurian land and deposited not very far from their present position during the old red period, but their present form and arrangement are the result of those changes in level which brought the carboniferous limestone round the Cumbrian region; the waters which washed up the valleys and spread out the old drifts, were, at the same time, depositing limestone out at sea, and this limestone, as the water deepened, spread over the rearranged drifts. It seems, therefore, simpler and more logical to consider these beds, one and all, as basement beds of the carboniferous limestone than to attempt to draw any arbitrary line in a series whose members appear so closely linked together. At the same time, the question as to the *name* is of secondary importance.

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* Professor Ramsay has noticed the occurrence of scratched stones. Professor McKenny Hughes, in a paper read before this Society, in 1867, pointed out that these stones are only found where the scratches might have been caused by subsequent disturbance. This explanation, however, does not seem quite satisfactory.

EXPLANATIONS OF PLATES II. AND III.

PLATE I.—Map showing the horizontal and vertical distribution of the red deposits near the Lake district. Unshaded portion—below 1,000 feet in elevation. Light shading—between 1,000 and 2,000 feet. Dark shading—above 2,000 feet.

PLATE II.—Section in railway cutting near Shap.

a. Silurian rock.

b. Very coarse and conglomerate, resting unconformably upon *a.*

c. Finer red conglomerate with sand.

d. Coloured clays and bands of limestone.

e. Dun Limestone.

f. Rubbish.

B.—Section between high and low water marks on W. of Langness.

a. Silurian schist.

b. Red conglomerate.

c. Carboniferous limestone.

C.—Natural arch at Langness.

a. Silurian schist.

b. Red conglomerate.

c. Dyke.

ON THE VARIATIONS IN THICKNESS AND CHARACTER OF THE SILKSTONE AND BARNSLEY COAL SEAMS IN THE SOUTHERN PART OF THE YORKSHIRE COAL-FIELD, AND THE PROBABLE MANNER IN WHICH THESE AND SIMILAR CHANGES HAVE BEEN PRODUCED. BY A. H. GREEN, M.A., F.G.S., PROFESSOR OF GEOLOGY IN THE YORKSHIRE COLLEGE OF SCIENCE, LEEDS. (PLATE IV.)

OVER the southern part of the Yorkshire Coal-field, as far north as the village of Cawthorne, the Silkstone coal maintains, in spite of local variations, a fairly constant character. It consists of two beds of coal, each averaging some 2 feet 6 inches in thickness, separated by a band of dirt. Over a very great part of the area where the coal is known, the dirt parting is very thin; here and there, however, it swells out to a very considerable thickness, and in one place it even reaches a thickness of ten yards. In the neighbourhood of Cawthorne a very important change comes over the seam, additional dirt partings come in and it breaks up into several beds of coal. Following it to the north-west the beds of coal decrease in thickness, whilst the dirt partings swell out, and there can be little doubt that if it were possible to trace the seam still further in this direction, it would be found that the coal thins away altogether, and that the seam is replaced entirely by stone and shale. On this point, however, it is impossible to speak with certainty, for after passing Cawthorne the seam becomes so much deteriorated that no attempts have been made to work it, and to the north-west of that village there is a belt of country some two or three miles broad which is totally unexplored. After passing this problematical ground, however, a tract is again reached yielding workable seams, and among these there is one known as the Blocking coal, which holds a position in the measures exactly corresponding to that of the Silkstone coal, and which, for this reason, the author considers to be the equivalent of that seam. The Blocking coal, however, differs totally from the Silkstone in character, for it is a single bed of coal averaging 1 foot 6 inches in thickness, and reaching but rarely an extreme thickness of 2 feet.

After the above general sketch, the author gave the following details of the variations of the Silkstone coal :—

About nine miles south of Rotherham the seam consists of two beds of moderate thickness, with a thin dirt parting. The section being

	Ft.	In.
Coal	1	2½
Dirt	0	8
Coal	1	9

About six miles north-west of Rotherham, where the seam may be said to be about at its best, it consists of the following subdivisions :—

	Ft.	In.
Branch Coal...	1	2
Coal	1	4
Dirt	0	7
Coal	3	7

About three miles to the west of Rotherham the parting of dirt has increased to a thickness of from 1 foot 3 inches to 4 feet, the top and bottom coals having a little less than their ordinary thickness. C, Plate II., Fig. 1.

Going on towards Chapeltown, the dirt parting continues to swell out till it reaches a thickness of ten yards. A little further on another singular change comes over the seam, the lower bed of coal decreases in thickness and passes into a mass of black shale with thin shreds of coal, the top bed still retaining its average thickness. D, Plate II., Fig. 1. The exact area over which the bottom seam is wanting has not been ascertained, but its disappearance is certainly only local, for a little further to the north the seam recovers pretty much its usual character. From this point up to the villages of Dodworth, Higham, and Silkstone, the seam has been very largely worked, and found to be very uniform in general character, the two coals average 2 feet 6 inches to 2 feet 7 inches, and the dirt parting never exceeds 9 inches. E to F, Fig. 1, Plate II.

Between Silkstone and Cawthorne, however, the important change described in the introductory sketch sets in; the main dirt increases in thickness, and other partings come in amongst the coal, splitting it up into a number of subdivisions.

The following two sections, in the neighbourhood of Cawthorne, will illustrate this change:—

		(1.) F. Fig. 1, Plate II. Ft.	In.		(2.) G. Fig. 1, Plate II, Ft.	In.
Top coal	Coal	1	4		1	10
,,	Dirt	1	9		2	0
,,	Coal	0	8		0	9
Main Dirt	Parting	22	8		23	2
Bottom Coal	Coal	1	9	Coal	1	5
				Dirt	0	4
				Coal	0	5

In both of these the thickness of the coals is below the average, and the old dirt parting has vastly increased in thickness; but besides these changes, the top bed has become divided by a new band of dirt, and in the second section a similar change has affected the bottom bed, so that the seam has become broken up into four beds. There seems reason to believe that the gradual breaking up may continue to increase towards the north-west, till the seam, if it does not altogether cease to exist as a coal, becomes so continually divided and subdivided by the coming in of new dirt bands, that for all practical purposes it may be looked upon as non-existent. Whether, however, it actually comes over to this or not, the seam has already, where the above sections are taken, become unworkable, and it is here that the belt of unproved ground, which has been already mentioned, is entered upon.

It remains only to add, that, when a productive district is again reached, the place occupied on the south by the Silkstone coal is taken by the Blocking bed, a seam ranging from 1 foot 6 inches to 2 feet in thickness.*

The Barnsley coal has now to be described. Its marked distinguishing character is the occurrence in it of a band of "hard" or "steam" coal. This lies in the middle of the seam, the upper and lower portions being of the so-called "bituminous" character. In the neighbourhood of Sheffield this coal ranges from 4 feet to 4 feet 6 inches in thickness; going north it thickens, till at Rotherham it reaches 7 or 8 feet. About Barnsley it is at its best, ranging from 9 feet to 10 feet, and sometimes even exceeding the latter figure. At Darton, near the station of that name, on the Lancashire and Yorkshire Railway, the coal is still of good quality, but a dirt parting, which first makes its appearance some way south of Barnsley, has somewhat increased in thickness. A little further on, as Haigh Station is approached, the coal has fallen off very considerably, and still further to the north, at Crigglestone, it has split up into so many small seams by dirt partings as to be utterly worthless; and, further north, the writer has found it by personal explorings to be still further deteriorated. Then, as in the case of the Silkstone seam, comes a belt of unexplored ground; and, after passing this, we find the coal, which occupies the same place as the Barnsley bed, putting on one form towards the north-east, and another towards the north-west. In the first

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* There is some difference of opinion about the identity of the Silkstone and Blocking coals. The reasons for thinking them equivalents will be given at length in the memoir of the Geological Survey on the Yorkshire Coal-field.

direction, *i.e.*, going towards Wakefield, the coal called the Warren House probably corresponds with the Barnsley; it is for the most part a mixture of thin bands of coal and dirt, never of much value, and frequently absolutely worthless. Going towards the north-west, the coal, which seems to be the equivalent of the Barnsley bed, is called the Gawthorpe, a seam from 2 feet to 3 feet in thickness, and of fair average quality. Neither the Warren House nor the Gawthorpe contain any "hard" coal.

The writer will now proceed to give a few details of the changes which have been broadly sketched out in the preceding paragraph. Near Sheffield, the three subdivisions of this coal range as follows (Plate II., Fig. 2):—the top soft, from 1 foot to 1 foot 8 inches; the hard coal, from 1 foot 6 inches to 2 feet; and the bottom soft, from 2 inches up to 1 foot. Northward, from Rotherham and on to Elsecar, the coal considerably increases in thickness, the top ranging from 1 foot 6 inches to 3 feet; the hards, from 3 feet to 4 feet 6 inches; and the bottom, from 1 foot 4 inches to 2 feet. Although these three subdivisions can be clearly separated one from another, there is nothing that can fairly be called a parting between them. Between Elsecar and Barnsley, however, a parting comes in between the tops and the hards, called the clay seam band, consisting of clay and a very inferior sort of coal. At Barnsley, the section of the seam may be taken as follows:—The top seam, from 2 feet 2 inches to 4 feet; then the "clay seam," ranging from 3 inches to 1 foot 8 inches; then comes the hard or steam coal, from 1 foot 9 inches to 3 feet 6 inches; and then the bottom coal, 1 foot 11 inches to 2 feet 8 inches.

The seam maintains this character up to Darton, where the clay band has very materially increased in thickness, the other divisions retaining their normal characteristics as to quality and thickness. At Haigh, this coal has been worked, but only to a limited extent. There can be no doubt that the coal at Haigh is the equivalent in a general way of the Barnsley bed, but the writer has never been able to satisfy himself as to the identity of the subdivisions of the bed at Haigh with those of the Barnsley seam. Of one thing, however, he is quite sure, namely, that at Haigh there is no "hard" coal, it has completely gone out, and thus a very important change has taken place within two or three miles. The next section is obtained in the railway cutting at Crigglestone Station, and here changes still more remarkable have come over the bed. It shows the following numerous subdivisions :—

	Ft.	In.
Coal...	1	7
Shale and Spavin, with thin layers of coal	5	3
Coal...	1	5
Spavin, black shale, and thin layers of coal	1	4
Coal and black shale	1	1½
Coal...	1	4
Spavin	1	6
Coal and black shale	1	4½

Some little way further to the north-west, the bed has further come down to the following insignificant representative :—

	Ft.	In.
Coal	0	9½
Spavin	0	2½
Coal...	0	0¼
Spavin	1	6
Coal...	1	11½
Spavin	0	8
Coal...	0	1

These sections show that changes, exactly similar to those which affect the Silkstone coal, come over the Barnsley bed as it is traced to the north-west. This leads to the belief that, if it could be followed further in that direction, it would be found to be entirely replaced by stone and shale; and the section last given seems to show that in the case of the

Barnsley bed, it has been possible to push explorations nearer to the probable extinction of the seam than in that of the Silkstone coal.

At this point, the rapid deterioration of the seam has forbidden any attempts to work it; and a tract of unexplored ground is entered upon, beyond which, as has been already mentioned, the Barnsley coal is represented on one side by the Warren House, and on the other by the Gawthorpe, which differ strikingly both from the Barnsley bed itself and from one another.

On the horizon of the Barnsley coal then there are changes still more striking than those met with in the case of the Silkstone seam. When the equivalent coals in different parts of the field are compared with one another, the representative beds are found to be *three* in number, and no two of these are in the least degree alike.

It now remains to offer some explanation of the probable manner in which changes like these just described are produced.

The occurrence of partings in a bed of coal, and the variations in thickness of these partings, are easily accounted for. Coal, it is well known, is the result of an accumulation of dead vegetable matter which grew on swampy flats at the spot where it is now found. When accumulation had gone on for some time, the ground was lowered and submerged beneath water. Into this water, sand and mud were carried by running streams, were piled up into banks, or spread out n layers, and covered up the sheet of dead vegetable material. Then upheaval followed, a land surface was again formed, and on it the growth of a fresh seam of coal took place. If the submergence was of long duration, the two successive coal beds are separated by a considerable thickness of shale and sandstone; but where the depression lasted for only a short time two beds of coal are formed, separated by a thin layer of sedimentary matter. The thickening of a parting requires that the sinking which followed on the growth of the lower coal bed should have gone on faster at some spots than others. By such an adjustment, the lower seam would become bent down into the shape A B, Fig. 3, Plate II.: if the sediment accumulated up to the level G D, and a fresh growth of coal, I G D F, took place over the level top of the deposit, there would be a double seam of coal with a parting rapidly swelling out towards the right.

The replacement of coal by sandstone is also often produced by what are known as "rock faults." In such cases a stream of water has flowed over the layer of dead plants before it became covered up, and eaten out in it a trough or channel, and this hollow has, during the subsequent submergence, been filled in with sand or mud.

But neither of these explanations will apply to the cases before us, for two facts have to be accounted for. First, the gradual breaking up of a seam of clean coal into numerous subdivisions by dirt bands, and the gradual diminution in thickness and eventual disappearance altogether of the coal out of the seam; and, secondly, when a spot is reached where coal again sets in, the appearance of a bed differing totally in thickness and character from the seam started with.

The latter fact may be accounted for if it is supposed that the swamps in which the growth of the two distinct forms of the same bed went on were not continuous, but parted from one another by some barrier, and that the physical conditions of the two swamps were so different that the vegetable growth of the one differed from that of the other both in nature and amount. For instance, the Silkstone and Blocking coals may both have been growing about the same time on two distinct swamps. Where the Silkstone seam accumulated, the growth was plentiful and rapid, and during the formation of the seam submergence occurred once and gave rise to a dirt parting. On the Blocking coal swamp plants did not flourish so luxuriantly, and no submergence occurred, and so a coal bed, thinner than the Silkstone, and with no dirt parting, was the result.

The breaking up of the seam as it approaches the margin of the swamp may have been caused in a way that will be understood by a reference to Fig. 4, Plate II. The barrier separating the two swamps may have consisted of a ridge of land, A B C, somewhat raised above the low ground on either side. On this barrier, for some reason or other, plants did not flourish so luxuriantly as over the adjoining swamps. While, therefore, vegetable growth went on freely at a point D, some way out on the flat, it would decrease as we approached the ridge, and a layer of coal would be found thinning away towards A. Again, rain and other denuding agents would sweep the loose soil produced by the atmospheric disintegration of the exposed surface of the ridge down its slopes on to the flat, but when the running water reached the level surface it would soon come to rest and drop its burden of sand or mud. In this way the margin of the ridge would become fringed with accumulations of sediment, but these would not reach out far on to the flat, but would be wedge-shaped banks, such as E F A. In the meantime, the growth of plants out on the flat would add another layer of coal material above A D; and away from the ridge this would be clear and pure, but on approaching the barrier would become mixed with sediment, and gradually thin away as shown at H. On the top of G H, another band of sediment would accumulate in the neighbourhood of the ridge, and another layer of clean coal material out on the flat. By a continuation of such a process as this there would result a seam of coal, thick and free from partings on the left, but splitting up into numerous subdivisions, and falling off in quality and thickness as the point A was approached: in short, exactly such a seam as the Silkstone and Barnsley coals have been found by actual explorations to be.

In particular instances, special modifications of the process may be required to explain the individual circumstances of each case, but some such general method seems quite competent to produce the modifications in the character of coal seams, of which examples have been given in the preceding paper.

THE WORK AND PROBLEMS OF THE VICTORIA CAVE EXPLORATION. BY R. H. TIDDEMAN, M.A., F.G.S., OF H.M. GEOLOGICAL SURVEY OF ENGLAND AND WALES. (PLATE V.)

In the course of the past six years the Victoria Cave, near Settle, has become by name at least well known to Yorkshiremen, and has attracted the attention of many outside the county. Many notices and papers have been written upon it, but are mostly not easy of access, and scattered up and down in various Transactions of Scientific Societies. In his interesting work on "Cave Hunting," Prof. B. Dawkins has given a valuable *resumé* of what has been done up to 1873. But very much has been done since that time, and some valuable results have accrued which deserve to be put on record in connection with what has been previously done. Moreover, as a considerable portion of the funds employed in the excavation is derived from Yorkshire, it is only right that scientific Yorkshiremen should have an opportunity of knowing in what those funds have been spent, what have been the results so far, and what may be the problems awaiting solution in our further work.

In giving a short summary of the work it will be necessary to recapitulate much that has been already published in various periodicals and other works.

The Victoria Cave is situated in a most picturesque locality in a line of limestone scars, which runs from the Settle rifle range at the Attermire Rocks, towards the N.N.W., and it faces S.S.W. It lies at a considerable elevation (about 1,450 feet) above the sea level, and 900 feet above the River Ribble at its nearest point. The mouth of the Cave commands an extensive panorama of the district of Craven, with distant views of Ingleborough, the Lake Mountains, the Valley of the Lune, the Fells of Bowland, and towards the south the lower valley of the Ribble, Pendle Hill, &c.

The southern aspect of the Cave, sheltered from the north and from the east by the cliff in which it is formed, would give it an advantage as a habitation, whether for man or beast. Strangely enough this cavern, which has been a resort in such widely separated ages of the world's history, was on the day of Her Majesty's Coronation completely concealed, and unknown to any one.

To Mr. Joseph Jackson, of Settle, belongs the honour of its discovery on that day, and still more of the intelligent perseverance with which he commenced and carried on its early exploration. The results of his researches may be seen in the British Museum, in the Leeds Museum, and in his own private collection. The Cave furnished him from time to time, as Prof. B. Dawkins states, with "a remarkable series of ornaments and implements of bronze, iron, and bone, along with pottery and broken remains of animals. Fragments of Samian ware and other Roman pottery, coins of Trajan, Constantius, and Constantine, proved that the stratum in which they were found was accumulated after the Roman invasion. There were also bronze fibulæ, iron spear-heads, nails, and daggers, as well as bronze needles, pins, finger-rings, armlets, bracelets, buckles, and studs. The broken bones belong to the red deer, roebuck, pig, horse, Celtic shorthorn, sheep or goat, badger, fox, and dog. The whole collection was just of that sort which is very generally found in the neighbourhood of Roman villas and towns, and was doubtless formed while the cave was a place of habitation." *

Late in the year 1869, Prof. T. McK. Hughes saw Mr. Jackson's collection, and appreciating the importance of a further and systematic exploration of the cavern, set to work at its accomplishment. He obtained permission from the owner of the property, the late Mr. Stackhouse, and induced some of the gentry of the neighbourhood and others to form a Committee, under Sir James Kay-Shuttleworth, for the purpose. A subscription-list was opened, and donations came in liberally. Prof. Dawkins kindly undertook the scientific direction of the work.† Mr. John Birkbeck, Jun., accepted the post of Hon. Treasurer and Secretary, and the Committee were fortunate in obtaining Mr. Jackson's assistance as superintendent.

Mr. Jackson's previous work had been entirely in the inside, from a narrow entrance in rock at the bottom of a niche in the overhanging cliff (now walled up), but light could be seen towards the right on entering the cave, and it was resolved to remove the screes at the outside which blocked up the aperture, and form a new entrance. The obvious advantage of this was that it would enable the workmen to work in daylight, and, moreover, the small plateau formed by the screes "could not fail," as Prof. Dawkins observes,‡ "to have been chosen by the inhabitants for kindling their fires and cooking their food. On the surface there was a talus, 2 feet thick, of angular fragments, broken away from the cliff above by the action of frost. It rested

* Journ. Anthrop. Inst., vol. i., p. 61.

† Prof. Dawkins was obliged by stress of work to resign this responsibility in the summer of 1873, and at the request of the Committee the Author undertook it.

‡ Op. Cit.

on a dark layer composed of fragments of bone, more or less burnt, burnt stones which had formed the fire places, very many fragments of pottery, and coins of Trajan and Tetricus. Fires had been kindled on the spot, and the broken bones of the animals strewn about, were the relics of the feast." As work continued the talus over this layer died out inwards, and "the black layer below rose to the surface, and was continuous with that from which Mr. Jackson obtained his ornaments and implements inside the cave."*

The objects found in this layer consist of spindle-whorls, beads, and curious nondescript articles of bone. Some of them are dress fasteners, much of the form of "frogs" used in military dress. The use of these was pointed out by Mr. Stevens, who called attention to traces of wear upon them by the thongs which held them. Then there were spoon brooches, a toothcomb similar in form to those now in use, a small bone object like a teetotum, and the ivory guard of a Roman sword hilt identified by Mr. Franks. In bronze many articles and ornaments were found, some of them beautifully enamelled in red, blue, yellow, and green, and of graceful designs. These, though some of them Roman in form, are considered by Mr. Franks to be of Celtic workmanship. Other brooches are of more distinctly Roman type. "The fragments of pottery were very abundant, and were all of the types usually found around Roman villas. The bones are very numerous, and afford fair testimony as to the food of the occupiers of the cave during the time of the accumulation of the Romano-Celtic stratum. The Celtic shorthorn (*Bos longifrons*) formed by far the staple animal food. The variety of *Capra ægagrus*, or goat with simple recurved horns, which is commonly met with in the Yorkshire tumuli, and in the deposits around Roman villas throughout Great Britain, furnished the mutton. A domestic breed of pigs, with small

* Op. Cit., p. 62.

canines, furnished the pork. This bill of fare was varied by the use of horseflesh. To this list must be added the venison of the roedeer and the stag, but the remains of these two animals were singularly rare. Two species of the domestic fowl, and a few bones of wild duck and grouse, complete the list of the animals which can with certainty be affirmed to have been eaten by the cave-dwellers." *

Prof. Dawkins shows that the coins of Trajan, Constantine, and Tetricus, and some barbarous imitations of Roman coins, assigned by numismatists to the time of the evacuation of Britain by the Romans, explain the singular abundance of articles of luxury in so rude a retreat. "We can hardly doubt that it was used in those troublous times by unfortunate provincials, who fled from their homes, with some of their cattle and other property, and were compelled to exchange the luxuries of civilised life for a hard struggle for common necessaries." This would place the occupation of the cave by the Romanised Celts as somewhere not earlier than the 5th century.

The Romano-Celtic layer was two feet down and two feet thick on the little plateau; the charcoal and refuse bones of the temporary dwellers no doubt considerably contributed to this thickness. Lower down the slope the same layer was only covered by a foot, and sometimes less, of Post-Roman talus, and as it entered the cave in the other direction it came to the surface. This greater thickness would lie at a spot beneath the cliff, which was most exposed to falls of rock-fragments.

The Neolithic Layer.—Beneath the Romano-Celtic layer was a thickness of about five or six feet of what had at some time been loose talus, but was now bound together, though not very firmly, by the deposition of carbonate of lime by dripping water. At the base of this the Committee discovered

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* Op. Cit., p. 65.

a singular bone-harpoon, with double barbs, facing in one direction, and a third reversed barb at the base (the last no doubt being intended to serve as an attachment to the shaft), a bone bead hexagonal in form to a section along a plane through its axis and incised with rectilinear ornamentation, and three flint flakes.

Just as the Roman layer thinned away in each direction, and came to the surface inside the cave and outside down the screes, so did the Neolithic layer thin away in each direction, and run into the Roman layer. In 1874 a well-worked small flint implement of lanceolate-leaf outline, similar to some figured in Mr. John Evans' valuable book * was found lying on the side of a cutting through the screes, and had probably fallen out of the Neolithic layer above. It was unworked on the flat side. Sections across it would give at $\frac{1}{3}$ from the point a triangular, and near the bulb a plano-convex, outline. Amongst Mr. Jackson's finds inside the cave was a small adze of melaphyr †, and the late Mr. Denny showed me this in the Leeds Museum, side by side with one from the South Sea Islands, so exactly similar, except in its larger size, that they might have been made by the same workman. So uniform is the teaching of the school of necessity! It is probable that this interesting relic is also from the Neolithic layer.

We have now got so far back in time in our account of the researches as to be already far below the earliest records of history. Let us see what light the cave throws upon still earlier and obscurer ages of the area now called Yorkshire.

THE BEDS INSIDE THE CAVE.

The Upper and Lower Cave-Earth.—In describing these I shall give the chief prominence to the Section as it appeared in Chamber D, the right hand hall of the cave at its present

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* Stone Implements, &c., of Great Britain.

† Cave Hunting, p. 114.

state of excavation, because it has been more thoroughly explored than the remainder. It has also received great attention in the careful registration of the bones, and the discrimination of those of different beds. Moreover, no account of it has been given as yet (save in the British Association Report for 1875). In the spring of 1871 I described to the Cave Committee the beds inside the cave below the Roman-Celtic, and Neolithic layers, as consisting of—

The Upper Cave-Earth,
The Laminated Clay,
The Lower Cave-Earth,

and this distinction still holds good, although the Upper and Lower Cave-Earth ran together in one portion. Still the great thickness of laminated clay demands a corresponding length of time for its formation, and its absence or thinness at one point or another does not invalidate its existence elsewhere. Moreover, as will be seen, its importance as separating two distinct life eras in which different climatal conditions obtained cannot justifiably be overlooked. In their physical aspect the Upper and Lower Cave-Earth have much in common. They both consist of large and small angular blocks of limestone, intermingled with a stiff buff clay, occasional beds of stalagmite, and fallen blocks of stalactite. The limestone and stalactite have undoubtedly fallen from the roof. The stalagmite has formed upon the floor from time to time, when circumstances have been favourable. In the Upper Bed much of the clay seems to be derived from the laminated clay beneath, worked up and redeposited by water, or *puddled* by the animals whose bones are found in it; certainly where bones have occurred in the surface of this clay, it has lost its characteristic finely-bedded structure, and is simply homogeneous. A good deal of this homogeneous clay has probably been washed down through fine crevices in the roof by little runnels during wet weather, although at present certainly all water that drops from the roof seems to be well filtered. In the Lower Cave-Earth, between the blocks of limestone, little chinks have been filled in with laminated clay,* which is possibly of the same age, and deposited under identical circumstances, with the great mass of it above—the conditions necessary for this only being a pre-existing chink and a crack leading to it, wide enough to permit water to trickle through it, bearing the finest impalpable mud. Both these beds, Upper and Lower, contain the remains of man and animals scattered along more or less definite horizons to be further described.

The Laminated Clay.—This lies between the beds already described, and the great contrast which it shows to them induced me in 1870 to study it more particularly with a view to getting some insight into the conditions under which it was formed. The laminæ into which it is divided are exceedingly thin, and flake away easily when pulled asunder, yet it is so stiff as to make the digging of it a work of great labour. It is found to consist of an exceedingly fine impalpable mud. About 8 per cent. of it is carbonate of lime. It varies in thickness, but has been found in all the chambers hitherto explored. In the left hand Chamber B, it showed a thickness of 12 feet, in other parts 7 and 8 feet have not been uncommon dimensions. It was thin at the entrance, thickened rapidly and thinned again, but it has been found to run continuously from the entrance inwards, a distance of more than 70 feet, which is as far as the explorations have gone along that horizon in the right hand Chamber (D). In casting about for an explanation of the singular contrast of this bed to those above and below it, I was unable to resist the conclusion that different physical conditions were necessary for its formation. Similar clays are found intercalated

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* See foot note, p. 85.

with true glacial beds in many places besides the immediate neighbourhood. At Ingleton I found two beds of this laminated clay resting between beds of ordinary till, with well scratched boulders, and *there* were well preserved glacial boulders in the laminated clay itself. The conclusion that these beds in the cave might be the result of glacial conditions, which imply the running of much muddy water in alternating periods of flow and rest was *primâ facie* not improbable, but seemed to explain the difficulties. The great thickness of pure mud, the numberless alternations, implying alternating conditions, the singular contrast in physical conditions to the deposits above and below, and the absence of life, all pointed to a state of things such as we know existed during the great ice age.* I communicated this opinion in a Report to the Cave Committee in February, 1871, and the further explorations have singularly confirmed it.† We have since found glaciated boulders in the laminated clay itself, and still later the important discovery of a great accumulation of boulders and glacial till at the cave mouth, resting on the edges of the lower cave-earth, goes far to establish the matter.

The Glacial Beds at the Cave Mouth.—As the explorations went on it was found necessary to remove a large breadth of the screes or talus at the entrance to a lower depth than previously, and most important results accrued. From year to

* For fuller arguments *vide* Geol. Mag., vol. x., p. 11.

† This conclusion is disputed by Prof. Dawkins (Cave Hunting, p. 122) on the ground of—1st, laminated clay occurring in crevices in the Lower Cave-Earth, beneath the main mass. On this point *vide supra* p. 84.* 2ndly. his discovery of laminated clay (one-tenth of an inch thick, as he informs me), in pools, in the Ingleborough Cave. This seems to me beside the question, which is not "Can laminated clay be deposited under other than glacial conditions?" (to which I would give a decided affirmative), but "What were the prevailing conditions when so large a mass of laminated clay was deposited in the Victoria Cave, contrasting so strongly with the great thickness of beds above and below it?"

year a great deposit of glacial till and other glacial deposits has been uncovered: some it has been necessary to remove, and some still remains. As we deepened the section we first came upon a line of boulders resting on the edges of the lower cave-earth, and dipping outwards at an angle of about 40 degrees. Deeper to the dip the deposit was found to be a true till of great tenacity, containing well scratched boulders, and in places intercalated with beds of sand and laminated clay. The boulders were of all sizes, from blocks weighing some tons to mere sand grains. Whence had they come? Some were semi-angular blocks of Carboniferous Limestone, but of these many were of a darker rock than that in which the cave is formed. But a very large proportion, nearly half, were of Silurian grit ("blue rock," as Yorkshire has it). Others were a conglomerate from the base of the Carboniferous Limestone, containing slate pebbles, telling of the time when all Yorkshire's mineral wealth was still in the lap of futurity. These must have travelled in the ice two miles or more. Carboniferous gritstones were there, for whose origin we must look up to the tops of Ingleborough or Pennigent.

The accumulation of these waifs and strays, lying as they do on a *col* 1,450 feet above the sea, at a place where there are no gathering grounds for a mere local glacier, must be attributed to the transport of ice when the Ribble valley alongside, and 900 feet below us, was filled with ice up to this point, and still higher. The ice scratches on the rocks at the base of King Scar hard by show us the direction in which it travelled across the *col* from Stainforth towards Long Preston by way of Attermire; and there are not wanting evidences in the district to show that this great confluent ice-sheet covered all the country visible from the cave mouth, and many miles beyond.*

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* Quart. Journ. Geol. Soc., vol. xxviii., p. 471, 1872.

It was suggested when we first found the boulders that they might not have been left there by the ice-sheet, but might have fallen from the cliff subsequently. This question has been thoroughly investigated since, and the evidence given in the British Association Report for 1874;* as the facts and arguments there used have not been disputed, I will not treat this question at length.

Briefly the evidence is this—

1. The boulders lie at the base of all the screes, which are 19 feet thick, and no other boulders occur throughout that whole thickness.

2. The cliff immediately above the cave is quite free from boulders for a considerable distance.

3. The screes (talus) are allowed to be the result of the destruction of the cliff above by atmospheric agencies, and, as they lie above all the boulders, must have fallen subsequently. Even now the boulders lie so close beneath the cliff that it would be barely possible for them to fall from it into their present position. But if we could restore to the cliff all the limestone screes lying above the boulders, such a fall would be quite impossible.

4. The extent of the glacial deposits now exposed is so great, covering an area of 1,200 square feet or more, that it is impossible that they can be a mere chance accumulation of boulders.

The Life of the Earlier Periods.—We have now briefly gone through the physical aspect of the earlier beds in the Victoria Cave. It remains, as far as we can from the facts at our disposal, to restore in imagination the living beings who roamed about in Craven at the different periods represented by these beds. In the Lower Cave-Earth in the lowest bone

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* P. 133.

bed yet discovered we have evidence of the presence of the following: *

Man.	*Rhinoceros leptorhinus.*†
Hyæna.	Hippopotamus.
Fox.	*Bos primigenius.*
Brown Bear.	Bison.
Grisly Bear.	Red Deer.
Elephas antiquus.	

The chief horizon along which these bones occur is a layer of occupation by the hyæna, whose dung occurs in great abundance. From the characteristic gnawing and cracking of the bones we may conclude that to him and the other carnivores we are indebted for probably the whole of this assemblage of fossils. Although a fibula of man was found there is no evidence so far sufficient to justify us in concluding that he used this cave *as a dwelling place* at that time. But that he lived in the district when these other animals were roaming over the hills of Craven, there can be no doubt. Whether other parts of the cave were used by him is a question which must await the light to be thrown upon it by further exploration.

It becomes an interesting question what was the climate of Great Britain when these animals were living in, or being brought piecemeal into, the Cavern. There are two very marked species, the hippopotamus and the hyæna, which point to a very warm climate; of the remainder, the elephant and the rhinoceros, of species both extinct, may be considered

* These bones have been chiefly determined by no less an authority than Prof. Busk, F.R.S.

† According to some late valuable observations by Mr. William Davies, Dr. Falconer's species *hemitœchus* is founded on a misconception, and will have to give place to Prof. Owen's term *leptorhinus*. "Catalogue of the Pleistocene Vertebrata in the Collection of Sir A. Brady, by William Davies, of the British Museum, 1874. Printed for Private circulation only."

from their frequent companionship with the hippopotamus, and as Prof. Dawkins points out from their range, to have also lived in warm countries. The rest are all either adaptable to a wide range of climate, or of temperate proclivities. Upon the whole, then, we have an assemblage of species which require, or could live in, a tolerably warm climate. Arctic species are entirely absent. This state of things must have lasted a long time, but higher in the Section the bones become more scarce, the more tropical animals are wanting. The bear, the fox, and the ox, are scattered about at rare intervals, eventually these vanish, and about twenty feet above the busy-looking hyæna floor we come upon the base of the laminated clay, interbedded with an occasional layer of stalagmite, but without a trace of any living thing. We work our way up through it, and find near the top of it some well-scratched boulders, and we look out at the cave mouth, and seeing the rubbish left by a vanished glacier, we naturally ask—Do not these represent the coming events which cast their cold shadows before them, and first drove from the district the tropical animals, and then those of greater powers of endurance. The laminated clay here fills the cave up to the roof, but we follow it along into Chamber D, and find trodden into its puddled surface several antlers of *reindeer*. A bed of mud and fallen stones comes on above it (the Upper Cave-Earth), and this contains the following:—

Man (traces of) as evidenced by *hacked* bones.
Fox.
Grisly Bear.
Brown Bear.
Badger.
Horse.
Pig.
Reindeer.
Red Deer.
Goat or Sheep.

This bed probably represents a considerable length of time, and contains remains from the reindeer age and cold conditions, down to the confines of history. But as apparently no great thickness of matter was accumulating they are mixed up together at the surface.

The reindeer gives us evidence of a cold climate, and we have here no animals which can be assigned to tropical conditions. The reindeer lived in the district subsequently to the waning of the ice-sheet; we have no evidence to say whether it lived there during the cold times preceding its full development, though that seems probable.

The great thickness of talus, 20 feet and upwards in depth, is the only record of the long time which has elapsed since the boulders on which it lies were left by the ice-sheet. There is no evidence throughout it of any change in conditions from subaerial to marine or fluviatile. But we know that in Lancashire, not far off, we have old sea bottoms resting upon the ice-sheet rubbish, and indicating a submergence to the extent of some six or seven hundred feet perhaps. The absolute depth is somewhat uncertain, but it appears here not to have reached the cave, and there is a marked absence of such deposits at like elevations in the district. Still this was one of the changes which was long subsequent to the first appearance of man in this country, as shown in the cave's records. As similar evidences of a submergence late in the glacial period have been observed over large areas in the Old and the New World, and in both hemispheres, in mean latitudes, it may be that the traditions so common to many races and religions of a great deluge, are but lingering memories of this great event. It matters not that these myths all differ in their surroundings. The central core still has the solid ring of truth, albeit masked and disfigured by the rust of time.

A LIST OF WORKS RELATING TO THE VICTORIA CAVE, SETTLE.

1844.

SMITH, ROACH, and JACKSON, JOSEPH ...On Victoria Cave. *Collectanea Antiqua.* Vol. i. No, 5.

1860.

DENNY, H..................On the Geological and Archæological Contents of the Victoria and Dowker-bottom Caves in Craven. *Proc. West Riding Geol. Soc.* Vol. iv.

1865.

SMITH, ECROYD............The Limestone Caves of Craven. *Trans. Hist. Soc., Cheshire.*

1871.

MORRISON, WALTER......On the Exploration of the Settle Caves, Yorkshire (Abstract). *Trans. of the Plymouth Institution.* Vol. iv., part 2.

1872.

DAWKINS, W. BOYD......Report of the Results obtained by the Settle Cave Explorations Committee out of Victoria Cave in 1870. *Journ. Anthrop. Institute.* Vol. i., p. 60.

TIDDEMAN, R. H. ....Discovery of Pleistocene Mammals in the Victoria Cave, Settle. *Nature.* Vol. vii.

1873.

BROCKBANK, WILLIAM...Notes on the Victoria Cave, Settle. *Proc. Lit. and Phil. Soc., Manchester, March,* 1873, p. 95.

DAWKINS, W. BOYD......Report on the Victoria Cave, the Archæological and Zoological Results. *Rep. Brit. Assoc. for* 1872. *Trans. of Sections, p.* 179.

TIDDEMAN, R. H. ....Report on the Victoria Cave. The Physical History of the Deposits. *Ibid.*

——————.........The Older Deposits in the Victoria Cave, Settle. *Geol. Mag. Vol.* x., *p.* 11.

——————.........The Age of the North of England Ice-Sheet. *Ibid, p.* 140.

——————.........The Relation of Man to the Ice-Sheet in the North of England. *Nature.* Vol. ix., No. 210, p. 14.

1874.

BUSK, PROF. G............On a Human Fibula of unusual form, discovered in the Victoria Cave, Settle. *Journ. Anthrop. Inst.* Vol. iii., p. 392.

——————............(Remarks on the same). Presidential Address. *Ibid* p. 516-7.

DAWKINS, PROF. W. B...Report of the Committee for assisting in the Exploration of the Settle Caves. *Brit. Assoc. Reports for* 1873, p. 250.

——————.........Cave Hunting, Researches on the Evidence of Caves, respecting the Early Inhabitants of Europe, 8vo. *Macmillan and Co.*

1875.

EVANS, JOHN..............Presidential Address. *Quart. Journ. Geo. Soc.* Vol. xxxi., p. lxxiii.

TIDDEMAN, R. H. ....Second Report of the Committee appointed for the purpose of assisting in the Exploration of the Settle Caves (Victoria Cave). *Brit. Assoc. Reports for* 1874, p. 133.

——————.........Abstract of the Third Report of the Settle Caves (Victoria Cave) Committee, read at Bristol, in August, 1875. *Privately printed.* Also in *Nature.* Vol. xii.

EXPLANATION OF PLATE V.

D.—Chamber D.
B. G.—Birkbeck Gallery.
V.—Vertical line from Cliff.
X.–Z.—Approximate present depth of workings (Dec., 1875).

a. Romano-Celtic layer.
b. Neolithic horizon.
c. Upper Cave—Earth with Reindeer, &c.
d. Laminated clay, with some layers of Stalagmite.
d'. Glacial Drift.
e. Lower Cave—Earth with bone bed containing Hyæna, Hippopotamus, Man, &c.
× Position of the Human Fibula.
s. Screes or Talus.
l. Limestone rock.

The numbered vertical lines represent the 2-foot Parallels from 1 to 40.

ERRATIC BOULDERS IN THE VALLEY OF THE CALDER.

BY JAMES W. DAVIS, F.L.S., F.G.S.

THE objects of this paper are, in the first place, to describe certain deposits of water-washed boulders existing in the valley of the Calder; and, secondly, to offer an explanation of the phenomena they present, hoping to gain information from the discussion that may arise from the attempt, rather than expecting that the theories I advance will prove of scientific value.

The river Calder has its source in numerous small streams draining the moorlands above Todmorden and Hebden Bridge. For many miles it runs in a deep valley, the sides of which are formed of steep slopes of shale, capped by one of the rocks of the millstone grit series. On reaching Elland, the millstone grit escarpments are left behind, the valley becomes a little wider, and the hills bounding it on either hand are composed of some members of the carboniferous group. Some of the valleys in this district, reaching from Elland to Wakefield, are quite flat and level, reminding one very strongly of the appearance of a string of lakes joined together by a broad river. Beyond Wakefield the river pursues its course through a much flatter country, and joins the river Aire near Castleford, its bed being formed in the series of rocks forming the upper coal measures.

Having thus briefly traced the course of the river, and noted the geological formations through which it passes, I will endeavour to describe a formation of much more recent origin than the rocks already mentioned.

Along the course of the Calder there are beds of gravel containing boulders, which occur most extensively in the lower parts of the valley. The contained boulders are partially of sandstone derived from the surrounding hills, and also include rounded blocks of granite, trap, and syenitic rocks, which must have travelled long distances to gain their present position. Above Sowerby Bridge the travelled boulders are rare, though specimens have been found as far up the valley as Hebden Bridge* (one or two of which may be seen on the table).

At Elland the bed of the river, which is 200 ft. above sea level, is composed of a sandy clay containing numerous rounded stones, principally of rocks occurring in the neighbourhood; but besides these, there are a good percentage that do not occur *in situ*, in any part of the valley of the Calder, and are not found nearer than the mountains of Cumberland and the Lake District. A short time since a well was dug near the river about 16 feet deep. The bottom of the gravel bed was not reached, so that I am unable to give the entire thickness of the deposit. To the depth of 16 feet, however, the boulders showed a considerable proportion of the granite and other rocks; and it may be noted, that the number of these old rocks was greatest when the deepest part of the well was reached.

Other sections have been exposed from time to time, in sinking wells and making excavations for other purposes. One of the most important which has come under my notice is at Thornhill, near Dewsbury, in an excavation for the accommodation of a gas holder. A thickness of 24 feet has been exposed, consisting of the following series of beds:—

Soil and earth	2 ft.
Gravel, fine	1 ,,
Earth	1 ,,
Grey sand and boulders	5 ,,
Alternations of gray and yellow sandstone and boulders	9 ,,
Grey drift	6 or 7 ft.
	24 ft.

* In a paper read some years ago to this Society, "On the Geology of the Parish of Halifax," Dr. Alexander mentions finding boulders of granite

The 5 feet of gravel below the soil and earth is composed of rounded sandstone boulders, derived from the rocks of the immediate neighbourhood. The lower part gradually becomes a yellow colour, due to the impregnation of water holding iron in suspension. Below this the sandstone deposit is decidedly ferruginous, and contains many stems of large trees, lying in a horizontal position. They have no smaller branches attached, but appear to have been much washed and rolled in the water before finding their present resting-place. The sand and pebbles present a stratified appearance, and bear an aspect of being deposited by water in motion, but from the inconstancy of the beds, the yellow and grey shingle dove-tailing into each other at short intervals, yet still preserving distinctive lines of stratification, we are led to the inference that they were deposited in an estuary subject to strong tidal currents.

The yellow drift gradually gives place to a grey, which is also principally composed of local sand and boulders, with an admixture of fragments of coal and shale; but besides these there are about 2 per cent. of foreign boulders, being most numerous near the base. Below this seven or eight feet are exposed, consisting almost entirely of rocks derived from the primary strata of the Lake District. The base of the drift was not reached. [Examples.]

A well sunk in Dewsbury has exposed a much greater thickness of boulders than has hitherto been reached, and presents the following section:—

1. Earth and sandy sub-soil	7 ft. 6 in.
2. Boulders, consisting principally of sandstone gradually merging into	24 „ 0 „
3. Boulders nearly all of crystalline rocks.. ..	6 „ 0 „
4. Clay, with sand and boulders	5 „ 0 „
5. White rock, of carboniferous formation ..	11 „ 0 „

and other crystalline rocks in the cutting for the railway at Hebden Bridge. Mr. Clay, of Rastrick, also read a paper, in 1841, to the Society, on a bed of boulders containing granite at Cromwell Bottom, between Elland and Brighouse.

In No. 2 the boulders are composed of sandstone and other local rocks, with a slight intermixture of travelled boulders; towards the lower part the latter become more numerous, until in No. 3 they predominate to such an extent that the local rocks are as rarely found as the crystalline ones were in the upper part of the series. Many of the granitic and other hard rocks were of large size, being near a foot in diameter, well rounded, but showing no marks of striæ.

The boulder beds contain two very inconstant beds of sand; the upper one is about five feet from the top, and ranges from two feet to one foot in thickness. It is distinctly stratified, and composed of fine sand. The beds occasionally divide, and a section a few yards distant would give three beds of sand instead of two, with a layer of boulders interposed.

Unfortunately, I was unable to be present when the clay, with stones resting on the white rock, was excavated. This bed might throw some light on the question of glaciers having occupied the valley before the mass of boulders was deposited.

This section, showing the base of the boulder beds to be 42 feet 6 inches below the surface, is in the same extensive level part of the valley as the gasometer section at Thornhill, being a little over a mile distant. By following the course of the stream to Wakefield, the valley will be found to be filled up with similar beds of boulders; and at the latter place a section gave a thickness of 27 feet of boulders and sand resting on the blue bind of the coal measures as follows:—

Soil	2 ft.
Yellow and blue clay	7 ft. 6 in.
Sand and gravel	18 ft.

Blue bind.

The sand and gravel were composed of similar materials to the sections at Dewsbury and elsewhere.

Reaching from Exley to Elland, on a plateau of grit rock, about three-quarters of a mile by one-quarter, there is a deposit of rounded stones and sand, all of which may have been derived from the rocks above or in the immediate neighbourhood. At the highest part, the bed is 350 feet above the sea level, from thence it covers the hill side as far as the level of the railway, which is 100 feet lower. A good section of it is got at the Elland Station, where it rests on the shale a little above the rough rock. It is about eight or ten feet in thickness. There is no clay present, nor do any of the stones present the slightest appearance of striæ; a few stones may be found of a subangular character, but by far the greater portion are rounded, and appear to be water-washed.

A similar mass of *debris* occurs in the Mytholm valley below Hipperholme Station, and another in Kirklees Park, near Mirfield, these three being all with which I am acquainted.

We have thus two distinct series of water-washed boulders. The first forms the level lands in the bottom of the valley in which the river has cut out its present course, and contains numerous travelled boulders; the second forms local patches of much smaller extent at considerably higher elevation, and contains only boulders derived from rocks in the neighbourhood.

The facts we have now before us point to at least three periods of deposition. The first was a period of extensive glaciation, during which an immense sheet of ice covered the northern parts of England and Scotland, in some places attaining a thickness of one or two thousand feet. This ice-sheet, moving in a southerly direction from the mountains of the Lake District, appears, in all probability, to have been divided into two principal parts by the Penine chain of hills dividing Yorkshire from Lancashire.

On the western flank of the hills the direct evidences of its action are plentiful; but on the eastern slopes no such evidences are observed further south than the valley of the Aire. Deposits of till or glacial mud, containing scratched boulders, are frequent in the valleys of the mountain limestone district north of the Aire. An example may be seen near the Skipton station on the Midland railway; numerous others have been exposed in the new line from Settle to Carlisle; and a very interesting bed has been exposed in the exploration of the Settle Caves. Besides these remains of the ancient glaciers in the valleys, traces of glacial action are found on most of the hills. Their summits are found scratched to the height of many hundred feet. Their slopes have been rounded, and a lateral moraine occasionally deposited; and numerous blocks, weighing in some cases tons, have been left by the ice, perched in all kinds of positions, on the tops or sides of the hills. These blocks, in most cases, are composed of rock not found in the district, but have been transported many miles from their original position. All these evidences indicate a period when the country was covered by great glaciers. The scratches and striæ generally have a tendency to an easterly direction, and indicate that the Yorkshire branch of the main glacier from the Cumberland district has travelled over the high lands composing Stainmoor Forest, and thence proceeded in a south-easterly direction down the valleys of the Swale and Ure, ending possibly in the low lands of the vale of York, where great quantities of *debris* would be deposited by the melting ice.

Turning again to the district through which runs the river Calder, we find none of the direct evidences of glacial action. There is no till or stiff glacial clay, containing scratched boulders, and, so far as I am aware, no striæ have been found on the hill tops; though, if any existed, they have had a good chance of being preserved beneath the peat, which is generally found covering the grit rocks in this neighbourhood. The drift remains found in the valley, as we have seen from the sections already given, consist of well-rounded stones, many of them being syenite from Ennerdale, and the greenstone found *in situ* in the Lake district is not uncommon.

Accepting the theory of the subsidence of the land to the extent of several hundred feet after the existence of the great glaciers, the whole of the vale of York and the surrounding districts, including the valley of the Calder, would be submerged beneath the water. The boulders would be washed from the clay imbedding them and subjected to the attrition of the waves; the scratches would, in course of time, be obliterated; all the sharp angles worn away; and, it will be easily imagined, how the water-washed boulders may have been re-deposited in their present localities, filling up the deep-sheltered valleys, and forming the level surfaces so often met with in Calder vale. The stratified appearance presented by the deposit, where a section can be seen, and the thin beds of sand interpolated amongst the layers of boulders, suggest very strongly an estuarine deposit subject to the tidal action of the waves. The presence of the trunks of large trees support this theory. Many of them are probably deposited near the situation they occupied whilst living; instances having been found where the roots and part of the stems are still imbedded in the soil in which they grew prior to the submergence of the land. The only serious objection to this theory is the absence of any remains of mollusca or other forms of animal life, none having hitherto been discovered. This difficulty, however, is no greater in the case of an estuarine deposit than it would be on the supposition that the boulders were brought down by a river or accumulated in a series of lakes. The discovery of any shells would tend, in a great measure to the solution of the question.

The theory of the deposition of the boulder beds by river action is scarcely tenable. There is no evidence that the general *contour* of the land has been altered since the glacial age. This being granted, we cannot conceive it possible that rivers of so great width and extent could exist within 20 miles of the water-shed. There is also the attrition the boulders have undergone; all traces of striæ or angular corners being removed, which would hardly have been possible in the case of such large quantities as exist in the district; even those found nearest the source of the stream presenting the same characteristics as those in the lower parts of the valley,—as witness the specimens collected by Dr. Alexander at Hebden Bridge. Another fact, which serves in some measure to support the theory that the boulders are an estuarine deposit, and have been washed into the Calder from the east, is the occurrence of fragments of chert, which have, in all probability, been derived from the chalk existing in the East Riding.

On the land being re-elevated there appears every probability that another very cold period existed, the country being again subject to glacial action, but to a much more limited or local extent than the preceding one. To this period may, perhaps, be attributed the beds of rounded boulders occurring at Elland Cemetery, Mytholm and Kirklees. They consist entirely of sand and boulders, derived from rocks existing in the immediate neighbourhood. I am bound to admit, however, that the subject still presents many difficulties, which must be left for further research to solve.

THE GLACIAL DEPOSITS OF THE BRADFORD BASIN.

BY THOMAS TATE.

The glacial deposits of this locality are interesting, as probably indicating the most southerly point reached by the North of England ice-sheet, east of the Pennine range.

Bradford lies in a horseshoe-shaped basin five miles in diameter, having a northern outlet into the Aire valley at Shipley. The watershed ranges from 600 to 700 feet along the eastern and southern border, but rises to 1,200 feet on the western margin of the basin. The floor of this area, where the various streams converge, lies about 320 feet above sea-level, and the drainage thence is conveyed by the Bradford Beck to the Aire, at a point only 200 feet above the sea, the true floor of the Aire valley lying more than 30 feet below this.

Where the Thornton Railway passes under the Lancashire and Yorkshire line in Ripley Fields, recent excavations have exposed, at a depth of 25 feet, a bed of till 8 feet thick, the base not reached. (Lat. 53° 47′. Altitude 400 feet.) It is a tough, fine-grained, unstratified blue clay, that resists the blast or the pick, and has to be removed by a slow and tedious process with the aid of a steel harpoon. This clay *effervesces very freely* upon the application of hydrochloric acid. Included within it, as though pitched in anyhow, lie numerous sub-angular or well-rounded fragments of grits, shales, and blue limestones, the latter polished and well ice-scratched. On some the striæ run lengthwise, while on others they cross each other at all angles. Many of the larger angular blocks, 18 inches to 2 feet in length, are polished and striated only on one surface. This till closely resembles the till recently opened out near the Skipton station, and is not unlike the blue till overlaid by red boulder-clay of Wigan, West Houghton and Chorley, in

Lancashire, a till which is largely charged with blue limestone, and the matrix of which effervesces as freely as does the Bradford till.

Resting upon an eroded surface of this lower till No. 1, lies another bed of blue clay 15 feet thick, but thinning out westwards near Manchester Road. It differs from the till No. 1 mainly in containing a large percentage of well-rounded small pebbles of Settle crystalline limestone; a rock rarely seen in the lower till. The included limestones are all more or less ice-scratched, in most cases but faintly. Its appearance when first exposed is such as to be hardly distinguishable from the till No. 1, but being of a looser and more open texture, it yields more readily to atmospheric action, and in a few weeks acquires a brownish tint. This is well seen at Shipley Fields, near the Red Beck, where a new siding on the Midland line shows the blue clay No. 2 resting upon an irregular surface of the till No. 1, from which it is clearly marked off by the difference in colour, save at one or two points where the two beds appear to shade into each other. Near the Shipley Fields bridge, in this same section, the lower till is seen to rest upon a pre-glacial river gravel, the pebbles all lying closely packed on their flat sides, with their long axes parallel to the direction of least resistance; evidently of fluviatile origin, and presenting, in fact, all the characteristics of the pre-glacial river gravels found in the Clyde Basin, as described by Mr. James Geikie in his "Great Ice Age."

The blue clay No. 2, or upper till, is widely distributed within the Bradford basin. From Bowling Old Lane it crosses Bowling Park, rising, laden with limestone pebbles, to a height of 626 feet near Bierley Chapel; or, following the East Brook, it may be traced from the Cattle Market, by Bowling Iron Works, thence to Bradford Moor and down Leeds Road. It is largely developed in the valley through which the Bradford Beck flows (20 feet is exposed at the new Gas Works); and it is spread out east of its junction with the Aire. North of the Bradford area may be seen, for example, a patch at the base of a sand pit near the Beck Road, Keighley; and another at the head of Shipley Glen, near the quarries. It is well exposed in a cutting on the Guiseley new line behind Tong Park. Fifteen or twenty feet rest against the rough rock cutting at Esholt Springs, and it forms the floor of the hollow in Esholt Hall avenue. It is nowhere present east, south, or west of the area drained by the Bradford Beck.

In a forthcoming geological work that will doubtless receive a hearty Yorkshire welcome, we may expect to find this bed defined as "Re-arranged Till." It is, however, difficult to conceive how such a mass of clay, covering 15 or 20 square miles, and in some sections 20 to 30 feet in thickness, could have been lifted by water and re-deposited without leaving any evidence of water action. For the stuff is not sorted, stratified, nor re-arranged at all; but the included stones, of all sizes and shapes, lie in every conceivable position, save the one they would have assumed if dropped by the ocean. Yet, on the other hand, the "ghostly scratches" on many of the imprisoned stones might lead to the inference that they have been subjected to the rolling action of moving water since receiving their striæ. But would it not be more accurate to regard these two beds of till as essentially one continuous deposit, resting where the land-ice left it? In that case, we may explain the rounded and small appearance of the pebbles of Settle crystalline limestone in the upper till as due to the farther distance they have had to travel; while the Skipton blue limestone, being so much nearer, would be the first to be pushed into our basin by the ice-sheet, and would thus supply that preponderance of angular blue limestone which we find in the lower till. And it may be further remarked, that preglacially weathered rocks lying on the slopes of the valley and in the bed of the river may have furnished many of the angular and round stones included in this portion of the till. The looser texture of the upper till may be the result of long-continued atmospheric influences. Air will percolate where water cannot pass, and the eroded surface within the till may mark the depth to which these atmospheric forces have penetrated since the final retreat of the ice.

That the ice-sheet travelled in the direction thus indicated by the contained rocks, is in harmony with the conclusions arrived at by those who have investigated the memorials of the Ice-age west of the Pennine watershed. Mr. Tiddeman* has demonstrated that a sheet of ice, eight miles broad and 750 feet deep, arising north of the Craven faults, crept along the Ribble valley parallel to the watershed for some considerable distance. The rock striæ left beneath the hillocks of drift in the neighbourhood of Hellifield take a direct easterly course across the watershed, and through this depression in the Pennine range—only 700 feet above the sea—a portion of the Ribble ice was discharged, and descended the valley of the Aire to the plain of York; where its course may have been deflected southwards by the York vale ice-stream, and so have given rise to the outlying patch of blue till occurring near Barnsley, as recorded by Professor Green.

No marine remains have been detected in the Bradford till. Mr. H. B. Brady, F.R.S., has kindly submitted to microscopic investigation specimens of the lower and upper till, and writes:—"The only evidence they yield is negative. Both are entirely azoic; neither contains a trace of animal remains great or small, and therefore palæontological evidence is not forthcoming to settle the vexed question."

The upper till within the Bradford basin is protected for

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* Quar. Jour. Geol. Soc. XXVIII. 477.

the most part by a thin coat of rain-wash and soil, as at the section in Ripley Fields; but beneath Manchester Road we have 25 feet of upper boulder-clay which, as it thins out, overlaps the upper till near Bowling Back Lane. It is a yellow clay with white partings, full of angular fragments of flagstone, shale, and coal—rarely ice-scratched—all derived from the parent rocks *in situ:* no rock foreign to the basin is to be found imbedded therein. This upper boulder-clay is moderately developed along the eastern brim of the basin, and is continuous to and beyond Leeds, always retaining its strictly local character.

Another blue-clay found in this neighbourhood presents some peculiarities deserving special notice. It occurs within a short distance of the upper altered till, but on the east side of the watershed, 600 feet high. It ranges from Quarry Gap across Calverley Moor to Eccleshill and Idle, that is, outside the Bradford drainage area. It is largely worked by Messrs. Cliff, at Thornbury, and a good section is obtained where the Idle Railway passes under the Leeds and Bradford turnpike road. It is a stiff tenacious clay, difficult to work. Its upper portion carries numerous large angular or sub-angular blocks of grit and sandstone, of from 10 to 30 cubic feet dimensions. Occasionally, lenticular patches and streaks of dark sand and fine gravel are exposed, such as one would expect to find in the *moraine profonde* of a glacier; while the close texture of the clay must be due to the heavy pressure of a sheet of ice. The blue clay represented by this section resembles so closely, in general appearance, the altered till, as to be known among the local excavators by the same name (Bowling tough), and both clays have been grouped together by previous observers.* But the essential difference between

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* T. P. Teale, Brit. Assoc. Reports, 1858. D. Mackintosh, Geo. and Poly. Soc. Report, 1870.

this blue till and the blue till inside the Bradford basin, will be readily discerned on a closer inspection. In the first place, it does not effervesce when tested by acid; and in the second place, it does not contain a single pebble of carboniferous limestone or limestone shales.

The *débris* found in this till is all from the millstone grit series and the lower coal measures; the shales, calliards, ironstone nodules, and bits of coal being well polished and scratched. The contained stones all point north of the Aire, between Shipley and Skipton, as the locality whence they were obtained. A similar bed of blue clay has lately been bared for the Shipley Waterworks reservoir at the head of Eldwick Beck, nestling below the edge of Bingley Moor at an elevation of 750 feet. The section is about 600 feet in length and 40 feet in depth. This bed is identical in every particular with the one at Thornbury, save that its upper portion is not characterised by large boulders; and the brown clay ironstone nodules, so plentiful in the Thornbury clay pit, are entirely wanting. Could we determine the locality of the parent rock whence these nodules were derived, it would aid us materially in mapping the direction taken by the ice-stream conveying them; but upon this point no satisfactory evidence is as yet forthcoming: probably the Halifax shales to the west of Hope Hill supplied these as well as other portions of the contents. If this glacial mud had been formed by the grinding action of an ice-sheet upon the surface of limestone rocks, it would have been highly charged with carbonate of lime, as is the Bradford till. This, and the entire absence of limestone pebbles, so abundant in the till within the basin, at an equal altitude with Thornbury, would seem to indicate that the section of the ice-sheet under which this till accumulated had not traversed the district west of Cononley. Is it possible that the ice-stream, already described as flowing down Airedale, was joined by an overflow from the Wharfedale stream, coming by way of the Silsden Pass, thus isolating the high ground to the east? An ice-sheet in Wharfedale thick enough to leave striæ at an elevation of 900 feet, as it is said* to have done, must have shed an offshoot through the gap in the intervening ridge between Addingham and Silsden. For this to be of any service, we must assume that Rombald's Moor was a separate gathering ground; a proposition which probably no glacialist is prepared to accept. Yet the area west of Hope Hill, and the hills below the Eldwick reservoir, present a strikingly *moutonnée* outline, which recalls at once the moulding power of a sheet of ice. The case in point is analagous to certain phenomena in the Eden valley; for the explanation of which Mr. Goodchild,† following Prof. Ramsay, suggests that there were various currents at different levels in any given ice-sheet over the same ground.

The Airedale glacier cannot well have exceeded 300 feet in thickness, for, while nearly filling, it did not overflow the Bradford basin. If we suppose that Rombald's Moor, 1,300 feet high, shed a stream of ice over the western shoulder of Hope Hill; such ice-stream—the Aire valley ice being 300 feet in thickness—might over-ride the latter, and so flow to the east of the Bradford watershed.

But whatever theories we propound, the subject of our inquiry is beset by difficulties, and it is only by patiently observing and noting all the facts, that we may hope to discover a satisfactory solution of these perplexing problems.

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* Since the above was read, quarrymen have exposed a grit surface well polished and ice-scratched, the striæ running due west and east, along the northern edge of Rombald's Moor, 900 feet above the sea.

† Quar. Jour. Geol. Soc. XXXI. 68.

ON THE GEOLOGY OF THE CENTRAL PORTION OF THE YORKSHIRE COAL FIELD, LYING BETWEEN PONTEFRACT AND BOLTON-ON-DEARNE. BY A. H. GREEN, M.A., F.G.S., PROFESSOR OF GEOLOGY IN THE YORKSHIRE COLLEGE OF SCIENCE, LEEDS, OF H.M. GEOLOGICAL SURVEY.

THE district with which I propose to deal in the present paper comprises one of the least known portions of the Yorkshire Coal Field. Workings naturally commenced along the edges of the basin where the coals lie nearest to the surface; as the shallower portions of the seams became exhausted, explorations gradually advanced more and more towards the interior of the field, and they now extend over an encircling belt of considerable breadth, and have even been pushed in some cases, where railways offer facilities of carriage, for long distances towards the centre of the field. In these explored districts the Officers of the Geological Survey have been able, thanks to the liberality of the coal owners in communicating information, to frame maps which show in considerable detail all the minuter features of the geology. But there yet remain tracts, of what the one now before us is an instance, where the sum total of our knowledge amounts to very little. They are unpierced by a single shaft or bore-hole, and unluckily it is very often the case that at the same time there are but slight natural facilities for making out their geology. They are for the most part flat and low lying, and are consequently covered to a great depth with superficial rain-wash, and the streams have not fall enough to enable them to cut down to the solid rock, so that natural sections are few and far between, and poor where they do occur. Again the few thick sandstone beds that occur are soft and very irregular, and their escarpments are hence feeble and ill-marked, fitful and liable to die away altogether, and cannot be traced with any degree of certainty. In such districts the best results that can be arrived at must evidently be no more than rough approximations, and it is in this light that the conclusions I am going to state must be considered.

Actual exploration has made us fairly well acquainted with the measures of the Yorkshire Coal Field up to a seam known as the Shafton, Billingley, Denaby, or Nostel Top Coal, which lies some 430 yards above the Barnsley Bed.

The outcrop of this seam from Bolton-on-Dearne to Royston Station forms the south-western boundary of the district under consideration. A line of fault ranging from Royston Station to Pontefract bounds it on the north-west. On the upcast or north-western side of this fault collieries are plentiful; on its down-cast side we have no information from actual exploration beyond a few unimportant bore-holes.

On the south the country for some distance within the boundaries just laid down is flat and tame, and it is quite hopless to attempt to make out anything of the details of its geology; but there are two tracts more elevated and rather more strongly featured, one extending from Clayton-in-the-Clay towards Brierley, and the other lying around Ackworth and Pontefract, which look more promising, and to these the geological explorer betakes himself with some little hope of meeting with a reward for his trouble.

The south-eastern portion of the first of these districts consists of an elevated plateau reaching from Clayton-in-the-Clay to Brierley Common; this high ground is capped by a mass of thickly bedded, softish, light brown or buff sandstone, which I have named the Houghton Common Rock. The escarpment of the rock is sufficiently well marked to allow of its being traced with a fair degree of accuracy, and there is good reason to think that the rock forms an outlier, the beds dipping on all sides gently into the hill.

To the north of this outlier we find a second thick bed of similar sandstone, which can be traced passing into the hill-side beneath the Houghton Common Rock; this I have called the Brierley Rock. It is seen on the north around the village of Hemsworth; it then passes beneath the measures which lie between it and the Houghton Common Rock, and it reappears on the south-west side of the basin at the village of Brierley. On the west it abuts against a fault parallel to our boundary fault. It may be followed to the south-east for some distance both from Hemsworth and Brierley; but on both the north-east and south-west sides of the basin its escarpment becomes after a while more and more indistinct in this direction, and at last ceases to be recognisable. The rock, therefore, probably dies out towards the south-east.

Such calculations as the data allow us to make, give the distances of the bases of these two rocks above the Barnsley Coal to be 560 yards and 680 yards respectively.

The district we have next to turn to lies to the north of a probable fault which runs from near Hemsworth Station nearly parallel to the line of the Great Northern Railway. In it the only conspicuous features are formed by two thick sandstone beds. The upper may be seen in the cutting of the Great Northern Railway a mile-and-a-half north-west of Hemsworth Station, and may be traced thence northwards through Taylor Wood up to our boundary fault. The lower sandstone is the rock so largely quarried on Ackworth Moor Top; the bed seems here to be at its thickest, for though it may be followed both to the north and south of this spot, it grows less marked in the first direction, and seems to thin away altogether in the second.

These two rocks resemble in character, thickness, and the distance between them, the Houghton Common and Brierley Rocks, and though the evidence is far from conclusive, there seems a strong probability that they are the same as these rocks.

The plateau of Ackworth Moor Top is separated by the valley in which the village of Ackworth stands, from a corresponding tract of high ground at the eastern end of which is the village of East Hardwick. This hill is capped by a sandstone bed, and unless there be faults in the valley between, this rock must be the same as the Ackworth Rock, and, therefore, probably the same as the Brierley Rock.

Another valley separates the range of high land just described from the rising ground about Pontefract. In the latter we again find a couple of thickly bedded, softish, light brown sandstones. The upper is largely quarried in Pontefract, and forms the bold bluff on which the castle stands; the lower is a much less conspicuous rock. These two sandstones again so far resemble the Houghton Common and Brierley Rocks, that it is a reasonable conjecture to suppose them identical with those beds.

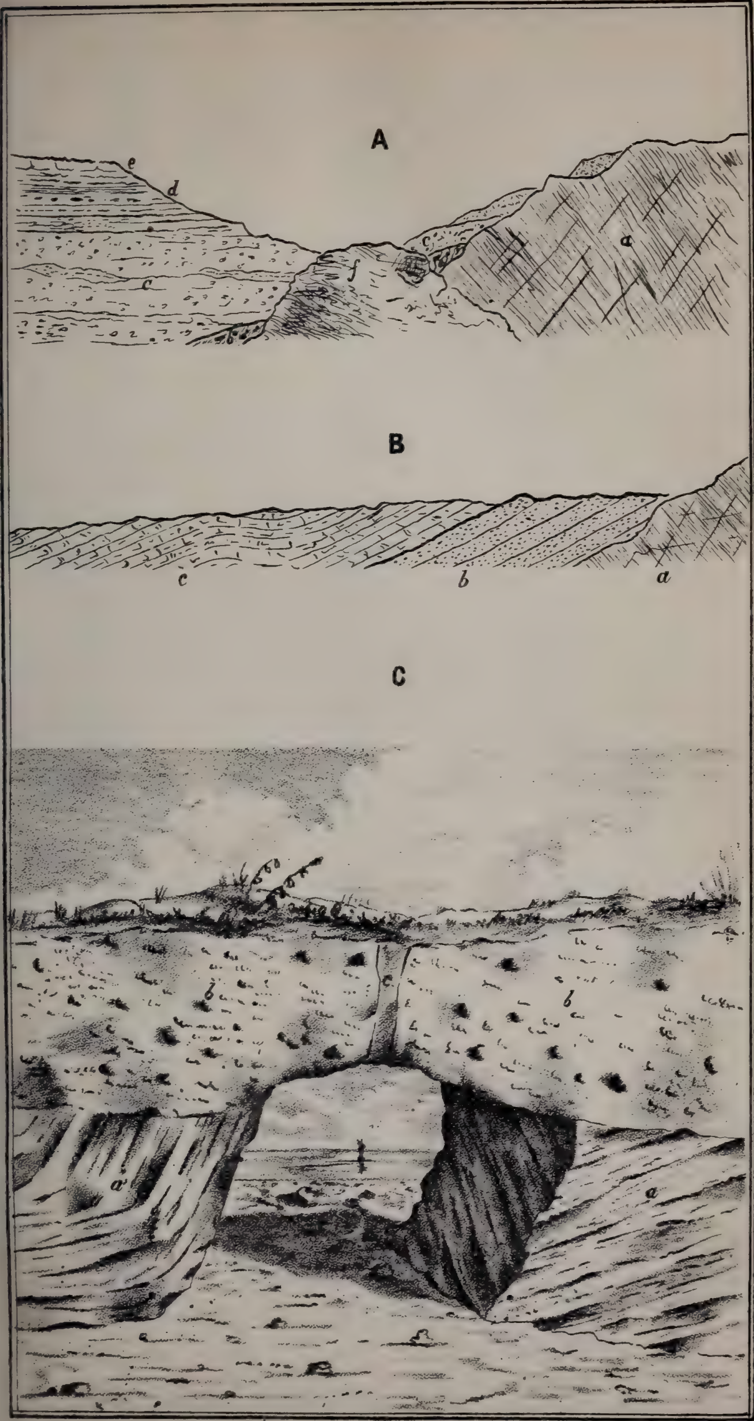
The above scanty facts are all that we have to guide us in our attempt to puzzle out the geological structure of the district; we recognise at three points a pair of sandstone beds which are much alike generally in thickness, character, and distance apart; there is an *a priori* probability that the corresponding sandstones of each pair are detached portions of one and the same bed; as far as the dip can be made out there is nothing in the lie of the strata to forbid this supposition; and we therefore have adopted it as the best of several explanations that have occurred to us.

It is probable that the rocks over the whole of the district undulate gently in broad shallow folds; in each basin an outlier of the upper sandstone occupies the centre, encircled, more or less completely according to the continuity of the rock, by a belt of the lower sandstone. The depth of the Barnsley Coal may be expected to vary from 500 to 700 yards.

It is somewhat in favour of the explanation just given that in the neighbourhood of Wickersley, near Rotherham, we again find a pair of thickly bedded, softish, light brown sandstones, and perfectly independent calculations give the distances of these rocks from the Barnsley Coal very nearly the same as those of the Houghton Common and Brierley Rocks, viz., 680 and 545 yards.

Further details respecting the geology of the country treated of in this paper may be learned from the maps of the Geological Survey, and from a Memoir on the Geology of the Yorkshire Coal Field that will be issued shortly.


Penrith
Shap
Kendal
Sedbergh
Kirkby Lonsdale
A MAP shewing the horizontal and vertical distribution of the red deposits near the Lake district.
below 1000 feet.
between 1000 and 2000 feet.
above 2000 feet.


A
e
d
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f
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B
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b
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c
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Fig. 1. Diagram to illustrate the changes in the Silkstone Coal.

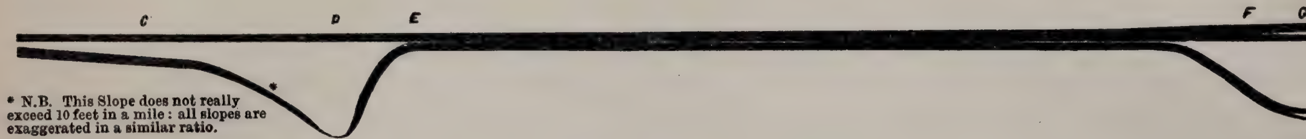


Fig. 2. Diagram to illustrate the changes in the Barnsley Coal.

Fig. 3. Diagram to explain the thickening of a parting in a Coal Seam.

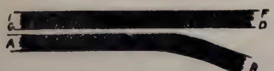
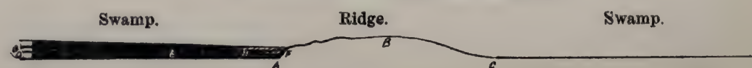
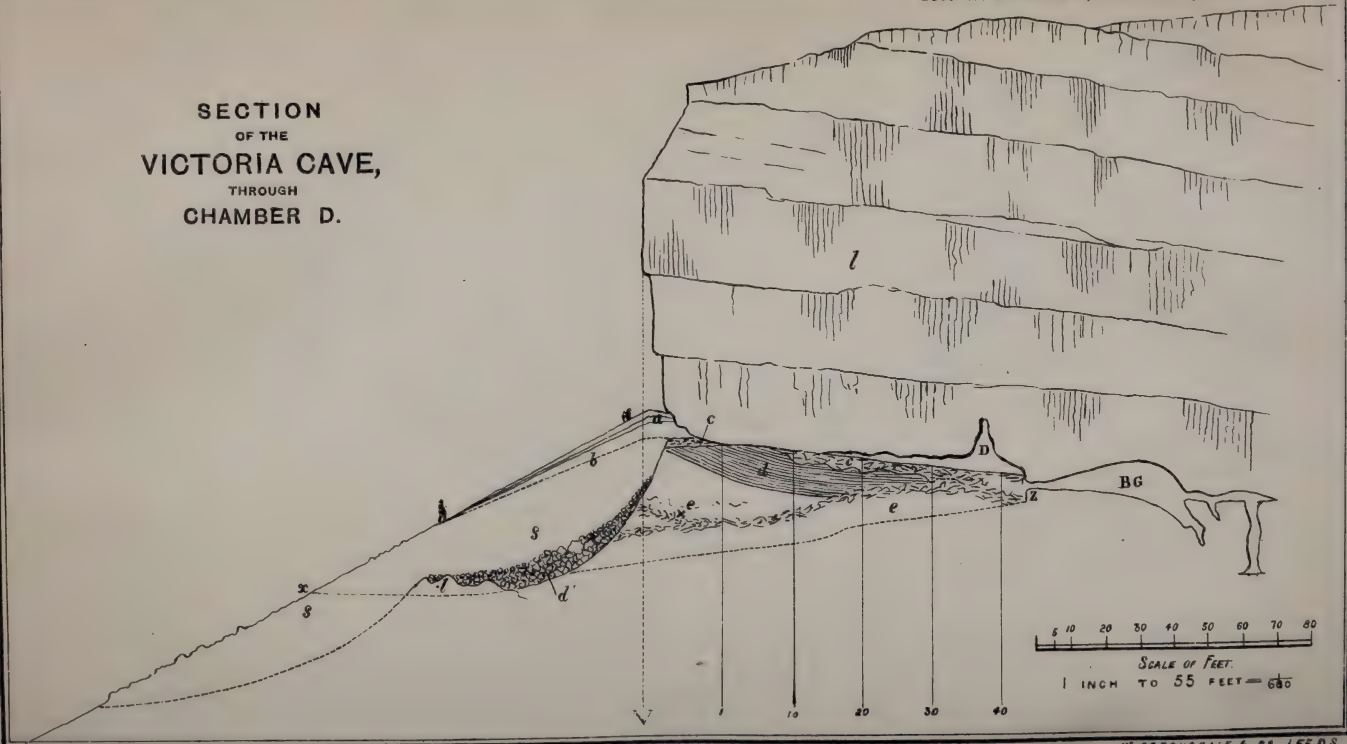


Fig. 4. Diagram to explain the breaking up of a Coal Seam and its replacement by Shale and Stone.



Proc. W. R. Geol. Soc., N.S. Vol. I., Pl. V.

SECTION
OF THE
VICTORIA CAVE,
THROUGH
CHAMBER D.



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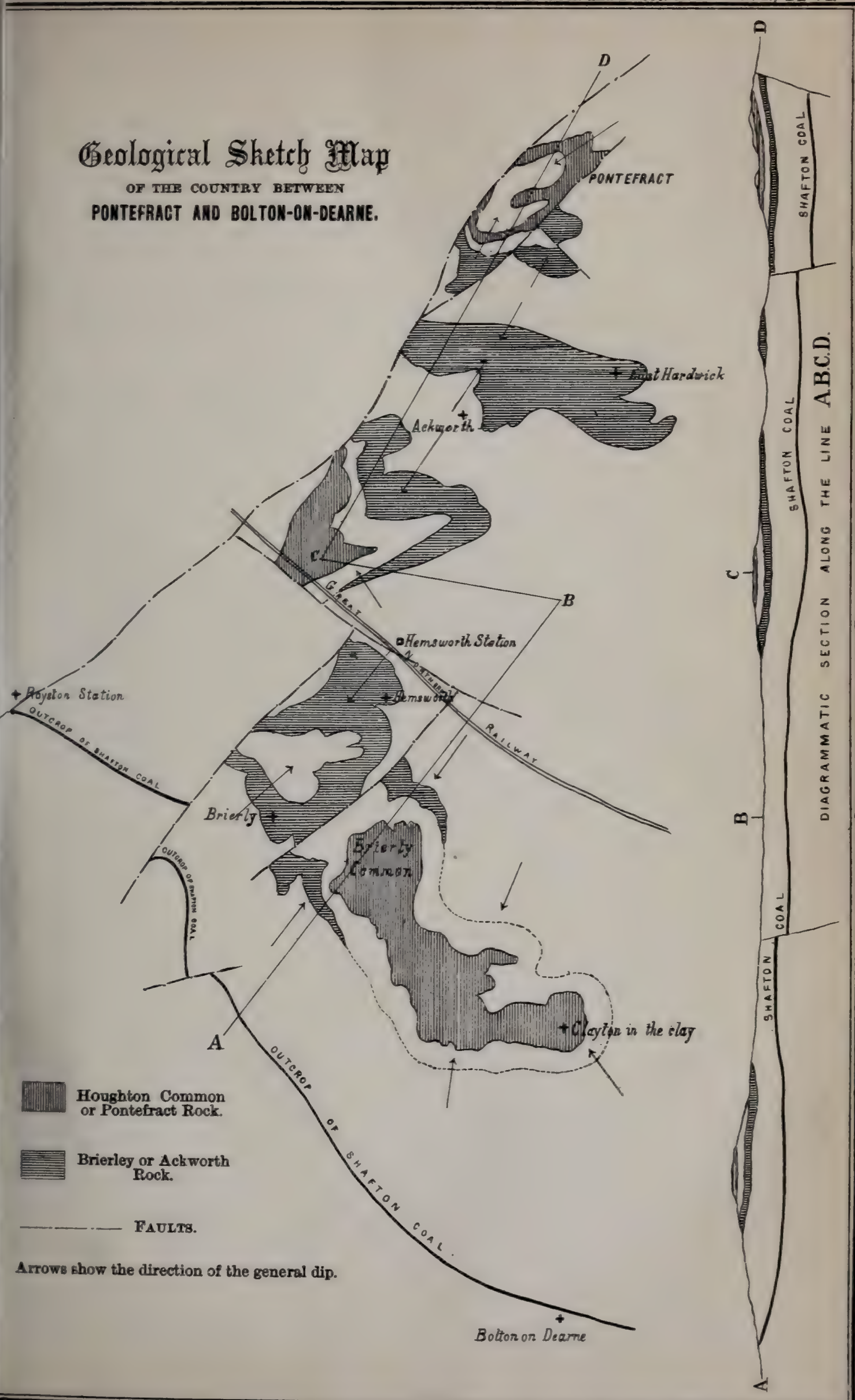

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PROCEEDINGS

OF THE

GEOLOGICAL AND POLYTECHNIC SOCIETY

OF THE

WEST RIDING OF YORKSHIRE.

NEW SERIES, PART III., p.p. 113 to 206.

1876.

NEW SERIES.] [PART III.

6428

PAPERS

READ BEFORE THE

Geological and Polytechnic Society

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CONTENTS.

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PAPERS

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1876.

CHAIRMAN'S ADDRESS, WITH OBSERVATIONS ON THE MINERAL ASPECTS OF THE WEST-RIDING COALFIELD. BY RICHARD CARTER, ESQ., C.E., F.G.S.

In addressing this assembly of the members of the West Riding Geological and Polytechnic Society, my first agreeable duty is, to bid you welcome to Barnsley; and next to congratulate the Society on the reanimation of its latent powers, fraught, as I believe them to be, with advantage and benefit to the vast and important district with which it is identified. Recent meetings of the Society at Halifax and Bradford, have afforded opportunities for explaining the interregnum, which has occurred in the ordinary meetings and operations of the Society; but it would border on ingratitude and negation of proper esteem for the long-sustained services of a most valuable officer, if I did not embrace the present opportunity of personally offering a tribute of respect to the memory of our late Secretary, Mr. Denny, and an expression of the high regard, in which his services to the Society are held by members in and around Barnsley.

Whilst, however, the reaping hand of Time is gathering one after another of those with whom we have loved to associate, in the work and labour of scientific progress, let us take courage from the fact, that good men and true are at hand, to fill the vacant chairs of those whose loss we mourn.

In our lamented friend Mr. Denny, we all know that the Society was bereaved of one whose devotion to science, in all its applications, was of the most earnest and sympathetic character.

Happily, however, for the promotion of all our future aspirations, we have worthy and most competent successors; in Mr. Louis C. Miall especially, we have one whose attainments have won him a well-defined mark in the scientific world, and whose kindness and generosity in promoting the acquisition of scientific knowledge, have established him in the esteem and regard of many laborious students in the West Riding of Yorkshire. I trust he may long enjoy health and satisfaction, in directing and promoting the aims and objects of this Society.

In this brief retrospect, forced by the absence of the Society for so many years from Barnsley and its immediate neighbourhood, we are reminded of many whose co-operation and society it is refreshing and agreeable to dwell upon. The late Rev. William Thorpe must always be remembered in connection with its history; and his elaborate Section of the Yorkshire Coal Field, will always remain as a testimony to his extensive research and accurate observation on its geological structure. No doubt the more recent publications of the Government Geological Survey display a more minute and exact record of our local stratification; and we hail the established residence amongst us of Professor Green, to whose careful investigation and accomplished skill, those records are chiefly due, as an unqualified pleasure and great local advantage. The published Sections of the Geological

Survey are doubtless familiar to all our members; and from their exact, mathematical delineation, they will have become the subjects of more frequent reference, and more confiding trust, than kindred productions which preceded them. There is, however, notwithstanding the quaint, and perhaps I might say eccentric, construction of Mr. Thorpe's Section or Diagram, a vast fund of information to be derived from it; and considering the time of its production, and the *then proved* knowledge and experience of our local Geology, it reflects a credit on our late townsman's genius and acquirements which time will rather strengthen than destroy; and as one of the founders and early supporters of this Society, the name of Thorpe will always serve as a binding link, between the Society and the locality of Barnsley, which has furnished so much material for its past investigation and record.

I must not dwell upon other familiar names of those who have been taken from us. That of Mr. Thomas Wilson, however, recurs with a melancholy force which we cannot resist, and carries us back to those good old days, which might perhaps be held to form a useful model for our imitation now. I refer, especially, to the arrangement which had all but formed the programme of our present assembly, when a social meal divided our introductory labours from an evening's discussion. This never failed in bygone days, to add greatly to our collective enjoyment, and stimulated the individual zeal we each felt, in all that pertained to the usefulness and progress of the Society's labours in the mining and commercial districts of Yorkshire.

The Chairman next spoke on the mineral aspect of the Coal-field of the West Riding. In the course of his remarks he said:—The experience of the last few years has added to our previous knowledge, and I think, established the striking change in character, which exists in the general stratification of our Coal-field, as divided by a line, running in an easterly and westerly direction, and coincident with the Calder Valley on the south side of Wakefield. The measures southward of this line may be said to characterise the *South Yorkshire,* or by way of distinction, I should prefer to style it, the *Barnsley Section*, or series of strata. Whilst those on the north side of the line, are more characteristic of what is known as the West Yorkshire Coal-field, and may be generally distinguished by Sections, which have long been associated with the several important seams, known as the "Stanley Main," the "Middleton," and the "Low Moor" Beds of Coal. These lines, of great physical distinction, are important on an occasion like the present, chiefly as affecting the identity of particular seams on each side of them. A few years have sufficed to solve many interesting doubts of this nature, which formerly excited geological controversy. As, for instance, whether the thick (9 feet) seam, familiarly known as the "Barnsley Bed," which seems to find its northern limit, for all practical purposes, in the divisional line I have referred to, is not represented on the north side of such line, by the seams known as the Warren House and Gawthorpe Beds. This identity is now accepted. And I believe it is equally well established, by the results of more enlarged experience, that the Stanley Main Seam, onthe north side of our divisional line, has its representative in the two distinct beds in the Barnsley Section, commonly known as the "Upper and Lower Beamshaw" Beds.

Such being the accepted facts, we get a clear and well-established definition, of the entire section of the West Riding Coal-field, from its upper or latest deposited beds, (the Glass Houghton and Shafton Beds), down to the level or zone of the "Barnsley Coal." In this we may assume an aggregate thickness of 400 or 500 yards of various stratifications. These include, besides the several beds of coal, too well known to require that I should stop to enumerate them here, the several beds of Sandstone Rock, known as the Cudworth Rock, the Oaks Rock, and the Woolley Edge Rock, which, by their escarpment, contribute so much to the boldness and beauty of the South Yorkshire scenery. Descending below the Barnsley Bed, the next important member in the West Riding Section, which claims especial notice at the present time, is the "Silkstone Seam," lying at varying depths, from 300 to 400 yards below the Barnsley. Until a few weeks ago, this seam could only claim to be known at its practical outcrop. The spirited enterprise which has recently been attracted to the South Yorkshire District, has, however, met with a species of reward, the importance of which it would be difficult at this moment to over-estimate.

The "Silkstone Coal" may safely be said to have acquired a household name and reputation throughout the United Kingdom. The purity of its mineral composition, and the generous thickness of the seam, combine to make it one of the grand hopes of South Yorkshire. No wonder, then, that as in the instance of its sister bed (The Barnsley), scientific skill should be exhausted in tracing it beyond, and to the north, of our imaginary line of transition, and that in the West Yorkshire section, we should be led with propriety and truth, to recognise one amongst its numerous members, which we could fairly affiliate as the true representative of the Silkstone bed. I may remark, parenthetically, that the *parent* name of this bed is scarcely to be controverted. Its natural outcrop in the village of Silkstone, would doubtless afford the first opportunity of ascertaining its qualities, and hence it obtained its primary definition and name.

I know that the task of carrying this important identification into the West Yorkshire district, is confessedly accomplished, and more than one instance exists, of important commercial results being realised, from the assumed identity of the Silkstone seam, with beds obtained in collieries to the north of our imaginary line of separation.

Whether these authorities may all agree amongst themselves, and ultimately prove to be correct, is more than I can venture to assert. I am free to admit that it is possible. But the evidence requires much care in its adequate collection and examination before it is fully accepted. I know my friend, Professor Green, has lent the importance of his high authority to the "Blocking Bed," a seam locally known in the district of Dewsbury and Flockton, as the true representative of the Silkstone, and his forthcoming Memoir, will doubtless convey such reasons as will claim our deepest respect. Mr. Thorp's diagram may also be referred to, as confirming this identity.

I will, however, anticipate the pleasure with which I am sure Professor Green's work will be hailed, by suggesting a line of investigation, which it is just probable he may not have pursued. I will now refer to that analogy, which may or may not be traced, between the lower members of the West Riding section, by pursuing them upwards from the great Millstone Grit base, which is well defined along the western and northern boundaries of our entire Coal-field, and extending from Sheffield in the south, by Huddersfield, Halifax, and Denholme, in the west, to Kirkstall, Horsforth, and Thorner, in the north.

It is not a little remarkable, that along this extended line of country, the two Halifax beds (the Hard Bed and the Soft Bed Coals) are to be traced in consistent relation to the outcropping Grit-stone, which lies in varying thicknesses of 15 to 25 or 30 yards, below the Soft or lower bed. The Halifax beds are overlaid by a series of alternating shales and bind, interspersed with a few very thin, but distinctive "bands" of coal, and generally, acquiring an aggregate thickness of 150 to 200 yards. The section then receives, in its ascending order, an equally persistent stratum along the entire margin of our Coal-fields, and well known as giving origin to the important flagstone quarries of Green Moor, Elland Edge, North and Southowram, Clayton, Bradford, Armley, and Leeds.

Having then obtained, in its ascending order, the continuous and important stratum of the Flag and Slate, we have what may be accepted as a higher and substituted base, for the Coal-measures proper of the West Riding Field. Below the Flag-stone, as we have already seen, there exists only the two Halifax beds of workable coal. All our mineral deposits of any real commercial importance are, therefore, subsequent in date, and are super-imposed upon the Flag-stone stratum. Taking the southern district, separated by our imaginary line of division, we find the Whin Moor Coal the *first* in order, and after that the Silkstone, which is followed in turn by the Park Gate, Flockton, Swallow Wood and other seams, which lie between the Silkstone and Barnsley beds. In the Northern District, we find the Flag-stone is first overlaid by the two important seams, known as the Low Moor Better and Black Bed Coals; these are followed in order, by the several beds characteristic of the Gildersome, Morley and Dewsbury fields; and it is amongst these, that the identity of the true Silkstone seam is to be traced. This, doubtless, will soon be accomplished, and so by the rapid spread of colliery workings in the district, the identity will be made complete.

In connection with the extent of our Coal-field, it is essential that I should direct attention to, and put on record, the rapid strides by which our experience has been advanced in the past two or three years. In this period of time, a totally unprecedented amount of capital and enterprise have been attracted to the South Yorkshire district, and in the area of coal leased, and number of new collieries established, all previous history has been totally eclipsed. Twenty years ago, our knowledge of the "Thick Coal," in the vicinity of Barnsley, was almost confined to collieries which were directly upon, or merely skirted the outcrop of the seam. It was subsequently extended by the opening out of collieries, pursuant of the "dip," from the locality of Worsborough, to the district of Wombwell and Lund Hill. It remained, however, for the extraordinary stimulus, arising from the condition of the coal and iron trades, some two or three years ago, to push the "Barnsley and Silkstone seams" into prominent notice; and in that brief interval, the vast extent of area leased, has carried the collieries by one huge impulse, from the practical horizon of the town of Barnsley to that of the Midland Railway. In this transition, it would not be unfair to say, that a fresh demand upon our unexplored, and therefore unexhausted treasury, has been made to an extent of country, measuring eight miles in length by two miles in breadth, or upwards of ten thousand acres; and if this were regarded with reference to the Barnsley-bed alone, it would represent in weight, about one hundred million tons of coal, bespoken from our natural resources within the last four or five years.

The Midland Railway, however, has also been exceeded, and two examples may be specially referred to, where the Barnsley-bed has been leased, and pits are now being sunk, with the view of working the Barnsley-bed to the eastward, and upon the "dip" from the parallel of the railway. I mean the Monkton Main, and the colliery which is being opened up at South Kirby, the latter being at least seven miles in the "dip" direction, from the lowest colliery established in the locality of Barnsley.

We regard the prosecution of the two last mentioned projects with peculiar interest, as tending to increase our knowledge of the probable extent of our coal-field in an easterly direction. It is a subject which opens up a rare amount of speculation, and well deserves the most careful and intelligent investigation. The probabilities are, that we have in this momentous question, results of *national,* as well as *local* importance, which would startle the most sanguine anticipations; and I know of no institution, so appropriate as our own, for treasuring the practical results of experience, and encouraging the processes of exact observation, upon their gradual development.

In hastening to a conclusion, I cannot withhold reference to operations which, even in the current year, have greatly added to our previous acquaintance with the importance and area of the Silkstone Seam, in the South Yorkshire District. The Barrow and Hoyland Silkstone Companies have both revealed the presence of the Silkstone Seam, by the spirited enterprises in which they have engaged, in the localities of Worsborough and Hoyland Nether. And here again, having reference to the previous winnings, we have an immense accession to the proved territory, over which this very important seam is known to extend. By the kindness and courtesy of my friends, Messrs. Kell, I am able to direct the attention of the members and friends present to a vertical section of the strata through which the Barrow Company's shaft has been sunk to a depth of 460 yards from the surface; and we shall all unite, in heartily congratulating the two Companies, on the very satisfactory results, which have followed upon the intelligent enterprise.

There remains only one subject more to which I can stay for a passing observation. It is that of greater safety in carrying on the operations connected with Coal Mining. Surely something may yet be done to diminish the risk, if not altogether prevent those sad fatalities, which thrill through our deepest sympathies. The Polytechnic aspect of our Society, should give encouragement to labourers in this most inviting field of research; and I do hope, that the gathering here to-day, in this most central town of the South Yorkshire district, may result in a deep and wide-spread feeling of fellowship and good will, and that a great accession to the list of our members, may show that the public and scientific interest of the West Riding, is being actively and effectively exerted, in sustaining the growth, and promoting the influence, of the Geological and Polytechnic Society.

ON A SECTION OF BOULDER CLAY, NEAR BARNSLEY. BY A. H. GREEN, M.A., F.G.S., PROFESSOR OF GEOLOGY IN THE YORKSHIRE COLLEGE OF SCIENCE, LEEDS. (PLATE VII.)

It is very well known that the distribution of drift, on opposite sides of the southern portion of the Pennine range of hills, is very unequal. While all the low-lying grounds of Lancashire and North Staffordshire, are thickly covered by broad sheets of Boulder Clay, Sand, and Gravel, the corresponding tract of the Yorkshire and Derbyshire Coal-field is all but a driftless area. Drift, however, is not altogether absent from the plains east of the Pennine ridge, and of the scattered patches which have been detected here and there in this district, one of the most remarkable is the deposit which it is the object of this paper to describe. It was laid open in the cutting of a mineral railway near the Carlton Lane Toll-gate on the Barnsley and Wakefield road, about two miles north of Barnsley, and the section of that part of the cutting in which the drift bed occurs is shown in Plate VII.

On the south, the section traverses the Woolley Edge Rock and the underlying Woodmoor Coal, and we soon reach the edge of a hollow, which has been cut out of the sandstone, and afterwards filled in with Boulder Clay. The surface of the sandstone at the junction, is very much shattered and smashed, and large blocks of the rock are embedded in the clay. The Boulder Clay is blue, very stiff, somewhat gritty, and without the least trace of bedding. The stones are mostly small, but a large block occurs every here and there; the majority have their angles and edges blunted; some are quite angular; a few are well-rounded pebbles. By far the larger quantity, probably 99 per cent., are coal measure rocks, chiefly sandstone, after which the most numerous are flat, blunted slabs of well-scratched black shale; bits of coal were not uncommon. Foreign stones, though not plentiful, were easy to find. Carboniferous limestone (ice-scratched), chert, and black earthy limestone were the most conspicuous, and a specimen was found of blue, closely-grained trap, with crystals of iron pyrites. This clay then, which we will distinguish as the Lower Boulder Clay, has all the characters of the deposit known as Till, which is generally believed to have been formed on land beneath an ice-sheet.

A little further to the north, the Lower Boulder Clay becomes covered up by a deposit of a somewhat different kind, which we will call the Upper Boulder Clay. This is by no means so stiff a clay as the lower bed. It is more sandy, and there are fewer stones in it. It contains irregular, interbedded masses of Warp (laminated clay), and nests and lenticular sheets of sand and gravel. The whole is rudely bedded, and the beds are in places very sharply contorted. The clay is traversed by curved joints or cracks, with polished faces, filled in with sand, along which great masses break off.

A little before reaching the Turnpike road, Warp makes its appearance in the lower part of the cutting. The relationship of the Warp to the Lower Boulder Clay was not very clear at this point, but the two seemed rather to dovetail into one another; along the remainder of the section, however, the Warp distinctly lay beneath the Upper Boulder Clay. The section at the turnpike road showed

	Ft.	In.
Upper Boulder Clay	13	0
Seam of Warp...	0	2
Upper Boulder Clay	9	0
Warp	9	0
Fine Gravel and Sand, not bottomed	5	0

The Warp is a bluish-brown, very finely laminated, tough clay, with small, well-rounded pebbles of carboniferous sandstone and coal; the bedding was unmistakable, but wavy and irregular.

The gravel at the bottom of the cutting was mostly small, but it contained a few large angular boulders of sandstone.

For some distance, the cutting now shows only Upper Boulder Clay resting on Warp, but after a while a boss of clay, agreeing exactly with the Lower Boulder Clay of the south end of the section, rises up in the bottom of the cutting. A short distance further on, the Drift Beds abut against a sloping face of coal measure shale. The Warp, near this southern termination of the drift, seemed to be replaced by some fine sand and sandstone-gravel, in lenticular beds, with nests and layers of broken coal; embedded in this gravel, were some very large angular blocks of sandstone, and at its base a layer of angular bits of black shale, some of which were ice-scratched.

The succession of events which this section would seem to reveal to us is as follows:—

First, a valley was excavated in the coal measure sandstones and shales. This valley was afterwards filled in, to a greater or less extent, by the clay we have called Lower Boulder Clay. The character of this deposit, is exactly such as is believed would be formed on land by the grinding of an ice sheet; such probably is the origin of this clay. It is, most likely, only a remnant of a mass of Till, perhaps never very large, which has been almost entirely removed by denudation; and it owes its preservation to the sheltered position in which it lies. Then the cold passed away; the valley was partly re-excavated, and a stream flowed along it by whose agency river-deposits of warp, sand, and gravel were laid down. The angular blocks and scratched stones in these beds, may well have been derived from the Lower Boulder Clay, which formed the bed and slopes of the valley.

The Upper Boulder Clay indicates a return of cold; it is not easy to decide what were exactly the conditions under which it was formed; being bedded, it was probably subaqueous, and its stones may have been carried by floating ice.

Though the cutting just described is the only *section* we have of the drift deposits, Boulder Clay covers a considerable area in the neighbourhood. Between the cutting and the villages of Carlton and Royston, the surface is seen to be formed of stiff clay; large angular blocks of carboniferous sandstone, and foreign rocks are plentifully sprinkled about. Among the strangers, boulders of highly metamorphosed breccias, which may well have come from the lake district, are not uncommon; and in the village of Royston there is an angular block of granite, which agrees very well in character with the granite of Shap Fell. There are also several patches of fine, well-rounded gravel, composed mainly of carboniferous sandstone of the neighbourhood, but the relation of the gravel to the Boulder Clay could not be ascertained in any instance from want of sections.

There are scattered over the generally driftless tract of the Yorkshire Coal-field, other patches of drift, but none, as far as I know, so large as the one just described, and in no other case have I been lucky enough to find a section, which allowed the character of the deposit to be minutely studied. But as in the one case when examination was possible, Till was found to constitute at least a part of the accumulation, it is probable that Till is present among the other drift patches. If this be so, it indicates that an ice sheet at one time overspread the area. But it seems likely that the amount of Till produced can never have been very great; for it is hardly probable that, if any large quantity had been formed, denudation would have made such a clean sweep of it as to leave only the few patches that now exist. At least, if any one maintains this, he must be prepared to explain why it was that denudation worked with such special thoroughness in this particular area. Why, if this part of the country was covered by an ice sheet so little Till was formed, it is not easy to say; but it may have been because the ice had its southern termination hereabouts, and being thin, was not able to exert any large amount of grinding action.

But the explanation of the distribution of the drift over the area in question is only part of a larger problem, to the solution of which but little progress has yet been made.

One instructive fact in connection with this patch of drift remains to be mentioned. Before the railway was made, a bore-hole was put down near the turnpike road. The borers had nothing but local experience to rely on, and having never seen Boulder Clay, were much puzzled by the strange stuff that came out of the hole. Finally, they came to the conclusion that they could account for what they had found in no other way, but by supposing they were on a fault, and it became an established article of faith that a large fault, which there was every reason to believe existed somewhere in the neighbourhood, but whose exact position was unknown, ran through the bore-hole. So little doubt was felt on the point, that an exchange of coal between the proprietors of two neighbouring collieries, on opposite sides of the supposed fault, was negotiated and all but concluded, when the railway cutting was made and the fault proved to be imaginary. It is hardly necessary to point out, that a very trifling amount of geological knowledge would have prevented the mistake, and enabled the borers to distinguish between Boulder Clay and Fault-stuff.

ON A STRATUM OF SHALE, CONTAINING FISH REMAINS, IN THE LOWER COAL MEASURES. BY JAMES W. DAVIS, F.L.S., F.G.S.

A PECULIAR stratum of shale, which contains so great a number of remains of fossil fishes that I venture to call it a Bone-bed, occurs immediately above the Better Bed Coal, and is known to extend over a surface 4 to 5 miles in length, by nearly 2 in average breadth.

The Better Bed Coal is a member of the Lower Coal Measures or Ganister Series. It occurs about 700 feet above the Rough Rock, the uppermost bed of the Millstone Grits, and is separated from the Black Bed Coal by overlying strata of an average thickness of 120 feet. It is extensively worked by the Low Moor Iron Company, and used by them in smelting the clay ironstone of the district. It is peculiarly valuable for this purpose, on account of its freedom from sulphur ; the excellence of the iron manufactured by this firm being in a great measure ascribed to the use of the Better Bed Coal.

The following section will explain the position of the Bone-bed. The section extends from the Elland Flag-stones below, to the Black Bed Coal above :—

	Ft.	In.
BLACK BED COAL	2	10
Seat Earth	3	0
Argillaceous Shale	20	0
Strong Stone	15	0
Galliard	5	0
Strong Stone	20	0
White Shale	10	0

	Ft.	In.
COAL	1	0
White Shale, with Thin Coal	20	0
COAL	0	6
Arenaceous Shale	15	0
Blue Shale, with Ironstone	20	0
Bone-bed	¼ to ⅝	
BETTER BED COAL ... ... 1ft. 3in. to	2	9
Seat Earth or Galliard	4	0
Shales and Raggy-stone	30	0
Elland Flag-rock, with Partings of Shale	200	0

The beds vary very much in thickness, the above may be taken as the average in this district. The Bone-bed rests immediately on the surface of the coal, and varies from a quarter to five-eighths of an inch in thickness. Above is a thick bed of blue argillaceous shale, containing layers of ironstone nodules, the only organic remains found in it being those of plants. The Bone-bed is composed, in a great measure, of comminuted bones, principally of fishes, though remains of labyrinthodonts are sometimes found, mixed with these are minute fragments of coal, often in thin layers of small extent. The whole presents the appearance of a brownish-black argillaceous shale, and is easily distinguished from the light-bluish shale above. It is continuous over a large area, being invariably found, where the coal has been got, from the north-west of Wyke to Clifton. Nearly all my specimens are from the latter district.

Before enumerating the species of fossil fish from this bed, I would draw attention to the section, in order to point out the probable circumstances attending the aggregation and deposition of the strata composing it. Beginning with the Elland Flag-rock, we have a great thickness of sandstones with intercalations of shale, which were probably of littoral origin, or may have been the estuary of a river. A gradual elevation of the land then took place, which was in due time covered by the plant life, ultimately forming the Better Bed

Coal. The roots of the plants are formed in the seat earth below the coal, which tends to prove that they grew where they are laid, and were not washed from a distance to the position they now occupy. The land was again submerged, and probably became an estuary, whilst the Bone-bed was being gathered together. That it is an estuary deposit receives confirmation from several sources; we shall find that the fish remains belong to two distinct groups: one of them, the Elasmobranchii, of which the sharks and rays are existing representatives, are confined entirely to salt water; whilst the second group, the Ganoidei, have several living representatives which are only found in fresh water, as the Lepidosteus, Amia, and Calamoichthys of the rivers of America; whilst others, as the sturgeon, can live either in salt or brackish water. By the supposition of the land being lowered sufficiently to form an estuary deposit, it is not difficult to conceive the detached spines and teeth of the Elasmobranchs being washed towards the shore by the tides, and there mixed with the Ganoids from the river. This also appears probable when the broken and fragmentary condition of the remains are considered, for being constantly subject to attrition by each succeeding wave, the condition in which they are found would be the natural result.

After some time the land was lowered still more, and the mud brought down by the stream, was deposited in deeper water, forming the bed of blue shale resting on the Bone-bed. The overlying strata of alternating beds of coal, shale, and sandstone, leads to the inference that the elevation and subsidence of the land occurred repeatedly.

Before proceeding to the enumeration of the fish remains I have been able to identify from the Bone-bed, I wish to acknowledge my indebtedness to the Earl of Enniskillen, Sir Philip de M. G. Egerton, and W. P. Sladen, Esq., who have kindly placed their valuable collections at my disposal, for comparison with my specimens, and also to L. C. Miall, Esq., who identified the labyrinthodont remains.

ELASMOBRANCHS.

Gyracanthus formosus. Ag.

G. tuberculatus. Ag.

Pectoral and dorsal spines of this genus are frequently found. The bones of the pectoral arch are also met with, and occasionally patches of shagreen covered with small tubercles.

The gyrating lines of Formosus are occasionally found divided into tubercules, which are the characteristic of the second species, Tuberculatus; but as the various intermediate stages can be traced in a series of the spines, I infer there can be no sufficient grounds for considering the latter more than a variation from the original type.

Ctenacanthus hyboides. Egerton.

Tolerably abundant. In good state of preservation, 12 to 15 inches in length.

Ctenacanthus sp.

Straight, ridges much broader than in C. hyboides and much fewer in number, having only 5 or 6, whilst C. hyboides has 16 or 18. The spine presents a fibrous appearance, as though the ganoine had been dissolved away, exhibiting the bony structure beneath. Its length is 4 to 6 inches.

Ctenacanthus sp.

This spine differs from the preceding in being more curved. The ridges being symmetrical and not running or branching into each other, and being closer and finer in appearance.

Lepracanthus Colei. Egerton.

Was described and named by Professor Owen in the "Geological Magazine" for 1869, p. 481, from a single specimen found by the Earl of Enniskillen in the coal shale at Ruabon.

The species occurs in the Bone-bed, about a score specimens having been found. The largest measures $3\frac{1}{2}$ inches in length and $\frac{3}{16}$ of an inch wide, being an inch longer than the one described by Professor Owen. He says:— "The spine is gently curved, moderately compressed, with the back or convex border rounded; the thinner concave border is armed by relatively large, recurved, pointed denticles, sub-compressed and strengthened by an almost ridge-like swelling along the middle of each side. These denticles are few in number compared with most similarly barbed fossil fish-spines; four project from about one-third of the length of the body of the spine, and not more than seven are traceable in the present specimen."

In one or two of the specimens from the Bone-bed, which have left the matrix without being fractured, the spine is seen to have been hollow, with a row of denticles on each side of the concave border; these are placed alternately, and not opposite to each other, so that there are 13 or 14 denticles, in place of 7 as seen by Professor Owen, one half of the type specimen being hid in the matrix.

Acanthodes Wardi. Egerton.

Spines of this species are common. They vary extremely in size, from one inch and a half long, and one-eighth of an inch broad, to seven or eight inches in length, and fully half an inch in breadth. All are characterised by the deep furrow running parallel to the convex portion of the spine.

Pleuracanthus lœvissimus. Agass.

Very rare. One specimen nearly 8 inches in length and

$\frac{5}{8}$ broad at the base, gradually tapering to a point. A double row of denticles extend on each side from the point, 5 inches along the spine.

Orthacanthus cylindricus. Ag.

The specimens of this genus are generally small, rarely exceeding 3 or 4 inches in length. They are rare in the Bone-bed.

Diplodus gibbosus. Ag.

These teeth are rather rare in the Bone-bed. It is probable that Diplodus are the teeth of Pleuracanthus or Orthacanthus. Dr. Newberry, an American palæontologist, has found the remains of the latter associated with the teeth of Diplodus in such a manner as to leave little doubt that they belonged to the same species. Both spines were cephalic, and nearly related. It is possible that the Diplodus teeth may belong to both genera.

Gen: Nov.

The spine is $4\frac{3}{5}$ inches in length, and has a diameter of $\frac{1}{5}$ of an inch. The only specimen I have is crushed from the base two inches towards the apex, the remaining portion is round, and gradually tapers to a point; being slightly recurved, the surface presents a fibrous appearance, otherwise it is quite plain and smooth. On the concave portion of the spine are 8 denticles, each separated about a quarter of an inch. The intervals between those nearer the base being wider, and gradually becoming smaller nearer the point. The denticles are comparatively large and blunt, and extend from the spine nearly the $\frac{1}{8}$ of an inch. A second specimen in the collection of W. P. Sladen, Esq., is completely separated from the matrix. It is nearly straight, and shows no evidence of a second row of denticles. It is probably a cephalic spine allied to Pleuracanthus. A transverse section cut from the sp. about $\frac{1}{3}$ its length from the base, and magnified 20 diameters, shows the internal part or core to be rather more than half the diameter of the spine, and apparently hollow. The bony structure surrounding this is composed of numerous ridges, without definite arrangment, between and amongst which are pits or vacuoles. The whole presents a labyrinthoid appearance. The bony part of the section has been cracked, both from the external and internal margin. The cracks are filled up with iron pyrites.

Hoplonchus, gen. nov.

Two or three spines from the Bone-bed present characters differing from any previously described, they are $1\frac{1}{2}$ inches long and $\frac{3}{16}$ broad at the base, they are straight except a slight curve on the anterior margin towards the point. From the apex to a quarter of an inch from the base, the side of the spine is ornamented by longitudinal enamelled ridges, six in number; the remaining portion has been imbedded in the tegument of the fish. The line dividing the two parts lies obliquely across the spine, the posterior border being the shorter one. The ridges in one or two instances run into each other, presenting a bifurcated appearance. The whole of the spine is slightly compressed. Along the posterior margin are a series of minute denticles, scarcely distinguishable without the aid of a magnifying-glass.

The two genera to which they are most nearly allied are Onchus and Homacanthus of Agassiz. It differs from the former in having denticles, and from the latter in being straight and having the furrows or ridges homogeneous. Sir Philip Egerton, who has a specimen of the spine, suggests the generic name "Hoplonchus," as signifying the character distinguishing them from Onchus.

Pleurodus Rankinii. Agass.

P. affinis. Agass.

I have nearly 200 teeth of Pleurodus from the Bone-bed. They differ very much in form, size, and character; some have broad, wing-like processes spreading from the main ridge of the tooth; others narrow and elongated; many are ornamented by a series of well-defined striæ running across them transversely; whilst the majority are smooth and plain, or slightly punctured. The size ranges from two-tenths of an inch to seven-tenths. I think it is more probable that the teeth are from different parts of the jaw of one species, than that there are two species. Professor Agassiz, who named them, did not describe the species, so that little is known of his reason for separating them into two species.

Helodus simplex. Agass.

Rare. Two or three teeth.

Helodus sp.?

Rare. Two teeth.

Cladodus mirabilis. Agass.

These are probably the teeth of Ctenacanthus hyboides.

Pœcilodus sp.?

Two teeth.

Harpacodus sp.?

Several teeth.

Petalodus Hastingsiæ. Owen.

Single teeth. Not uncommon.

Ctenoptychius apicalis. Agass.

Teeth. Not uncommon.

GANOIDS.

Ctenodus ellipticus. Hancock and Athey.

Very rare. Two or three teeth. A few head bones and ribs are all I have seen.

C. tuberculatus. Hancock and Athey.

A single tooth, ribs, and dermal headplates.

Holoptychius sauroides. Agassiz.

Strepsodus sauroides. Huxley.

Scales of the former and teeth of the latter are found in tolerable abundance. They are usually found detached.

Megalichthys Hibberti. Agass.

The remains of this fish are tolerably abundant. They vary extremely in size. The scales are occasionally found connected, oftener detached; teeth, vertebræ, and head bones are common.

A large, nearly complete specimen, measures two feet six inches without the head, which is unfortunately wanting.

Acrolepis sp.?

Rare. Fragments of headplates and scales, very beautifully preserved.

Platysomus sp.?

Rare. A mass of detached scales is the only example I have seen.

Acanthodopsis Egertoni. Hancock and Athey.

Part of a jaw with teeth.

Amphicentrum sp.?

A tooth and a spine attached to the dorsal fin.

Rhizodopsis sp.?

Very rare.

Cycloptychius sp. ?

Rare. Part of a jaw, nearly an inch long, with 14 sharp lanceolate teeth $\frac{1}{16}$ of an inch in length.

Gyrolepis Rankinii. Agass.

One of the few examples from this district of a fish being found with the fins and scales in situ. It is 5 inches long, and exhibits part of the head, two dorsal fins, and a mass of small scales.

Palæoniscus.

I have found no good specimen of this usually abundant genus. Occasionally a few detached scales and teeth are met with, which exhibit its peculiarities.

Cælacanthus lepturus. Agass.

The remains of this species are fairly numerous, and indicate a fish from 12 to 15 inches in length, and as the specimens figured by Professor Huxley in Decade XII. of the "Mem. of the Geological Survey," are only 4 to 5 inches long, the present examples may be regarded as large. All my specimens are disarticulated; as single bones they are very perfect, and many of the external ones exhibit most beautifully the sculpturing peculiar to the genus. I have, of the bones forming the head, the hyomandibular and palato-quadrate, which are always found anchylosed into one piece, irregular plates, ramus of lower jaw with teeth, opercula, and frontal bones. Bones forming the pectoral arch and large interspinous bones connecting the unossified vertebræ with the dorsal fin-rays. A number of bones presenting very much the appearance of vertebræ, but of a more cruciform shape, were, doubtless, the ossified centres from which were suspended the branchiostegal rays, some examples show the rays in situ, connected with their cruciform support. Fragments of the rays exhibit ossified processes developed along the two flattened edges of the ray, which served to support the gills.

The ossified walls of the air bladder are occasionally found ; one specimen in my cabinet is nearly six inches in length by three in breadth.

LABYRINTHODONTS.

Vertebræ and other bones of labyrinthodonts recognised by L. C. Miall, Esq., as those of Loxomma have been found. They are rare.

THE MINERALS OF THE YORKSHIRE COAL-FIELD AS APPLIED TO THE MODERN MANUFACTURE OF IRON. BY BENJ. HOLGATE, ESQ.

The large quantity of Iron, that in the form of oxides and carbonates, combined with earthy matter, is found distributed over the world, and in every Geological formation, is frequently unutilized owing to the want of means for reducing it to the metallic state. Its reduction into the state of pig, or that in which it may be cast into any required form, and its manufacture into the malleable state and steel, so that it may be worked under the hammer or drawn out by means of rollers into bars, is dependent upon the means of obtaining fuel, a large quantity being required for its manipulation, and upon a plentiful supply of substances, not fusible at high temperatures nor chemically acted upon by either the fuel or the Iron in a state of fusion. Thus the Iron-ore of Spain, though of no use in that country, is brought to England in large quantities, and mixed with the ores of this country. The oolitic and liassic ores of North Yorkshire would be less valuable were they not contiguous to the Durham Coal-field. The supplies of coal and fire-clay obtained from this district in large quantities, make the Cleveland Iron the cheapest in the world.

The district known as the Yorkshire Coal-field (from Leeds southward) contains in its ganister beds and various fire-clays, its carbonaceous iron ores, and its excellent coals, all the materials necessary for making the best iron that can be produced; the reason of this superiority may perhaps be best explained if we first consider what is required in these substances. 1st—

FIRE-RESISTING MATERIALS.

The requisite materials for withstanding heat are various, and have to be regulated by the kind and quantity of heat used; they must be of such a nature that they may not be decomposed by, nor combine chemically with, the substances heated in the furnaces or crucibles made of them.

Thus, graphite crucibles are perhaps the best for resisting absolute heat, but when used for melting steel cause a deterioration in quality, by its chemical combination with the carbon.

It is practically impossible to melt silica, but at the same time, a furnace made of silica would be of no use, because repeated heating and cooling would crumble it into sand, though it would not melt it. Materials must therefore be found containing silica, with such a proportion of alumina and an alkaline earth, such as lime, potash, or soda, as will combine chemically and flux with it to such an extent as to prevent its crumbling down, and at the same time, not so much as to allow it to flow into a liquid.

It will be seen that these proportions will vary with almost every use to which these materials can be put. It would be useless to provide the same substances for moderate temperatures, which are absolutely necessary when high temperatures must be used. But besides this, furnaces are only heated on the inside, and they must be made sufficiently thick to bear the wear and tear to which they are subjected. The bricks are bad conductors of heat, and being heated only to a little depth, the consequence is, that many fire-bricks, even those considered of good quality, become worn out, not by gradual fusion, but by breaking off to the depth penetrated by the heat. The pieces that snip off sometimes fall into the furnace at once, and at others remain semi-detached; when the heat is again increased, it gets behind the detached piece and fuses it into the form of drops; should the fused brick fall on the iron it will cause a bad forging. It has been attempted to prevent this, in the case of fire-bricks used for some of the Durham coke ovens, (which have to be heated frequently and then suddenly cooled to a certain extent, by injecting water, in order to cool the coke before it is drawn out), by making them considerably less in section (about $2\frac{3}{8}$ in. square), but of the same length as ordinary bricks. It is also sometimes attempted, instead of building furnaces with the ends of the bricks presented to the heat, to build them a double thickness, with the side of the brick presented to the heat, so as to allow the inner row of bricks to expand; but it is clear that if a single brick gives way, the flame will get behind that thickness of bricks, and will soon bring down the whole side. Fire-bricks, therefore, will be better and last longer, if they contain a substance which will conduct the heat through the brick, and make the expansion more regular, even though this substance does not improve its infusibility. This quality appears to be present in bricks containing a greater proportion of peroxide of iron than the ordinary fire-brick. The minerals to meet these wants are found in the Ganister which lies in the Lower Coal Measures, just above the Millstone Grit, both at the north and west boundaries of the

Coal-field from Leeds by Bradford, Halifax, Huddersfield, and Deepcar, and in the fire-clays which underly some of the coal seams. Some of the Millstone Grit and other stones also resist moderately high temperatures. The Ganister is a hard, siliceous sandstone; the best qualities contain about 97 per cent. of silica.

In the vicinity of Leeds, it is worked at Meanwood, and at Laister Dyke, near Bradford. Though the Meanwood is not equal to Sheffield ganister, it is so near, that the cost of carrying the Sheffield ganister to Leeds outweighs its superiority. It is full of the rootlets of the trees which have formed the coal seams, generally found overlying it; it breaks into irregular pieces, without stratification, being very hard and brittle, and it cannot be used for building purposes. It is ground for the purpose of lining cupolas for melting iron, furnaces for melting steel, and Bessemer converters. In all these it has to be often replaced, as it cracks away; but it is not suited for making crucibles for steel or glass, because it would crack away too rapidly, or fall into a powder. It is ground and mixed with fire-clay and other sandstones, to make what are called silica bricks; though these are used for very high temperatures, they can only be used where the temperature is constant and regular, and are not suitable for furnaces which are subject to great and rapid variations in temperature, as they crumble to pieces.

The bricks made from the fire-clay which is found among the Ganister measures underlying the Halifax Hard-bed coals at Shipley, near Bradford, is, perhaps, the best suited for building reverberatory furnaces; while those made from the clay found in the same measures in the neighbourhood of Huddersfield, have long held the reputation of being the best for glass furnaces, and I think would also build good iron furnaces, as they expand and contract without cracking, and do not form into drops so much as many other fire-bricks do.

These clays contain a larger proportion of peroxide of iron, than is found in the majority of the clays of the district. The clay underlying the Low Moor Better-bed Coal is of very good quality, and is made not only into fire-bricks, but into sanitary tubes, chimney pots, and terra cotta work of all kinds. To the east of Farnley it is found generally as a fire-clay; but at Farnley, Bowling, and Low Moor, it sometimes becomes a ganister.

The fire-bricks made from the Better-bed clay are those in general use in this district, and are very beautiful in appearance. They are used in building all kinds of furnaces, from the fire backs of our homes, to furnaces for making steel. Many of the sandstones of this district are well adapted for furnace building where moderate temperatures are required, and before the fire-clays became generally used, a period of quite recent date, they were largely used, and are still in some instances. The ground ganister which is sold in Sheffield, often contains a considerable amount of sandstone ground with it when not required for the highest temperature, in order to prevent its breaking down.

A rough stone from the Millstone Grit, found near Moor Allerton, Leeds, when ground into sand, makes a very good reverberatory furnace bottom, and the flag-stone in the quarry near the Armley Midland Station, has been used to a considerable extent for building the furnaces of glass-houses. Newcastle fire-stones are still offered for sale for this purpose. A sandstone which is found at Deepcar also possesses fire-resisting properties, and I have no doubt that many other sandstones, if tested, would be found to resist heat to a considerable extent. The great drawback to their general use is their want of homogeneousness, for though the stone of one part of a quarry may resist heat well, that in another part might be only an indifferent quality.

IRON.

Iron is used for its strength, but how differently various qualities of iron perform this function, everyone is not aware; thus some iron is of such a brittle nature that it will break with a slight shock, while other iron though no stronger under a pull or thrust applied gradually, will bear a heavy weight applied suddenly, and this principally constitutes the difference in the quality of iron. It is of the greatest importance, that our structures should not only be strong under regular weights or work, but that they should remain firm if this weight or work be applied suddenly.

The iron made from the ores found in the Leeds and Bradford districts, is the best in the world that can be produced in large quantities. The pig-iron is converted into wrought-iron, and used for the manufacture of crank axles for locomotives, wheels, wheel tyres, and boilers; crank axles and screw shafts and boilers for steamers, and indeed for any purpose, where the cost is not so much an object as safety, and where the result of breakage would be disastrous.

In some places, iron is made from magnetic ore directly into wrought-iron of very good quality, by melting it in small hearths with charcoal, but in this way it is only made in very small quantities, quite inadequate to supply the large demand for iron of the best quality.

In the vicinity of Leeds and Bradford, however, it is made largely, but the supply of ore must in a short time become worked out, as, although iron nodules are diffused all through the coal measures of the district, it is in such small quantities as not to be worth working.

The Ironstone worked is in three principal layers of nodules, which lie about 2 feet above the Black-bed coal, their aggregate thickness would only make a seam of about 4 or 6 inches; its value may thus be judged, for in the Cleveland district, the ores sometimes attain a thickness of 30 feet, then again, the yield of iron in the Bradford district is only from 30 or 35 per cent.

The Ironstone of South Yorkshire is also of very good quality. It is nodular, and in some places these nodules are so numerous as to form a seam, yet it retains its nodular character, and these seams are intermittent, extending only a few feet and then being absent a few feet more. It is worked at three different depths, the Black Shale Mine, about 13 yards above the Silkstone coal, is got through a depth of 5 or 6 feet; the top, or what is called the Brown Mine giving the most plentiful supply, being 9 inches thick. In the remaining height, the balls are picked out of the shale. All the ore in this working added together, would only give a solid thickness of about 1 foot.

About 62 yards above this ironstone, or 20 yards below the Parkgate coals, is the White Mine.

Twenty-five yards above the Parkgate coal is the Black Mine. On account of the great cost of getting these ores, they are fast going out of use, their place being supplied by others, such as those of Lincolnshire and Barrow, which are found in much larger quantities, and are considerably cheaper. The South Yorkshire ores are also mixed with, and improve the quality of, those above mentioned.

Iron is found associated with sulphur, phosphorus, silicon, and other substances, and occasionally with titanium. These substances are all more or less deleterious to the metal, for while phosphorus makes it *cold-short*, that is to say, brittle when cold, while it does not affect it when hot, sulphur makes it *red-short*, that is, it causes it to fly to pieces or brittle when hammered red-hot, but does not affect it when cold, and silicon renders the iron brittle and weaker in tension. There are large quantities of very rich titanic ores in Norway, New Zealand, and other places. These are only used to a limited extent to mix with other kinds of iron, owing to the great hardness of the iron produced, by the presence of even a very small quantity of titanium, and hitherto the impracticability of separating them.

Iron is manufactured in two forms: as cast-iron, which is the condition produced in the blast furnace, and wrought-iron, made by decarbonizing the cast-iron, and thus rendering it malleable. In order to effect this conversion, great care is required. The pig-iron is first refined—that is, melted in an open hearth with the purest coke, derived from the Better-bed coal, or the Churwell thin coal. When in a molten state, it is run into iron troughs, and water is thrown upon it, as soon as it begins to cool. This process causes the separation of the silicon; it is then puddled and made into stampings. The iron is so manipulated in the furnace, that nearly all the sulphur and phosphorus are eliminated. The iron is next broken up, and, according to the fracture exhibited, is made into different articles to correspond with the work which these articles have ultimately to perform. The iron is characterised by containing a very small percentage of sulphur, phosphorus, and silicon, by its great tenacity, by its ductility, and by the closeness of its grain, rendering it susceptible of a very fine polish. Its value may be judged when we consider that bar-iron of common quality may be bought at the present time at £8 10s. per ton; whilst £23 per ton is paid for similar bars made from this ore, and locomotive cranks, made of this iron, are sold at about 1s. 1d. per lb.

COALS.

We cannot consider the uses to which coals are put, without the very important fact of enormous waste forcing itself on our attention. In the most economical mode of using them, only about $\frac{1}{10}$ of the heating power is utilised, and science has, as yet, done little towards economising their use. The determination of the quantity of hydrogen and carbon, which are the combustible constituents of coal, has really very little to do with forming an estimate of their value, except in cases where the differences are very wide. The great use of chemistry, is in determining the quantity of sulphur and phosphorus, contained in the coals intended to be used for the manufacture of iron, with a view to rejecting all coals containing a large quantity of those substances. The uses to which coal should be put, with furnaces as at present constructed, depends in a great measure, on the rapidity with which it is intended to consume it—that is, the greater or less intensity of the fire, and whether it will coke or not, and if it will, upon the kind of coke the coal will produce; upon the ash, and the temperature at which it melts; upon the sulphur and phosphorus it may contain; and on the physical condition of the coal as to hardness, manner of cleavage, &c. According to Dr. Percy,* analysis cannot show whether a coal will coke or not; and my own opinion is, that this property, while of course it depends partially on the chemical constitution of the coal, depends also, in a great measure, upon its structure, modified by geological changes and disturbances. It appears probable, that if a good, clean coal does not coke, the whole of the coals above and below it in that locality, will be similarly influenced, other conditions being the same. I know a locality in the neighbourhood of Leeds, where the coals are considered as non-coking, and yet the same seam of coals will make good coke about three miles distant to the north-west. Coals have not only the planes of bedding, which are often somewhat irregular, but they have a vertical plane of cleavage, which is, speaking generally, in this district about north-east and south-west, but it is very variable. I think it possible, that this cleavage plane has been produced by the lateral pressure which caused the ele-

* Dr. Percy's Metallurgy, Article—Fuel, p. 308.

vation of the Pennine Range. The cleavage is often locally changed in the neighbourhood of faults, and occasionally it is without any definite direction. Now, if a piece of coal of this district, with clear, bedded planes be put on a fire, it will be found that the gas is emitted more rapidly, from the side or end in the direction of the bedding plane, than from the other, and, I believe, that the coking coals are those in which the gas has not free access to the exterior, but has to work its way through broken cleavage planes, or through long bedded planes, thus becoming condensed. It may be mentioned, in support of this, that small coals coke better than larger ones.

The operation of coking is a simple one. The coals are thrown into a fire-brick oven of considerable thickness, previously heated to redness; the heat from the oven gradually communicates itself to the coal, roasting it, so to speak, without the admixture of atmospheric air, and slowly driving off the hydrogen and volatile parts of the coal, and leaving the carbon or coke in a solid and often hard condition. When used in this condition it makes no smoke, and the introduction of a blast or strong current of air, makes it burn with a very intense heat. In this form it is used for melting iron, steel, brass, etc., and, indeed, any purpose where intense heat is required in the body of fire. Coals that will not coke by this process, are called non-coking, yet by reducing a coal that is considered a non-coking one to a fine powder and heating it slowly, I have obtained a fair coke.

Nearly the whole of the coals of the West Riding will make coke of some kind. That made from the Better-bed and the Churwell Thin coals is very hard and good, and contains such a small quantity of sulphur, that it is exclusively used for the manufacture of the best Yorkshire iron. Indeed, the demand for this coke is greater than the supply, and the Better-bed coal cannot be bought, being all consumed by the proprietors of the collieries and ironworks. I am informed that the Churwell Thin in the neighbourhood of Tong, where it is known as the Shertcliffe Little coal, contains too much sulphur. The Black-bed coal makes a hard coke, which may be used for any purpose where the amount of sulphur is of little importance.

The Beeston bed, which is the Churwell Thick and Thin coals joined, makes a coke which is used for malting purposes.

The Middleton Main, in some places, will make a coke which is used for malting purposes, and might be used for iron smelting if necessary.

The Haigh Moor coal, so far as my experience goes, will not coke, but from its appearance in some districts, it may be possible to coke it. These cokes are quite as hard as some of the Durham cokes used for blast furnaces, but the coals are worth more for other purposes than coking. The coke, however, used in the foundries in the neighbourhood of Leeds is made in the County of Durham. A first-class quality is made at Brancepeth, near Bishop Auckland. It is much harder, and will bear a greater burden—that is, will melt a larger quantity of iron by weight, for the same weight of coke, than that made in the Leeds district. The top and bottom of the Barnsley, Parkgate, and Silkstone coals are all made into coke, some of which, when washed and picked, are as good as the best Durham ; and the whole of the South Yorkshire coke is of good quality, and is used in the blast furnaces, and for steel melting, &c.

Another property, which regulates the uses to which coals may be put, is the *Ash* and its melting point.

But even if a coal yields a considerable amount of ash, if the ash drops between the fire bars in a dry state, thus, leaving the grate open so that the air has free access through it, it will give better results than a coal, containing a larger proportion of hydrogen and carbon, but yielding an ash which runs and blocks up the fire bars.

The hardness plays an important part in the use of coals. All coals used for a reverberatory furnace should be hard. A soft coal will not produce the long flame necessary to fill the body of the furnace, and though the heat will be intense in the midst of the fuel, it will be local. The best coals for these purposes, in the northern part of the coal field, are derived from the Better-bed, which is almost entirely free from sulphur, and is moderately hard. The Beeston-bed to the south-east of Leeds, is about the same hardness as the Better-bed, but not so free from sulphur, and the Middleton-bed coals, from the little seam, have been long used for making best iron. But the best of all for hardness and long powerful flame, for keeping clear in the fire bars, and for giving a good yield of iron, is the hard coal from South Yorkshire, which I consider to be the type of what furnace coals, for making iron, should be. The Barnsley hards are used in Leeds for making the best Yorkshire iron, and the hards of the Parkgate seam are sufficiently hard to be used raw for blast furnaces. The Silkstone hard coal is used almost exclusively for domestic purposes.

Although the seams of the northern part of the Coal-field are not so hard, and do not yield so much iron as those of South Yorkshire, they are much harder than the Durham coals used in the Cleveland district. The latter fall away into small if exposed. On the whole, we may congratulate ourselves on having coals which cannot be surpassed, on the possession of large quantities of the best ganister, fire-clays, and fire-stones, and also of ironstone, which cannot be equalled for strength and durability.

ON THE PHYSICAL PROPERTIES OF ICE IN CONNECTION WITH THE GLACIAL PERIOD. BY W. M. WATTS, M.A., D.Sc.

When I found myself committed to read a paper before you to-day, I was in this difficulty, that I, not being a geologist, had to address a Society of Geologists. Under these circumstances, it seemed to be all that I could do to select some subject, which, though not a geological subject, is of the utmost importance to geologists, in their attempts to unfold the past history of the globe; and I thought it might be of interest to pass in review some of the properties of ice, to which, as a geological agent, very great effects are now attributed. The subject was suggested to me by a passage in the address delivered by the late Professor Phillips to the Geological Section of the British Association at the Bradford meeting.

Professor Phillips says: "One is almost frozen to silence in presence of the vast sheets of ice which some of my friends, (followers of Agassiz), believe themselves to have traced over the mountains and vales of a great part of the United Kingdom, as well as over the kindred regions of Scandinavia. One shudders at the thought of the innumerable icebergs, with their loads of rock, which floated in the once deeper North Sea, and above the hills of the three Ridings of Yorkshire, and lifted countless blocks of Silurian stone from lower levels, to rest on the precipitous limestones round the sources of the Ribble.

"Those who, with Professor Ramsay, adopt the glacial hypothesis in its full extent, and are familiar with the descent of ice in Alpine valleys, where it grinds and polishes the hardest rocks, and winds like a slow river round projecting cliffs, are easily conducted to the further thought, that such valleys have been excavated by such ice rubbers, and that even great lakes on the course of the rivers have been dug out by ancient glaciers, which once extended far beyond their actual limits. That they did so extend is in several instances well ascertained and proved; that they did, in the manner suggested, plough out the valleys and lakes is a proposition which cannot be accepted, until we possess more knowledge than has yet been attained, regarding the resistance offered by ice to a crushing force, its tensile strength, the measure of its resistance to shearing, and other data required for a just estimate of the problem. At present it would appear that under a column of its own substance 1,000 feet high, ice would not retain its solidity; if so, it could not propagate a greater pressure in any direction. This question of the excavating effect of glaciers is distinctly a mechanical problem, requiring a knowledge of certain data, and till these are supplied, calculations and conjectures are equally vain."

In reviewing the points in Professor Phillip's address, with the somewhat presumptuous intention of criticising his conclusions, I shall offer no apology for beginning at the beginning, though, in so doing I shall have to state facts perfectly familiar to all my hearers.

Let me, then, first of all, call your attention to the change in volume suffered by water, cooled from the boiling point to 12° F., passing into ice at 32° F. The volume decreases, always at a decreasing rate, till it attains its minimum value at 4° C., or 39° F., then slowly, increases. By carefully cooling water so as to avoid agitation, the temperature may be reduced to 9° C. without its freezing, and through this range of temperature the anomalous expansion continues. But if the water be allowed to freeze, then at the moment of the change of condition, an enormous increase of volume takes place. There is thus, apparently, a perfectly sudden change from the mobility of a liquid, which enables it readily to assume the form of the vessel in which it is contained, to the rigidity and permanency of form, characteristic of a solid. There is no passage through a viscous condition intermediate between the liquid and solid states, as we find, for example, in wax, which softens before it melts. But with wax, as with most substances, there is no increase of volume takes place, at any point, as the cooling goes on. In this respect water is the most remarkable exception to a nearly universal law, but the contraction is not uniform in its rate. Wax melts at 64°C.; at the moment of solidification there is a sudden, small contraction, amounting to $\frac{1}{2}$ per cent. (the expansion of water, in freezing, amounts to no less than 9 per cent.), and the melted wax then contracts, at first rapidly, but afterwards with decreasing rapidity. The *brittleness* of ice is familiar to every one. A slight pressure with the point of a pin suffices to split a small lump, and it refuses to bend between the fingers. It is very unlike such a viscous substance as warm sealing-wax, a stick of which, long before it melts, bends easily even under its own weight. Yet we shall, I think, arrive at the conclusion, that in consequence of its peculiar properties, ice in such masses as glaciers and ice-sheets, behaves exactly as a viscous fluid would do. It may be well, before we proceed further, to state definitely in what exact sense several terms we shall have to use are to be understood. A rod of any substance, say of glass, firmly held at one end and weighted at the other, experiences, in consequence of this *stress*, a *strain*, shown by its bending. The force, or system of forces, which alters the form of a body is called *stress*—the change in form itself, *strain*. A body which, when subjected to *stress* experiences no *strain*, would be a perfectly rigid body. None such exist.

If the stress, after acting for a time, be removed, and the body returns to its original form, it is elastic, but if the form of the body be permanently altered, the body is soft or plastic. If the change of form of the body increase continually with the time, the body is viscous. If a tallow candle and a stick of sealing-wax be supported by the ends and slightly weighted in the middle, the candle, though a soft substance, will remain straight, while the sealing-wax will gradually bend more and more. Tallow is thus a soft or plastic solid ; sealing-wax a viscous fluid. Observe, that with the viscous fluid, it is time which is required to produce the effect.

Imagine a horizontal fixed plane, a short distance above which, a parallel fixed plane is made to move horizontally, and suppose the space between the two filled with some viscous fluid, as treacle, the stratum of the fluid in contact with the fixed plane will be at rest, the stratum in contact with the moving plane will be moving with the same velocity as the moving plane, and intermediate strata will move with velocities proportional to their distances from the fixed plane. If the application of force to the moving plane be not continued, it will soon be brought to rest by the viscosity of the fluid, and the measure of viscosity is the force necessary to maintain this velocity. The viscosity of a substance is measured then by the tangential force, or the unit area of either of two horizontal planes, unit distance apart, necessary to maintain a relative velocity of the planes of unit amount, the space between the planes being filled with the substance.

This tangential force constitutes a shearing stress. Now, if ice be not allowed to melt, and the shearing stress be not enough to forcibly rupture the piece of ice, no motion at all takes place, that is, the ratio of force applied to velocity produced is infinite, or ice is an infinitely viscous fluid, or an eminently rigid solid. We shall return to this subject of the force necessary to shear ice.

Another consequence of the great increase of volume when water becomes ice is, that ice is lighter than water. It is important to bear in mind, that the masses of ice, which are seen floating above the surface of the Polar seas, form only small portions of the actual icebergs.

The specific gravity of ice at 0° C. is 0·9175, the specific gravity of sea water at the same temperature 1·029. Hence the volume of ice below the water is 8·2169 times that above. Next, as to the resistance offered by ice to crushing and extension. In experiments made by Canon Moseley, a rod of ice 12 inches long and 1½ inches diameter was firmly clamped at the top and gradually weighted at the bottom till the ice gave way, the rod of ice being vertical. The results vary from 70 to 116 lbs. per square inch; the ice was in a melting condition.

The tenacity of other materials expressed in the same way is for brick, 280 to 300 lbs.; lead, 3,300 lbs.; oak, 10,000 lbs.; cast-iron, 16,000 lbs.; wrought-iron, 51,000 lbs.; and steel, 130,000 lbs.

Canon Moseley also determined the pressure necessary to crush ice directly, and found that an inch cube of ice bore 308 lbs., and then gave way. This is about the same as for chalk, the weight necessary to crush chalk being 330 lbs. per square inch; for brick, 1,000 lbs.; for marble, 5,500 lbs; and cast-iron, 112,000 lbs.

An easy calculation shows that the height of a column of ice which would just crush at the base by its own weight is 748 ft. The force necessary to shear ice has been found by Canon Moseley to be 118 lbs. per square inch. Yet this substance which crushes more easily than chalk, and tears asunder almost more easily than any other substance, is found in huge masses descending irregular valleys of gentle slope, apparently by its own weight, moulding itself like a plastic substance to the form of its channel, flowing here more quickly, here more slowly, in the very same way that water would flow down the same channel, though, of course, at a much slower rate. The explanation of this remarkable behaviour is perhaps to be sought in the peculiar effect of pressure on the melting of ice. I have here an experiment in progress in which a weight of 56 lbs. is suspended by a wire passing over a block of ice, and the wire is gradually making its way through the ice, but without destroying its continuity; the ice melts at the points of pressure, and freezes again as soon as the pressure is relieved.

Professor James Thomson first pointed out, from theoretical considerations, that the melting point of ice must be lowered by pressure; and calculated from the expansion which takes place, when water passes into ice, that an increase in pressure of the atmosphere would lower the melting point of ice by 0·0075° C., and this result was experimentally verified by Sir W. Thomson, who subjected a mixture of water and ice at 0° C. to pressure, and found that the mixture became colder; some of the ice melting, and the latent heat thus abstracted from the remainder, lowered the temperature of the whole. Under a pressure of 16·8 atmospheres, the melting point was lowered 0·129° C.

Next, Mousson succeeded in maintaining water in a liquid state at—5° C.,and by a pressure of 13,000 atmospheres caused ice to melt at—18° C. The apparatus employed consists of a strong iron vessel with a cylindrical cavity, in which ice can be compressed by means of a powerful screw. The apparatus being filled with water, and a loose piece of copper having been dropped in, was inverted, and in this position surrounded by a freezing mixture so as to freeze the water. When the water was frozen, the apparatus was placed upright, and the piece of copper was of course now frozen into the ice at the top. Pressure was then applied, the whole apparatus being kept at a temperature several degrees below freezing; on relieving the pressure and opening the apparatus it was found still full of ice, but the piece of copper was now at the bottom, showing that under the strong pressure the ice had been melted and had frozen again when the pressure was removed.

The consideration of this remarkable property goes far to explain how a mass of glacier-ice can behave like a viscous body. If the bed of the glacier were smooth, and the ice could move on it without friction, it would of course slide down by its own weight. But the bed not being smooth, but offering projections of rock, the pressure exerted by these obstacles on the ice will be very great; the ice cannot yield like a viscous body would, but it can melt if time be given it, and this comes to much the same thing. Usually the water formed by the melting of the ice is forced out of the way, and the mass of ice moves forward. In melting, also, the ice takes up heat, and this is supplied by the surrounding ice which is thus cooled below 0° C. Consequently, when the water shifts its position slightly, to escape from pressure, it finds itself in contact with cold ice and is thus frozen again. In this experiment the wire is a good conductor of heat, and the circumstances are favourable for the transfer of heat from behind the wire when the water is freezing, to the point of pressure under the wire where the ice is melting. There is thus in each minute as much ice re-formed as is melted, and the wire passes through, leaving the block entire. In the case of a glacier, all the water from the melting ice will not be re-frozen, a considerable proportion will escape, and find its way down between the ice and rock or through the crevasses of the ice, escaping in the stream of water, which issues from the foot of every glacier. And even of that water which is re-frozen, it must be remembered that while free to move as water, it will tend to descend by its own weight, and when re-frozen will occupy a lower position than before. There is also the large amount of heat received from the sun upon the surface of the glacier, and that resulting from friction over the bed, all of which causes the melting of a considerable quantity of ice. There is, therefore, probably sufficient cause for the descent of a glacier in its own weight, though certain objections may be urged against this theory.

Whenever ice is crushed and the fragments are forced together into a new shape, they reunite, forming again a solid block; or, if two pieces of melting ice be only gently pressed together, they gradually freeze together into one piece. The explanation of this phenomenon of regelation is probably also to be sought in the effect of pressure on the melting point. When the pressure is greatest, then a small part of the ice will melt and the rest will be cooled; the water escaping out of the way forms a thin film round the point of contact, which is gradually frozen by contact with the cooled ice, and though the pressure be very slight, yet, if time be allowed, the effect will become sensible.

An interesting experiment of Helmholtz shows how small a difference in pressure is sufficient to decide whether ice shall melt or water shall freeze, when they are in contact at 0° C. He surrounded a flask containing water, but no air, with melting ice, and found that the water in the flask gradually froze. The freezing-point of the water in the flask was higher by 0·0075° C., in consequence of the defect of pressure, and the melting ice, by which it was surrounded, was colder by this amount than the temperature at which the water in the flask passed into ice, and therefore acted like a freezing mixture to it. The earlier regelation theory of glacier motion supposed that the ice was crushed against obstacles. We have already seen that a column of ice must be 748 feet high, in order to crush at its base by its own weight, and this is a depth greater than that of our present glaciers. No doubt, the pressure may be much greater at particular points than that due merely to the depth of ice, but the motion which takes place would hardly be intelligible, if it were not for the slow melting which goes on under pressure.

The ice of a glacier moves most quickly in the middle, and again the surface moves more quickly than the ice below the surface. Precisely like a river of a viscous fluid, the sides and bottom are retarded by friction against the bed. Again, in passing down a sinuous channel, the point of swifter motion is not the centre, but always in the outside of the curve, the ice following exactly the same law as the current of water in a river. When the valley narrows, the ice current becomes more rapid, when the valley widens, the ice stream extends its width. Wherever pressure is put on the ice it slowly yields, but it does not yield to extension in the slightest degree. Hence, wherever the ice of a glacier is subjected to tension crevasses open, whose direction is transverse to the line of stream.

The motion of a glacier under pressure, is dependent on the fact, that the temperature of the glacier throughout its mass is little less than the freezing point. Its mass is penetrated by streams of ice-cold water in every direction, and its temperature can then be little different from 0° C. The only direct observations I have been able to find on the internal temperature of a glacier are those of Agassiz, who found that in a hole sunk 200 feet deep in the ice a thermometer averaged 31·24° F., and in winter 28·24.°

The daily motion of a glacier in winter is in fact found to be about half of its summer motion.

If the temperature of a glacier is 0° C., the slightest pressure is sufficient to cause it to melt at the point stressed, but if its temperature be below 0° C., the pressure must reach a certain amount, which can be calculated, before it can move, so that in a cold climate the ice will be actually a rigid body, and will not move under the same condition as in a warmer climate. In fact, it can only move by the process of crushing.

If the temperature of a glacier were 1° C. below freezing, it would require a pressure represented by a column of ice

4,765 feet high, or nearly a mile, before the melting-point sank to the temperature of the ice and any motion of the ice could take place.

The theory of the ice-sheet, as generally stated, assumes, I believe, the epoch to have been one of intense cold. It has been pointed out previously that extensive ice deposits do not indicate merely a time of great cold, but rather a time when there were greater contrasts of temperature on the earth than now,—great heat being just as necessary for the production of aqueous vapour as cold for its rapid condensation into snow. And now a consideration of the physical properties of ice seems to show that if the climate were one of intense cold, the ice deposits when formed would not move down their valleys, at least not in the same way as glaciers do now-a-days.

Experiments on the bending of ice planks by their own weight, put in a clear light the great plasticity of ice at the melting point, and its rigidity at low temperatures. Mr. Matthews found that a plank of ice 6 feet long and $2\frac{3}{8}$ inches thick, supported by its ends, bent in the middle 7 inches in 7 hours; during a thaw, when the temperature was 30° F. only $1\frac{1}{2}$ inches in 24 hours.

Another plank of about the same length, but only $1\frac{7}{8}$ inches thick, bent $1\frac{3}{4}$ inches in 22 hours, at a temperature of 26° F.

Similiar results were obtained by Taff, who found that a bar of ice 18 inches long, 1 inch wide, and $\frac{1}{2}$ inch thick, bent 2 or 3 m. m. in 24 hours when the temperature was several degrees below zero, but when the temperature rose to nearly the freezing point the bending amounted to 9 m. m. in 24 hours.

Professor Phillips concludes, from Canon Moseley's experiments, that no glacier of greater depth than 1,000 ft. could exist. If I understand the recent observations of Geologists aright, there is evidence that the present Irish Sea was formerly filled with ice to a depth sufficient to bury the Isle of Man, or 2,000 ft. But I doubt whether the conclusion of Professor Phillips follows from the facts. At the foot of a glacier the ice is of course less than that depth, so that it would not there crush at its base; and higher up the glacier, where the depth is sufficient to crush the base, the crushed ice could not escape since it would be confined by the uncrushed ice in front. It would, therefore, act like a fluid, and would assume the shape of the rocky basin. We may, perhaps, imagine that the crushed ice at the base of the glacier, might, in consequence of lateral pressure, crush its way through the icy barrier in front, and make its escape like water breaking down the banks of a reservoir; but it is doubtful whether crushed ice would thus transmit pressure equally in all directions. The most probable result would be that this barrier of ice, with its unfrozen stone, would be forced forward with all the pressure dammed up behind it, and would constitute an excavating tool of greater energy than any to be found in the present glaciers of the Alps.

In an enclosed rocky basin the ice might certainly be of any depth.

The paper was illustrated by numerous photographic views, shown with the oxy-hydrogen lantern.

ON SILURIAN ERRATICS IN WHARFEDALE. BY J. R. DAKYNS, ESQ., M.A., F.G.S., OF H.M. GEOLOGICAL SURVEY.

Some years ago I called attention, in a paper on the "Drift of the Yorkshire Uplands," read before the Geological Society of London, and in the pages of the "Geological Magazine," to the occurrence of Silurian Boulders in a part of Wharfedale. These boulders are foreigners, as no Silurian rocks exist in place in any part of Wharfedale, at the surface at least, and, being foreigners, they form an exception to the general character of the Drift of the Dales. Generally speaking, the Drift of the Dales contains no blocks or pebbles of any other rocks, than such as are found *in situ*, within the limits of the various Dales themselves.

Thus, in Wensleydale, at least below Hawes, no boulders are found except of carboniferous rocks ; the same is the case in Coverdale, Bishopdale, Semmerdale, and Nidderdale. In Ribblesdale we have, besides Carboniferous boulders, Silurian ones as well, derived from the outcrop of Silurian rocks, which is well known to occur in that dale near Horton. In Dentdale, too, I have not seen any but carboniferous boulders in all that part of the dale which lies above the Silurian strata. The same is the case in Littondale, and also, with the single exception I am going to describe, in Wharfedale.

Wharfedale consists of two distinct portions, in neither of which do any but carboniferous rocks appear at the surface. From its source in the recesses of the Fells, to the southern edge of Grass Wood, near Grassington, the river Wharfe runs in a narrow valley. This forms the upper part of Wharfedale. From Grass Wood to Burnsall, the river is bounded by Fells on the east side, but on the west by an open, drift-covered country, which stretches away westward beyond the river Ribble ; in fact, between Grass Wood and Burnsall, the dale is discontinuous. Below Burnsall, the river again flows in a narrow dale to below Otley. In this lower part of the dale none but Carboniferous rocks exist, and no other rocks are found in the Drift or as boulders. Between Burnsall and Chapel House, however, Silurian Erratics are very plentiful. It is true, they have been mostly cleared off the surface of the land and built into the walls, where they are plentifully used as "throughs ;" but in the walls they are numerous, so much so as to strike the attention, and already to indicate their former presence in great numbers on the surface, before the land was cleared. Some boulders, however, still remain on the surface, and an examination of a beck course cut through drift, will readily disclose them in the drift.

When I first found these boulders, seeing they mostly occurred in the open space between the higher and lower dales, I connected them with the drift of the open country, which, south of the limestone escarpment of the Craven Fault, contains many Silurian Erratics. Even so, it was difficult to see how such boulders should have got so far east of any outcrop of Silurian strata.

The ice emerging from Ribblesdale, at Settle, would have to bend sharply to the east, nearly at right angles to its course, on entering the low ground, to enable it to carry boulders to the Wharfe at Grassington. For I quite satisfied myself, that these boulders had not come direct over the Fells from the Silurian strata of Ribblesdale ; I felt sure of this, because I carefully examined the ground, and not a boulder of Silurian rock could I find any where on the Fells, though boulders of Millstone grit were met with. It was only when one got below, say, the 800 contour, and therefore, down to the level of the spread of drift forming the lowlands, that they were to be met with. There is, not only no apparent reason, why the Ribblesdale ice should make such a sharp and sudden bend out of its course eastward, but every reason against it, for the ice from the Fells east of the Wharfe above Grassington, would be pressing away west. However, it is not only in the open part of the Wharfe valley that the boulders are found, though they are or have been more plentiful there ; but north of the gorge through which the river flows, between Netherside and Grass Wood, Silurian boulders are found well within the limits of the upper dale. There are several, lying on the alluvial flat on the west bank of the river, above Netherside, and there is one, tolerably conspicuous on the roadside, rather more than a mile south of Kilnsey.

If these boulders came from Ribblesdale, round by Settle, how did they get over the barrier that closes in Upper Wharfedale? What made the ice move northward and up the dale, when all the evidence goes to show it was everywhere else moving southward and down the dale?

At that time I saw no solution of the difficulty, but since the date of my previous papers, it struck me, now some years ago, that I saw a possible explanation. I now conceive, that were we able to remove the covering of drift and alluvium, that conceals the solid rocks of the valley bottom near Kilnsey, we should find Silurians in place in the valley bottom. With reference to this idea, it is noteworthy that some strong springs break out at the foot of Kilnsey Crag. This, though it does not prove, itself suggests and favours the idea that we are *near* the base of the limestone. There is also a certain portion of the lower part of Littondale, in which no solid rock is seen in the valley bottom, being entirely hidden by drift, screes, or alluvium, along which two strong springs break out at, or near, the base of the limestone scars. Briefly, I would suggest that somewhere in the lower part of Upper Wharfedale, or less likely, in the lower part of Littondale, Silurian rocks exist in the valley bottom beneath the covering of superficial detritus, and that it was from this outcrop of rock that the Silurian boulders, found so exceptionally in the limited part of Wharfedale, indicated above, were derived. It will be observed that all the Silurian boulders occur south of, and below the area, which, from the existence of strong springs may be supposed to be at the base of the Carboniferous rocks.

This supposition, that Silurian rocks exist below the alluvium and drift beneath Kilnsey Crag, or, for the matter of that, in the lower part of Littondale, is quite consistent with what we know of the thickness of the Carboniferous Limestone of the district, and it explains in an easy way the existence of the Silurian boulders, which otherwise are difficult to account for.

P.S.—The Silurian boulders, now to be seen on the surface of the ground, are generally compact, close-grained Silurian Grits, similar to the rock of this character which occurs in, or near, Ribblesdale. I am not sure of its exact position.

DEEP MINING AND RECENT ACHIEVEMENTS OF ENGINEERING IN CONNECTION THEREWITH. BY WALTER ROWLEY, C.E., F.G.S.

It is sometimes both interesting and profitable to refresh the mind, by taking a retrospective view of what has been achieved up to the present time, in any of the staple branches of industry, especially those branches which constitute the foundation, to a great extent, of our country's prosperity It is scarcely necessary for me to state that I refer to the Coal and Iron trades.

The writer will endeavour (1) first, to refer to the Early Records and Growth of Mining; (2) secondly, to mention the Deepest Mines in Europe; (3) thirdly, the Deepest Boreholes; (4) fourthly, Boring, Sinking, and Winding Machinery; (5) fifthly, Haulage, Lighting, and Signalling;

(6) sixthly, Coal-getting and Drilling Machinery; (7) seventhly, Miscellaneous Improvements; and lastly, the Probable Future of Deep Mining.

(1) EARLY RECORDS AND GROWTH OF DEEP MINING.

It will give an idea of the rapid growth of coal mining, if attention is called to the earliest records of coal-getting in this country. Among the first are the "Bassett Workings" in Durham and Northumberland, described by Horsley as a Coaling (colliery), and stated to have been worked by the Romans. In the "Bolden Book," published in the reign of Henry II., there are two references to coal at Wearmouth, then called Vernouth; and at Counden, as stated by Bishop Pudsey, a grant of land was made in 1180 to a collier, for providing coals for a smith's workshop.

Another record of the early knowledge of coal, dated 1395, was inspected by the writer in the "Rolls of Whitley Abbey," in which it is stated that coals were shipped from Sunderland, and that one William Reed was paid 13s. 4d. for four chaldrons, or, one hundred and two hundred weights of the recognised measures of that district. Further notices of early coal-getting will be found in Hull's "Coal-fields," Chap. I.

Tables of the area and production of the various Coal-fields of the world will be found in Smyth's "Coal and Coal Mining," and the figures there given show the wonderful growth of Coal-mining, especially in this country, which at the present time supplies nearly half the entire production of the world.

(2) DEEP MINES.

The following table gives the depths and situations of the deepest mines in the world up to the present time, arranged according to the greatest depth reached in each of the countries referred to:—

No.	Country.	Name of Mine.	District.	Mineral Worked.	Depth in Yards.
1	Austria ...	Adalbert ...	Prizibram...	Silver & Lead	1,093
2	Belgium ...	Viviers ...	Gilly	Coal	940
3	Saxony ...	... ...	Zwickaw ...	Coal	879
4	Prussia ...	Samon ...	St. Andre ...	Silver... ...	844
5	Gt. Britain	Rosebridge..	Wigan ...	Coal	814
6	Norway ...	... ...	Konsberg ...	Silver... ...	623
7	Hungary ...	Amalia ...	Schmeritz ...	Gold & Silver	590
8	Prussia ...	Camphausen	Saarbruck...	Coal	550
9	Spain ...	La'Luerti ...	Canada ...	Silver... ...	516
10	Italy	Monte Masio	Gavarrono...	Lignite ...	481
11	Sweden ...	Bersbo ...	... ...	Copper ...	459
12	Pays-bas ...	Whilhelm ...	Kerkrade ...	Coal	364
13	Baden ...	... .	Hagenback	Coal	360
14	Portugal ...	Taylor ...	Palhal ...	Copper ...	359
15	Bavaria ...	Max	Stockholm	Coal	286
16	Russia ...	Turjinsk ...	... ...	Copper ...	202

From this statement you will see that the shaft of the argentiferous lead mines of Prizibram, in Austria, has achieved the greatest victory up to the present time, the silver and lead being now actually worked and drawn from a depth of 1,093·1 yards. These mines were first explored about the sixteenth century, but only commenced actual working to any extent about the year 1779, and up to 1800 the shaft was only 290 yards deep. In 1865 they had reached a depth of 781·2 yards. This shaft seems, from the earliest period, to have, year by year of its existence, had the honour of testifying to the practicability of deep mining; for, during the first 96 years of its working, the annual increase of its depth was 34 feet, and during the last ten years it has annually increased on the average 88 feet.

From the table I have given, you will see that the deepest coal mines in the world are the Viviers, Remus shafts, near Gilly, in Belgium, which are sunk to a depth of 940 yards in one perpendicular shaft. From a drift at this depth another shaft has been sunk to a further depth of 222 yards, making a total of 1,162 yards. The above shaft was continued 50 feet lower, to a depth of 1,178·2 yards, but, as the coal sought for at this depth was not satisfactory in its character, the present mining operations are confined to the depth of 940 yards.

In Belgium there are at the present time about 112 shafts 500 yards deep and upwards; whereas in England there are only 15 exceeding that depth. It is not intended to consider any of less depth than 500 yards, as under that distance they are not uncommon, and therefore do not come within the scope of the present inquiry.

The following is a table of the deepest mines in Great Britain at the present time :—

No.	Colliery.	County.	Mineral Worked.	Depth in Yards.
1	Rosebridge	Lancashire	Coal	815
*2	Dukenfield	"	"	686
3	Monkwearmouth ...	Durham	"	580
4	Pendleton	Lancashire	"	526
5	Sharlston	Yorkshire	"	512
6	Shire Oaks	Nottinghamshire ...	"	510
7	Annesley	" ...	"	504
8	Ince Hall	Lancashire	"	600
9	Douglas Bank ...	"	"	525
10	Lindsey	"	"	505
11	Worthington	"	"	600
12	Seaham	Durham	"	508
13	Ryhope	"	"	542

* Reached by incline a total depth of 940 yards from the surface.

As Monkwearmouth seems to have been the pioneer of deep mining in this country, it deserves a passing reference to its history. The sinking of the colliery commenced in the year 1826, and continued for nine years, struggling with great engineering difficulties, without meeting with any material success. The enterprising spirit of the owners was not encouraged at that time by colliery managers generally, some of whom predicted that, owing to the fact of the Permian rocks overlying that portion of the country, the coal measures there would be found either absent or unworkable—an opinion that a very moderate amount of geological knowledge would have shown to be without foundation. The shaft was continued down to a depth of 46 yards, when the water found in the limestone stopped operations for a while. The second shaft was then commenced, which reached, at a depth of 360 yards, in the year 1835, the Maudlin Seam, which was found of an inferior quality.

The sinking of the first shaft was resumed in 1841 and continued to a depth of 160 yards, from which point a drift was driven to the coal reached in the second shaft. The seam of coal referred to was then worked for some years, after which the Hutton Seam was sunk to, and reached in 1869 at the depth of 550 yards.

You will thus see, that for nearly half a century the proprietors and managers of this colliery, struggled bravely against difficulties of the most serious character before they attained the reward which their energy so richly merited.

(3) DEEP BORE-HOLES.

As boring bears such an intimate relationship to the extension of mining operations, I shall now give a list of the deepest bore-holes of which there is any record :—

No.	Name of Boring.	Situation.	Country.	Depth in Yards.
1	Artesian Spring	Potsdam ...	Missouri ...	1,833
2	Rock Salt Bore-hole... ...	Sperenberg	nr. Berlin Prussia	1,392
3	Boring for Coal...	Creusiton ...	France ...	1,007
4	Boring in progress for Coal, reached up to the present time	Scarle, nr. Lincoln	England ...	700
5	Boring for Minerals by the Eden Valley Mining Company	Eden Valley, Cumberland	England ...	766
6	Swinderby	Nr. Lincoln	England ...	666
7	Sub Wealden	Suffolk ...	England ...	635
8	Artesian Well	Gunelle, nr. Paris	France ...	599

(4) BORING, SINKING, AND WINDING MACHINERY.

The Sub-Wealden boring, which has up to the present time reached a depth of 635 yards, was instituted to decide at what depth Palæozoic rocks lie, between the English Channel and the Thames. When the boring was started it was thought they might be reached at a depth of 500 yards. The result shows that this was an under-estimate.

The Sub-Wealden boring, as also No. 6 in the above table, were executed by means of the Diamond Rock Boring Machine, the ingenious invention of Major Beaumont, R.E., M.P. In this process, a steel tube, which is faced at the lower end with a number of rough uncrystallised carbonites or diamonds, is fixed on the bottom of the boring-rod. This tool is then made to revolve with its face in constant contact with the rock, like the drill or cutter used in boring iron or other metals. A jet of water is forced down the centre of the hollow boring-rods, which keeps the face of the cutter cool, and which at the same time carries up the *débris* to the surface.

The rate at which this machine usually accomplishes its work, under ordinary conditions, is about 8 feet per day.

Some excellent borings have been executed by the invention of Messrs. Mathers and Platts, but as yet the greatest depth they have reached is about 466 yards, which was done at the rate of 4 feet per day, the diameter of the bore-hole being 18 inches throughout the entire depth. This arrangement differs from the others, herein described, in the mode of working the machine at the surface, and in the character of the tool used, the latter consisting of a long heavily weighted iron rod, made by an ingenious appliance to revolve the tool. The tool is suspended by a flat steel wire rope.

Having briefly presented to you a general account of the greatest achievements in deep mining and boring with which the writer is acquainted, I shall now endeavour to recapitulate some of the most improved appliances and inventions used in sinking, developing, and working mines. The invention of M. Chaudron, a Belgian engineer, enables shafts to be sunk through water-bearing strata, where otherwise the operation would not be possible, except at a ruinous expenditure of time and capital. The difficulty which this contrivance is intended to overcome is one that must increase as our explorations for coal extend under the Magnesian Limestone or Permian Rocks, where such large feeders of water usually exist. A remarkable instance of this kind is furnished by the recent abandonment, for the present at any rate, of the mining at Whitburn, in Durham, intended to sink through the limestone nearer to the sea than has been attempted previously. Ten thousand gallons of water per minute were raised, down to a depth of 20 yards, beyond which the shaft could not be continued, the circumstances indicating that the water from the sea passed into the shaft through the fissures of the limestone. The fate of this enterprise alone, shows the importance of an efficient and economical arrangement for sinking through rocks containing such large quantities of water.

The invention of M. Chaudron may be briefly described as follows :—First, an artificial shaft is built on the surface, of the same size as the proposed shaft is intended to be, and sufficiently high to prevent the water as it comes in from overflowing. By this means the water is impounded, and its movements stopped, thereby avoiding the usual difficulties arising from shifting or loose sand. The process of boring under water then proceeds by means of a cutter, so constructed as to cut the ground ready for excavation and the size of the shaft required. The *débris* is extracted by means of an ingenious arrangement, whereby the difficulty of collecting it, to bring up to the surface is overcome ; and a shaft is sunk in precisely the same manner as a bore-hole is made, standing full of water, and unlined until the bottom of the shaft is reached. The tubbing is then lowered into the shaft. It is finished at the bottom with a telescopic joint, whereby a water-tight junction with the rock on which it rests is effectually secured.

If any person wishes to obtain a more detailed knowledge of this improved invention, the writer would refer him to the very able paper by Mr. Warrington Smyth, in vol. 20 of "The Transactions of the North of England Institute of Mining Engineers;" and if desirous to see the process in actual working in England, he may do so at the works of the Cannock and Huntingdon Colliery Company, near Walsall, South Staffordshire.

Another process of sinking through water-bearing strata is that designed by J. T. Woodhouse, Esq., Civil and Mining Engineer, Derby, and carried out by him at Bagillt Colliery, North Wales, which is sunk in the bed of the River Dee. During the sinking operations, which the writer had the pleasure of inspecting, the present Resident Engineer, Mr. Arnold Lupton, C.E., with great mechanical ability, carefully explained to him every detail of the operation, which may be briefly described as follows:—The first shaft was sunk by the pneumatic process, through about 80 feet of quicksand, and was done partly by means of a vertical cast-iron tube, 6 feet in diameter, and moved about the shaft, which was 20 feet in diameter, by machinery constructed for that purpose; the pressure of air inside the tube keeping out the water, while a double trap-door at the top provided for the passage of the excavated material, and the ingress and egress of the workmen. During a great part of the sinking, the work was done entirely by divers. The second shaft, 11 feet in diameter, was sunk through the sand entirely by the pneumatic system. A cast-iron cylinder, 13 feet in diameter, with a cutting edge at the bottom, was sunk down to about 28 yards, and tubbing put in and secured to a depth of 34 yards, the water being kept out entirely by the pressure of air, amounting to 45 pounds per square inch above the atmospheric pressure; the men working in this pressure for shifts of two hours each in duration.

An inner tube, 6 feet in diameter, connected by a bell-mouthed piece to the outer tube, contained the compressed air, and the locks through which the men and materials passed. The sea surrounded the pit, and the pressure of air required to keep out the water rose and fell with the tides. This shaft was completed down to the solid ground without pumping a drop of water, and was then continued down to a depth of 290 yards. This successful process is one that the special conditions of sinking in the bed of the river Dee rendered necessary, and consequently is not so generally applicable in this district, unless at some future time it was considered desirable to sink in the bed of the Humber at, or in the neighbourhood of, Goole or Selby.

The surface arrangements of a mine, with regard to pumping and winding engines, show a great improvement on those in use at the beginning of the present century. The best types of the winding engine indicate a wonderful improvement in speed and economy of power, as compared with the low-pressure beam engines that characterised early mining operations; and greater safety is now secured by means of the hooks or catches for disengaging the cages in case of over winding, and where the rope breaks in passing up and down the mine. A similar improvement is observed in the spiral drum and round steel ropes, as also in the iron head gearing now frequently used.

(5) HAULAGE, LIGHTING, SIGNALLING, AND VENTILATION.

The writer will now, to a great extent, leave the surface of the mine, and beginning at the bottom of the shaft endeavour to record such marks of progress as distinguished the operations of extracting the mineral and bringing it to the surface. In considering the question of haulage, it is interesting to record what is not generally known, viz. :—That the first railway in the world was made for the haulage of iron and coal on the surface at Merthyr Tydvil, in South Wales, in the year 1804, when the locomotive was also used for the first time. In conveying the minerals through the various channels of the mine to the bottom of the drawing shaft, the use of boys is to a great extent abandoned, and horses are used only when the application of mechanical power is impracticable.

The systems of haulage are usually one of the following:—First, the endless chain; second, the endless rope; third, pneumatic or compressed air. The first is adopted where it is required to carry minerals over very heavy gradients, and where it is not practicable to make a continuously level road. It requires very little power to work it, especially where the same level is secured at both ends of the distance traversed, as this has the effect of equalising the power to such an extent, as to propel the empty and full wagons in both directions at the same time. Recent experiments in the North of England have demonstrated the great advantage of this system in point of economy and convenience. The second system is usually applied where the road is very level, enabling the rope to be worked without that great amount of wear and tear, which could not be avoided over an uneven piece of ground. The third system is one, that until the last few years, has not been applied for the purpose of underground haulage, but seems destined to be the means of supplying a most valuable power for conveyance over long distances. It has hitherto been principally used as a stationary power; but the writer believes it is not impossible that at some future time, air engines underground will there supply the same place as locomotives do on the surface on our railways, and must ultimately be used for conveyance of passenger and goods traffic in all large towns.

Another very valuable system of haulage, of recent invention, is that of the wire tramway; this is, however, not applicable for underground purposes, but is peculiarly useful on the surface in undulating and hilly districts, where it is required to convey minerals over rivers and valleys.

In the lighting of mines, there has not been that marked improvement one might have expected from the progress made in other departments of mining industry; for the only improvements since the Safety Lamp introduced by Sir Humphrey Davy, in the year 1816, are matters of detail in construction, securing more perfect means against the lamp being tampered with by the workman, and such modifications as the lamps of Mueseler and Dubrulle. The lighting of mines is still imperfect, and affords the very best field for invention. The writer looks forward to the time when this problem will be satisfactorily solved, and the light in a mine be so good, as to render it unnecessary that lamps should be carried about or suspended; involving, as this practice does, the greatest risk to life and property.

Safety in the lighting of mines may possibly be secured by paying more attention to ventilation, and placing less reliance upon lamps for safety, and as one means possible, by the introduction of an Exhaust Fan, or other arrangement, for boring or draining off the gas in a coal seam, and storing it in reservoirs, as we do with water, and utilising it for the purpose of lighting, somewhat after the manner proposed by Mr. Falkner, of Manchester, the inventor of, probably, the best-known system of electric signals for underground application.

The same inventor is engaged in perfecting his system of Electric Signalling, so as to indicate the disarrangement of doors, and other means of ventilation. In this department, the inventions of Messrs. Ansell and Bagot also call for notice. The modes used in the ventilation of mines, being a subject so extensive as to make it impossible, even to give a summary, within the limits of this paper, the writer will, on the present occasion, merely state that, in all extensive mines, and especially fiery ones, the old natural system of ventilation has been given up for the better appliances of ventilating machinery, which may be divided into two classes, the Centrifugal and the Exhaust Pump; the former, best represented by the inventions of Faboy, Guibal, Lambert, and Harze; latter, by the Mine Exhauster of the Ateliers de Construction de la Meuse, Liege, Belgium, and Mr. Cook's machine, Darlington, England, as an auxiliary to the above; Korting's Jet Ventilator is valuable, and very necessary as an independent power, for securing ventilation in case of accident befalling the ordinary means. Belgium may, with pride, claim the honour of first introducing machinery for ventilation amongst themselves, and afterwards diffusing the benefits of the same throughout every mining district of the world, and enabling mining operations to be conducted with so much greater safety and comfort than is possible under a natural system of ventilation.

(6) COAL-GETTING AND DRILLING MACHINERY.

The application of machinery for getting coal will have to be more considered than hitherto. As mining operations increase in depth, further necessity will compel every effort to be made to lessen the risk to life and property, and diminish the cost of production in every possible way. In doing this, the use of powder for breaking down the coal will have to be dispensed with altogether, and the coal got larger in size than would be possible by manual labour. It is a matter of surprise that the latter has not been superseded before now by machinery, which, in every other department, has contributed so largely to the development of mining industry. There have been some efforts made to overcome this difficulty, conspicuously amongst which stands out the machine of Mr. William Firth, of the West Yorkshire Colliery, Leeds, whom, I believe, for nearly a quarter of a century, has laboured to overcome the difficulties which circumstances and the prejudices of both coal-owners and miners presented to him, in demonstrating the great saving in cost, besides other advantages, which a coal-getting machine possessed.

He may not live to see his machine in general use, but he will, at any rate, be rewarded for his labour by having the satisfaction of leaving behind him a principle, the slow extension of which at the present time, will be the wonder of those who come after us. There has also been introduced recently some very valuable machinery for drilling into rock or other minerals, of which the Ferroux and Burleigh Rock Drills may probably be the best examples, and which has established its reputation in a remarkable manner by the work it has executed in the construction of the Mont Cenis and St. Gothard's Tunnels. The principle of this machine, modified to meet the special requirements of mining, seem peculiarly adapted to coal-getting in mines where the works are not restricted to a moderate area.

(7) MISCELLANEOUS IMPROVEMENTS.

There are other inventions less important, but still worthy of being considered in the progress of mining, such as the mechanical appliances for the utilisation of coal dust, mine respirators for continuing existence in an irrespirable atmosphere, of which, those of Sinclair, Galibert, and Fayol are a type; diving apparatus, which has been the means of saving a mine from almost irretrievable destruction. Time, however, will not permit reference to these on the present occasion. But the writer may possibly be permitted to call attention to an improved theodolite, for Mine Surveying, &c., which he had the honour of bringing before the Mining and Geological section of the South Kensington Museum, on a recent occasion.

(8) PROBABLE FUTURE OF DEEP MINING.

Having endeavoured to present to you a record of the achievements in mining engineering up to the present time, our attention may now be profitably directed to the inquiry as to the probable limit in depth that coal mining may reach. This subject is one that has been touched on by Mr. Hull, in his "Coal Fields of Great Britain," and recently very ably treated by Mr. Bainbridge, in a paper read by him before the Institute of Civil Engineers, and is also discussed in the Report of the Royal Coal Commission. It is not necessary, nor will time permit, of a detailed recapitulation of the investigations that have been made on this subject, and it is proposed to confine attention to the evidence on the two following points:—First, depth at which coal may ultimately be worked, and adequate ventilation obtained; second, cost of production at such increased depths.

By reason of the improved methods of mining, the cost of production, down to a depth of 1,000 yards, has not been materially increased, or prevented such mines from competing, to some extent, with those of shallower depths; and their ventilation has not presented any extraordinary difficulties to be overcome. In passing from 1,000 yards to greater depths, the engineering difficulties increase, but not to such an extent as to interfere with its practicability.

The most serious difficulty that has been, and will continue to be felt, is the cost which must be increased the deeper we go, by reason of the greater outlay in sinking and plant, &c., but that will not be so serious a charge upon cost as is sometimes estimated.

The most difficult obstacle to engineers in deep mining is the increase of the temperature of the superincumbent strata; this has been estimated by numerous experiments, and the following conclusions arrived at:—

First, that the depth of the stratum of invariable temperature, *i.e.*, the depth at which the temperature of the rock is unaffected by atmospheric influences in England is 50 feet, at which the temperature is 50°

Second, that there is a possibility that the rate of increase may diminish as greater depths are reached; and that at a depth of 2,000 feet, the average rate of increase may possibly not exceed 1° Fahrenheit, for every 68 feet, continuing beyond that depth at that rate, or it may be in a diminishing ratio.

The latter probability is supported by the evidence of Monsieur Lambert, Government Inspector of Mines for Belgium, who informed the writer, when on a visit to that country, that at the Simon Lambert Colliery, at a depth of 3,489 feet, the temperature was only 78°, or an increase of 1° in 119 feet. Calculations made in accordance with this hypothesis, give the results tabulated below.

AT 50 FEET TEMPERATURE = 50° CONSTANT.

From									
50 ft.	to	2000 ft.	an increase of	1°	in	68 ft.	=	78° at	2000 ft
2000	,,	4000 ,,	,,	,, 1°	,,	75 ,,	=	104° ,,	4000 ,,
4000	,,	6000 ,,	,,	,, 1°	,,	80 ,,	=	129° ,,	6000 ,,
6000	,,	8000 ,,	,,	,, 1°	,,	85 ,,	=	152° ,,	8000 ,,
8000	,,	10000 ,,	,,	,, 1°	,,	90 ,,	=	174° ,,	10000 ,,

If these conclusions turn out to be correct, the normal temperature at 4,000 feet will be about 104°, and about 152° at 8,000 feet. It may be possible to reduce the temperature to such an extent as to secure adequate ventilation at these great depths.

Experiments made at Rosebridge Colliery (the deepest in England) to a depth of 2,400 feet, as well as many on the Continent, fully support this opinion. The normal temperature of the coal at the above Colliery is 93°, whereas, the temperature is reduced at the face of the workings, to an amount varying from 77° to 63°, according to the length of time exposed.

The importance of this subject cannot be over estimated, when we consider that the next fifty years will, in this district, see the practical exhaustion of the coal now being worked within a moderate depth, and that then, we shall be compelled to turn our attention to the hidden wealth lying at greater depths, under the Permian and other formations overlying the Coal measure.

It is altogether beyond the range of this paper to do justice to so comprehensive a subject; sufficient has, however, been said to induce us to confidently believe, that the difficulties of deep mining will all be overcome in due time by that increase of knowledge, in which the record of the past shows mining to have made such wonderful progress.

In conclusion, it is a matter for congratulation that there has been achieved in the cause of Education so great a work as the Establishment of a College in Yorkshire, where that scientific training can be obtained which the country so much lacks, and which she must have if she is not to be distanced in the race for commercial superiority by foreign nations.

THE STEMS AND ROOTS OF FOSSIL TREES IN THE LOWER COAL MEASURES, AT WADSLEY, NEAR SHEFFIELD. BY J. W. DAVIS, ESQ.

The fossil plants represented in the photograph issued with the volume of Proceedings for 1876, occur in a bed of dark, ferruginous shale, exposed in excavating a site rendered necessary for the extension of the South Yorkshire Lunatic Asylum, at Wadsley. The section exposed consists of,—

	ft.	in.
Raggy Shale, with thin Sandstones	6	0
Sandstone inclined to split into Flags ..	2	0
Dark Shale	20	0

The roots, which in each case bifurcate, grew in the lower bed of shale. They are five or six feet in length, and appear to be Stigmaria, but the surface markings are not well preserved. The trees evidently grew where they are now situated, and afterwards the stems appear to have decayed to the level of the surface of the muddy-shale in which they are imbedded, leaving only the roots to become fossil. The shale was then evenly covered by the stratum of sandstone, as shown in the photograph. The section is represented about $\frac{1}{12}$ natural size, or on a scale of one inch to one foot.

During former excavations, at the same place, ten or a dozen similar stumps of trees were discovered, in an area fifty yards in length. Three or four of the best examples have been preserved, and are protected from the disintegrating influences of frost and rain by wooden sheds. Further particulars respecting these may be found in a paper read to the Geological Society, at London, by H. C. Sorby, Esq., F.R.S., F.G.S., &c., and published in the Quarterly Journal of that Society for August, 1875.

The thanks of the Society are due to the Directors of the Asylum, and more especially to Dr. Mitchell, for their kindness in allowing the specimen to be photographed, and for the care taken in exposing it and preserving it from injury.

SECRETARY'S REPORT.

The Committee, in presenting this Report, have the pleasure of congratulating the members on the continued success of the Society, on the increased interest taken in Geological Science in the West Riding, and on several additions to the list of members of the Society, which now numbers one hundred and fifteen.

It will be remembered by many members, that a debt of £20 was owing to Messrs. Edward Baines & Sons, for printing the Proceedings of the Society; this amount had accumulated during several years up to 1869. The money necessary to pay this long standing debt has been subscribed and the account settled.

Local Secretaries have been appointed in Barnsley, Bradford, Halifax, and Huddersfield; an extension of the number to other towns in the Riding is very desirable, so that the usefulness of the Society may have a greater field for its operation, and that it may be strengthened by additional members being enrolled.

In accordance with the Resolution passed at the Seventy-seventh Meeting, held at Leeds, a Summary of Geological Literature, relating to the West Riding, published during the past year, is in preparation, and will be inserted in the Annual Report of Proceedings. A list of Titles of Papers on West Riding Geology, contained in the Transactions and Journals for past years of the various Geological Societies, as well as of separate Publications on the same subject, is also in course of preparation.

The appended list of Societies periodically send us copies of their printed Transactions or Proceedings, which are accessible to the members of the Society, and may be obtained by application to Mr. Crowther, at the Museum, Leeds.

LIST OF SOCIETIES WHOSE PROCEEDINGS ARE FORWARDED TO THE WEST RIDING GEOLOGICAL AND POLYTECHNIC SOCIETY.

"Yorkshire Archæological and Topographical Society."
"Warwickshire Natural History Society."
"Royal Society of Tasmania."
Journal of the "Royal Dublin Society."
" " "Royal Historical and Archæological Association of Ireland."
Proceedings of "Geologists' Association."
Transactions of "Manchester Geological Society."
Proceedings of "Literary and Philosophical Society of Liverpool."
"Royal Institution of Cornwall."
"Royal Geological Society of Ireland."
"United States Geological Survey of the Territories." (F. V. Haydon.)
"Boston Society of Natural History."
"Hull Literary and Philosophical Society."
"Connecticut Academy of Arts and Sciences."
"Academy of Science of St. Louis."
"Historical Society of Lancashire and Cheshire."
"Geological Society, Burlington House, London."
"Leeds Naturalists' Field Club and Scientific Association."
"Schriften den Königl Norwegische Universität zŭ Christiania." (C. Holst.)

There are a number of copies of the Proceedings for past years, which may be had of the Secretary, at 2s. 6d. each. The following is a list of the dates, and the number of copies. In several of the years there are very few copies left, and as they are now difficult to obtain, members wishing to complete their sets, will do well to do so at once. Many of the earlier numbers are especially valuable, and constantly referred to in recent scientific literature :—

1840	30 Copies	1854-5	48 Copies
1841	8 "	1858-9	8 "
1842	104 "	1860	14 "
1843	72 "	1862	18 "
1844-5	6 "	1864-5	30 "
1845-6	92 "	1865-6	7 "
1847	80 "	1867	9 "
1848	112* "	1868	38 "
1851	12 "	1869	50 "
1853	2 "	1870	73 "

* Containing an Index of Vols. I. and II.

An interesting excursion to the Victoria Cave, near Settle, was participated in by many of the members, on Wednesday, July 12th. They were met at the Giggleswick Museum by Mr. R. H. Tiddeman, who conducted the party to the cave, and explained, in a lucid and interesting address, the early history of the cave, the important results that had been already obtained, and the method in which the operations are at present being conducted. The thanks of the Society were presented to Mr. Tiddeman, for his services, on the motion of Mr. Miall, seconded by Mr. Davis.

Thanks were also accorded to Mr. Styles, who had kindly placed the Museum of the Giggleswick School at the service of the Society, and enabled the members to inspect the large collection of animal remains gathered at the cave.

STATEMENT OF RECEIPTS AND EXPENDITURE OF THE WEST RIDING GEOLOGICAL AND POLYTECHNIC SOCIETY, FROM FEBRUARY 22ND TO DECEMBER 31ST, 1876.

The Treasurer in Account with the West Riding Geological and Polytechnic Society.

Dr.	£	s.	d.	Cr.	£	s.	d.
To Balance	0	9	11½	By Cash paid into the Bank	18	12	0
,, Subscriptions	24	1	0	,, Stationery	29	3	6
,, Beckett & Co.	54	8	0	,, Postage and Carriage	3	3	5½
,, Reports sold	0	5	0	,, Cost of Photographs	10	5	7
,, Error in McCorquodale's Account..	0	1	0	,, Representatives of the late Treasurer	4	18	0
				,, Expenses of Assistant Secretary at Barnsley	0	15	0
				,, Salary of Assistant Secretary (eight months)	10	0	0
				,, Balance in hand	2	7	5
	£79	4	11½		£79	4	11½

The Treasurer in Account with Beckett & Co.

Dr.	£	s.	d.	Cr.	£	s.	d.
To Balance at Bank	44	2	7	By Cash from Bank	54	8	0
,, Cash paid to Bank..	18	12	0	,, Balance in Bank	8	11	11
,, Interest	0	5	4				
	£62	19	11		£62	19	11

Examined and found correct, Feb. 21st, 1877.—A. H. GREEN.

Meeting of Council at the Philosophical Hall, Leeds, January 11th, 1876.

Mr. Baily in the chair. Present—Messrs. Baily, Filliter, Wilson, W. Sykes Ward, Miall, and Professor Green.

Moved by Mr. Filliter, seconded by Mr. Ward, and carried—"That Messrs. Beckett & Co. be the Society's bankers."

Moved by Mr. Wilson, seconded by Mr. Filliter, and carried—"That the circular requesting subscriptions, now read, be printed and distributed."

Moved by Mr. Filliter, seconded by Mr. Ward, and carried—"That the report of the proceedings be printed and distributed to the members, and that Messrs. McCorquodale & Co. be the printers."

Meeting of Council at the Philosophical Hall, Leeds, February 22, 1876.

W. Baily, Esq., in the chair. Present—Messrs. Baily, Brigg, Shaw, Miall, Filliter, W. Sykes Ward, Davis and Holt.

A report of the financial state of the Society was laid before the Council, together with a draft of the proposed new rules.

Moved by Mr. Brigg, seconded by Mr. Davis, and carried —"That the Rules be recommended to General Meeting for adoption."

Moved by Mr. W. S. Ward, seconded by Mr. Davis, and carried—"That Mr. John Brigg be requested to undertake the office of Treasurer until the next Annual Meeting."

Moved by Mr. Bentley Shaw, seconded by Mr. Holt, and carried—"That the next meeting of the Society be held at Barnsley, in April."

Moved by Mr. Miall, seconded by Mr. Bentley Shaw, and carried—"That the Erratic Blocks at Norber be photographed, and that the plate be issued for the current year."

A vote of thanks to the Chairman concluded the meeting.

The Eighty-first Meeting of the Society was held in the Court-House, Barnsley, April 27th, 1876.

R. Carter, Esq., C.E., in the chair. Mr. L. C. Miall tendered his resignation of the office of Hon. Secretary, which was accepted.

Moved by Mr. Seal, seconded by Mr. Lister, and carried —"That the best thanks of this meeting be given to Mr. Miall for his past services."

Moved by Mr. Miall, seconded by Mr. Baily, and carried —"That John Brigg, Esq., be elected Treasurer."

Moved by Professor Green, seconded by Mr. Stott, and carried—"That James W. Davis, Esq., be elected Hon. Secretary in place of Mr. Miall."

Moved by Mr. Carter, seconded by Mr. Davis, and carried—"That the Rev. H. J. Day, Messrs. Peacock, Bedford, Kell, Booth, and Farrer be elected Members.

The following papers were read:—"The Mineral Aspects of the West Riding Coal-field," by the Chairman (R. Carter, Esq., C.E.); "On the Exceptional Occurrence of Boulder Clay near Barnsley," by Professor Green, M.A.; "On a Stratum of Shale, containing Fish Remains, in the Lower Coal Measures," by J. W. Davis, Esq., F.L.S., F.G.S.;

"The Minerals of the Yorkshire Coal-field, as applied to the Modern Manufacture of Iron," by Benj. Holgate, Esq.

Moved by Mr. Miall, seconded by Dr. Sadler, and carried —"That the best thanks of the meeting be given to the Authors of Papers, and to Mr. Lister, as Local Secretary."

A vote of thanks to the Chairman concluded the meeting.

The Eighty-second Meeting, held in the Philosophical Hall, Leeds, October 18th, 1876.

Professor A. H. Green, M.A., in the chair.

The Hon. Secretary read the Annual Report.

Proposed by Mr. L. C. Miall, seconded by Mr. W. Rowley.—"That the Report be printed in the next volume of Proceedings." Carried.

Professors A. H. Green, M.A., F.G.S., L. C. Miall, F.G.S., Mr. John Brigg, F.G.S., and the Honorary Secretary, were requested to act as a Committee of Publication and Revision.

Moved by Mr. Miall, seconded by Mr. Rowley, and carried—"That Messrs. Edward Herring, John Hopkinson, George Morley, and John Hardcastle, jun., be elected Members."

Moved by Mr. Seal, seconded by Mr. Davis, and carried—"That Mr. James Goody be eleoted a Member."

The following papers were read:—"On the Physical Properties of Ice in connection with the History of the Glacial Period," by W. M. Watts, Esq., M.A., D.Sc. A discussion followed, in which the Chairman, Professor Miall, Messrs. Brigg, Holgate, and Bird took part.

"On Deep Mining, and recent achievements in connection therewith," by Walter Rowley, Esq., F.G.S. A discussion followed, in which the Chairman, Messrs. Holgate and Seal, took part.

A vote of thanks to the Chairman concluded the meeting.

The Geological and Polytechnic Society of the West Riding of Yorkshire originated at a meeting of the coal proprietors of that district, held in Wakefield, on Friday, December 1st, 1837, Thos. Wilson, Esq., of Banks Hall, near Barnsley, in the Chair. The extent and importance of the Yorkshire Coal-field, comprising not less than 462 square miles, and the imperfect information possessed respecting its numerous beds of coal and ironstone, having been considered, and also that in the winning and working of the same a large amount of capital was embarked, and extensive machinery and a numerous population employed, it was suggested that great advantages would result from the institution of a Society for collecting and recording Geological and Mechanical Information, with the accuracy and minuteness necessary for the successful prosecution of mining. These objects, it was hoped, would be most effectually attained by the formation of a collection of maps, plans, sections, models, mining records, and every kind of information respecting the geological structure of the country; the construction ultimately of a complete geological map or model; the formation of a museum, as well of the various fossils and mineral products of the district, as of drawings and models of the machinery and tools employed in mining; the consideration of the various systems of ventilation in use; the holding of public meetings in the principal towns of the West Riding, for reading communications and discussing topics connected with these subjects; the publication of papers, reports, and transactions; and the corresponding and co-operating with the metropolitan and other similar societies. While these subjects would occupy the principal attention of the society, it was considered desirable (particularly as there was no other society embracing these objects) to extend its operation to whatever was connected with the staple manufactures of the West Riding; together with the bearings of geology and chemistry upon agriculture, and the application of mechanical inventions to the common arts of life.

This proposal having met with the unanimous approbation of the meeting, immediate steps were taken for organising the Society, of which forty gentlemen at once signified their wish to become members, and the Right Hon. Earl Fitzwilliam, F.R.S., accepted the office of President.

The preliminary business having occupied the first two or three sittings, Professor Johnston, of Durham, in May, 1838, delivered the first public lecture, "On the Economy of a Coal-field," which was published in a separate form.

The following papers were submitted at the subsequent Meetings, of which no permanent record is preserved, except in the local journals of the period:—

"On the Dislocations in the Valley of the Don," by H. Hartop, Esq.

"Illustrations of the Geology of the Yorkshire Coal-field," by the Rev. W. Thorp.

"On the Inefficiency of the Compass for Mineral Surveying, and Suggestions for taking the Magnitude of Angles," by C. Morton, Esq.

"On the Mode of Ventilation adopted at Middleton Colliery," by T. W. Embleton, Esq.

"On the Non-identity of the Haigh Moor and Rothwell Haigh Seams," by Henry Briggs, Esq.

"A Comparison of the Yorkshire and Lancashire Coal-fields," by the Rev. W. Thorp.

"On the Miners' Safety Fuze," by T. W. Embleton, Esq.

"On an Improved Safety Lamp, and Suggestions for Lighting Mines by means of the Fire Damp," by Mr. Fletcher.

"Remarks on the Section from the Bradgate Rock to the Forty Yards Coal at Middleton," by T. W. Embleton, Esq.

"On the Geology of the Neighbourhood of Sheffield," by the Rev. W. Thorp.

"On the Utility of Geology as applied to Mining, Agriculture, and the Arts," by C. Morton, Esq.

The printed Proceedings of the Society, therefore, commence with the Meeting held at Leeds, December 6th, 1839.

CONTENTS OF VOLUME I.—1839-1842.

*** The first Two Reports which were Printed were not paged consecutively.

CONTENTS OF VOLUME II.—1842-1848.

CONTENTS OF VOLUME III.—1849-1859.

CONTENTS OF VOLUME IV.—1859-1868.

CONTENTS OF VOLUME V.—1869-1870.

*** In the List of Papers given above, several have been omitted, being on subjects having no relationship to the Geol ogy, or kindred sciences, of the West Riding.

Summary of Geological Literature relating to the West Riding, published during 1874.

Compiled by J. W. Davis.

Aitken, John. Notes on the Discovery of a New Fish of the genus Acrolepis, Ag., in the Millstone Grit near Hebden Bridge. *Trans. Manch. Geol. Soc.*, vol. iii., pp. 36-47.

Anon. Extraordinary Development of the Yorkshire Coal-field. *Coll. Guard.*, vol. xxvii., p. 756.

Aveline, W. T., J. R. Dakyns, C. F. Strangways. Sheet 93 N.W. of Geological Survey of England—Knaresborough, Ripley, Boroughbridge, and Easingwold.

Aveline, W. T., J. R. Dakyns, and J. C. Ward. Sheet 204 of the Map of the Geological Survey (England), scale 6 in. to a mile—Aberford, Barwick, Thorner.

Barr, Thos. M. On the Geology of the North Eastern District of Yorkshire. *Trans. Scot. Soc.*, Glasgow, vol. iv., pt. 3, pp. 291-300, Plate (Map).

Blake, Rev. J. F. Additional Remains of Pleistocene Mammals in Yorkshire. *Rep. Brit. Assoc.* for 1873, *Sections*, p. 75.

——— Note on the Red Chalk of Yorkshire. *Geol. Mag.*, Dec. 2, vol. i., pp. 362-364 (Woodcut).

Bower, John. Whitby Jet and its Manufacture. *Jour. Soc. Arts*, vol. xxii., No. 1101, pp. 80-87.

Brigg, Jno. On such of the Industries of Bradford as relate to its Geological Position. *Rep. Brit. Assoc.* for 1874, *Sections*, pp. 76-77; published in full under the title, "The Industrial Geology of Bradford," 8vo, Leeds, pp. 18.

Busk, Prof. G. Notice of a Human Fibula of Unusual Form, discovered in the Victoria Cave, near Settle, Yorkshire. *Jour. Anthrop. Inst.*, vol. iii., pp. 392-395. (Plate.)

Dakyns, J. R. On the Geology of a Part of Craven. *Rep. Brit. Assoc.* for 1873, *Sections*, pp. 78-79.

——— Sheet 28 of Vertical Sections of the Geological Survey of England. Millstone Grit, Yoredales, and Carboniferous Limestone of Grassington Moor and Kettlewell.

Davidson, Thomas. Monograph of the British Fossil Brachiopoda, vol. iv., pt. 1. Supplement to the Recent, Tertiary, and Cretaceous sp., pp. 1-72, pls. i.-viii., *Palæont. Soc.*, vol. xxvii. (R. Spectonensis described as new).

Dawkins, W. B. Report of the Committee appointed for the purpose of Exploring Settle Caves. *Rep. Brit. Assoc.*, 1873, pp. 250-251.

——— Observations on the Rate at which Stalagmite is being Accumulated in the Ingleborough Cave. *Rep. Brit. Assoc.* for 1873, *Sections*, p. 80. (See also *Proc. Manch. Lit. and Phil. Soc.*, February, 1873).

——— Cave Hunting. Researches on the Evidence of Caves respecting the Early Inhabitants of Europe (coloured Plate and Woodcuts), pp. xix., 455, chap. iii., 8vo. London.

Dickenson, J. On the Saliferous Strata. *Trans. Geol. Soc., Manchester*, vol. xiii., pt. 2, p. 23.

Ellis, J. W. Note on the Stump Cross Caverns at Greenhow, near Pateley, Bridge. *Rep. Brit. Assoc.* for 1873, *Sections*, p. 80.

Etheridge, R. On the Geology of Coal and Coal Deposits in the British Islands. *Rep. of Proc. of 11th Annual Meeting Brit. Assoc. Gas Managers*, pp. 84-109.

Fairley T. Analysis of Water taken from the "Old Crescent Well," Harrogate, Nov. 14, 1873. *Chem. News*, vol. xxx., No. 774, p. 151.

GOMERSALL, W. The Round Boulder Hills of Craven. *Rep. Brit. Assoc.* for 1873, *Sections*, p. 80.

GOTT, C. On the Bradford Waterworks. *Rep. Brit. Assoc.* for 1873, pp. 451-458

GREEN, A. H. Sheet 262 of the Map of the Geological Survey (England), scale 6 in. to a mile—Darton, Royston, West Bretton.

——— J. C. WARD and T. V. HOLMES. Sheet 288 of the Map of the Geological Survey (England), scale 6 in. to a mile—Ecclesfield, Oughtibridge, Wadsley.

——— J. R. DAKYNS, J. C. WARD, and R. RUSSELL. Sheet 88 of 1 inch Geological Survey of England—Halifax, Huddersfield, and Dewsbury.

HILL, J. S., and W. FAIRLEY. The Coal Deposits of Great Britain, and the Oolitic Coal of England, Scotland, Sweden, and Denmark. *Coll. Guard.*, vol. xxviii., pp. 670, 705, 743, 815, 851, 887, 923. (Refers to Cleveland Coal).

HOBKIRK, C. P. On the Morses of the West Riding of Yorkshire. (Geological Introduction). *Rep. Brit. Assoc.* for 1873, *Sections*, pp. 104-105; and *Jour. Bot.*, U.S., vol. ii., p. 327.

HORNE, W. On the Occurrence in the Yoredale Rocks of Wensleydale of Fish and Amphibian Remains. *Rep. Brit. Assoc.* for 1873, *Sections*, p. 84.

HUDLLESTON, W. H. The Yorkshire Oolites. Pt. 1 *Proc. Geol. Assoc.*, vol. iii., No. 7, pp. 283-333, eight Woodcuts (Sections).

HUGHES, PROF. T. MCK. Exploration of Cave Ha, near Giggleswick. *Jour. Anthrop. Inst.*, vol. iii., No. 3, pp. 383-387.

LUCY, W. C. The Submerged Forest, Holly Hazle, Sharpness. *Proc. Cottes-wold Nat. Club*, vol. vi., pp. 105-125. (Refers to Hull).

MEADE, R. Iron Industries of the North Riding of Yorkshire. *Mining Jour.* Dec. 19.

MIALL, L. C. Note on the Occurrence of a Labyrinthodont in the Yoredale Rocks of Wensleydale. *Quart. Jour. Geol. Soc.*, vol. xxx., pp. 775-776.

NEILL, A. On the Bradford Building Trades. *Rep. Brit. Assoc.* for 1873, *Sections*, pp. 196-199.

——— On Stone-Dressing in Bradford. *Ibid*, p. 214.

PAINTER, REV. W. H. More about Carboniferous Fish. *Science Gossip*, No. **119**, pp. 253-254. (Fish Remains at Baildon, near Bradford).

PLANT, J. On Bones of Elephas Primigenius, from a Cavern near Skipton. *Trans. Geol. Soc., Manch.*, vol. xiii., pt. 3, p. 54.

RENEVIER, PROF. E. Tableau des terraries sedimentaries, avec leurs représentants en suisse, et dans les régions classiques, leurs synonymes et les principaux fossiles de chaque étage. (Table of Sedimentary Rocks). *Bull Soc., vaud. sci. nat.*, t. xiii., pp. 218-252. (Gives Yorkshire Equivalents).

RUSSELL, R. Geology of the Country round Bradford. *Rep. Brit. Assoc.* for 1873, *Sections*, p. 83-91; and *Iron*, n. s., vol. xi., pp. 458-491 (1873); and *Coll. Guard.*, vol. xxx., pp. 563-564 (1875).

SMITH, E. J. Agricultural Geology (No. 2, Northern Division). *Trans. Inst. Surveyors*, vol. vi., pp. 323-342.

SPENCER, J. The Third Part of the Description of the Millstone Grit Series of the Parish of Halifax. *Trans. Manch. Geol. Soc.*, vol. xiii., pt. 7, 1874.

STEAVENSON, A. L. Ironstone Mining in Cleveland. *Jour. Iron and Steel Inst.*, No. 2, 1874, pp. 329-337. (Plate).

STRANGWAYS, C. F. Memoirs of Geological Survey of England—Geology of the Country North and East of Harrogate (93 N. W.), 8vo, London.

TUTE, J. S. Organisms in Carboniferous Flint or Chert. *Science Gossip*, No. 116, p. 188 (Woodcut); see also p. 217. (Yoredale Series).

Willcock, J. On the History, Progress, and Description of the Bowling Ironworks. *Rep. Brit. Assoc.* for 1873, *Sections*, p. 219-222. (The paper has been printed in full by the Bowling Ironworks Company).

Summary of Geological Literature relating to the West Riding, published during 1875.

Compiled by J. W. Davis.

Crosskey, Rev. H. W. Second Report of the Committtee appointed for the purpose of recording the Position, Height above the Sea, Lithological Characters, Size, and Origin of the more important of the Erratic Blocks of England and Wales, reporting other Matters of Interest connected with the same, and taking Measures for their Preservation. *Rep. Brit. Assoc.* 1874, *Sections*, pp. 192-200.

Dakyns, J. R. The Sediment Theory of Drift. *Geol. Mag.*, Dec. 2, vol. ii. pp. 168-172. (Phenomena in Yorkshire Dales).

Goodchild, J. G. Glacial Phenomena of the Eden Valley and the Western Parts of the Yorkshire Dale District. *Quart. Jour. Geol. Soc.*, vol. xxxi., pp. 55-99, pl. ii. (Map), 15 Woodcuts.

——— Glacial Erosion. *Geol. Mag.*, Dec. 2, vol. ii., pp. 323-328, 356-362.

——— On the Origin of Coums. *Geol. Mag.*, Dec. 2, vol. ii., pp. 486-487. (Refer to Valleys and their Formation in Yorkshire in each Paper).

Green, Prof. A. H. Variation in Thickness and Character of the Barnsley and Silkstone Coal-seams in South Yorkshire, and the Probable Origin of this and Similar Changes. *Coll. Guard.*, vol. xxx., pp. 601-602.

Huddleston, W. H. Excursion to East Yorkshire. *Proc. Geol. Assoc.*, vol. iv., No. 5, pp. 326-336.

Hull, Prof. E., J. R. Dakyns, R. H. Tiddeman, J. C. Ward, W. Gunn, and C. E. DeRance. The Geology of the Burnley Coal-field, and of the Country around Clitheroe, Preston, Chorley, Haslingden, and Todmorden. [Edited by H. R. Tiddeman]. Table of Fossils, by R. Etheridge. *Geological Survey Memoir*, pp. xi., 221, 42 Woodcuts, 8vo, London.

Hunt, Robert. Mineral Statistics of the United Kingdom of Great Britain and Ireland, for the year 1874, with an Appendix, pp. xv., 279, 8vo, London.

Jeffreys, J. G. Note on the so-called Crag of Bridlington. *Rep. Brit. Assoc.* for 1874, *Sections*, pp. 83-87.

Judd, Jno. W. On the Classification of the Jurassic Strata of the Midland District, and their Correlation with those of the Cotteswold Hills and the North East of Yorkshire. Introduction (pp. 1-52) to Geological Survey Memoir, "The Geology of Rutland, &c.," 8vo, London.

Kerr, James. On Lead Mining in the Districts of Stansfield, Holmes Chapel, Rossendale, and Great Hambledon, N. W. Yorkshire and N. E. Lancashire. *Trans. Manch. Geol. Soc.*, vol. xiii., pp. 344-360.

Meade, R. The Iron Industries of the West Riding of Yorkshire. *Mining Journal*, vol. xlv., p. 343.

Lebour, G. A. On the Limits of the Yoredale Series in the N. of England. *Geol. Mag.*, Dec. 2, vol. ii., pp. 539-544.

Mortimer R. An Account of a Well Section in the Chalk at the North End of Driffield, E. Yorkshire. *Quar. Jour. Geol. Soc.*, vol. xxxi., p. 111-112. Analyses by T. Hodgson.

PHILLIPS, PROF. J. Illustrations of the Geology of Yorkshire, or, a Description of the Strata and Organic Remains. Part 1: The Yorkshire Coast. Edition 3. Edited by R. ETHERIDGE, pp. xiii., 354, Maps and 28 Plates, 4to. Lond. [Articles by J. G. JEFFREYS and T. R. JONES, and Bibliography by W. WHITAKER.]

READE, T. M. Speculation on the Probable Distribution of Land and Sea during the Deposition of the Marine Boulder Clay and Sands. *Proc. Liverpool Geol. Soc.*, vol. iii., pt. 1, pp. 35-52.

RUSSELL, R. Geology of North Yorkshire Coal-field. *Coll. Guard.*, vol. xxx., pp. 563-564.

SORBY, H. C. On the Remains of a Fossil Forest in the Coal Measures at Wadsley, near Sheffield. *Quar. Jour. Geol. Soc.*, vol. xxxi., pp. 458-460. Two Woodcuts.

TIDDEMAN, R. H. Second Report of the Committee appointed for the purpose of assisting in the Exploration of the Settle Caves (Victoria Cave). *Rep. Brit. Assoc.* for 1874, *Sections*, pp. 133-138. (Reprinted, 8vo, Lancaster).

*** The compiler is much indebted to Messrs. W. Whitaker and W. H. Dalton, of H.M. Geol. Survey, and to Prof. L. C. Miall, for assistance in preparing the foregoing list.

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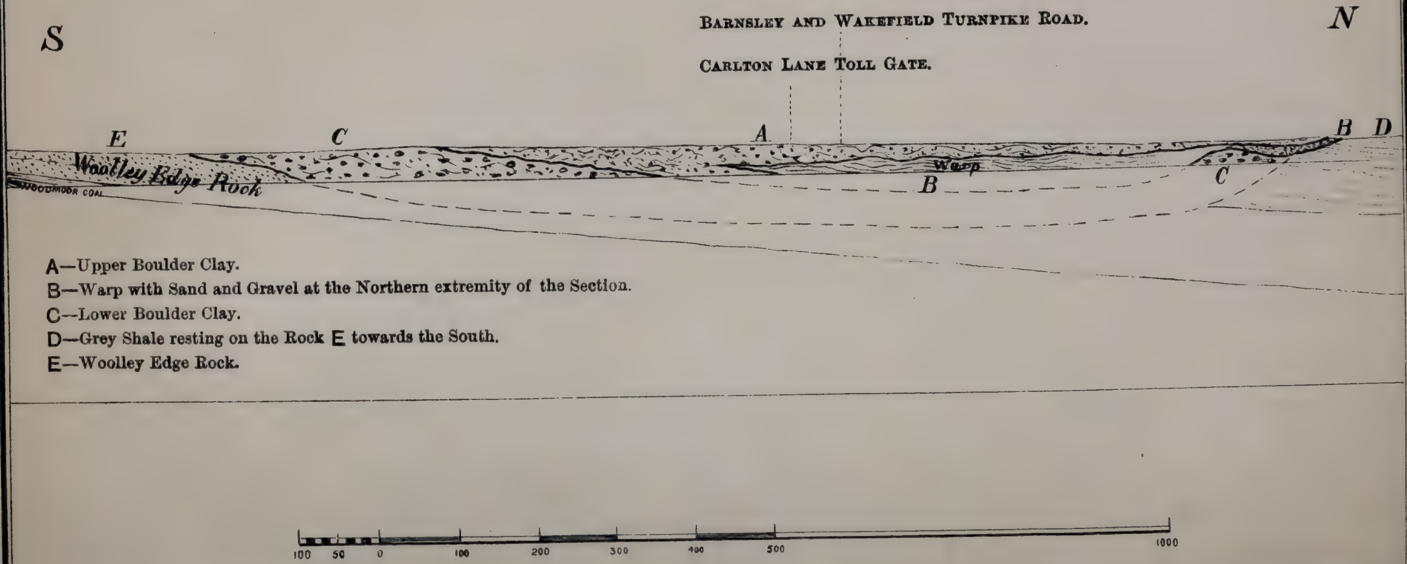
SECTION IN THE CUTTING OF THE MINERAL RAILWAY TWO MILES NORTH OF BARNSLEY.



PROCEEDINGS

OF THE

GEOLOGICAL AND POLYTECHNIC SOCIETY

OF THE

WEST RIDING OF YORKSHIRE.

NEW SERIES, PART IV., pp. 201 to 324.

With Four Plates.

Edited by JAMES W. DAVIS, F.L.S., F.G.S.

1877.

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PAPERS

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PAPERS

READ BEFORE THE

GEOLOGICAL AND POLYTECHNIC SOCIETY

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1877.

ON SCIENTIFIC RESEARCH. BY THE MARQUIS OF RIPON.

The noble Chairman said he believed it now became his duty to address a few words to those present in opening the proceedings of the day, and he confessed that he presented himself to them for that purpose with no little diffidence. When he came to inquire of Mr. Davis what would be the nature of his duties upon this occasion, he was somewhat dismayed to find that one of them would be to make an address to a body of gentlemen so well versed in the science to which they devoted themselves, and whom he had so little claim to address upon these topics. At one moment he was tempted to endeavour to make some remarks with respect to the recent progress of Geological Science, and upon any questions connected with that science which might be pre-eminently engaging the attention of scientific men at this moment. And, indeed, he had gone so far as to request an eminent scientific friend to supply him with information which would have enabled him, to a certain extent, to discharge that duty; but he confessed that when he came to reflect upon the matter, he felt that if he were, by endeavouring superficially to "cram"—to use a common phrase—the most recent knowledge upon these questions, for the purpose of addressing them, he should have really been presenting himself before them, to a certain extent, under false pretences. It was quite true that he had been for many years a student of natural science in several of its branches, and to some extent of Geological Science; but his various avocations, Parliamentary and official, during the last quarter of a century, had so much taken up his time as to have rendered it impossible for him to pursue those delightful studies in any solid or continuous manner, and consequently, he felt that it would be an impertinence on his part, being but an humble student of these sciences, to attempt to speak to those who had studied them so long, and many of them so carefully, in any degree in the position of a teacher. Consequently he abandoned that idea, because he had always had a very great dislike to people talking about what they did not thoroughly and completely understand; and he was quite sure that if there were any branch of knowledge in which that was undesirable it was in the various branches of natural science; for, surely, it was of the first importance for any student of those sciences that, as he made step by step in pursuit of them, he should keep constantly before him the recollection of the limits of the knowledge he had made his own, and that in each step he took, before he took a new one, he should be confident that he had really firmly established himself upon the ground which he occupied. Therefore he would confine himself to the more modest, but, as it seemed to him, far more fitting position of heartily welcoming the members of the Society to the city of Ripon, and expressing the great satisfaction which it gave him that they should have visited it, and to say one or two words to those who, like himself, were only students of those interesting and attractive sciences, to which many of them had devoted their lives. He felt very great satisfaction that they had chosen Ripon for the place of their meeting, and there was but one drawback to that satisfaction, which was the small number that he saw assembled in the room. He could not help thinking that the free access which they afforded to this meeting could not have been generally known, or that the interesting nature of the papers to be submitted to their consideration could not have been sufficiently circulated in the neighbourhood, otherwise he felt sure they would have had a larger attendance—for surely it was a great advantage that a society like this should from time to time visit the various towns and districts in the great Riding with which it was connected; and that by the papers which were read upon those occasions, and the information which was thus brought before the notice of those who attended the meeting, there should be spread throughout all the different districts of the country a taste for the pursuit of those sciences which it was the object of this society to encourage. When he looked at the list of the various papers which were to be read, he saw that it covered a wide and very attractive field, and that those who might be present from that neighbourhood would find from these papers, he had no doubt, that within a very few hours' journey from this town they would be enabled to carry the glance of their investigation over the vast ages which were embraced in Geological time; for he found that among the papers there was one which would recall to them the circumstances, and to some extent, doubtless, the history of the Silurian period, with its vast population of Molluscs, and would explain how it was that Boulders belonging to that period had found their way into the beautiful valley of Wharfedale. He found, also, that coming down from that very ancient time they would have recalled to them, to some extent, the history of the Carboniferous Era, in which, in God's providence, there was stored up for the present generations of men that vast accumulation of mineral wealth that formed the foundation of the manufacturing prosperity of this great country. He also found that his friend, Mr. Tute, was about to recall to his neighbours in this district that there was a time when, instead of enjoying the genial climate with which we were blessed in these days, this part of the world, in common with others, was plunged in the cold and misery of the Glacial period, and in a condition which, to us who were living on the earth now, it was difficult, except by an effort of the imagination, to realise; until at length, by the paper of Dr. Parsons, we were brought down to the period of Alluvial Deposits, in which we were reminded of the immediate results of those natural processes which were going on day by day under our eyes, in the times in which we lived. Now, surely, in that brief survey of the papers before them, and the varied subjects which it was proposed to discuss, and the vast extent of uncounted ages to which they referred, there was proof enough of the immense interest of the topics with which they especially dealt, and proof enough that in this neighbourhood, as in every other part of the world, there might be found ample employment for those who were able to make these studies the occupation of their lives; and also ample, useful, and attractive employment for those who could only devote to them the leisure that their more pressing occupations might leave to them. He rejoiced, therefore, to think that the Society had come to Ripon, and he could only hope that there might go forth from that room an account of the papers which were read which might stimulate many who were not present to devote themselves to those studies, and might enable them to derive from them that reasonable, that rational, and that intense enjoyment which was felt by all who devoted to them any portion of their time. With the view of encouraging any who might be inclined to take up these studies as the occupation of leisure, even though that leisure might be little, he would say that he thought he was not wrong in supposing that it might be the good fortune of any student of natural science, however humble might be his position in the scientific world, or however limited might be the time which he might devote to the study—it might be his good fortune, if he were a careful and accurate observer, to bring to light some fact which in the hands of the masters of science might throw great and valuable light upon the regions of scientific knowledge which up to that time might have been obscure. If he might be pardoned, he would mention a circumstance which came to his recollection that day connected with his own boyish life, just to show how any youth who engaged in the study of natural history might find out some fact or discover some creature hitherto unknown. Having been as a boy very much devoted to the delightful study of entomology, it was his good fortune, when quite young, to possess himself of an insect belonging to the genus of the saw flies, which on showing with youthful pride to a scientific friend, the late Mr. John Curtis, he announced to be a species hitherto unknown. What happened to him as a boy might happen to any other boy in Ripon or anywhere else, and he only mentioned the fact—it was his sole scientific discovery—his sole claim to scientific distinction of any kind, so naturally he was proud of it—but he mentioned it only to show that which was possible for even the most humble investigations of nature; and those who had but little time to give to it might, if only they pursued the study with accuracy and with care, be the means through the instrumentality of those who were more learned than themselves, of arriving at new facts which might turn out ultimately to be of great value to science. But the basis of all scientific investigation was the spirit of accurate and careful observation. Those who gave any portion of their time to those inquiries must not think that science was a thing to be taken up like a novel, and read hastily, or investigated in a superficial manner. If the study of science were to do any good to themselves or to the general knowledge of the world in regard to those inquiries to which they addressed themselves, it must be conducted in a painstaking manner, and whatever they did, be it much or little, they should do with all their might, and with the utmost thoroughness they could command. Loose knowledge, superficial inquiry, the lazy readiness to accept facts without complete investigation, or an obstinate rejection of facts because they did not accord with their preconceived ideas or the theories they were inclined to favour themselves, he took it were habits of mind which were fatal to scientific inquiry—and it was only by cultivating a different spirit—by approaching nature in a reverent spirit, desiring to learn the lessons which she had to teach, and believing that these lessons were only to be learned by careful investigation, and by reverent study—it was only in that mode that any of them could hope to derive any solid profit from studies of this description. The true spirit, then, of an investigator of nature—be he student or be he teacher—was, he ventured to think, a modest, teachable, reverent spirit—a mind open to receive all facts from whatever quarter they might come; ready to test them to the utmost, and ready to accept the conclusions to which these facts might lead. It had always seemed to him important to all engaged in these investigations ever to keep distinctly in mind the almost infinite difference which there was between fact and theory. The foundation of all true science was fact, and it had been by the investigation of facts — the careful, painstaking, minute, individual investigation of facts—that science had made that wonderful progress which was an astonishment to all who devoted themselves in these days to the study of any branch of natural science. It was only in that spirit that they could approach with any advantage those studies, and it was only by approaching them in that spirit that they could hope to derive any good from them, either for themselves or for others. A poet had told us that "a little knowledge is a dangerous thing." Of course there was a sense in which that saying announced a great and indisputable truth. A little knowledge was a dangerous thing if it puffed up those who possessed it, and made them fancy that their knowledge was extensive and great. A little knowledge was a dangerous thing if it were used to show our superiority to those who were somewhat more ignorant than themselves. But he did not believe that a little knowledge was a dangerous thing if they knew accurately the limits of that knowledge, and if they ever kept before them the extent of their own ignorance. After all, surely it was true that the knowledge of the wisest among us was in reality small indeed. Great as had been the advance which had been made during the last century in the knowledge of the outward world, there still remained vast regions into which our knowledge had not yet penetrated, or had only just begun to enter; and the difference between what we did know and what we did not know was infinitely greater than that which existed between the knowledge of the mere student and of him who had devoted his life to learning in these various branches of knowledge. He said, then, that a little knowledge was not a dangerous thing, provided they knew well what was the extent of their knowledge, and provided that they appreciated at its real value that which they did know. And surely it was encouraging for all, and particularly for the young students of science—if there were any present—to know that, provided they devoted themselves to those studies in the spirit which he had endeavoured so imperfectly to describe, whether the time they could give was much or little, every step they took would lead them on in a path in which they might proceed, through a long life, with no hope, no doubt, of ever reaching the end, but which would open to them, as they advanced, new fields of ever-increasing beauty, attraction, and delight; and whether they learned much or little of the history of this beautiful world, in which, by God's bounty, we were called to dwell—as they looked back over that vast expanse of ages which geological science opened so widely before their view, they would find, if he mistook not, in every lesson that they learned, in every fact that they made their own, in every branch of knowledge that opened fresh to them, an ever-increasing proof of the wisdom, the power, and the goodness of Him by whom this mighty universe was made, and by whose laws it was continually ruled.

NOTES ON THE GLACIAL DRIFT NEAR RIPON.

BY THE REV. J. STANLEY TUTE, B.A.

The Beds of Glacial Drift near Ripon seem to be of three distinct ages, probably separated from each other by long intervals of time. The earliest of these is a bed of Black Boulder Clay on the south side of the valley of the Laver, a section of which has been exposed in a quarry of Magnesian Limestone near Oldfield. Upon the eroded surface of this lies the Brown Boulder Clay, which is the common Drift of the district. Over this again, on each side of the Ure near Ripon, is a mass of sand, clay, and gravel, derived partly from the Boulder Clays and partly from the disintegrated New Red Sandstone against which it rests. The sand is sometimes red, sometimes white, and occurs in lenticular masses or in thin contorted beds.

Of the same age is a Gravel Deposit at Wormald Green, at the east side of the stream, which, in its false bedding and the roughened surfaces of the Limestone pebbles, exhibits clear traces of having been washed out of older beds and re-deposited.

It is to a fact belonging to the second of these beds, the Brown Boulder Clay, that I wish to draw your particular attention.

On its eastern side the Boulder Clay spreads widely over the vale of York, and is mixed with or overlaid by more recent deposits. But its western side is more or less sharply defined, and lies upon the eastern edge of a very singular valley, which intersects the direction of the ordinary river courses almost at right angles.

In the Memoir of the Geological Survey of the district this peculiarity is noted. * "Another curious circumstance is that although the stream coming down from Haddockstones now flows eastwards by Markington and South Stainley into the Ure at Newby, this does not appear to have been its original course; for at Dole Bank, and thence southwards to Ripley, there is a well marked gorge, which in some places is fully as wide and deep as that of the Nidd at Knaresborough, and considerably larger than that in which the present stream flows. This valley is now only drained by the diminutive stream of Cayton Gill, which joins the Nidd below Ripley; but it is evident that a much larger stream must have cut this streamless defile at Dole Bank, where it is interesting to observe the abrupt turn the Markington Beck makes to avoid this valley."

This valley is continued to the north of Haddockstones, forming the Dean, out of which flows a little tributary to the Markington beck, and a very small stream runs out northwards into the Skell.

* P. 21, Memoir of Geological Survey, 93 N.W.

On the western side of this valley the deposits of Clay and Sand are generally very shallow, and are entirely derived from the formations either immediately below or very near them; but showing, by the shape of the included fragments of rock, that they are not only the result of aerial influences, but of some other force which has taken off their edges and worn them round.

On the higher grounds near How Hill, the beds of Boulder Clay run in long mounds, parallel with the valley which I have mentioned, and attain a thickness of 50 or 60 feet, or perhaps more. Along the lower levels the mounds of Drift follow to a certain extent the direction of the streams, but the thickness of the drift is much less; and in some places it has been completely washed away so as to expose the underlying rocks.

Such, then, are the facts, and they appear to point to a very interesting conclusion. For since this north and south valley forms a natural boundary between that Drift which is local and the Glacial Drift, the conviction is forced upon one that here was the edge of an Ice-cap which covered all the hills to the west, and was cut off along this line by the Glacial Sea. This sea, which was covered with floating ice, burdened with Clay, Sand, and Boulders from the older Carboniferous rocks, and occasional pieces of Greenstone and Shap-Granite which had been carried over Stainmoor, seems to have moved along the edge of this Ice-cap with a strong current running from the north-east. The valleys in which the present streams run were filled with glaciers, which pushed their way slowly towards the sea. Beneath the Ice-cap, which was gently moving towards the east, there was formed the *local* Drift; and at its edge a definite boundary of Boulder Clay. And the valley, so often mentioned, may have been produced by a strong current running along the edge of the Ice-cap, and bearing away the broken pieces of ice which from time to time fell in larger or smaller masses. These by degrees would plough out this valley, and leave it pretty much in the same form as that in which we now find it, though perhaps a little deeper.

The existence of Glaciers in the valleys is indicated by the fact, that when the Drift approaches a valley its natural north-and-south direction is altered, and it runs parallel with the direction of the valley, along its *northern side*; showing that the Glacier which filled the valley extended so far forward, or was of sufficient size, to deflect the tidal current. Thus at Haddockstones, the Glacier which came down from the valley of Hebden Wood to the west, pushed itself up the opposite hill, and appears to have terminated a little to east of the place where the farm-house now stands. For immediately to the north of the house is a long mound running east and west; the Millstone Grit which is here denuded, is worn smooth, and there are many large rounded blocks of Millstone Grit which seem to have been carried down from the upper part of the Hebden Wood Valley and dropped here.*

A little to the north of Ripley, there is also another long mound of drift running to the east, at the place where the valley of Cayton Gill opens out into the wider valley of the Nidd; the northern current being here again turned aside by the masses of ice which were in the valley of the Nidd.

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* It is from these stones that the name of the farm, Haddockstones, is derived.

THE ALLUVIAL STRATA OF THE LOWER OUSE VALLEY.

BY H. FRANKLIN PARSONS, M.D., F.G.S. (PLATE VIII.)

It may seem as if something like an apology were needed for asking the West Riding Geological Society to leave the rocky dales of the Mountain Limestone, the wild hills and moorlands of the Millstone Grit, and the mineral wealth of the Coal Measures, around which so much geologic interest centres, and to turn in imagination to a flat and tame district, where sections are few and far between, and fossils hardly to be found. Nevertheless a tyro like myself may with less presumption hope to find something worth bringing before you in a region which seems to have been almost passed over by abler geologists, than in more attractive and better worked fields. I propose, moreover, to show that the district to which I refer is not without an interest of its own, for here we may read the last page of the earth's story, where geology merges into history, and may witness in progress changes which elsewhere we can only infer to have taken place.

The district of which I speak is the low-lying level tract forming the southern part of the Vale of York, where the great tidal rivers Ouse, Wharfe, Derwent, Aire, Don, and Trent unite to form the Humber estuary, which then cuts its way towards the sea through the hills to the east. This broad plain occupies the space between the ranges of hills formed by the outcrops of the Chalk, Oolites, and Lias to the east, and of the Magnesian Limestone to the west. Beneath this area lie the Triassic rocks, the soft and friable nature of which has caused them to be eroded into this broad valley, while the harder rocks above and below stand out as ranges of hills. The Triassic rocks are for the most part covered up by the Quaternary Strata, but here and there they rise to the surface, forming low detached hills like islets, which, indeed, the names borne by some of these places, as Holme, Ealand, the Isle of Axholme, &c., seem to testify that they have really been within the historic period.

The Keuper rises to the surface about Epworth and Belton, in the Isle of Axholme, as a red and green Marl, with layers of Gypsum; and again at Holme-on-Spalding-Moor, between Selby and Market Weighton, where it forms a hill 150 feet high. In some borings for coal undertaken in 1835, at Reedness, five miles east of Goole, it appears to have been reached at a depth of about 70 feet, and to have been 272 feet in thickness (see Section 3 in appendix to this paper). In sinking the cylinders for the Hook bridge, a mile north-east of Goole, a blue Shale, with layers of Gypsum, was met with at a depth of 19 feet 6 inches below the bottom of the river, or 39 feet 6 inches below high water mark (see Section 4). This Shale seems to represent the Keuper. At Goole, borings strike the Red Sandstone without the intervention of any gypseous Marls or Shales (Section 5), so that the lower boundary of the Keuper must lie somewhere between Goole and Hook. In the rising ground by Crowle a gravel is exposed, which consists of flat fragments of green micaceous shaley Marl, in all probability derived from and resting upon the Keuper. At Sandtoft, in the same neighbourhood, a white gritty Sandstone struck lately in some borings (Section 1), seems to represent the same rock.

The Bunter is exposed in the railway cutting at Doncaster, and other patches capped with gravel occur at Barnby Don, Hatfield, and Thorne. A low ridge of the same rock extends east and west from Cowick to Kellington, a distance of nine miles, and the same ridge may be traced under the recent strata as far east as Rawcliffe, or even Goole. The highest point of the ridge at Pollington is about 60 feet above the sea level. Over this area the Red

Sandstone is for the most part covered up with gravel; but it may be seen exposed superficially near the railway a little to the east of Snaith Station. On a smaller patch of the Red Sandstone rock, separated from that last-mentioned by the River Aire, the villages of Carlton and Camblesforth are situated; and the Red Sandstone may be seen on the surface, in sand pits near Carlton. There is another small detached patch at Whitley. West of Selby the Bunter rises into two little hills—Brayton Barf and Hambleton Haugh—each about 150 feet in height. Around the base of these hills the Red Sandstone is covered with gravel; but it is well exposed in a quarry on Hambleton Haugh, and again at Thorpe Willoughby. The Bunter is also struck by deep borings at Reedness (Section 3), Goole (Sections 5, 6 and 8), Rawcliffe (Sections 9, 10 and 11), Selby (Section 13), Osgodby (Section 15), &c. Borings at New Bridge, near Snaith, have penetrated into it 450 feet (Section 12), and at Reedness 687 feet (Section 3), without reaching the bottom. At Cawood a soft Grey Sandstone 240 feet and more in thickness is said to have been met with (Section 14), which is probably the same rock. The usual character of the Bunter in this district is a loose red sand, or friable semi-coherent red sandstone, often micaceous, with more coherent clayey bands, and with occasional partings or pockets of red, green, or yellow ochrey marl. Unfortunately it contains neither fossils nor beds recognisable by constant physical characters, so that it is impossible to correlate one section with another. It is always strongly current-bedded.

Upon the Triassic rocks rest the Post-Tertiary beds, which are the especial subject of my paper. The aggregate thickness of the latter, as proved in the deep borings of which I have been able to obtain records, has been found to be as follows :—

	FEET.
Sandtoft (Section 1)	28 (?)*
Reedness (Section 3)	70
Hook Bridge (from bottom of river) (Section 4)	20
Do. (from ground level, about)	34
Goole, Old Goole (Section 5)	60
Do. Pemberton's Brewery (Section 6)	75
Do. Booth Ferry Road (Section 7)	28
Rawcliffe Station (Section 11)	8
Do. Hall (Section 10)	16
Do. Helliwell's Brewery (Section 9)	60
New Bridge (Section 12)	56
Selby (Section 13)	75
Osgodby (Section 15)	25
Cawood (Section 14)	90

These data are from records kept at the time, with the exception of the two last mentioned, which, consequently, are less to be depended upon than the others, having been given me from memory after the lapse of a number of years. As the ground level at all these places is nearly the same, it is evident that the surface of the New Red Sandstone must present considerable inequalities; for instance, Rawcliffe Hall and Helliwell's Brewery are only about 200 yards apart, yet the Red Sandstone lies 44 feet deeper at the latter place than the former. Most of the sections in the Goole neighbourhood show a thickness of about 60 feet—the exceptions are Hook Bridge, Booth Ferry Road (half a mile north-west of Goole), and Rawcliffe Station and Hall. On referring to the map you will find that these places are almost in a line with each other, which line, if prolonged, would nearly coincide with the axis of that ridge of new Red Sandstone which I spoke of as extending from Snaith to Kellington; this ridge is, therefore, prolonged eastwards under the newer strata for at least six miles.

The following is the general arrangement of these newer strata so far as I have been able to make it out. Beginning

* I am not sure where the Keuper begins in this section.

at the bottom we have, 1, Boulder clay ; 2, Gravel ; 3, Laminated Clay ; 4, Sand ; 5, Peat ; 6, Warp.

1. The *Boulder Clay* is not to my knowledge exposed in the Ouse valley lower down than Escrick, where it forms low undulating mounds, running transversely to the general course of the valley. A good section is exposed in the railway cutting at Escrick station, where it is seen to consist of a dark unstratified clay, part tough, part sandy, with round imbedded masses and contorted layers of sand, and containing many pebbles and boulders of all sizes up to two feet diameter, chiefly of Coal-measure sandstone, Millstone Grit, and Mountain Limestone ; the sandstone and grit being rounded, the limestone angular, with blunted corners, and characteristically smoothed and striated. In an adjoining field is a small gravel pit, in which are seen alternate layers of gravel, brown sand with imbedded boulders, and tough laminated clay ; all dipping strongly to south-west. Some limestone pebbles in the gravel still preserve ice scratches. Similar beds at York and Fulford contain fragments of Shap Fell granite, and other stones from the Lake district.

In three of the borings near Goole I find mentioned what appears to be the Boulder Clay. At Pemberton's Brewery, Goole, at a depth of 65 feet, we have "clay and cobbles" (Section 6). At Booth Ferry Road (Section 8), at 25 feet, "warp clay, a large pebble," which pebble, I am informed, took three hours to break ; and at Helliwell's Brewery, Rawcliffe (Section 9), at 47½ feet, "clay with gravel ;" in each case resting immediately on the Red Sandstone. I did not, in either case, see the specimens, and the evidence from borings is less satisfactory than that from exposed cuttings, as the pebbles may have fallen out of superjacent gravel beds.

2. Wherever in this district the Triassic rock approaches the surface, we find resting upon it a coarse *Gravel*, with alternations of sand ; even where the Trias is superficially

exposed, as at Brayton Barf, Carboniferous sandstone boulders, lying scattered upon the ground, bear witness that the gravel has been removed by denudation. A very fine section at Heck Station (represented in Fig. 1) shows the gravel resting upon the denuded surface of the Red Sandstone. The mode of junction is peculiar: the surface of the Red Sandstone, which dips at a small angle to the south, is eroded into a number of cavities, which are filled up level with gravel and sand; upon the plane surface so obtained rests a single layer of pebbles, all about the size of the fist, and above this a layer, six inches thick, of sand cemented with clay into a more coherent bed; upon the plane, and slightly inclined surface of the latter bed, rests the gravel, strongly current bedded, and dipping at a high angle to the south. Similar sections are seen at Whitley Thorpe, and at Pollington; the gravel at the latter place being 20 feet thick, and rising to a height of 60 feet above the sea-level. This gravel consists of rounded boulders of Coal-measure Sandstone and Millstone Grit; the larger ones being, as a rule, about six inches in diameter, although I have found some as large as 20 inches, together with small brightly-coloured chert pebbles. Pebbles of Carboniferous and Magnesian Limestone are, so far as I have observed, entirely absent. A similar gravel is seen at Thorne. At Gateforth House, near Hambleton, the gravel contains a few fragments of Magnesian Limestone, and I have found one of Silurian slate. At Hensall Station, near Heck, but on a lower level, and again in the borings at Newbridge, near Snaith, a similar gravel is met with, but containing many flat fragments of Magnesian Limestone, which at Heck is absent. At Askern, resting on the Magnesian Limestone, is a gravel composed entirely of angular pieces of that rock; at Crowle, resting on the Keuper, is one consisting of the green indurated Marls of that rock; and at Whitton, on the Lincolnshire shore of the Humber, the Lower Lias is covered up by a gravelly accumulation of its own *débris*, containing numerous worn specimens of Gryphæa incurva; these gravels are evidently entirely of local origin. By what means the materials of the Heck gravel were transported to their present position I cannot form an opinion, but they have evidently been arranged by water during a period of great depression of the surface. It seems at first sight a plausible conjecture that they are the result of the action of water upon the Boulder Clay; the stones and sand being deposited on the spot, and the clay carried away in suspension to form the Laminated Clay, of which I shall have to speak. Against this, however, is the absence of boulders of Carboniferous Limestone, so abundant in the Boulder Clay in the nearest spot at which it is seen: at any rate, if the materials of this gravel have been brought by ice, they must have come from the west or south-west, not as at Escrick and York from the north-west. I find an interesting confirmation of this inference at Holme-on-Spalding-Moor. At this place, as I have mentioned, the Keuper rises into a picturesque little hill, 150 feet in height, steep on three sides, but somewhat shelving to the south. The summit of the hill is capped with gravel about 10 feet thick, very similar to that at Heck, with no fragments of the local rock; on the slopes of the hill the red and green Marls are exposed, only covered with a few scattered pebbles; but on the east side a low gravelly ridge stretches away nearly half a mile from the hill, the gravel being composed in great part of flat water-worn fragments of green marly sandstone derived from the Keuper. Here, as in the neighbourhood of Heck, we find fragments of the local rocks only at the lower levels, and we find them only on the side of the hill sheltered from a current from the west.*

* Since this paper was written I have visited some sections near Brough. In some gravel pits, near the Cave Road, we see a gravel composed of angular

As we get away from the outcrops of the older rock, we find that the gravel gets finer in character, and in some of the sections, *e.g.*, Selby, it seems to be represented by "quicksand." A "quick sand," or "crying sand," as it is locally termed, is a loose sand with worn particles and saturated with water; in more elevated districts a quicksand usually rests upon a bed of clay, which holds the water up, but in this instance the quicksand rests upon the Red Sandstone, and it is saturated because it lies below the sea-level, so that there is no means for the water to get away. I have seen no fossils in this gravel.

3. *Laminated Clay.*—This is a bed very constant in character over a large area, although usually covered with a thin bed of sand; it is a strong clay, of a dark grey colour, with occasional tints of brown and blue, and splits, when dry, into fine Laminæ. At Selby it is 48 feet thick, and at Cawood it is said to be 57 feet. At Goole it is about 20 to 30 feet thick, but over the subterranean ridge of red sandstone, of which I have spoken, it thins out, so that at Rawcliffe Station it is only 3 feet, and at Hook Bridge apparently only 1½ feet thick. There is a difficulty, however, in correlating this section with others. At the brick-yard at West Cowick, near the edge of the Red Sandstone ridge, the clay contains thin ripple-marked partings of red sand and small fragments of coal. About Selby and Barlby this clay contains a seam of sand a foot or more thick (Sections 13 and 16). The clay contains no fossils to show whether it be of lacustrine, estuarine, or marine origin, but from its finely laminated character, and its resemblance to the modern warp, I think that it must have been formed in a

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fragments of local rocks, mostly oolite and lias, in highly inclined beds, resting unconformably upon horizontal strata of sand and laminated clay. At a higher level, nearer Elloughton, is a gravel with rounded boulders of Carboniferous Sandstone and Millstone Grit.

tidal estuary similar to that of the Humber. In the maps of the Geological Survey it is marked as "ancient warp." The very absence of fossil shells is in favour of this view, for mollusca appear to be entirely absent from the tidal Ouse; at any rate, I have never succeeded in finding any.

4. Upon the clay there usually rests a bed of *Sand*, which indeed forms the surface layer over the greater part of the area of which I am speaking. Its usual thickness is about four feet, sometimes more, but occasionally, as in parts of Goole, it is absent, and then the peat rests directly on the clay. The base of this sand is sometimes gravelly, but it increases in fineness towards the top. Its texture is very loose; when saturated with water, it is a "quicksand," and when dry and newly turned up with the plough, it sometimes drifts in a strong wind almost like snow, so that farmers call it "blow-away sand." Indeed, from its appearance, and the resemblance of some of the mounds formed of it, as at Riccall and Holme-on-Spalding-Moor, to the dunes on the sea coast, I cannot help surmising that the wind may have been at least one of the agents concerned in its distribution. The colour is generally yellow or ferruginous, except when covered with peat, when it is often white. I should be inclined to explain this by supposing that the decomposing carbonaceous matter reduces the iron which gives the sand its colour, from the ferric to the ferrous state, and that the excess of carbonic acid formed partly dissolves out the ferrous carbonate. The water which drains from the sand under the peat on exposure to the air throws down a rusty precipitate, which accumulates largely in some of the marsh ditches, especially in the district drained by the River Foulness, near Holme-on-Spalding-Moor. I am informed on good authority, although I have not seen them myself, that there are near this village the remains of ancient iron-smelting furnaces; if so, this

marshy deposit is perhaps the source from which the ore was obtained. In some of the marsh-land ditches a copious white flocculent deposit is formed, the nature of which I have not yet made out.

5. *Peat and Forest Bed.*—Over the lower part of the area of the Vale of York there extends a bed of Peat, resting sometimes directly on the clay, at other times on a thin layer of water-logged sand above the clay. On Thorne Waste this Peat bed attains the depth of 20 feet, but as we approach the older cultivated lands it becomes much reduced in thickness; at Goole being only six inches thick. This thinning out is due partly to the shorter time during which it has been forming, the formation of Peat being put a stop to when the land was warped, partly to the compression which the peat has undergone by the weight of the overlying soil. The mere act of cutting a drain through the Peat causes it to collapse, for, although the Peat is almost as impervious as Clay, yet the water, which it holds like a sponge, gradually drains away, and the Peat then shrinks. It is said that points in the landscape are now visible across the moor which formerly were hidden, owing to the shrinking of the drained land. It is only where the surface of the sand lies low that we get any considerable development of Peat; where it is elevated above the tide level, the Peat is either absent or represented only by black vegetable mould, mixed with Sand.

At the very bottom of the Peat, and rooted into the Sand (as shown in Fig. 2), are the stumps of innumerable trees, many of large size; the majority of them are Scotch fir, but oak, willow, birch, hazel, and other trees are also met with. The leaves and fruit of the cranberry are found, and the remains of other plants now living on the moors may be recognised. Elytra of beetles and other insect remains are common, but these are the only relics of animals that I have seen; horns of deer are, however, found; I am informed that one of the roebuck was got out at Hook Bridge. Mollusca are entirely absent so far as I have seen, nor is this surprising, for they seem to be equally absent in the living state from the present moorlands. Probably this absence of mollusca is due to the want of lime; for on the warp lands there are plenty close to the edge of the moor, and their shells are abundant in certain Peaty deposits near the Limestone, of which I shall have to speak. The interesting point about this Peat bed is that the whole thickness has been formed apparently during the historic period. This is shown by the fact that the trees which lie beneath it have been felled by the agency of man, as proved by the marks of tools and of fire on the stumps and felled timber. Nor could their destruction have been the work of savage man, for the forest extended over a considerable area, at least 10 miles in diameter; the trees were, many of them, of large size, and stood close together—in the angle between the North Eastern and Lancashire and Yorkshire Railways at Goole, where the forest bed is well shown by the removal of the top soil to form the embankments, I counted the stumps of 21 good-sized trees in a space 20 yards square—and although the marks which the stumps bear are those of rougher and less efficient tools than we possess at the present day, the clearing of such a forest must have been the work of a powerful and enterprising people. The common belief is that it was the work of the Romans, done to dislodge the British tribes; this opinion was propounded by Abraham de la Pryme, of Thorne, in the latter part of the 17th Century, and I see no reason to doubt its correctness; but the question is one for the Antiquary, rather than for the Geologist, and I do not feel competent to enter into it.* The felling of the forest has been the cause of the development of the Peat, partly by interfering

* Camden reports that "it is said, in the cut river to Gowle, there was found a Roman coin, either of Domitian or Trajan."

with the drainage, partly by affording a pabulum of decomposing vegetable matter, congenial to the growth of mosses and other Peat-forming plants. The heart-wood of the fir trees is very hard and tough, and in excellent preservation, but the tool marks are soon lost on exposure. There are large woods of Scotch fir in the East Riding, growing on the wet heathy surface of the same bed of Sand, and I am of opinion that these firs may be lineal descendants of those which anciently inhabited the district; if so, the Scotch fir must be considered a native here. The forest bed may be traced from Eastoft to Long Drax, thus crossing the Aire, and from Thorne to Goole, where stumps of trees may be seen in the river-bed between tide marks; but I do not know any instance of its occurring east of the Ouse. It is puzzling to find in the Hook Bridge section (Section 4) a bed of Peat seven feet six inches thick, 18 inches below the bottom of the river, *i.e.*, some 12 feet below the level of that at Goole. I am inclined, however, to suspect that this must be an older bed, occupying a hollow scooped out in the clay, which here is only 18 inches thick; no trees are mentioned. At Reedness (Section 3), a bed of Peat, nearly 12 feet thick, with fragments of rotten wood, occurred at the depth of 30 feet, and at Rawcliffe (Helliwell's Brewery, Section 9), six inches of Peat were found at a depth of 47 feet; these beds must have occupied hollows in the clay at the time when the land stood at a higher level than at present. At Askern and at Monk Fryston, close to the edge of the Magnesian Limestone, and filling up hollows in the clay, are superficial Peaty deposits containing abundance of shells. At each place there is a swampy pool, no doubt the remains of a large one which at some time filled up the whole area occupied by the shelly Peat; both these pools are fed by mineral springs—that at Askern by the stream from the Spa well; that at Monk Fryston by the spring which supplies the ancient aqueduct, known as the Hambleton Dyke—the water of this contains 182 grains per gallon of mineral matter, mostly Sulphate of Lime. The shells are all of existing kinds, most of which are found still living in the adjoining ditches and hedge-banks. The species which I noticed at Askern, were Limnæa stagnalis, L. palustris, and L. peregra, Planorbis corneus and P. marginatus, Helix nemoralis and Bithinia tentaculata. At Monk Fryston I found Helix caperata, H. rufescens, H. nemoralis, H. rotundata and H. pulchella, Zua lubrica, Limnæa peregra, L. truncatula and L. palustris, Bithinia tentaculata, Planorbis marginatus and Valvata piscinalis and a Pisidium.

6. *Warp.*—This is the name locally given to a peculiar sediment held in suspension in the tidal waters of the Humber and its tributaries. It is of a light chocolate colour, containing shining flakes of mica, and of a peculiar soft silky feel by which it may readily be recognised. The appended analysis (Table 1) by my friend Mr. Hunter, F.C.S., of Goole, shows that three parts out of four of it consist of sand, mica, and other matters insoluble in acid; lime and magnesia together constitute about 6 per cent., and alumina an equal proportion. The appearance and physical characters of the Warp are very different from those of the sediments deposited by the rivers in the non-tidal portion of their course, that of the Ouse being a coarse brown sandy loam; of the Aire, a black, loose, woolly-looking earth. The Warp too is most abundant at high-water, at spring tides, and in dry weather; and least so at low-water, during neap tides, and when much fresh water is coming down the rivers. These facts seem to show that it has a different origin from the ordinary detritus carried down by rivers, and that origin seems to be the materials removed from the rapidly perishing coast of Holderness. If so, it consists of the disintegrated materials of the boulder clay. It appears to reach its maxi-

mum in the lower reaches of the Ouse, probably because the opposing tendencies of the tide to wash it up, and of the river current to carry it down, are there most counterbalanced (See Table 2). On the hypothesis that the Warp is brought up by the tide from below, the fact that it occurs higher up the rivers than the salt water reaches, may be explained by supposing it to be washed up, bit by bit, at consecutive tides, the part deposited at one tide being carried up a little higher and again deposited at the next. The velocity of the flow of the tide being much greater than that of the ebb, its carrying power would be proportionately larger. On the other hand, the sea-salt being in solution, would be completely washed away by the water coming down from above.

In water that is at rest, or comparatively still, the Warp is soon deposited, and the sand and clay subsiding at different rates, the deposit is in distinct laminæ, often so thin as to resemble the leaves of a book. Hence the sloping sides of the river channel are covered with a deposit of firm mud in strongly-marked sloping layers; and as these mud-banks are readily removed and re-deposited by a change in the force or direction of the current, instructive examples of denudation on the small scale, and of cross-bedding, may often be seen. Of course, when the river overflows the land, the Warp held in suspension in the comparatively stagnant water is soon deposited. In the Goole district much of the surface lies below high-water mark, so that until the river was embanked it would be submerged at every tide, or at any rate every spring tide, consequently over a great part of this district the peat is covered with a layer of Warp, either natural or artificial. The land nearest the river would naturally get a greater share of warp than that at a distance, as the water which reached the latter would have been already partially purified by subsidence, consequently we find that the land adjoining the river is the highest part of the district. This bed of Warp is at Goole six feet in thickness, and is often clayey or sandy at the base. It contains no fossils. For the last century or so the practice of artificial warping has been carried on. To effect this, large drains have been cut from the river; the land intended to be warped is enclosed with a high bank, and a communication is then made with the warping drain, which allows the water to flow over the land at every tide. Sometimes in summer-time the cloughs at the mouth of the drain are closed at spring tide, so as to hold up the water and allow it more effectually to deposit its sediment. This process is continued two or three years, at the expiration of which time a deposit of sometimes three or four feet of rich soil will have accumulated. The pressure of this bed of soil compresses the subjacent peat, so that where the latter is thick the surface subsides to such an extent that another warping may be required in the course of a few years, otherwise it is not repeated.

The physical characters of this district must have been greatly changed by the embanking of the rivers, which is said to have been done in the reign of Edward III. (1327-77), and again by Vermuyden's drainage of Hatfield Chase, in the 17th century; this engineer having cut a new channel for the River Don, from Newbridge to Goole, and closed that which ran past Crowle into the Humber at Adlingfleet. The other mouth, which opened into the Aire at Snaith, has been silted up almost within the memory of men now living. These old river channels can now hardly be traced, except by the local names, and by the course of roads and position of buildings. In several places, as at Wistow, Selby, and Hemingbrough, the course of the Ouse has altered greatly in historic times by cutting through the isthmus between two bends, and the silting up of the old channel.

The severed portions of land still legally belong to the Riding and parish of which they were originally a part, thus showing that the solid crust of the earth may change sooner than parochial conservatism.

I have thus endeavoured to give an account of the appearances presented by the strata of the district in which I reside, so far as I have been able to ascertain them; but I can only guess at the way that they have been formed, and must leave the explanation of their origin to more experienced geologists.

Our secretary suggests that a microscopic examination of the sands and clays might possibly throw some light upon their origin. The time at my disposal has, however, been insufficient to allow me to do anything in this direction. Should I have opportunities in the future I will work at the subject, and if I obtain any results worthy of your attention I will bring them before you in another communication.

APPENDIX.

TABLE 1.

Analysis of Warp from Bank of River Ouse, Goole, by E. HUNTER, F.C.S., *Goole.*

(Dried at 160° C.)	PER CENT.
Sand, &c., insoluble in H Cl after 20′ boiling	76·67
Magnesia	1·41
Lime	4·79
Chlorine (= Na Cl 1·06)	0·68
Oxide of Iron and Alumina (latter about ⅜)	9·17
Phosphoric Acid (P_2O_5)	0·09
Carbonic Acid	3·00
Sulphuric Acid ($S O_3$)	0·40
Organic Matter (containing Nitrogen 0·168) (and Ammonia 0·204)	2·51
Potash, Soda, &c., not determined	1·38
	100·00

Table 2.

Analysis of River Water taken at High-Water Spring Tides, on October 1st, 1875. H. F. P.

Place.	Miles from Sea.	Contents Grs. per Gallon.			Per centage of Sea-water.
		Suspended Solids. (Warp.)	Dissolved Solids.	Sea-Salt.	
R. Humber, Whitton	37	30	790	700·	30·
R. Ouse, Whitgift	43½	88	297	242·	10·5
,, Swinefleet	46½	148	122	85·7	3·7
,, Goole	49	47	123	90·7	3·9
,, Booth Ferry	54	45	15	4·9	·15
,, Langrick	57½	27	15	2·9	·07
,, Newhay	60	18	17	2·6	·04
,, Selby	65½	12	15	1·1	·0
Sea-water, Bridlington	—	Trace	2483	238 3·	100·

Section 1.

Artesian Well, Sandtoft, near Crowle, sunk in 1876, by Hatfield Chase Commissioners.

STRATA.	THICKNESS IN FEET.	FROM SURFACE.
Warp	3	3
Fine Red Quicksand	25	28
Red Clay...	6	34
Coarse Red Sand	16	50
Coarse Red Gravel (size of beans)	5	55
White Gritty Sandstone	26	81

Particulars given by Mr. E. C. B. Tudor, Surveyor, Goole.

Section 2.

Well at Luddington. Sunk in 1875, by Goole Rural Sanitary Authority. Site close to bed of Old Don River.

STRATA.	THICKNESS IN FEET.	FROM SURFACE.
Warp	13	13
Quicksand	12	25
Clay	12	37
Sand and Gravel	23	60

Particulars given by Mr. Tudor, Surveyor, Goole.

SECTION 3.

Trial Borings for Coal at Reedness, near Goole, made by the late Mr. Egremont, in 1835.

	STRATA.	THICKNESS. Ft. in.	FROM SURFACE. Ft. in.
1	Dark Soil	1 6	... 1 6
2	Yellow Sandy Warp	0 3	... 1 9
3	Dark Blue Warp	7 6	... 9 3
4	Fine Blue Clay	6 0	... 15 3
5	Blue Sandy Warp	6 0	... 21 3
6	Light Grey Sand with Water	9 0	... 30 3
7	Black Moor Earth, with some rotten wood, green moss (?) at the bottom	11 9	... 42 0
8	Strong Blue Clay	3 3	... 45 3
9	Grey Sand, with Water...	0 9	... 46 0
10	Black Gravel and Quicksand	10 3	... 56 3
11	Red Sand	1 5	... 57 8
12	Grey Sand and Gravel	5 4	... 63 0
13	Red Sand	3 4	... 66 4
14	Gravel and Sharp Sand	3 4	... 69 8
15	Red Marl, metal with grey specks ...	3 2	... 72 10
16	Red Sandstone, with gypsum and thin lists ...	8 1	... 80 11
17	Strong Blue Stone, with thin white beds ...	9 2	... 90 1
18	Dark Red Bind, with thin beds of Gypsum...	18 3	... 108 4
19	Strong Blue Stone	1 8	... 110 0
20	Red Bind, with thin beds of Blue Stone ...	10 3	... 120 3
21	Blue Stone..	4 10	... 125 1
22	Red Bind, with thin white beds, and hard lists of Blue Stone	8 6	... 133 7
23	Blue Bind	2 0	... 135 7
24	Red Bind, with thin hard lists of Blue Stone and Gypsum	7 7	... 143 2
25	Red Stone	8 8	... 151 10
26	Red Bind, with hard lists of Stone and some Gypsum	16 10	... 168 8
27	Blue Stone...	4 4	... 173 0
28	Red Bind, with thin beds of Gypsum ...	17 11	... 190 11
29	Blue Bind	1 9	... 192 8
30	Red Bind, with thin beds of Gypsum ...	6 8	... 199 4
31	Blue Stone and white parting	0 2	... 199 6
32	Red Stone, with blue lists	19 8	... 219 2
33	Blue Bind, with thin beds of Gypsum ...	22 6	... 241 8
34	Red Stone	5 6	... 247 2

	STRATA.	THICKNESS. Ft. in.		FROM SURFACE. Ft. in.
35	Blue Stone...	4 0	...	251 2
36	Red Bind, with hard lists and some white partings	6 6	...	257 8
37	Red Sandstone, with thin white partings ...	5 6	...	263 2
38	Blue Stone, thin beds, and Blue Bind partings	6 6	...	269 8
39	Blue Bind, with thin beds of Blue Stone ...	16 6	...	286 2
40	Red Bind, with thin beds of Gypsum ...	11 0	...	297 2
41	Blue Bind, with soft beds of Gypsum ...	8 3	...	305 5
42	Dark Soft Red Bind	32 5	...	337 10
43	Blue Stone	4 0	...	341 10
44	Red Sandstone	169 6	...	511 4
45	Red Bind	2 0	...	513 4
46	Red Sandstone	16 6	...	529 10
47	Red Bind, with lists of Blue Stone ...	3 6	...	533 4
48	Red Sandstone	233 6	...	766 10
49	Red Bind, with bright shining specks ...	3 2	...	770 0
50	Dark Red Bind	2 10	...	772 10
21	Red Sandstone	11 6	...	784 4
52	Dark Red Bind	1 0	...	785 4
53	Red Sandstone	19 6	...	804 10
54	Red Bind	2 3	...	807 1
55	Red Stone	74 3	...	881 4
56	Red Bind	1 0	...	882 4
57	Red Stone	24 6	...	906 10
58	Soft Red Bind	3 10	...	910 8
59	Red Sandstone	20 2	...	930 10
60	Dark Red Bind	1 0	...	931 10
61	Red Sandstone	24 0	...	955 10
62	Dark Red Bind	1 3	...	957 1
63	Red Sandstone	38 3	...	995 4
64	Light Red Sandstone	3 0	...	998 4
65	Red Sandstone	30 8	...	1029 0

Records of Borings given me by Mr. John Bennett, Goole.

N.B.—In this section I take 1–6 to represent the Warp; 7, the Peat; 8, the Laminated Clay; 9–14, the Gravel; 15–43, the Keuper; and 44–65, the Bunter. The site of the boring is near the river Ouse.

H. F. P.

Section 4.

Section met with in sinking Cylinders for Bridge over River Ouse, at Hook, near Goole, on Hull and Doncaster Branch of North Eastern Railway.

	Thickness Ft.	in.		From High-water Mark. Ft.	in.
Low-water Mark	12	0	...	12	0
Bottom of River	8	0	...	20	0
River Mud	1	6	...	21	6
Peat	7	6	...	29	0
Sand and Gravel	3	0	...	32	0
Clay	1	6	...	33	6
Sand and Gravel	4	6	...	38	0
Soft Clay	1	6	...	39	6
Soft Blue Shale	12	0	...	51	6
Strong Blue Shale with Gypsum	3	6	...	54	0

From drawing preserved in Mechanics' Institute, Howden.
N.B.—Ground-level about four feet below high-water mark.

Section 5.

Well in George Street, Old Goole. June, 1876.

	Thickness in Feet.		From Surface.
Warp	4	...	4
Quicksand	1	...	5
Peat	1	...	6
Quicksand	7	...	13
Strong Blue Clay	20	...	33
Sand, bluish, then rusty, then red	30	...	63

From particulars given me at time of sinking well by Mr. J. W. Jackson, Builder, Goole.

Section 6.

Artesian Well at Pemberton's Brewery, Goole. 1876.

Strata.	Thickness. Ft.		From Surface. Ft.
Top Sand	4	...	4
Peat	2	...	6
Clay	22	...	28
Gravel	7	...	35
Red Clay	5	...	40
Sand	6	...	46
Hard Sand	10	...	56
Gravel and Sand	9	...	65
Clay and Cobbles	10	...	75
Red Sandstone	—	to	200

Particulars from Mr. Tudor, Surveyor, Goole.

Section 7.

Well in Bennett's Town, Goole. September, 1876.

Strata.	Thickness. Ft.	in.		From surface. Ft.	in.
Warp, Clayey towards base	4	6	...	4	6
Peat	1	0	...	5	6
White Quicksand	1	6	...	7	0
Strong Clay, about	35	0	...	42	0
Gravel, consisting of water-worn fragments of Coal-measure Sandstone ...	—			To bottom.	

H. F. P.

Section 8.

Trial Borings for Waterworks, Booth Ferry Road, Goole. Made by Goole & Hook Parochial Sanitary Committee, in 1876.

Strata.	Thickness. Ft.	in.		From surface. Ft.	in.
Warpy Sand	4	4	...	4	4
Warpy Clay	0	6	...	4	10
Peat	0	6	...	5	4
Fine stiff Clay	6	8	...	12	0
Red Clay	5	0	...	17	0
Rough Gravel	8	0	...	25	0
Warp Clay—a large Pebble	3	0	...	28	0
Red Sand	6	0	...	34	0
Hard coarse light red Sand	24	0	...	58	0
Red Marl	10	0	...	68	0
Hard Sand	11	0	...	79	0
Red Marl	3	0	...	82	0
Hard Sand	26	0	...	108	0
Red Marl	1	0	...	109	0
Hard Sand	61	0	...	170	0
Red Marl	3	0	...	173	0
Hard coarse Sandstone, with small Pebbles ...	3	0	...	176	0
Red Sand and Marl, mixed	84	0	...	260	0
Red Sand	22	0	...	282	0
Stiff Red Marl	2	2	...	284	2
Marl and Red Sand	22	1	...	306	3
Red sandy Marl	—		to	366	0

Particulars given by Mr. E. C. B. Tudor, Surveyor, Goole.

Section 9.

Artesian Well at Helliwell's Brewery, Rawcliffe. Well deepened in 1876.

	Thickness. Ft.	in.		From Surface. Ft.	in.
Old Well	18	0	...	18	0
Yellow Sand	27	0	...	45	0
Blue Clay	2	0	...	47	0
Peat	0	6	...	47	6
Clay, with Gravel	12	0	...	59	6
Red Sand	—		to	200	0

At 139 feet a thin layer of Red Marl.

Particulars from Mr Helliwell, Rawcliffe.

Section 10.

Artesian Well at Rawcliffe Hall. 1877.

	Thickness. Ft.		From Surface. Ft.
Silty Stiff Red Warp	16	...	16
Red Sand and Marl	114	...	130
Coarse, Loose Red Sand Stone, and Marl ..	120	...	250

Particulars from Mr. Tudor, Surveyor, Goole.

Section 11.

Well near Rawcliffe Station.

	Thickness. Ft.		From Surface. Ft.
Black Top Sand	3	...	3
Brown Coarse Sand	2	...	5
Mottled Brown Clay	3	...	8
Red Sand	—	...	Bottom.

H. F. P. Nov. 10th, 1876.

Section 12.

Trial Borings for Water, at New Bridge, near Snaith, in Site of Ancient Course of River Don, made in 1876 *by Goole Local Board.*

	Thickness. Ft.	in.		From Surface. Ft.	in.
Brown Warp	6	0	...	6	0
Grey Loamy Warp	2	0	...	8	0
Peat (contained a hazel nut)	1	0	...	9	0
Whitish Sandy Loam	4	0	...	13	0
Brown Warpy Clay	20	6	...	33	6
Brown Sandy Warp	7	0	...	40	6
Brown Alluvial Earth, with Pebbles ...	5	6	...	46	0
Gravel containing worn pebbles of Sandstone and Chert, and Flat Fragments of Magnesian Limestone	5	0	...	51	0
Coarse reddish-brown Sand	5	0	...	56	0
Light green Marl	1	0	...	57	0
Red Marly Sandstone	23	0	...	80	0
Coarse Red Sandstone	7	0	...	87	0
Red Marly Sand	43	0	...	130	0
Red Sand, with Green Marl	3	0	...	133	0
Red Marly Sand	37	0	...	170	0
Blue Marl	3	0	...	173	0
Red Marl	2	0	...	175	0
Red Marly Sand	88	0	...	263	0
Variegated Marl	2	0	...	265	0
Red Marly Sand	44	0	...	309	0
Coarse Red Sand	20	0	...	329	0
Red Marly Sand	48	0	...	377	0
Variegated Marl	2	0	...	379	0
Red Marly Sand	24	0	...	403	0
Variegated Marl	1	0	...	404	0
Red Marly Sand	—		to	500	0

Particulars given, and samples shown me, by Mr. Tudor, Surveyor, Goole.

SECTION 13.

Section in Artesian Well, Selby Waterworks, 1853. *From plans preserved by Selby Local Board.*

	THICKNESS. Ft.	in.		FROM SURFACE. Ft.	in.
Alluvial Soil and Sand	5	0	...	5	0
Clay	24	0	...	29	0
Sand, with Water	1	0	...	30	0
Clay	24	0	...	54	0
Quicksand	21	0	...	75	0
Red Sandstone, increasing in hardness with depth	211	6	...	286	6
Very hard Rock	10	6	...	297	0
Red Sand Stone	6	3	...	303	0
Very hard Rock	—		to	330	0

N.B.—At 93 ft. occurred 1 inch of Marl, like Fuller's Earth. At 103 ft. 3 in. an inch of Grey Sandstone.

SECTION 14.

Artesian Well at Smith's Steam Flour Mill, Cawood. Made in 1852.

	THICKNESS. Ft.		FROM SURFACE. Ft.
Sand	3	...	3
Clay...	57	...	60
Quicksand	30	...	90
Red Sand	4	...	94
Grey soft Sandstone	240	...	334

Communicated by Mr. Matthew Smith, from memory.

November 30th, 1876.

SECTION 15.

Artesian Well at Osgodby Hall

	THICKNESS. Ft.		FROM SURFACE. Ft.
Loamy Soil	2	...	2
Clay	4	...	6
Sand	4	...	10
Clay	15	...	25
Red Sandstone	—	...	200

Boring made a good many years ago. Particulars given from memory, by Mr. Riley, Osgodby.

Section 16.

Well at North Eastern Railway Lodge, between Barlby and Riccall. Sunk in 1876.

	Thickness. Ft. in.		Total. Ft. in.
Top Soil	1 6	...	1 6
Sand	3 0	...	4 6
Clay	12 0	...	16 6
White Quicksand	1 0	...	17 6
Clay	—	...	Bottom.

Particulars given by Mr. W. Wetherill, Sanitary Inspector, Selby.

Section 17.

Brickyard between Riccall and Escrick.

	Thickness. Ft. in.		From Surface. Ft. in.
Top Soil	1 0	...	1 0
Brown Peaty Sand	1 0	...	2 0
Yellow Sand; surface eroded; hollows lined with thin parting of Clay	2 0	...	4 0
Coarse Brown Sand	1 0	...	5 0
Gravel	0 6	...	5 6
Laminated Clay		To bottom	15 6

H. F. P.,

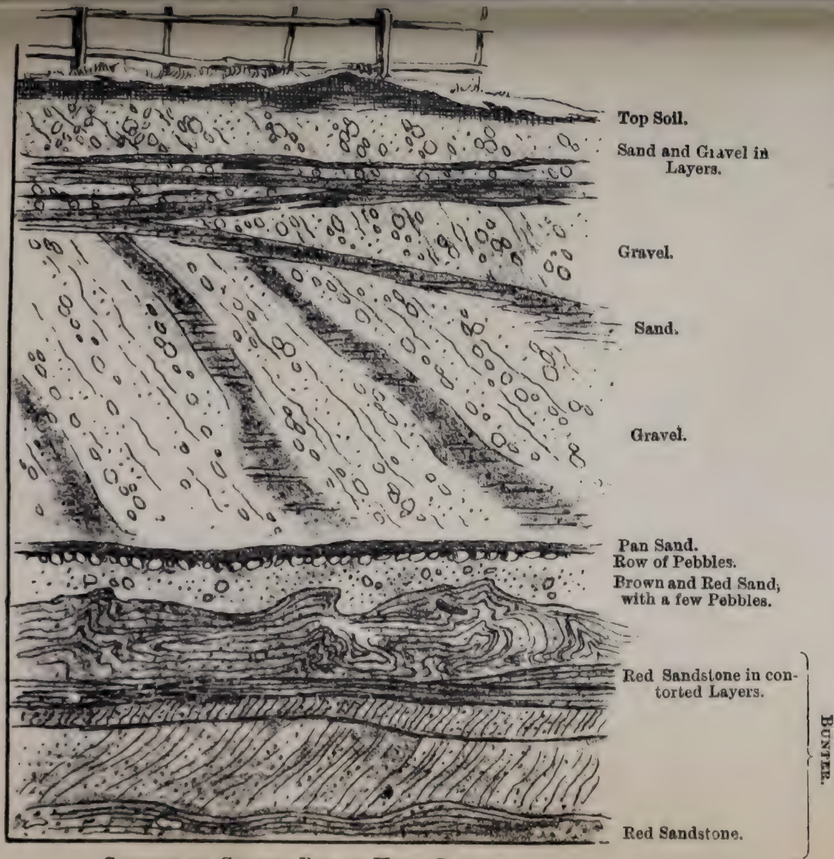
March 19th, 1877.

Section 18.

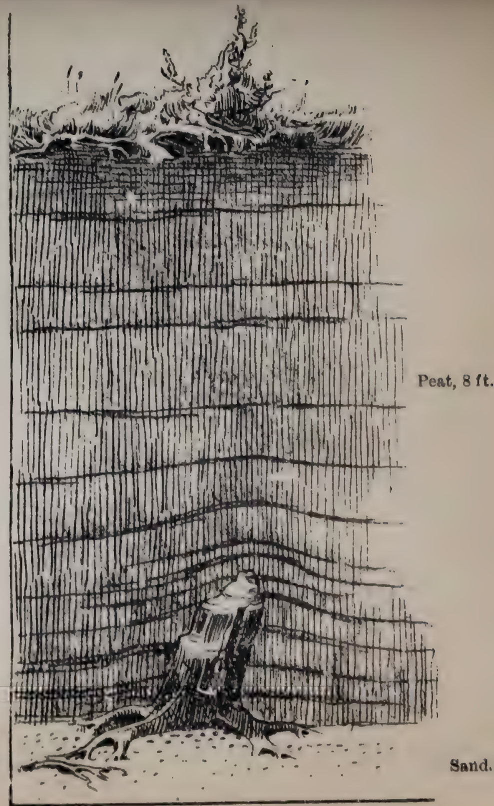
Brickyard at River Bridge, by Market Weighton Canal.

Strata.	Thickness. Ft. in.		From Surface. Ft. in.
Warp	1 0	...	1 0
Peat	0 6	...	1 6
Sand, white under Peat, then strongly ferruginous, then yellow, gravelly at bottom ...	8 0	...	9 6
Grey Clay, strongly laminated	15 0	to bottom	24 6

H. F. P., March 22nd, 1877.



Section in Gravel Pit at Heck Station.



Section in Drain on Goole Moor, Near Moor Ends Farm.

A. Parsons, del. et lith.

McCorquodale & Co., Printers, Leeds.

ON A BASE TO THE CARBONIFEROUS ROCKS IN TEESDALE.

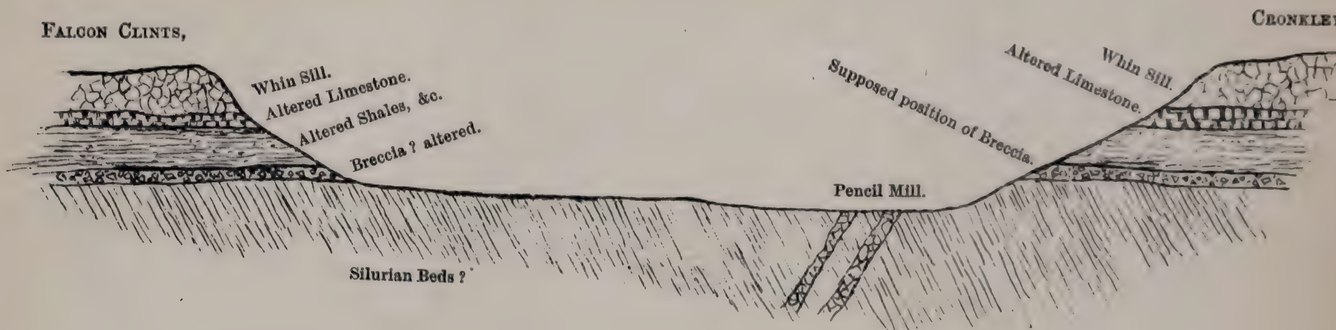
BY J. R. DAKYNS, ESQ., M.A., OF H. M. GEOLOGICAL SURVEY. (PL. IX.)

I PAID a visit early in November, 1876, to Teesdale, where I saw certain sections, the bearing of which is not generally known to Geologists. The part of Teesdale I refer to is that above the High Force. I may premise that this part of the dale is in the heart of the Carboniferous area; Fells composed of Carboniferous rocks rise on all sides; and I never heard it suggested that any other than Carboniferous beds were to be found in any part of the dale, with the exception, of course, of intrusive rocks; but this suggestion I am about to make, or rather have already made.

The sections I wish to call attention to are two; one at the foot of the Falcon Clints, and the other on the bank of the Tees at the Old Pencil Mill below Cronkley, and about a couple of miles below the section at Falcon Clints. (Plate ix.)

The section at Falcon Clints has, I believe, been described by Sedgwick. It is on this wise: The precipitous crag called Falcon Clints is formed by the Whin Sill; immediately beneath the Whin is a bed of Limestone (one of the Carboniferous beds) highly altered into a sugary crystalline rock; below the Limestone we have what seemed to be alternations of Shale and Sandy beds and Limestone, all more or less altered; and at the very foot of the bank, just above the alluvium, is seen about a foot of peculiar Breccia. This Breccia, of which I have sent a few small hand specimens to Professor Green, reminds me of the basement bed of the Carboniferous series as seen in Ribblesdale and Chapel Dale, above Ingleton. As all the beds between the Breccia and the Whin are more or less altered, I should suppose that the Breccia is itself altered; and it is possibly owing to this alteration, induced by the Whin above, that the round pieces of quartz owe their existence. They may be the kernels of an amygdaloid, due to alterations; or some of them may be true pebbles.

The next section in going down the river is at the Old Pencil Mill, below Cronkley. Cronkley, too, like Falcon Clints, is composed of Whin; and beneath the Whin Crag can be seen in various places, particularly at the White Force (which probably takes its name from the conspicuous white Limestone there seen), a white sugary crystalline Limestone; but the beds below the Limestone are not seen; at least we do not see as far down as the Breccia. The hill side is covered with *débris* all the way down to the Pencil Mill. Here we have a very interesting section: beds of hardened Shale traversed by dykes of Mica trap. These dykes were discovered by my friend, Mr. W. Gunn, who remarked their total dissimilarity to anything else in the country. They are, however, like dykes in the Kendal country, which are not known to pierce the Carboniferous beds, but seem to be confined to the Silurians. The beds traversed by these dykes on the banks of Tees looked to me a deal more like Skiddaw slate than Carboniferous Shale; and they are crossed by divisional planes (whether bedding or cleavage) at high angles, while the Carboniferous beds are lying at low angle, and (it is needless to say) are not cleaved. Putting these three things together, viz., the Silurian character of the Mica trap dykes, the uncarboniferous look of the pencil beds (and I may here remark that in Westmoreland the Skiddaw Slate was once similarly worked for slate pencils, before such could be got more cheaply from elsewhere), and the presence of Breccia at the foot of Falcon Clints, it struck me that we might have in the Breccia the base of the Carboniferous rocks reposing on Silurian rocks, possibly Skiddaw slate, but at all events Silurians; and I made the suggestion then and there to Messrs. Gunn and Clough, who accompanied me on my visit to the pencil beds.



Diagrammatic Section to show the relation of the Beds in Teesdale.

The observer is supposed to be looking down the river and across it, so that Falcon Clints is on the left-hand bank, and Cronkley on the right.

J. R. Dakyns, del. A. Parsons, lith

McCorquodale & Co., Printers, Le

The following diagrammatic section will render plain what I conceive to be the relation of the beds.

I mentioned above, that at the White Force the Whin overlies a bed of altered Limestone; in some places, however, a bed of baked Shale intervenes between the Whinsill and the altered Limestone; and the specimen I sent to Mr. Green is from this band at the White Force.

Before closing, I would like to say a word on the term "Sill." This term simply means bed or layer, as we say a bed of coal; it is the usual word for bed in the North. They talk of Grit Sills as well as Whin Sills. They say Whin Sill, because the Whin so generally lies horizontally, in a bed-like form, between the other beds. The word "Sill," though confined in this use to certain parts of the country, is the word familiar to all in the term "window sill." In parts of Lancashire they call the rock over a coal-seam the "Roof," and the rock below it the "Sill Rock."

The first part of the name, Falcon Clints, indicates the crag as an abode of falcons. The word "clints" is probably expressive of the ringing sound made by the bits of broken whin when struck as one walks over them. In parts of Westmoreland ground covered with similar ringing fragments of limestone is called "clinty ground."

Postscript.—Since my visit to Teesdale in November, 1876, the suggestions I then made of there being a bottom to the Carboniferous system in that dale has been completely verified by Messrs. Gunn and Clough. See their paper on the subject, read before the Geological Society of London, and Mr. Gunn's paper, read before the British Association at Plymouth.

Since writing the above paper I have had another opportunity of seeing the Pencil Beds. While I still think them more like Skiddaw slate than anything else, where I first saw them, yet, in other spots they are more like the Pale

Slates. Unfortunately there is no dip to be made out in the Teesdale sections, and I have had no opportunity of examining the exposures of Silurian rocks beneath the Permian escarpment, so as to be able to form an idea of the probable age of the Teesdale Beds.

ON THE GENUS POTERIOCRINUS AND ALLIED FORMS.

BY W. PERCY SLADEN, F.L.S., F.G.S. (PLATE X.)

HAVING had occasion latterly to devote some attention to the different species of Crinoids which have been referred by various writers to the genus *Poteriocrinus*, the author is induced to lay the following notes before this Society, in the hope that they will prove interesting and useful to other members who may be occupied with the determination of our Yorkshire fossil Echinodermata.

The basis upon which modern biological classification rests is so much more extensive than that which sufficed only a few decades ago, and the principles which are involved in the process are so much more fundamental and real, that no apology is requisite for undertaking all such necessary revision as the advance of knowledge imposes, *pari passu* with its own progress, upon the naturalist who conscientiously applies himself to the study of any special group of organisms.

Furthermore, less hesitation is felt in bringing the results of this examination to notice, than might otherwise be the case, since the ground which it is intended to cover has not been traversed for a considerable number of years, during which time, it is hardly necessary to say, very numerous additions have been made to the knowledge of the group both at home and abroad.

The genus *Poteriocrinus* was established by Miller in 1821, and in the systematic arrangement of the Crinoidea which he then proposed, stood as the representative genus of an entire section, in consequence of certain peculiarities presented by the plates, which compose the calyx or body-cup of the animal, being regarded by him as constituting characters of primary value in classification. Subsequent investigation having shown that these details of structure were not associated with other special features, and presented no distinctions which would warrant their employment for such a purpose, this arbitrary and erroneous view has long since been discarded; and it will not, therefore, be needful to encumber the following remarks with further allusions upon the subject.

The present paper will be confined solely to the consideration of British Carboniferous forms of *Poteriocrinus*, leaving for some future occasion a review of the extreme limits of the variability of the genus, as indicated by its distribution in time and space.

I.—*A List of British Carboniferous Crinoids which have been assigned by various Authors to* POTERIOCRINUS, *Miller.*

The following species have been described as belonging to the genus *Poteriocrinus* :—

By MILLER[1]	*P. crassus.*
	P. tenuis.
By PHILLIPS[2]	*P. impressus.*
	P. conicus.
	P. granulosus.
	P? nobilis.
	P? Egertoni.

(1) Miller—A Natural History of the Crinoidea.

(2) Phillips—Geology of Yorkshire. Part II.

By MM. Austin[3] *P. isacobus.*
P. rostratus.
P. plicatus.
P. radiatus.
P. quinquangularis (Miller).
P. latifrons.
P. dactyloides.
P. pentagonus.
P. longidactylus.
P. abbreviatus.

By McCoy[4] *P. nuciformis.*
P. crassimanus.
P. gracilis.
P. (Cupressocrinus) impressus.
P. (Cupressocrinus) calyx.

By De Koninck[5] *P. McCoyanus.*
P. spissus.

II.—*Diagnosis of the genus as now restricted, with a List of Species referable thereto.*

Poteriocrinus (Miller), Amend.

Calyx longer than broad; contour, truncate obconical.

Basal plates, five; more or less elongate, springing directly from the column, and at no great angle of outward divergence.

Sub-radials, five; alternating with the basals; usually longer than broad.

First radials connected laterally, generally wider than long; pentagonal, except the two postero-lateral, which are subject

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(3) Austin (T. and T. jun.)—A Monograph on Recent and Fossil Crinoidea.

(4) McCoy—Annals and Mag. of Natural History. Series 2, vol. iii., p. 244. Griffiths—Carb. Limest. Foss. Ireland, p. 178.

(5) De Koninck and Le Hon—Recherches sur les Crinoides du Terrain Carbonifère de la Belgique.

to modification according to the development of the anal plates. One of the first-radials generally rests upon the upper truncate margin of a sub-radial.

Free radials variable in number and also in relative breadth, according to the species; generally broader than long.

Arms bifurcating more or less frequently; ossiculæ arranged in single series, with their articulating margins parallel. "Brachial plume" meagre, and generally incapable of being so closely apposed as was the habit in such genera as *Zeacrinus* and *Scaphiocrinus*.

As thus limited, the genus *Poteriocrinus* will include the following British Carboniferous forms, viz.:—

(i.) *P. crassus*, Miller.
P. spissus, De Koninck.
P. conicus, Phillips.
(ii.) *P. plicatus*, Austin.
P. impressus, Phillips.
(iii.) *P. radiatus*, Austin.
P. quinquangularis (Miller), Austin.

III.—*Diagnoses and Descriptions of Allied Genera, with Synonymy of the Species assigned to each.*

Dactylocrinus, gen. nov.

Calyx, very elongate; contour, truncate conoid.

Basal plates, five, long; of the same character as in *Poteriocrinus (ante)*.

Sub-radials, five, large; longer than broad.

First radials, connected laterally; pentagonal, rather long.

Free radials, a single plate to each ray (with an additional intermediate plate in some species); very elongate (the length generally exceeding the width several times); the upper margin bearing two articular facets.

Arms, simple after their first bifurcation on the articular primary radial; or bifurcating more frequently; composed of very elongate ossiculæ.

Forming a brachial system of the most meagre description when compared with some of the allied genera*; and quite incapable of being brought together into a closed plume.

The fossil which was figured by MM. Austin under the name of *Poteriocrinus tenuis,* may serve as the type of this genus. The general facies of the crinoid will readily distinguish it from the members of the allied groups. Its very elongate calyx, the single free-radials, and the simple arms with very elongate ossiculæ, present together an array of characters well worthy of being regarded as of generic value; and when compared with the true *Poteriocrinus*-forms, are indicative of morphological features of greater divergence than relationship within a single genus would reasonably admit. The following species will pertain to this genus.

DACTYLOCRINUS LOREUS, *mihi.*

Poteriocrinus tenuis, Austin (non Miller), Monog. Rec. and Foss. Crinoidea, pl. 10., fig. 5.

A comparison of MM. Austins' figure with that given by Miller in "A Natural History of the Crinoidea," clearly shows that the fossil of the former authors (apart from the inaccuracy of drawing ascribed by them to their predecessor), cannot be included in the same species, and that, consequently, another *nomen triviale* is required.

DACTYLOCRINUS TENUIS (Miller), Sladen.

Poteriocrinus tenuis, Miller, Nat. Hist. Crinoidea, p. 71, pl. 21, 23.

Poteriocrinus isacobus, Austin, Monog. Rec. and Foss. Crinoidea, p. 74, pl. 8, fig. 4a, 4b.

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* From our present knowledge it is impossible to say whether this was in any way compensated for by a larger development of pinnulæ; although such might be very naturally inferred.

Miller, in 1821 *(l.c.)*, when describing *P. tenuis*, himself expressed doubt as to the correctness of including the crinoid which he so named in the same genus as *P. crassus*, Miller. The *P. isacobus* of MM. Austin seems identical with the present species. In any case it is very much nearer than the fossil figured by them *as P. tenuis!* It should not be lost sight of, however, that in these forms the differences of appearance between various stages of growth may, in all probability, have been very considerable.

DACTYLOCRINUS ELONGATUS, *mihi.*

Poteriocrinus rostratus, Austin, *pars.* Monog. Rec. and Foss. Crinoidea, pl. 9, fig. 2b. *(caet. fig. exclu.)*

One of the fossils figured by MM. Austin under the name of *P. rostratus*, differs so widely from the others included by these authors under the same denomination, that little or no hesitation can be felt as to the correctness of its removal from that species.

MM. Austin themselves remarked (*l. c.* p. 84,) on the affinities existing between *P. rostratus* and *P. tenuis*.

SCAPHIOCRINUS. Hall.

Calyx, broad, depressed; contour turbinate or basin-shaped, gradually enlarging to the base of the arms.

Basal plates, five, small.

Sub-radials, five, small; hexagonal, except that on the anal side, which is truncated above by the first anal plate.

First radials, broad, pentagonal, with the upper side straight or slightly concave.

Free radials, a single series only, pentagonal, with the lower side straight; often much elongated, and the plate contracted or concave on each side.

Arms, double from their origin; and continuing simple to the extremity, or once bifurcating at a considerable distance from the primary articular radial; ossiculæ (arranged in single series) longer on one side than the other, and often wedge-form, with pinnulæ originating on the longer side.*

Brachial plume closely apposable.

SCAPHIOCRINUS LATIFRONS (Austin), Sladen.

Poteriocrinus latifrons, Austin, Monog. Rec. and Foss. Crinoidea, p. 82, pl. 10, fig. 4.

This crinoid presents many resemblances to *Scaphiocrinus scoparius,* Hall (Report Geol. Surv. Iowa, vol. i., pt. 2, palæont, p. 680, pl. 25, fig. 3). Our English specimen, however, differs mainly in the greater length of the second (or free) radials, and the proportionally smaller size of the other plates of the calyx. MM. Austins' figure does not indicate the wedge-shaped character of the brachial elements so pronouncedly as the American figure. S. *latifrons* possesses a greater number of plates in the secondary radials, and the arm-system or "plume" is more closely constrict and drawn together, in consequence, presumably, of the smaller development of pinnulæ. In *S. latifrons* the brachial plume is much more largely developed, and more robust in proportion to the size of the calyx-body than in *S. scoparius.*

ZEACRINUS (Troost), Hall.

Calyx, broad and gibbous; contour subglobose; base always rotund, more or less impressed, often deeply concave.

Basal plates, five, usually small and hidden by the column in the deep cavity of the base.

Sub-radials, five, pentagonal or hexagonal (rarely with six sub-radials).

First radials, five, pentagonal.

Free radials, one to each first-radial plate (and one or two additional intermediate plates on the anterior ray); pen-

* Sutures between the radial and arm plates usually more or less gaping exteriorly, with the edges of the plates rounded, as if the space had been filled with some cartilaginous or muscular substance during the life of the animal. *Cf.* Hall, Report Geol. Surv. Iowa, vol. i. pt. 2 (palæont.), p. 551.

tagonal, of the same form as the first radials, but relatively reversed.

Arms, bifurcating frequently, very robust; ossiculæ broad, arranged in single series, with inferior and superior margins parallel. The whole forming a very compact brachial plume capable of close apposition.

ZEACRINUS MCCOYANUS (De Koninck), Sladen.

Cupressocrinus impressus, McCoy, Ann. Nat. Hist., ser. 2, vol. iii., p. 244.

Poteriocrinus McCoyanus, De Koninck, Rech. s. les Crin. Carb. Belgique, p. 91, pl. 1, fig. 7.

There is little doubt that this species is a true *Zeacrinus*; apart from its general resemblance, the very character which led to McCoy's specific name is a striking feature in the genus. The trivial designation *impressus*, was pre-occupied by Phillips, for a true *Poteriocrinus*.

ZEACRINUS CALYX (McCoy), Sladen.

Cupressocrinus calyx, McCoy, Ann. Nat. Hist., ser. 2, vol. iii., p. 244.

Poteriocrinus calyx, De Koninck, Rech. s. les Crin. Carb. Belgique, p. 90, pl. 1, fig. 6.

As a *Poteriocrinus*, this would be a most abnormal form! It naturally associates itself much more closely with the present genus. More perfectly preserved specimens are, however, greatly to be desired.

ZEACRINUS GRANULOSUS (Phillips), Sladen.

Poteriocrinus granulosus, Phillips, Geol. Yorks., Pt. II., p. 205, pl. 4, figs. 2, 4, 8.

The depressed calyx, the almost hidden basal plates, and the character of the radial articulating surfaces, all warrant the inclusion of this species in the present genus.

ZEACRINUS PHILLIPSII, *mihi.*

I have no hesitation in referring the fine plume designated by Phillips "arms of Cyathocrinus" (Geol. Yorkshire, Pt. II., pl. 3, fig. 38) to this genus. The figure calls to mind such forms as *Z. Troostianus,* Meek and Worthen (Pal. Illinois, pl. 16, fig. 2), and *Z. elegans,* Hall (Geol. Surv. Iowa, vol. i., pt. 2, palæont., pl. 9, figs. 1 and 2).

IV.—*Comparative Review of the Groups above-mentioned.*

An examination of the resemblances and differences presented by these genera will find place more appropriately here than at the close of the description of each type separately; since the affinities which exist between allied groups render such a review more intelligible and interesting when the forms in question are considered together and placed side by side for comparison.

In the first instance it should be borne in mind that Naturalists have been content, hitherto, in the classification and grouping of Crinoids, to base their determinations upon differences in the arrangement and relative proportions of those plates alone which enter into the composition of the calyx or body-wall of the crinoid; and have neglected almost entirely any consideration of the general morphology, or physiognomy even, of the forms to which they have assigned type-characters.

Although it be true that through the action of co-relation every portion of an organism will become altered more or less, according as the surrounding conditions of life induce changes in the organs upon which these parts stand in immediate dependence; yet it is self-evident that a classification founded upon a general comparison of type with type, *taken as wholes,* is more likely to be a natural and philosophical grouping, than one which is based solely upon the variations of an isolated feature, however great its importance *per se* may be. For although slight differences may be maintained with a persistency which points to organic and functional relations of undoubted importance; in most instances, ignorance of the anatomy and physiology of extinct organisms prevents any definite indication of *what* value such characters may really be, in a classificatory point of view.

The fragmentary condition in which fossils are often found preserved, and the frequently limited supply of material, as well as total uncertainty about the functions dependent on obscure peculiarities of structure, too often limit the number of characters available for classification. On the other hand, the continuous increase which has been made of late years to Palæontological knowledge has rendered the solution of many problems possible, with which formerly we were unable to cope. Perhaps few better examples could be named than the subjects of the present communication.

The four Groups of Crinoids herein described all agree in the number and general arrangement of the plates which form the calyx or body-cup; in other words, the numerical elements of the essential portions of their generic formulæ are identical. The special proportions of these plates, however, and the general characters of the crinoids, differ in each; and when the whole sum of the resemblances and differences of genus with genus is compared, and when the types are examined in their entirety, few will dispute the propriety of establishing the Groups as above indicated.

In *Poteriocrinus* and *Dactylocrinus*, the form of calyx and the mode of attachment to the column, are similar; but *Dactylocrinus* differs from *Poteriocrinus* in having only a single series of very elongate free radials, a character suggestive of the genus *Scaphiocrinus*, from which *Dactylocrinus* is clearly separated by the contour of the calyx, the more elongate plates, and the much longer ossiculæ of the arms, which are not wedge-shaped, but have their articulating margins parallel.

Scaphiocrinus resembles the genus *Zeacrinus* in the depressed basin-shaped form of the calyx, though in the latter type the base is sunk in a deep concavity which usually hides the basal plates entirely from view. The two genera are further distinguished by the characters of their brachial plume; in *Zeacrinus,* the free radials are broad and touch one another laterally, having the arms many branched, and composed of broad, short ossiculæ with parallel margins; whilst in *Scaphiocrinus,* the free radials are usually more elongated, with generally more or less intermediary space between; and the arms are seldom, if ever, bifurcated more than once; and are composed of wedge-shaped plates, having one side longer than the other.

Although *Dactylocrinus* resembles *Scaphiocrinus,* in possessing but a single series of free radial plates in each ray, it is readily distinguishable from that genus by the obconical and elongate form of calyx, which in *Scaphiocrinus* is depressed and turbinate; and yet further separated by the relative proportion of the plates, all of which in *Dactylocrinus* greatly exceed the breadth by the length. The arms, too, present a very marked feature of difference, being in *Dactylocrinus* of meagre habit and composed of very elongate ossiculæ, with generally parallel articular margins, and are quite incapable of being folded together, or brought into close lateral contact; whilst in *Scaphiocrinus,* the arm-plates are cuneiform, and generally form, when closed, a compact and somewhat elongate brachial plume.

Explanation of Plate.

The References indicate the Original Figures.

Fig. 1.—*Poteriocrinus,* Miller.

(*Cf.* Austin, Monog. r. & f. Crinoidea, pl. 10, fig. 1, restored.)

1.

2.

3.

4.

Poteriocrinus and Allied Forms.

Fig. 2.—*Dactylocrinus*, Sladen.
(*Cf. id. ibid.*, pl. 10, fig. 5.)

Fig. 3.—*Scaphiocrinus*, Hall.
(*Cf. id. ibid.*, pl. 10, fig. 4.)

Fig. 4.—*Zeacrinus* (Troost), Hall.
(*Cf.* Hall, Geol. Surv. Iowa, vol. i., pt. ii., pl. 9, fig. 1.)

NOTE.—The figures here given are intended simply as diagrammatic representations of groups; and are not to be regarded as conveying any expression of acquiescence in their accuracy as delineations of species.

CHAIRMAN'S ADDRESS AT HUDDERSFIELD.

THOS. BROOKE, J.P., F.S.A.

THE Chairman, in the course of his opening address, said he regretted that he had not been a member of the Society for a much longer period than he had. One great object he had in joining the Society was that he might support and strengthen the hands of their local Secretary (Mr. Bentley Shaw), who had taken great interest in the Society for many years, and had been local Secretary for the Huddersfield district for thirteen or fourteen years. Mr. Shaw was extremely anxious to interest the public of his own neighbourhood in the Society. Since he (the Chairman) had been a member of the Society, he had looked over its papers and publications, and he had at least convinced himself that it had done, and was doing, and was able to do a great and valuable work for the district over which its area extended. In the neighbourhood of Huddersfield, especially, they ought to feel an interest in geological research and enquiry. One of the great trades—the staple industries of this neighbourhood, was in the stone which was sent out to various places; and surely the development of that trade must depend a good deal on the accurate knowledge of the geological formations out of which the stone was gathered. Huddersfield was a great manufacturing district, and they drew very largely from the products of the coal-measures of other parts of the Riding, and an intelligent knowledge of what these coal-measures consisted, and what was the origin of the article which they used so freely, must be of very great value to every one in the neighbourhood. Taking it as a general thing, he had found great interest shown in all matters of scientific education ; and the ceremony of laying the foundation stone of the new buildings for the Yorkshire College, which had taken place at Leeds the day previously, was a very good example of the increased interest in scientific learning and knowledge. After some further observations, the Chairman concluded by calling upon the Secretary to read the minutes of the previous meeting.

ON THE OCCURRENCE OF VERMICULITE IN ENGLAND.

BY GEORGE H. PARKE, F.L.S., F.G.S., ETC.

THAT the discovery of a mineral new to Britain cannot fail to be of interest to geologists, is my apology for bringing the matter before the members of this Society to-day ; but my desire is not so much to record the discovery as to obtain the help of those interested in geology in elucidating the geographical distribution of the mineral in question. The district of Furness, in North Lancashire, is rich in glacial *débris*, and it was during a field-day amongst the Boulder clay, on Walney Island, that the Vermiculite was first found by my friend Mr. C. E. Manby.

Walney is a small island separated from Barrow by a narrow channel, fordable in some places at low water, and very probably at one time formed a portion of the mainland.

Along the shore, and over the greater portion of the island, there is a mass of glacial *débris*, in the shape of a heterogeneous assemblage of Granites, Felsites, Quartzites, Slates, &c., &c.

Amongst the Granites, the Porphyritic Granite, of Wastdale, is most common, and when newly dug out of the clay is as fresh, hard, and perfect as if recently detached from the rock; but where exposed to the action of the weather and sea-waves, the boulders are quite soft from decomposition. The Vermiculite is found in both Red and Grey Granite, taking the place of Mica, with Quartz and Felspar; but although I have made very careful examination, I have been unable to trace it in the Shap or Wastdale Granite, boulders of which are so plentifully strewn over the Furness district.

The only notice of this mineral I am acquainted with appears in Dana's Mineralogy, page 493, wherein it is mentioned as having been named by Mr. T. H. Webb, in the American Journal of Science for 1824, and it is described as "Hexagonal, being optically uniaxial. Occurs in small foliated scales, distributed through a steatitic base, and hence scaly—massive; lustre somewhat talc-like; colour greyish, somewhat brownish. When heated, exfoliates prodigiously, the scales opening out into long worm-like threads, made up of the separate folia. Exfoliation commences at 500° to 600° F., and takes place with so much force as often to break the best tube in which the mineral may be confined. Occurs at Millbury, near Worcester, Massachusetts. Named by Webb, as he says, from the Latin *Vermiculor, I breed worms.*"

An analysis follows this description by a Mr. Crossley—"Silica, 35·74; Alumina, 16·42; Protoxide of Iron, 10·02; Magnesia, 27·44; Water, 10·30=99·92." I am able to give very complete analyses—both before and after the application of heat—made from specimens cleanly separated from the base :—

Percentage Composition of Vermiculite.

	Before Ignition.	After Ignition.
Ferric Oxide	22·78 (15·95 Iron)	26·00 (18·20 Iron)
Manganic Oxide	1·50	1·72
Alumina	6·24	7·12
Titanic Oxide	1·15	1·32
Lime	2·19	2·50
Magnesia	11·83	13·50
Phosphoric Acid	0·49	0·56
Soda	3·19	3·64
Insoluble Residue*	38·23	43·64
Water, *combined*	12·40	None
	100·00	100·00

*Percentage of Insoluble Residue.

Silica	85·00
Alumina	10·20
Soda	4·80
Magnesia	Trace
Sulphuric Acid	Trace
	100·00

The examples I have here vary in size from $\frac{1}{32}$ to $\frac{5}{32}$ of an inch. When carefully detached from the matrix and placed on a platinum dish exposed to the flame of a spirit lamp or Bunsen's burner, the water in combination is driven off, and each piece of the mineral seen to exfoliate, lengthen, and twist about like a worm. Some attaining a length of $\frac{3}{4}$ of an inch without any decrease in diameter. The colour is now of a rich reddish brown, with a strong metallic lustre, and a slight pressure will separate the scale-like discs, which if crushed in the palm of the hand and well rubbed on the skin, leaves a stain with a dark brown bronze-like lustre.

Since the discovery of these boulders of Vermiculite Granite—as I propose to call it—I have met with examples some two miles inland, at an elevation of about 200 feet above the sea-level; and more recently have had a specimen given to me, said to have been found in Cornwall, but I am somewhat dubious about the accuracy of this locality. I am under the impression that Vermiculite Granite will be found in Yorkshire, especially in the northern division of the West Riding; and I trust our geological friends will carefully examine any granite boulders they may meet with in their excursions. It is only when the Granite is decomposed that the mineral can be properly separated from it; but even *in situ*, by careful observation, there will be no difficulty in detecting it. That these Granite boulders have travelled a long distance I am fully persuaded, and my belief is they have been transported to our shores in floating ice, very probably from Labrador.

NOTES ON CARBONIFEROUS CEPHALOPODA. PART I. RECENT CEPHALOPODA. BY WILLIAM CASH, F.G.S. (PLATE XI.)

The true method of reasoning on natural objects and phenomena, is from that which is well known to that which is unknown; hence it follows, that a sound knowledge of the structure and relations of Fossil Animals can only be acquired by a careful study of the structure and relations of their living analogues. These and similar considerations have resulted in prefacing the proposed "Notes on Carboniferous Cephalopoda," with the following remarks on the structure, habits, distribution, and classification of their living representatives.

The class Cephalopoda includes the most-highly organised members of the great Molluscan sub-kingdom. Its best known living types are the Argonaut, or Paper Nautilus, the Cuttle Fish, the Squid, and the Pearly Nautilus; whilst its extinct types include the Ammonite and the Belemnite, Fossils familiar to visitors at Lyme Regis and Whitby, who may see them offered there for sale in the shop-windows of the dealers, or may collect them for themselves from the Liassic strata, which are exposed in the cliffs and along the coast at those watering places.

The Cephalopoda have always been objects of great interest to the Naturalist. So long ago as the reign of Alexander the Great, Aristotle, the father of Natural History, aided by the munificent liberality of his royal patron, wrote his remarkable "History of Animals," and with wonderful discrimination pointed out the difference between the naked forms (μαλακια) and the Nautilus, a true shell-bearer; and though more than 2,000 years have passed since then, it is surprising how marvellously little alteration is required to adapt his descriptions, so far as they go, to the results of modern research. It is recorded of the great French Comparative Anatomist, Baron Cuvier, that whilst a young and ardent though comparatively unknown student of Zoology, he collected the Cuttle Fishes cast up on the sea shore, near his home in Normandy, dissected them and made drawings of them with their own ink, and thus laid the foundations of that brilliant reputation which he subsequently so justly won. Nearly half a century ago, Mr. George Bennett had the good fortune to capture, in Marekini Bay, at the island of Erromango, in the New Hebrides, a Pearly Nautilus (N. pompilius, Linné); this specimen was presented to the Royal College of Surgeons, London, and formed the subject of a valuable memoir, by Professor Owen.* The researches of such distinguished Naturalists as Van Beneden, Carus, Chéron, Clarke, Cuvier, D'Orbigny, Eschricht, Férrusac, Grant, Grenacher, Hancock, Harting, Hensen, Van der Hoeven, Huxley, Keferstein, King, Kölliker, Krohn, Lankester, Macdonald,

* "Memoir on the Pearly Nautilus," by Richard Owen. London, 1832.

Milne Edwards, Owen, Prosch, Rang, Rathke, Risso, Steenstrup, Trinchese, Valenciennes, Vérany, and Vrolik, some still living and working at the Cephalopoda, others speaking to us through their already accomplished work, have thrown a flood of light on the subject, and prove that the interest in this class of invertebrates has been handed down from one generation to another, and still survives; nor must we forget that the recently returned, and now celebrated "Challenger Expedition" has furnished material which promises to add to our knowledge of the Cephalopoda, for the numerous marine treasures brought to England include at least one perfect specimen of the Pearly Nautilus, which was captured between New Zealand and the Fijis, in a depth of 300 fathoms,* and it is very gratifying to learn that this and the other Cephalopods collected have been placed in the hands of a distinguished English professor for examination and description.

STRUCTURE.

The name Cephalopoda (Greek, κεφαλή, head; ποῦς, foot) has reference to the peculiar arrangement of the lobes (brachia) of the foot, in a circle around the head of the animal; this feature alone serves to distinguish the members of the group from all other molluscs whatsoever; whilst their highly developed nervous system and complex sensory organs at once declare their great superiority physiologically, and place them at the head of their sub-kingdom.

General Form and Relations of the External Parts.

Figs. 1 and 2 are sketches of a Cephalopod,† showing the relation of the arms to the head just mentioned, a relation which is constant in all the genera; and also illustrating the following common characteristics:—

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* "Log Letters of the Challenger, by Lord George Campbell." London, 1877.

† From a specimen of Ommatostrephes todarus, Delle Chiaje, preserved in spirits, and collected in the Irish Sea, 1875.

The presence of a muscular mantle (M), enveloping a cylindrical or pouch-shaped body, to which anteriorly is attached a well-developed head (H), furnished with a pair of complex eyes (E), the lobes (brachia) of the so-called foot (A A A) are arranged in a circle around the mouth, which latter organ is armed with a pair of horny, bird-like mandibles (B), which work vertically. In the ventral region a fold of the mantle is prolonged into a funnel or siphon (F.)*

GENERAL FORM AND RELATIONS OF THE INTERNAL PARTS.

Fig. 3 is a diagram of the internal anatomy of a Cuttle Fish. The buccal mass (A), and the horny mandibles (B), along with the fleshy tongue or odontophore, with its siliceous radula, crown the long œsophagus or gullet; it is into this latter organ that the salivary glands (D) pour their secretion. The stomach (E) is connected anteriorly with the alimentary canal, and posteriorly with the plyloric cœcum (F), the liver (I) is connected with this organ by its hepatic ducts, the pyloris is continued to the intestine (G), which, bending upon itself, has its flexure neural, that is towards the nerve masses, and away from the heart (N); the intestine opens by the anus (H) into the mid-ventral region. Close by the orifice of the anus is that of the ink-bag (K), an organ, however, which is only found in the Dibranchiates. The position of the generative organs is indicated by the letter (O), and that of the plume like gills on the one side, by the letter (M).

* For description of the general anatomy of the Cephalopoda, see "The Anatomy of Invertebrated Animals," T. H. Huxley, Lon., 1877; and "Forms of Animal Life," by George Rolleston, Oxford, 1870. For classification, &c., see "Manuel de Conchyliologie," Tome 1, J. Chenu, Paris, 1859; "Mollusques Vivants et Fossiles, Céphalopodes," A. D'Orbigny, Paris, 1855, and "Manual of the Mollusca," with appendix by Ralph Tate, S. P. Woodward, Lon., 1871. For description of Species, see "A Description of British Mollusca and their Shells," E. Forbes and S. Hanley, Vol. iv., Lon., 1853. "British Conchology," by J. G. Jeffreys, Vol. v., Lon., 1859. "Conchologica Iconica," "Lovell Reeve, Monographs on Nautilus and Argonauta," Lon., 1861. "Mollusques Meditn. Céphalopodes," J. B. Vérany, Genoa, 1851; and "Histoire Naturelle des Mollusques, Monographie Céphalopodes," Férrusac et D'Orbigny, Paris, 1834-5.

Fig. 4 is taken from a dissection of the nervous system of Eledone cirrosa,* Lamarck. The three principal pairs of nerve ganglia, namely, the cerebral, pedal, and parieto splanchnic, occur, as in the rest of the true Mollusca, but, being aggregated together, their connecting threads (commissures) are not easily made out.

In Fig. 4 are displayed the nerves of the arms (A A A), &c.; the auditory nerves (B); the nerves of the funnel (C); the accessory nerve of the mouth (D); the pallial nerves (F) terminating in the singular bird-foot-shaped ganglia; the branch of the visceral nerve to the muscles of the body (G); the ganglia of the branchial hearts (H); and the branchial ganglia (I). The nerves of the eye (optic) are largely developed.

The Cephalopoda are divided into two orders: the *Dibranchiata* furnished with *two* gills, and the *Tetrabranchiata* having *four* gills; the *Dibranchiata* are divided into two groups: the *Octopoda,* including Cuttle Fish, with *eight* arms only, and the *Decapoda,* provided with eight brachia and two tentacles—ten arms.

Having briefly enumerated the salient structural characters common to the class, we proceed to note some of the variations which occur in the lesser groups:—

The *Mantle.*—This is the external skin which protects the viscera; in the naked forms it is usually tolerably thick and tough, but in the shell-bearing Nautilus, it is soft and membranous.

Chromatophores.—The Cuttles, Squids, and Argonauta have the skin provided with singular bodies called chromatophores: these are cells filled with pigment which, by means of radiating muscles, can be made to contract or expand at will, and thus blushes of varying hues may be made to play over the skin's surface; the most general colour is that of the ink

* For this and several other species of British Cephalopoda which adorn my collection, I am indebted to the disinterested liberality of T. Moore, Esq., Liverpool.

contained in the ink-bag. The pigment cells are black and brown in the Cuttle-Fish (Sepia); brown, red, and yellow in the Squid (Loligo); and in the Argonaut there are said to be blue cells as well. According to Dr. Carpenter, "there are very commonly different layers of these pigment cells, their contents having different hues in each layer; and thus a great variety of coloration may be given, by the alteration in the form of the cells of which one or another layer is made up. It is curious that the changes in the hue of the skin appear to be influenced, as in the case of the chameleon, by the colour of the surface with which it may be in proximity." *

The Arms (*brachia*).—The Cephalopoda furnish two well-defined types of brachia. The Nautilus† has arms which are quite devoid of suckers or acetabula, such as are found on those of the cuttle fishes and their allies. The foot of the Nautilus, as described by Huxley,‡ "has its margins produced externally into a sort of sheath, which, in front, has the form of a broad hood, with a tuberculated surface; while at the sides it is divided into many processes of unequal lengths. Behind, the halves of the sheath are separated throughout the greater part of their length by a wide interval, but are united above by a thick muscular isthmus. The central portion of the sheath is a broad triangular hood-like plate, the apex of which is free. It contains two long, narrow cavities, each of which lodges a tentacle. The tentacle consists of a slender

* "The Microscope and its Revelations," Dr. W. B. Carpenter, Chap. xiv. p. 658, 5 ed. Lon., 1875.

† For Anatomy of Nautilus, besides the memoirs, &c., already cited, see:—"Nouvelles Recherches sur le Nautile flambé," M. A. Valenciènnes, Paris, 1839. "Bijdragen tot de Ontleekundige Kennis aangaande Nautilus Pompilius," L. VanDer Hoeven, Amsterdam, 1856. "Over Het Ontleedkundig Zamenstel van den Nautilus Pompilius," W. Vrolik, Amsterdam, 1848. "On the Anatomy of Nautilus umbilicatus compared with that of Nautilus Pompilius," J. D. Macdonald, London, 1855; and "On some Points in the Anatomy of Nautilus Pompilius," T. H. Huxley, London, 1858.

‡ "The Anatomy of Invertebrated Animals," by T. H. Huxley, London, 1877, p. 532.

stem, on which are set a great number of transverse plates, in such a manner that the axis of the stem passes through the centre of the plates. The anterior and lateral regions of the hood are completed by two narrower processes, each of which contains a similar tentacle, and the lateral portions of the sheath are formed by sixteen or seventeen smaller tentaculiferous processes, the surfaces of which are more or less distinctly annulated. When the sheath is opened out, there is seen to be attached to its inner surface, on each side, close to the re-entering angle between it and the lip which surrounds the beak, and along the line of junction of the lateral part of the sheath with the isthmus, a thin, free quadrate lobe, which carries twelve tentacles. The isthmus joins the posterior edges of these *outer tentaculiferous lobes*, as well as those of the two halves of the sheath, and it exhibits on its anterior, or inner surface, a broad area beset with delicate, close-set, curved laminæ. Two other similar, but much thicker, *inner tentaculiferous* lobes, which also carry twelve tentacles, lie between these and the lip. They are quite free from the outer tentaculiferous lobes, and unite with the sheath only above and behind. Like the halves of the sheath, these two lobes are united behind by a thick isthmus, the surface of which presents a number of parallel longitudinal laminæ. The beak, which is hidden by the sheath and the lobes, is surrounded by the thin circular lip already mentioned, the free margin of which is papillose. Besides these, there is a short, conical tentaculiferous process above the pedunculate eye, and another below it." The Cuttle Fish and their allies (*Dibranchiata*), have fewer arms, the number being eight in the *Octopoda*, to which group the genera Octopus and Eledone are referred; whilst in the *Decapoda*, which includes, amongst other genera, Sepia, Sepiola, Loligo, and Rossia, there are two additional arms, which are elongate and club-shaped at their extremities. In both groups the inner surfaces of the arms, and the posterior inner face of tentacular organs, are provided with suckers. In the Argonaut, the superior pair of arms are produced into broad, extensible membranes, suitable for embracing and protecting the thin, papery shell.*

The *Acetabula*, or suckers, are cup like, and usually round bodies, containing a soft fleshy pimple, situated in their central cavity; by the aid of a circle of radiating muscles, this pimple may be depressed, and thus a vacuum be produced, enabling the sucker to attach itself strongly to any desired object. In the *Octopods* the suckers are sessile, and in the genera Eledone and Cirroteuthis† are arranged upon the arms in single rows, but form two lines on each arm in the genera *Octopus*, *Philonexis*, and *Argonauta*. In the *Decapoda*, the suckers are placed in two alternating lines on each arm, except in the genus *Sepia*, which has four rows of suckers displayed on each arm. In the Decapods the suckers are borne on a pedicel, or stalk, and have their muscular portion strengthened by the presence of flat, circular, horny rings. In the genera Onychoteuthis, Enoploteuthis, and some others, the arms, or tentacles, or both, are armed by rows of horny hooks and spines.

The arms are sometimes of enormous length. Mr. Johnson cites a Madame Graham as having seen a Cuttle Fish with arms 18 feet long; and Schwediaver reports that a whaler harpooned a Cachalot, having in its mouth the arm of a Cuttle Fish nearly 23 feet long. M. Harting‡ has described the remains of some gigantic Cephalopods preserved in the Museums of Utrecht and Amsterdam, which prove the

* For the Anatomy of the Argonaut, see "Mémoire sur l'Argonaute par." P. J. Van Beneden. Brux, 1838.

† See "Cirroteuthis Mülleri eine neue Gattung der Cephalopoden bildend," von Dr. Eschricht. Copenhagen, 1836.

‡ "Description de quelques fragments de Deux Céphalopodes Gigantesques." P. Harting, Amsterdam, 1860.

existence of immense Cephalopods in the seas of our own epoch, and show that the fears entertained by pearl divers, coral fishers, and bathers of the Polynesian islands, of being captured by these creatures, and enveloped in their snake-like limbs, armed with cupping instruments, hooks, and veritable claws, are not absolutely without foundation.

Though the arms of Cephalopods doubtless assist in the function of locomotion, enabling them to crawl head downwards over the rocks or along the sand of the sea floor, yet they aid them but little in the act of swimming; this aid is afforded by other organs, viz., the Fins and the Funnel. *The Fins* are not found in all genera, and indeed are confined to the *Decapoda;* they are fleshy, lateral expansions of the mantle. In Sepiola * and Rossia * they are latero-dorsal; in Sepia they are lateral and narrow; in Cranchia † Histioteuthis, Onychoteuthis, Loligo and Ommastrephes, they are latero-terminal.

The Funnel or Siphon is situated under the head at the point of its junction with the body; in the *Dibranchiata* it consists of a flexible tube, with continuous walls throughout its entire length, and is situated in the mantle cavity, from which it projects; in the *Tetrabranchiata* its edges are free, and the tube is formed by simply bringing these into contact. The Cephalopods swim backwards; this motion is effected by the forcible expulsion of sea-water through the funnel and the consequent rebound of the animal in the water; the funnel is provided with a valve which allows the expulsion of water, but prevents its return. The organ also assists in the function of respiration, for by it the liquid which has already aërated the blood, and consequently become charged with effete materials, is got rid of.

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* "On the Anatomy of the Sepiola vulgaris, Leach." Robert Grant, London, 1833.

† "Nogle nye Cephalopoder bre-krevne og anatomisk undersögte af Victor Prosch." Kjöbenh, 1849.

In both orders of the Class the *Head* is well developed, and provided with highly organised sensory organs; foremost among these are the *Eyes;* * they are usually large and complex. The *Dibranchiates* have eyes which are lodged in orbital cavities; each eye possesses an optic nerve, a sclerotic, choroid, retina, vitreous humour, aqueous humour, and lens. It must, however, be remembered, as Professor Huxley points out, that these "apparent resemblances between the cephalopodous and the vertebrate eye are merely superficial, and disappear on detailed comparison." The *Tetrabranchiate* eyes are of much simpler construction ; they are not placed in orbital cavities, but are attached by stalks or pedicels to each side of the head, and consist of simple cup-like organs lined with a retina.

The Olfactory Organs, which are represented by little depressions, and by minute soft prominences of the skin, which are situated near the eyes, either above them or below them, have been investigated and described by Kölliker.

The Auditory Organs in the *Dibranchiata* are lodged in the cartilaginous case which protects the great nervous centres, and consist of cavities each of which is furnished with a single otolith. In the order to which the Nautilus belongs the auditory capsules were first discovered by Dr. Macdonald. "The inner wall of each ear-sac in the Nautilus is somewhat flattened, lying in contact with the nervous matter, but its more convex external surface rests in a little depression on the upper and internal border of the cephalic cartilage. It is enveloped in a kind of fibrous tissue, and filled with a cretaceous pulp, consisting of minute elliptical otokonia, which, when under a high power, present a bright and

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* For the anatomy of the eye in Cephalapoda see "Beitrag zur nähern Kennt, niss des auges der Cephalopoden von, Dr. Krohn, 1833." "Hensen, ueber das auge einiger Cephalopoden, in Siebold und Kölliker Zeitschrift für wissenschs Zool," 1865; and "Structure of the optic lobes of the Cuttle Fish." J. L. Clarke, London, 1866.

strongly refracting point near each extremity. These particles vary much in size, and are sometimes curiously combined, so as to appear double, or assume the form of a star or cross." *

The Mouth and Appendages.—In the centre of the circle of arms which crown the head lies the mouth, which in the *Decapoda* is provided with an investing and surrounding skin (buccal membrane), covering the exterior of the mouth, and capable of being pouted out in the form of a large funnel; this organ is wanting in the Nautilus, and in the long-armed Octopods. In all the mouth is furnished with two lips, one of which is external, the other internal, fleshy, and covered with papillæ. Within the cavity of the mouth are situated the mandibles, which in shape are not unlike those of a parrot, and by the aid of strong muscles act in a vertical direction. These mandibles, in all living species except the Nautilus, are of a horny or chitinous consistency throughout, but in the Nautili their extremities are tipped with a dense calcareous substance; the anterior mandible is always the shortest, and is overlapped by the posterior one (the reverse order to what obtains with birds). The tongue and *Odontophore*, or lingual ribbon, perform an important part in the economy of the animal. The anterior portion, or tongue, is fleshy and sentient, the posterior portion resembles the lingual ribbon of the Gasteropoda, being armed with transverse series of silicious teeth.

The Alimentary Canal.—The mouth cavity opens into a long gullet or œsophagus, and two or four salivary glands are connected with it in the *Dibranchiata;* in the *Nautili* these glands are very feebly developed, if, indeed, they be present at all. The stomach is situated at the lower part of the body, and at its anterior end it is connected with the œsophagus, whilst its posterior portion is joined to the

* "On the Anatomy of Nautilus umbilicatus," &c., J. D. Macdonald, London, 1855.

pyloric cœcum, which is often large and spiral. (In the Nautilus the œsophagus dilates into a pear-shaped crop, which is joined to the gizzard or stomach by a short canal.) In all Cephalopods the liver is of large size, and the two hepatic ducts connect it with the pyloric cœcum; from the pyloris the intestine is continued by a neural flexure (that is with its bend towards the principal nerve centres, and away from the heart), and ends in an orifice (the anus) in the mid-ventral region. The hepatic ducts are clothed with peculiar glandular bodies, which are supposed to be pancreatic in their functions. The *Ink-bag* is only found in members of the Dibranchiate order, it is a sac-like body, invested with powerful muscles, contained in a thin silvery skin, and secretes an inky fluid which its owner can expel at pleasure, and by discolouring the surrounding water can often escape from those who seek to capture it. The ink-bag is situated in the postero-ventral portion of the body, and opens by an orifice near the anus.

The Cephalopoda are carnivorous, feeding upon crustacea, mollusca, and even fish. Professor Owen found in the stomach of the Nautilus, from Marekini Bay, the remains of a non-swimming Crustacean. Dr. Macdonald says that the Fijians esteem the pearly Nautilus very highly, as an agreeable viand, and capture it in basket-traps, baited with boiled cray-fish (Palinurus), and sunk amongst the ledges of rock or coral, which it is known to haunt.

The Circulatory and Respiratory Systems.—A true systemic heart, consisting of a single ventricle, receives the colourless blood from the gills, and passes the aërated liquid to the body; there are, also, accessory contractile organs, corresponding in number with the gills, these are branchial hearts or auricles, and pass the blood into the heart; they are situated at the foot of each plume-like gill; in the Dibranchiata a capillary system obtains, connecting arteries and veins.

The respiratory function is performed by means of gills, which lie in the branchial cavity on the ventral aspect of the body; these gills are two in number in the higher forms, and, along their whole length, are joined to the walls of the mantle cavity, which, as it expands and contracts alternately, allows the ingress and egress of water to aërate the blood. In the lower group, the gills are four in number, and are only attached to the walls of the mantle cavity by their posterior ends. The gills form a cylinder in *Octopus* and *Sepia*, whilst in *Loligo* and other genera they form only half a cylinder.

The nervous system consists of three large pairs of nervous ganglia, which are arranged around the upper part of the œsophagus, and are protected by a cartilaginous covering; this concentration of the nervous system, correlated as it is with a high development of the sensory organs, justifies the position in which systematists have placed the Cephalopoda at the head of the Molluscan sub-kingdom. The three pairs of nervous ganglia (pedal, cerebral, and parieto-splanchnic), characteristic of all true Mollusca, are supplemented in the Cephalopods by subsidiary and accessory ganglia and their connecting commissures.

According to Owen, the nervous system of the Nautilus is inferior to that of the Dibranchiata; "the part which corresponds to the brain of the Cuttle Fish is neither enlarged nor lobulated, nor contained in a cartilaginous receptacle; but is a simple, rounded chord, or commissure, placed transversely upon the œsophagus, and connected at its extremities to the great nervous ganglions."*

* For description of Nervous System of Cephalopoda, see "Recherches pour servir a l'histoire du systèmo nerveux des Céphalopodes Dibranchiaux," Jules Chéron, Paris, 1866. "Memoria sulla Structura del Sistema Nervoso dei Cefalopodi," S. Trinchese, Firenze, 1868. "Nervous System of the Cephalopoda," A. Hancock, Ann. and Mag. Nat. Hist., ser. ii., vol. i., London, 1852.

The Shell.—The Nautilus is the only living Cephalopod which can be said to possess a shell homologous to the true molluscan shell; it is true that the Argonaut is provided with a beautiful thin, papery, translucent, involuted shell, but this is secreted by the broad web-like extremities of the anterior pair of arms of the female only, who uses the unoccupied spiral portion of the shell as a nidemental chamber for the safe deposition of her eggs. The shell, unlike that of any other mollusc, is not attached to the animal by any muscular connection.

The true type of a Tetrabranchiate shell is furnished by the Pearly Nautilus, the only surviving representative of a great number of genera, and thousands of species which once swarmed in the seas of the palæozoic and secondary epochs, and whose fossilised remains abound in all formations from the Silurian to the Cretaceous epoch, one genus alone having been continued through the tertiary age to the present day.

The shell of the Nautilus is involuted, and divided by transverse partitions (septa) into numerous chambers, each of which has in its turn been inhabited by the owner; each septum is curved with its concave side turned towards the last formed chamber, and all the partitions are pierced centrally by a tube (siphuncle); the edges of the septa (sutures) are simple. The inner layers of the shell are nacreous or pearly, whilst the outer ones are porcellanous.

The fossil genera, which are numerous, agree with the Nautilus in having external chambered shells, with their septa pierced by a siphuncle; they differ from it in the shape and proportions of the shell, the position of the siphuncle, and the markings of the sutures. In the genera Orthoceras and Baculites the shell is straight; in Trochoceras and Turrilites it is spiral; in Ascoceras and Ptychoceras it is bent on itself; in Cyrtoceras and Toxoceras it is curved; whilst in Gyroceras and Crioceras it is discoidal.

The sutural markings in the Ammonites are very complicated, being what is termed foliaceous. In Goniatites they are zigzag, whilst in Ceratites they are alternately lobed and crenated. The position of the siphuncle, too, is variable in the Nautilidæ, being central or sub-central, whilst in the Ammonitidæ it is dorsal and external.

The internal shells belonging to the Dibranchiate group may consist of:—

α—A pen (gladius) which is horny or chitinous, as in Loligo.

β—A "Sepiostaire" or cuttle-bone, which is calcareous, as in Sepia.

λ—A more complex structure, with a chambered portion (phragmacone), as in Spirula.

In Spirula the shell is entirely pearly or nacreous; it is chambered, the whorls are separate, and there is a ventral siphuncle. Though the animal of Spirula is exceedingly rare, the shell is cast up by thousands on the shores of New Zealand. The shell contains the ink-bag.*

Generative Organs.†—The Cephalopoda are diœcious. In both sexes the generative organs open into the mantle cavity by an oviduct; they contain ova or spermatozoa according to the sex of the individual. Peculiar lamellated glands are developed in the female, which secrete a sticky substance which serves to coat the eggs and hold them together in aggregated masses; in the male a gland provides the substance out of which are composed the spermatophores, the

* Through the kindness of J. Tyerman, Esq., Tregoney, Cornwall, the animal of Spirula, preserved in spirits of wine, was exhibited at the meeting of the West Riding Geological and Polytechnic Society, held at Huddersfield in the autumn of this year (1877). It was the same specimen that Dr. Jeffreys spoke of in his address to the Biological Section of the British Association, held at Plymouth.

† See "Hectocotyldannelsen hos Octopods lægterne, Argonauta og Tremoctopus," J. J. Sm. Steenstrup, Kjöbenh, 1856.

latter are little cases filled with spermatozoa; when these cases are moistened, they burst, and expel their contents. In the male cuttle fishes, one of the brachia becomes altered, an oval sac is developed, and filled with spermatazoa; this process is called hectocotylisation. In some species the hectocotylised arm is detached and left in the mantle-cavity of the female, when the spermatophores, becoming ruptured, the male elements have access to the ova, and fertilise them.

The male of the Argonaut has no shell, and is only about an inch in length; one of the arms is developed into a sac-like body containing a hectocotylus, which, by its movements, eventually frees itself, and becoming detached, is lodged in the mantle chamber of the female Argonaut. This organ was for a long time a puzzle to naturalists, and has been described first as a parasitic worm, and then as the whole male Argonaut, and it is only of late years that its true nature has been made out. .

Embryology.—Nothing whatever is known of the development of the Nautilus—According to Kölliker, in the Dibranchiata the yolk division is only partial, the embryo is developed in a distinct germinal area, and a yolk-sac is formed, which is small in *Argonauta,* and large in *Loligo* and *Sepia.* The first process of development is the differentiation of the embryo into mantle and foot, the latero posterior margins of the foot are produced into processes (4 or 5 on each side) which become arms, ridges develop upon the body, the posterior ends of which are free, but ultimately unite to form the funnel. Rudimentary gills appear between the funnel and the mantle. At first the alimentary canal is straight. "The embryo now grows faster in a vertical than in a longitudinal direction, so that it takes in the Cephalopodic form. The intestine as a consequence becomes bent upon itself, and the anterior pair of arms grow over in front of the head, and unite so as eventually to throw the mouth nearly in the centre of the arms" (Huxley).* It is worthy of notice that the edges of the funnel are free in the embryo Dibranchiates, a condition which is persistent in the Nautilus.

HABITS.

Woodward, speaking of the distribution and habits of the Cuttle Fish, says: "They are generally nocturnal, or crepuscular animals, concealing themselves during the day, or retiring to a lower region of the water. They inhabit every zone, and are met with near shore, as well as in the open sea, hundreds of miles from land. They attain, occasionally, a much greater size than any other Mollusca. MM. Quoy and Gaimard found a dead Cuttle Fish in the Atlantic, under the equator, which must have weighed 2 cwt. when perfect; it was floating on the surface, and was partly devoured by birds. Banks and Solander also met with one under similar circumstances in the Pacific, which was estimated to have measured six feet in length. From their habits it is difficult to capture some species alive, but they are frequently obtained uninjured from the stomachs of dolphins and other cetaceans which feed upon them."

DISTRIBUTION.

The Cephalopoda occur in all seas, and in every quarter of the globe. The Argonauta are found in both hemispheres, ranging between 40 degrees on both sides of the equator; on the other hand, the Nautili appear to be confined to the waters of the tropical regions of the Pacific and Indian Oceans.

The distribution of the Cephalopoda in time is a subject of

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* For Embryology, see "Zur Entwickelungsgeschichte der Cephalopoden," Grenacher, 1876. "Observations on the development of the Cephalopoda," Lankester, ("Quarterley Journal of Microscopical Science, 1875.") "Recherches sur l'embryogénie des Sépioles," P. J. Van Beneden, Brux. 1841. "Entwickelungsgeschichte der Cephalopoden," Dr Albert Kölliker, Zurich, 1844.

great interest. They occur in all formations, from the Cambrian to the latest tertiaries. Such genera as Orthoceras and Nautilus appear in the Cambrian and Silurian strata, and the latter genus still survives. Argonauta is found fossil in the Pliocene strata only. The Dibranchiata are of comparatively recent origin, occurring for the first time in the early secondary rocks. The families Octopodidæ and Spirulidæ have no representatives in the rocky strata.

The following tables will serve to illustrate the geological distribution of the families and genera of recent and extinct Cephalopoda:—

Distribution of Characteristic Genera.

1. Pliocene.	Argonauta.
2. Miocene.	Spirulirostra, Aturia.
3. Eocene.	Beloptera.
4. Cretaceous.	Scaphites, Hamites, Ptychoceras, Turrilites, Conoteuthis, Belemnitella, Baculina, Toxoceras, Crioceras.
5. Oolite.	Leptoteuthis, Nautilus.
6. Lias.	Belemnites, Beloteuthis, Geoteuthis, Ammonites.
7. Trias.	Ceratites.
8. Permian.	
9. Carboniferous.	Goniatites, Nautiloceras.
10. Devonian.	Clymenia, Bactrites.
11. Silurian.	Actinoceras, Phragmoceras, Trochoceras, Ascoceras.
12. Cambrian.	Camaroceras, Endoceras.

Distribution of Families in Time.

	Cambrian.	Silurian.	Devonian.	Carboniferous.	Trias.	Lias.	Oolite.	Cretaceous.	Eocene.	Miocene.	Pliocene.	Recent.
Argonautidæ.											×	×
Teuthidæ.						×	×	×	×	×	×	×
Sepiadæ.						×	×	×	×	×	×	×
Belemnitidæ.						×	×	×				
Ammonitidæ.			×	×	×	×	×	×				
Nautilidæ.		×	×	×	×	×	×	×	×	×	×	×
Orthoceratidæ.	×	×	×	×	×							

CLASSIFICATION.

If we generalise the points of structure described in the foregoing pages, we shall find that the genera of Cephalopoda may be arranged into natural groups, somewhat as follows:—

CLASS—CEPHALOPODA.

Mollusca, having eight or more arms surrounding the mouth, which is situated at the anterior end of a cylindrical, oval, fleshy body; a muscular mantle covered with pigment spots investing the body, and forming a ventral cavity, within which are situated two or four plume-like gills; a tubular organ (the funnel), and having the intestine with its flexure towards the nerve centres.

ORDER A. TETRABRANCHIATA.—Animals having four gills, numerous arms (exceeding ten), which bear no suckers; a chambered shell, which is external, and bears a siphuncle; no ink-bag; pedunculated eyes; mandibles, with calcareous tips; and funnel not a complete tube.

FAMILY A. *Ammonitidæ.*—Animal unknown; shell chambered straight, spiral, curved, or discoidal; aperture guarded by processes, or closed by an operculum; the septa giving rise to sutural markings, which may be angulated or complexly foliated; provided with an external siphuncle.

All the species fossil, includes genera Goniatites, Bactrites, Ceratites, Ammonites, Crioceras, Toxoceras, Ancyloceras, Scaphites, Turrilites, Hamites, Ptychoceras, Baculites, &c.

Family B. *Nautilidæ.*—The Nautilus being the only known living type, the diagnosis of the order serves for this family also. Shell: curved, discoid or straight; sutural markings simple or contracted, with central or sub-central siphuncle.

Genera.—Nautilus, Aturia, Lituites, Trochoceras, Orthoceras, Gomphoceras, Phragmoceras, Cyrtoceras, Gyroceras, &c.

Order II., Dibranchiata.—Animal without true external shell, sometimes with a rudimentary internal one; has sessile eyes, horny mandibles, two gills, not more than ten elongate arms, which are provided with suckers; a funnel which forms a complete tube, and an ink-bag.

Section (1), Decapoda.—Animal having eight arms, and two clavate tentacles (ten altogether), bearing pedunculated suckers, strengthened by a horny ring; having eyes movable, body elongate, and furnished with a pair of fins, and an internal shell, gills partly attached.

Family C. *Spirulidæ.*—Animal provided with an internal, pearly shell, having a central siphuncle, and being discoidal, with the whorls separated.

Genus.—Spirula.

Family D. *Sepiadæ.*—Animal furnished with an internal calcareous broad plate (cuttle-bone) which terminates behind in an imperfect chamber. Genera: Sepia Spirulirostra, Beloptera, &c.

Family E. *Belemnitidæ.*—All fossil; shell internal, consisting of a pen (gladius), a chambered portion (phragmacone), and sometimes a surrounding guard; siphuncle ventral. Genera: Belemnites, Belemnitella, Acanthoteuthis, Belemnoteuthis, &c., &c.

Family F. *Teuthidæ.*—Animal provided with fins or lateral expansions of the mantle, and an internal chitinous pen (gladius). Genera: Loligo, Gonatus, Sepioteuthis, Beloteuthis, Geoteuthis, Cranchia, Sepiola, Loligopsis, Cheiroteuthis, Histioteuthis, Onychoteuthis, Enoploteuthis, Ommatostrephes, &c., &c.

Section (2) *Octopoda.*—Animal possessing eight arms only, furnished with sessile suckers, gills attached by the stalk only. No shell, but the female Argonaut forms an external involute egg-capsule, which is not attached to the animal by any muscular connection.

Family G. *Octopodidæ.*—Internal rudimentary styles represent the internal shell, fins usually absent, arms webbed at the base. Genera: Octopus, Pinnoctopus, Eledone, Cirroteuthis, Philonexis, Scæurgus, Bolitœna, &c.

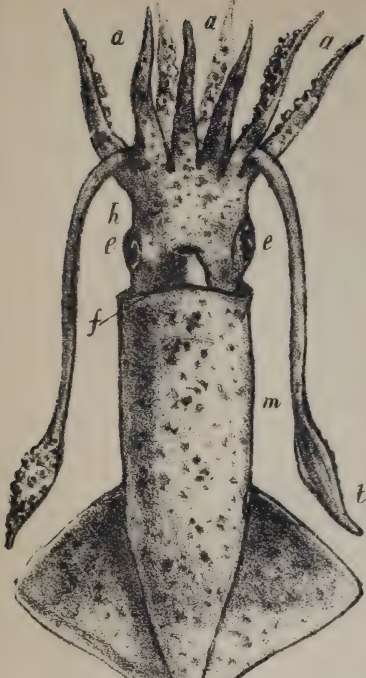
Family H. *Argonautidæ.*—Mantle supported anteriorly by a ridge on the funnel. The female, with the webbed extremities of her anterior arms secretes a white papery involute single chambered shell.

Genus.—Argonauta.

As to the phylogeny of the Cephalopoda it may be said that little more than a guess could be made in the present state of our knowledge of their embryology, for absolutely nothing is known of the development of one whole order, the Tetrabranchiata, and as Owen has well remarked of the development of the cuttle-fish, "there is no metamorphosis; the Cephalopodic character is manifested long before the parts of the embryo are completed." It may, however, be expected that light will be thrown on this difficult subject when the embryology of the Nautilus shall be discovered, and when palæontologists have studied the fossil forms more thoroughly than has hitherto been done. We cannot conclude our remarks on the Cephalopoda better than by a quotation from Professor Huxley's valuable work "On the Anatomy of Invertebrated Animals," in which he discusses the value of generalisations based on morphological facts, and of certain attempts at the construction of animal genealogies:—"It is important to remark that these morphological generalisations, so far as they are correctly made, are simple statements of fact, and have nothing to do with any speculations respecting the manner in which the invertebrated animals with which we are acquainted have come into existence. They will remain true, so far as they are true at all, even if it should be proved that every animal species has come into existence by itself, and without reference to any other. On the other hand, if there are independent grounds for a belief in evolution, the facts of morphology not only present no difficulty in the way of the hypothesis of the evolution of the *Invertebrata* from a common origin, but readily adapt themselves to it.

"Hence the numerous phylogenic hypotheses which have of late come into existence, and of which it may be said that all are valuable, so far as they suggest new lines of investigation, and that few have any other significance—in the absence of any adequate palæontological history of the *Invertebrata,* any attempt to construct their phylogeny must be mere speculation. But the oldest portion of the Geological record does not furnish a single example of a fossil, which we have any reasonable grounds for supposing to be the representative of the earliest form of any one of the series of invertebrated animals; nor any means of checking our imaginations of what may have been, by evidence of what has been, the early history of invertebrate life on the globe.

"Already, indications are not wanting that the vast multitude of fossil Arthropods, Molluscs, Echinoderms, and



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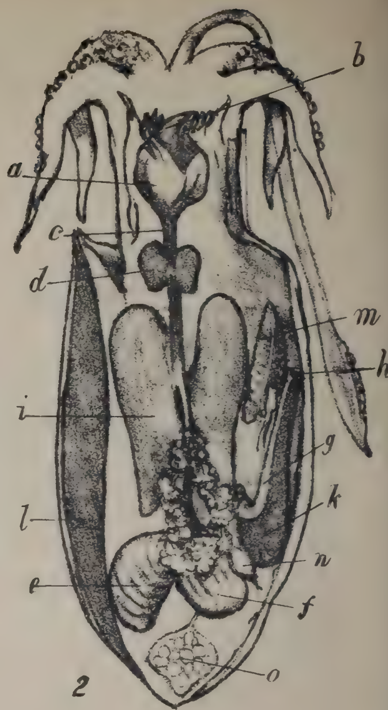

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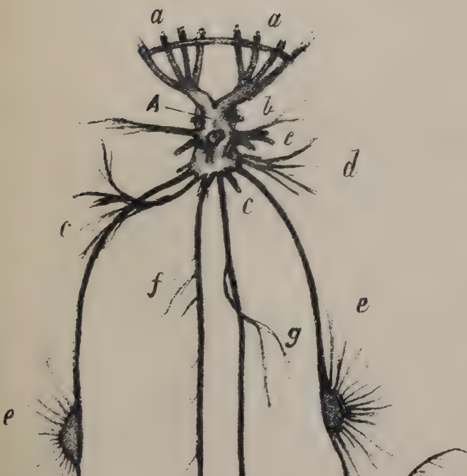

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Zoophytes, now known, will yield satisfactory evidence of the filiation of successive forms, when the investigations of palæontologists are not merely actuated by the desire to discover geological time-marks, and to multiply species, but are guided by that perception of the importance of morphological facts, which can only be conferred by a large and thorough acquaintance with Anatomy and Embryology. But, under this aspect, the palæontology of the *Invertebrata* has yet to be created."

Explanation of Plate XI.

Fig. 1.—Ommatostrephes todarus. Delle Chiaje (ventral aspect).

a. Arms (brachia).
e. Eyes.
f. Funnel
h. Head.
m. Mantle.
t. Tentacula.

Fig. 2.—Diagram of the anatomy of a Cuttle fish.

a. Buccal mass.
b. Beak.
c. Œsophagus.
d. Salivary glands.
e. Stomach.
f. Pyloric cœcum.
g. Intestine.
h. Anus.
i. Liver.
k. Ink bag.
l. Internal shell.
m. Gill.
n. Heart.
o. Ovary.

Fig. 3.—Nervous system of Eledone cirrosa. Lamarck.

A. Cerebral, pedal, and parieto-splanchnic ganglia surrounding the gullet.
a. Nerves of the arms.
b. Auditory nerves.
c. Nerves of the funnel.
d. Accessory nerve of the mantle.
e. Pallial nerves.
f. Visceral nerves.
g. Branch of the visceral nerves to the muscles of the body.
h. Ganglia of the branchial heart.
i. Branchial ganglia.

Fig. 4.—Ommatostrephes todarus. Delle Chiaje (oral aspect).

a. Arms (first pair).
b. Arms.
c. Tentacles.
d. Oral aperture.

UNCONFORMABILITY OF THE PERMIAN LIMESTONE TO THE RED ROCKS WEST OF ITS ESCARPMENT IN CENTRAL YORKSHIRE.

BY JAMES W. DAVIS, F.L.S., F.G.S., ETC.

CONTENTS.

(1) INTRODUCTION.

EXTENDING in a north and south direction, across nearly the whole of Yorkshire, are certain beds of Sandstone and Shales, which are frequently of a deep red or purple colour. They are generally found immediately below the Permian Limestone, but in some instances extend considerably westward from its escarpment. Large masses of it may be seen in the southern part of the county, locally known as the "Red Rock of Rotherham;" and further north, remarkable examples occur at Plumpton and Spofforth. The Red Shales may be studied at Conisborough, Pontefract, Barwick-in-Elmete, and numerous other places. These Red Rocks have been described as New Red Sandstone, or the equivalents of the Rothe-todte-liegende of the Continental Geologists, from their resemblance to that formation as existing in Germany and Russia; they have also been considered as rocks of the Carboniferous formation, which, from their close proximity to the Limestone, have been transformed to a red colour by some chemical change, probably by the percolation of water-bearing Carbonate of Lime, or Carbonic Anhydride in solution, which on coming in contact with the Iron existing in the Sandstone or Shales, as a colourless protoxide, has been changed by the addition of oxygen to a peroxide, or red oxide of Iron, and may have caused the red colour of the rocks. This theory is borne out to some extent by the fact, that in many instances where the rocks have been traced to a greater depth, the red colour has been found to disappear, giving place to the usual, or natural grey or yellow colour, and further, by the frequent occurrence of isolated patches, or nodular concretions of a deep red or purple colour, whilst the general colour of the rock is grey.

The object of this paper is to give a little fuller consideration to the relation of the Red Rocks to the overlying Permian Limestone than, so far as I know, has hitherto been done, and to endeavour to show that the Limestones are, throughout their entire extent, deposited uncomformably to the rocks beneath them, and that where any apparent conformability exists, it is merely the effect of parallelism of the beds of very local extent.

(2) SHORT NOTICES OF PREVIOUS WRITINGS ON THE SUBJECT.

J. FAREY.—"Uncomfortable position of the Pontefract Rock of Sandstone, with respect to the subjacent Coal Measures, as shown in the new geological map of Yorkshire; and regarding some errors therein as to parts of the ranges of certain rocks, in the Coal Series." Ann. of Phil., Ser. 2, Vol. v., p. 270.

PROF. JNO. PHILLIPS.—"Geological observations made in the neighbourhood of Ferry Bridge, in the years 1826-28." Phil. Mag., Ser. 2, Vol. ii., p. 401.

REV. A. SEDGWICK, F.R.S., &c.—"On the Geological Relations and Internal Structure of the Magnesian Limestone and the Lower portion of the New Red Sandstone Series, in their Ranges through Nottinghamshire, Derbyshire, Yorkshire, and Durham, to the southern extremity of Northumberland." Trans. Geol. Socy., 2nd. Series., Vol. iii., pt. i., p. 37.

Traces the western escarpments of the Permian formation throughout its entire length, giving a minute and elaborate description of the physical and geological features of the country. The Red Sandstone underlying the Permian Limestone in several localities was at first considered by the professor to be a peculiar formation of Gritstone, subordinate to the Coal Measures. This decision was arrived at in consequence of the grit-like appearance of the deposits, and its frequent unconformability to the overlying Limestone. A reference to the geological map of Wm. Smith, however, caused a change in this opinion, and he adopted that of Conybeare—that they were the equivalents of the Rothliegende of Germany. Sedgwick considers it to preserve a general uniformity of character, and divided it into seven principal varieties—from a Conglomerate, resembling the Newer Red Conglomerate which overlies the western coal districts ; a coarse Siliceous Sandstone, containing quartz pebbles an inch in diameter, and usually coloured red or purple ; finer Sandstone ; nearly incoherent Sandstone ; Sandy Micaceous Shales, often stained red or purple ; and Marls much varied both in colour and composition. The author next proceeds to describe the range and extent of the Lower Red Sandstone, with the remark that in its "Subordinate parts there does not appear to be any constancy, if we except the red and variegated Marls which are so commonly found immediately under the Limestone ; and also the obscure Conglomerates above-mentioned, which in a few instances occur in the same position."

Rev. W. Thorpe.—"On the Agriculture of the West Riding of Yorkshire, considered Geologically ; and first of the New Red Sandstone District." Proc. Geol. and Polyt. Soc. of West Riding of York, Vol. i., No. 1, p. 46. 1840.

Rev. W. Thorpe.—"On the Agriculture of the West Riding of Yorkshire, considered Geologically ; of the Permian Limestone District." Proc. Geol. and Polyt. Soc. of West Riding York., Vol. i., No. 1, p. 91. 1841.

E. W. Binney.—"On the Relation of the New Red Sandstone to the Carboniferous Strata in Lancashire and Cheshire (refers to Yorkshire). Quar. Jour. of Geol. Soc., Vol. ii., p. 12. 1846.

J. W. Kirkby.—"On the occurrence of Lingula Credneri, Geinitz, in the Coal Measures of Durham ; and on the Claim of the Permian Rocks to be entitled a System." Quar. Jour. Geol. Soc., Vol. xvi., p. 412. 1860.

Cites 15 species of Mollusca, Entomastraca, fish and plants, which are common to the Carboniferous Series and to the Permians ; from this Palæontological relationship draws deductions, and endeavours to show that the Permian formation ought to be included in the Carboniferous System.

J. W. KIRKBY.—"On the Permian Rocks of South Yorkshire; and on their Palæontological Relations." Quar. Jour. Geol. Soc., Vol. xvii., p. 287. 1861.

Describes the Permian Formation, as exhibited between Pontefract and Roche Abbey. Considers the Lower Red Sandstone of this district the equivalent of similar rocks in Durham, as well as the typical Rothliegendes of Germany. Enumerates, or describes, 31 species of fossils found in this district, and compares them with those of Durham and other districts.

JOHN PHILLIPS, M.A., F.R.S., &c., Prof. of Geol. at the Univ. of Oxford.—"Notes on the Geology of Harrogate." Quar. Jour. Geol. Socy., Vol. xxi., p. 232. 1865.

Describes the Yoredale Anticlinal, at Harrogate, and a section exposing the sequence of the Third Grits in a cutting of the N.E. Railway. Then reverting to the "Lower Permian Sandstones and Shales," he says:—"Few rocks are more variable in composition, whilst regular in sequence, where the sequence is immediate from the Upper Coal Measures to the Permian Beds, as in Durham, North Staffordshire, and a part of Yorkshire and Derbyshire, the analogy of the two sets of strata is considerable, even if they do not exchange beds. But in this part of Yorkshire the Permian Beds are in no sense or manner conformed to the Coal System, or any part of it." In this particular district the Millstone Grit probably underwent enormous waste after the anticlinal was formed, and before the Permian Beds were deposited. These Permian Beds, of coarse and fine purple sandstone, are full of the detritus of Millstone Grit. The author further states, it is undistinguishable from Millstone Grit in hand specimens, and that the purple colour sometimes fails, and that both north and south they lose their similitude to the Grits, and draws "a confirmation of the opinion, very probable on other grounds, that the Lower Permian Beds were of littoral aggregation, by currents operating on the waste of the neighbouring coasts."

E. W. BINNEY, F.R.S., F.G.S., &c.—"A few remarks on the so-called Lower New Red Sandstone of Central Yorkshire." Geol. Mag., Feb., 1876.

Describes sections in Millstone Grit and Permian Limestone, at Bramham, Plumpton, Knaresborough, and from Fountain's Abbey to Ripon; and after reviewing the opinions of Profs. Sedgwick and Phillips, decides that "All the Gritstones appear to pass into, and are quite conformable with, the Carboniferous Rocks on which they repose," and that this being the case, they had better be classed with the latter. He is further convinced that the Grits are Millstone Grit or Rough Rock.

Sir Roderick I. Murchison, Bart., K.C.B., &c.—"Siluria," 5th Edit. p. 327, *et seq*. 1872.

Traces the occurrence of the New Red Sandstone from Ripon, until it gradually thins out to a very thin flaggy stone near Conisborough, and at Nottingham dies away altogether. He "has no hesitation in affirming that the well-known picturesque 'Plumpton Rocks,' near Harrogate, are identical with the Quartz Conglomerates of Germany, whether as regards their ingredients, colour, false-bedding, or massive stratification." He entirely disagrees with Mr. R. Howse and Mr. E. W. Binney.

J. Clifton Ward, F.G.S.—"On Beds of supposed Rothliegende age, near Knaresborough," &c. Quar. Jour. Geo. Soc., Vol. xxv., p. 291. 1869.

Describes numerous sections, from Barwick-in-Elmete, East of Leeds, northwards, showing, in some cases, the strata underlying the Permian Limestone to consist of Shales, and in others of various Grit Rocks, and that in every instance they are not deposited conformably to the Limestone, and concludes, "that along the base of the Magnesian Limestone, from Garforth, East of Leeds, to Knaresborough, striking across partly Coal-measures and partly Millstone-grit, there is no such thing as 'Lower Red Sandstone,' or 'Rothliegende,' but that any red or purple Shales, Sandstones, or Grit, occurring along this line, are simply Coal-measures or Millstone-grit beds, as the case may be, which have been coloured through the agency of the overlying Limestone."

Jas. W. Kirkby.—Note on the "Geology" of Messrs. Baker & Tates' "New Flora of Northumberland and Durham." Nat. Hist. Trans. of Northumberland and Durham, 1870, p. 357, Vol. iii., Pt. ii.

Disagrees with the authors in their classification of the New Red Sandstone, and says: "When it is seen following the course of the Magnesian Limestone, from where the Coal-measures lie comparatively flat in North Durham, and passing into Yorkshire with the Magnesian Limestone, and there seen with it, resting sometimes on Coal-measures (Pontefract, Pebbley Dam, &c.), and sometimes on Millstone Grit (Knaresborough, Bramham Park, &c.), and in some cases actually passing up gradually into the overlying Magnesian Limestone so as to render their exact separation impossible (Knaresborough), it is my opinion that the physical evidence quite suffices to show that the most appropriate classification for this Sandstone is with the Permian, and not with the Carboniferous Rocks."

W. T. Aveline, F.G.S., A. H. Green, M.A., J. R. Dakyns, M.A., J. C. Ward, F.G.S., and R. Russell.—"Illustrating the Geology of the Carboniferous Rocks North and East of Leeds, and the Permian and Triassic Rocks about Tadcaster." Mem. of Geol. Survey (Quar. Sheet 93, S.W.) Pub. 1870.

Classify the Lower Limestone as the base of the Permian, and the Shales and Sandstones below this base, as members of the Carboniferous Formation.

C. Fox-Strangways, F.G.S., Mem. Geol. Survey.—"The Geology of the County North and East of Harrogate." (Quar. Sheet 93, N.W.) 1873.

Several sections exhibiting the unconformability of the Magnesian Limestone to the Underlying Rocks are given. The Plumpton Grit is considered as the uppermost bed of the Third Grits.

A. C. Ramsay, LL.D., F.R.S.—"On the Red Rocks of England of older date than the Trias." Quart. Jour. Geol. Soc., Vol. xxvii., p. 241. 1871.

Refers to the Yorkshire series.

A. H. Green, M.A., F.G.S., "On the Method of Formation of the Permian Beds of South Yorkshire." Geol. Mag., Vol. ix., p. 99. 1872.

Given an inland sea, as suggested by Prof. Ramsay, without outlets, having tributary streams bringing water holding the salts necessary for the formation of the limestone in solution, and by evaporation the Permian Limestone would be deposited. Such a state of things would be very unfavourable to animal life, and would account for its scarcity. Each division of the Permian Series is treated separately, and it is suggested that the salts may have been derived from volcanic springs. The same source would abundantly supply the peroxide of iron, which gives the colour to the red beds of the formation.

Joseph Lucas, F.G.S., of the Geological Survey, "On the Permian Beds of Yorkshire." Geol. Mag., Vol. ix., p. 338. 1872.

Accounts for the derivation of the Permian Limestone by the disintegration and re-deposition of the Mountain Limestone to the west; and the red colour of many of the sandstones he attributes to the presence of oxide of iron, which, in some instances, has stained the rocks red or purple, and in others has not. That the Permian and Craven Anticlinal were formed prior to the Permian Limestone being deposited. The author finds that of 15 sections, extending over a distance of thirty-two miles, *not one* exhibits purple grit immediately under the Magnesian Limestone. In one case only is the grit red, and in that instance there is an intermediate bed of red marl. Cites some cases in which red rocks are found in the Millstone Grits, far away from the Permian Limestone.

III.—GENERAL CHARACTER OF THE CARBONIFEROUS ROCKS WEST OF THE PERMIAN ESCARPMENT, INCLUDING THE RED ROCKS, OLDER THAN THE PERMIAN LIMESTONE.

An important Fault, running in an easterly and westerly direction, about three miles north of Leeds, from Meanwood to Kiddal Hall, where it passes beneath the escarpment of the Permian Limestone, roughly separates the series of Carboniferous formations into two parts. North of the Fault, the various sandstones of the Millstone Grit Group extend to the boundary of the Riding, or until they are displaced by the upheaved Yoredale rocks in the neighbourhood of Harrogate. Southwards from the Fault, the members of the Coal Measures occupy all the ground and form a large basin-shaped hollow, the eastern part of which is hidden beneath the Permian Limestone.

The Millstone Grit rocks to the north of the Fault will be described first. The series consists of three principal groups; at the base are beds of a massive pebbly grit, usually divided into two or more parts by thick beds of shale. They have been named the Kinderscout Grits, from their extensive development at the western escarpment of the Peak in Derbyshire. Above the lowest Grits is a series of Sandstones and Shales of a more complicated structure. They are the Third Grits, and between these and the Coal measures is the Rough Rock. As its name implies, it is a rough gritty Sandstone, sometimes containing quartz pebbles in great abundance; frequently there is at its base a more or less thick bed of flagstones. The latter have sometimes been considered as constituting a second group, and in Lancashire are distinguished as the Haslingden Flagrocks, being very extensively developed and quarried. The lowest member of the series, or Kinderscout Grit, extends from Derbyshire in a broad line northwards into Yorkshire, forming the high hills constituting the "Back-bone of England." To the westward it presents a long series of rugged and precipitous escarpments, which have the local designation of Edges. Such are Howden Edge, Diggle Edge, and Blackstone Edge. They rise to a height of 1,400 to 1,600 feet, and mark the line of the Pennine Anticlinal, the southern extension of the Great Pennine Fault. Eastward the Kinder Grits slope gradually beneath the higher members of the formation, and they in turn disappear beneath the overlying Coal measures. The Kinder Grits extend in a northerly direction as far as Skipton, and then turning eastwards may be seen flanking each side of the valley, as far as Bolton Abbey, being separated into two parts by the internal pressure which forced up the Anticlinal of contorted Mountain Limestone which extends along the centre of the valley for the same distance. Beyond Bolton Abbey the Kinderscout Grit forms the undulating moorlands, wholly given up to grouse and sheep, as far as the valley of the Washburn, being again broken through by the extension of the Skipton Anticlinal, to Blubberhouses and Kex Gill. In the picturesque gorge of Kex Beck the Grit forms a bold cliff on either side, in places clothed with trees, in others standing out boldly in huge weathered masses. In the bottom of the valley Limestone is worked by an adit, and occasionally veins of lead are found, evidence that there has been violent eruptive action in the immediate neighbourhood. From Blubberhouses the line of Fault proceeds eastwards to Beckwith, and thence north-eastwards through Harrogate to Knaresborough. The Kinder Grit occupies all the elevated land of Forest Moor. For a distance of three or four miles from Beckwith House to Harrogate the Anticlinal has again brought to the surface the Yoredale Rocks, consisting of limestones, sandstones, and shales. The limestone was considered by the late, still lamented, Professor Phillips as the equivalent of the Main Limestone of Penyghent and Ingleborough. The Kinder Grit above it being the Ingleborough Grit of the same author. The Yoredale Rocks are extensively quarried at Low Harrogate, Shaw Green, and several other places. Dipping rapidly in every direction from the slopes of these Yoredale Rocks are thick beds of Kinderscout Grit, separated into two, and in some cases three beds, by thick masses of Shale, the whole being near 1,400 feet in thickness. The lowest and the highest Sandstones are thick-bedded, coarse, massive Gritstones, frequently containing pebbles of quartz; they are extensively quarried for building purposes near Pannal and at Hookstone Wood. Southwards the Upper Bed of Grit forms the bold eminence of Great Almias Cliff rising to a height of 700 feet above the sea-level. North-eastwards they gradually sink and disappear beneath the Permian Limestone escarpment at Bilton Park and near Starbeck Station.

We have seen that the lowest member of the Millstone Grits in the West Riding forms roughly two sides of a square, extending from south to north and west to east, and owing its present position to the elevating influence of the Pennine and Craven systems of Anticlinals. The Rocks have a general dip towards the centre of the square, and above them, rising to still greater eminence, are the members of the Third Grit Group. Like the Fourth or Kinder Grit, they present a bold escarped face to the westwards, whilst towards the east they sink gradually with a dip-slope under the superincumbent beds of the series. They rise frequently to the height of 1,700 to 1,800 feet, and usually form moorlands covered with heather and peat bogs. The hills composed of these rocks extend northwards from Holme Moss, on the south-west border of the county; Marsden, Rishworth, Wadsworth, and Keighley Moors being amongst the number. From Keighley, Rumblesmoor, Otley Chevin, and Arthington Bank, the series extend eastward to Harewood, and a little further, in the same direction, at East Keswick and Bardsey, the Grit Rocks dip under the Escarpment of the Permian Limestone. Northwards they have been denuded into a broad valley, along which the river Wharfe has its course. On the opposite side of the valley the Third Grits are again in force at Kirkby-Overblow, Spofforth, and Plumpton. Again they disappear beneath the Permian Limestone, dipping south-east, and giving place to the Kinder Grits and Shales of Starbeck and Bilton Park. Beyond this point they re-expand into broad heathery moorlands, deeply carved by the channels of the river Nidd and its tributaries. From Hampsthwaite to Brimham Rocks, Grantley and Kirkby-Malzeard, and thence eastwards, they may be seen at Fountains Hall, Markington, South Stainley, and Knaresborough, at the latter places laying unconformably to and disappearing beneath the Permian Limestone; the junction of the two series of rocks, however, is much obscured by deposits of drift in the more northern part.

The Third Grits form a considerably more varied series than those above or below. They are perhaps as well developed in the country between Harrogate and Ripon as anywhere, and the following section from this district may be taken as a type:—

	Ft.
1. Plumpton Grit	150
2. Shale	50
3. Follifoot Rock	75
4. Arenaceous Shales and Flagstones with Worm-Tracks..	60
5. Cayton Gill Beds	
a. Thin Flags, with Encrinites.	
b. Calcareous Sandstone with Brachiopods.	
c. Hard Sandstone with Bellerophon.	
6. Shales	60
7. Follifoot Coal Grit with Shales and Coal	200
8. Shales	400
Kinderscout Grit.	

The Follifoot Coal Grit forms the base. It is a hard, compact sandstone, and its outcrop forms bold ridges at Long Crag and Oak Beck, and also near Harrogate End. They also crop out at Bilton, near the edge of the Permian Limestone Escarpment. At the latter place two seams of coal have been worked for the purpose of burning the Limestone. They occur in the Grit which is here separated into two beds by Shale. The upper bed of Coal is 3 feet 2 inches thick, and is divided from the lower by 10 or 12 feet of shale. The lower bed of Coal is more variable in thickness, but in some places reaches 2 feet 9 inches. The Coal has also been found, in a small stream, west of Thornton Moor House, at a depth of 60 feet. It was there only 18 inches thick.

The Cayton Gill Beds are very fossiliferous—a circumstance of considerable interest—the Millstone Grits generally being nearly devoid of fossils. The three beds are rarely found well developed in one locality; in a quarry near the roadside, between Sawley and Ripon, they are mentioned by the Rev. John S. Tute as all being present; the lowest is a sandstone, close-grained and hard, full of the remains of plants and shells, of which Bellerophon costatus is the most common. The second bed is a sandstone, containing the remains of Brachiopods, Productus, and others. The upper bed is more flaggy in character, and is crowded with the stems of Encrinites. At Cayton Gill only the two upper beds are developed, but usually one representative is alone to be found. It has been extensively quarried for repairing the roads at Hampsthwaite, on Scarah Moor, and in a quarry on the roadside, between Pannal and Follifoot. It is locally termed the "shell bed," and has also been found flanking the hillside beneath Brimham Crags, thus extending from Hampsthwaite to Sawley, and from Brimham to Cayton, or, in other words, underlying the whole of the moorland track comprised in that area, and as we shall presently see, overlaid by the uppermost bed of the Third Grits, usually of a deep red or purplish colour.

The following fossils have been identified :—

Orthis resupinata Mart.
„ Michelina, L'Eville.
Productus semi-reticulatus, Mart.
„ Cora, D'Orb.
„ aculeata.
Spirifera lineata.
„ trigonalis, Mart.
„ striata.
Spiriferina cristata, Sch.
„ octoplicata.
Streptorhynchus crenistria, Phill.
Arca Sp. ?
Nautilus Sulcatus.
N. Sp. nov.
Avicula-pecten.
Stroponema analoga, Phill.
Chonetes Hardrensis, Phill.
Rhynchonella pleurodon, Phill.

The strata Nos. 4 and 3 of the section may be seen in the railway cutting between Harrogate and Spofforth, a short distance from the quarry of "shell limestone" already mentioned, on the Follifoot road. Near the Prospect Tunnel, the Flagstones and Arenaceous Shales are well exposed. They are grey and sandy, without much consistency, and easily weather in a somewhat peculiar manner, presenting the appearance of a very neatly pointed wall. The grey colour is occasionally variegated by small purplish blotches. The Sandstones contain traces of vegetable matter, and are often covered by worm-tracks, and probably those of some mollusca. These Flags and Shales pass gradually, as we approach Spofforth, into No. 3, the Follifoot rock. It is a coarse, quartzose grit, containing many pebbles of quartz; it is thick-bedded, usually of a yellowish white colour, but in places changing to a purplish tint. The Shales, No. 2, succeed next, and above them is the Plumpton Grit, about half-a-mile from Spofforth.

The Plumpton Grit is the uppermost bed occurring in this district. It is very coarse-grained, thick-bedded, massive-looking sandstone, and in the lower part is rendered quite a conglomerate by the great number of contained quartz pebbles. It is usually divided into two beds by a parting of shale, and measures from 150 to 200 feet in thickness. In some places it affords an excellent building stone; it is of a deep red or purplish colour, which is probably due to the presence of a large amount of ferruginous matter. The upper beds are often flaggy, those lower down being softer and thicker bedded. This Grit is remarkably conspicuous throughout the district, from its tendency to weather into picturesque forms; fine examples may be seen in Plumpton Park. On the road side between Plumpton, Spofforth, and Wetherby, large blocks frequently occur standing alone, or in groups in the fields adjoining the road. The surrounding soil is generally found to be composed of the disintegrated rock. The Plumpton Grits extend beneath the Permian Limestone to Knaresborough, where they may be seen in the bank of the Nidd underlying the Permian Limestone. Under the Castle a huge boss rises up into the Limestone, proving the unconformability of the two rocks. From Knaresborough they extend northwards to Fountains, and form a cap to all the hills westwards to Brimham Rocks and Guy's Cliff, near Pateley Bridge. Brimham Rocks are composed of the lower members of the Plumpton Grit, and they exhibit the same tendency to assume all kinds of peculiar and extraordinary forms as those of Plumpton and Spofforth.

In the stretch of country occupied by the Third Grits, ranging southwards from Keighley Moor, very similar sections are obtained to those in the northern part of its area.

Coal seams have been wrought in the lower members of the series, varying very much in thickness. In the valley of the Aire, at Morton Banks and Thwaites, beds of coal are, or have been worked, which have a face of 4 feet 6 inches to 6 feet thick. Coals, not so thick, have also been got from the same horizon in the valleys west of Halifax, and are found generally distributed over the lowest bed of Grit further south. These are, in all probability, the equivalent of the Follifoot Coal Grits. The peculiar fossiliferous beds of the Cayton Gill series seem to have also their representatives in the southern district. In Luddenden Valley, and on Wadsworth Moor, two beds of dark-coloured shale occur, which contain numerous specimens of the genera Goniatites and Avicula-pecten. The lower bed also encloses many nodules of limestone which, when broken, are found to be full of similar fossils and also Posidonia, Orthoceras, Nautilus and Modiola. Remains of fish were also found, of the genera Acrolepis, Acanthodes, and probably the teeth of Cladodus and Orodus, in making an aqua-conduit through the Third Grits under Wadsworth Moor. In other localities, at Warcock Hill and Pule Hill near Mossley, similar beds of shale are found, with fossil Molluscs. The Shales and Flagstones, with worm-tracks, appear to be very persistent beds; and southwards may be seen, in many sections, to the west of Halifax, and in a fine section exposed in the bed in the stream in Ramsden Clough, near Holmfirth. In the latter the whole series of the Third Grits are exposed, resting on the Kinderscout Grit in the bottom of the valley.

The Uppermost Grit usually forms a very decided feature in the landscape where it occurs. It is a massive, well-jointed, thick Sandstone, and extends for considerable distances in tabular, wall-like escarpments. In several localities it is a decidedly red colour, like its equivalent at Plumpton and Brimham, and shows a tendency to weather into isolated blocks or masses. Numerous examples of the latter phenomenon occur along the edges of the escarpments: rocking stones and detached monoliths are common. The red colour of the rock may be seen on Warley Moor, and the Upper Grit in Ramsden Clough is quite a red colour.

The Rough Rock, with occasionally the Flag Rocks at its base, forms the next ring within the circles of the Third Grits. They extend northwards to Halifax and Shipley, and thence eastwards two or three miles north of Leeds. Along their entire course they are very extensively quarried, forming a very durable building stone, and furnishing ashlar stone of nearly any size that can be carried away. From Meanwood to Kiddall Hall they are brought into juxtaposition with the Coal-measures by a fault; both the Coal-measures and Rough Rock disappear beneath the Permian Limestone. In Bramham Park, three or four miles east from the Limestone escarpments, more than usual denudation has taken place, and the Rough Rock is exposed beneath the Limestone, and is quarried in several places in or near the park. The Grit Rock, in this instance, is the usual yellowish-grey colour, and has not been changed by the overlying Limestone. The Lower Coal-measures overlie the Rough Rock, and extend from the southern extremity of the county, a little west of Sheffield, northwards to Penistone, Huddersfield, Halifax, and Denholme, thence, turning eastwards, they continue a few miles north of Bradford and Leeds, and near Barwick-in-Elmete pass under the Permian Limestone escarpment. The constituents of the Lower Coal-measures differ but little from those of the Millstone Grits. Beds of sandstone, perhaps finer-grained and more flaggy than those of the rocks on which they rest, are associated with thick masses of shale, and amongst these, beds of coal, usually lying immediately above the sandstone, are the characteristics of the Coal-measures. The coals occur more frequently, and are generally thicker and of greater value than those of the Millstone Grits. As the higher members of the Coal Series are reached, the sandstones become less and less persistent, and exist only in areas of small extent, thinning out and giving place to shales, or splitting and dovetailing with strata of shale until, the latter gaining preponderance, the Sandstone finally disappears. The coals occur with greater frequency, and are thicker and more valuable than those of the Lower Coal-measures. The Upper Measures of the Yorkshire Coal Field are more broken by faults than those lower in the series, and as a natural consequence the seams of coal are correlated with much greater difficulty.

The Lower Coal Measures rest on the Rough Rock conformably; and on the western side, after forming bold escarpments of the Elland Flag Rock, they dip gently with the inclination of Grits to the eastwards. From Denholme, to the junction with the Permian Limestone, the rocks dip to the south, whilst in the extreme southern part, below Sheffield, the dip is northwards. It is thus evident that they form a trough or basin, with a framework of Millstone Grit Rocks. The higher beds of the Coal Formation form concentric circles, one within the other, whose radii are ever becoming smaller the nearer the top the series is approached. The eastern part of the trough is lost beneath the escarpment of the Permian Limestone, which bisects it in a north and south direction. It is, however, known to exist, the Limestone having been pierced in numerous instances to obtain the coal from the seams below.

Some of the sandstones of the Upper Coal Measures, where they are in apposition to the Permian Limestone, are coloured red or purple, whilst in other instances they remain unaltered, and exhibit the ordinary colour of the rock, as seen further to the westwards. On Brierley Common, and extending southwards to Clayton-in-the-Clay, the ground rises to a slightly higher elevation than the district westward; this is due to the presence of a thick-bedded, softish, light brown or buff Sandstone. A short distance northwards, at Hunsworth and Brierley, a second Sandstone occurs; these have been described in a paper read to this Society by Professor Green as the Houghton Common and Brierley Rocks respectively. The uppermost bed, the Houghton Common Rock, is extensively quarried on Ackworth Moor Top, extends to East Hardwick, and probably passes under the escarpment of the Permian Limestone. On the higher ground, near Pontefract, two Sandstones may be seen separated by Shales. The upper one is the most important, and is extensively quarried. It is a yellowish colour, soft, and thick-bedded. The bold projection on which Pontefract Castle is built is composed of the same rock; is very probably the equivalent of the one on Houghton Common. A little eastward it disappears beneath the Permian Limestone Escarpment, being still of the same yellow colour as elsewhere. There is still another important Rock which bears a close relation to the Permian Limestone. It may be seen at Harthill, and extends in a north-westerly semi-circular form by South Anston, Aston, Whistow, and Rotherham. It is known as the Red Rock of Rotherham. It is a thick massive Grit of a red, purple, or salmon colour. It was considered and described by Professor Sedgwick as the New Red Sandstone, the equivalent of Rothliegende. Since Sedgwick's time it has been a source of continual difficulty. Messrs. Thorpe and Farey regarded it as a regularly interbedded Sandstone of the Coal-measures, of local extent. Recent investigations of the Geological Survey point to its deposition some time after the measures on which it rests, to which it does not appear to be quite conformable, had become consolidated and smoothed down after being upheaved and denuded. That it is a member of the Coal-measures cannot be doubted, beds of Shale and Coal lie above it which are exactly similar to those below. The whole series was sunk through in the Shireoaks Pit, and they may also be examined about a couple of miles south of Masborough Station on the Midland Railway.

(4) GENERAL CONTOUR AND EXTENT OF THE PERMIAN FORMATION.

The Permian Limestone extends in a narrow strip, rarely exceeding four or five miles in breadth, from Tanfield, north of Ripon, in a southerly direction to Tickhill and Harthill, on the boundary of the county with Lincoln and Nottinghamshire. Its western boundary forms generally a bold escarpment overlooking the Coal-measures of the southern half of the Riding and the Millstone Grits of the northern, whilst in an easterly direction the Limestone falls with a gentle dip of from 2° to 6° under the Bunter Sandstone, mostly enveloped in the superficial deposits of detritus, which form the extensive and low-lying vale of the Ouse. The western boundary, which is the one with which this paper is concerned, rises to a height of 400 feet above the sea-level in the northern part of the Riding, dipping from the Gritstone moors of Kirkby-Malzeard and Pateley. In its progress southward this elevation is reduced at Knaresborough 225 feet, rising again at Rigton to 350 feet; and about 300 feet is the average height, until the promontories are reached on which Conisborough Castle and Roche Abbey are built. The Limestone at these places attains its greatest elevation of about 500 feet. As its exact boundaries will be tolerably well indicated in the following pages, they are not given here.

From the abrupt and often precipitous termination of the Limestone, and the frequent occurrence of outlying masses along its western edge, there appears great probability that its extension in this direction was at one time much greater than at present. Periods of denudation have since occurred, and the immense quantities of pebbles and boulders of Limestone, rounded and water-worn, existing in the deluvium of the Ouse Valley, testify to the great extent of its abrasion. It may, perhaps, be possible that the initial direction of the water-courses, which cut through the Limestone escarpment in an easterly direction, may have been received when the country to the westward had a very different contour to its present one—in which case this seeming anomaly might be much simplified.

The tract of country covered by the Permian Limestone is peculiarly beautiful. Its rich soil affords nourishment to innumerable orchards, and a variety of flowering plants grow here which cannot subsist elsewhere in the Riding. Truly this may be called the "Garden of Yorkshire." Richly wooded and gently undulating, its park-like appearance has been seized upon by the nobility for centuries, and the numerous mansions which crown its eminences or lay half hidden on its wooded slopes give a peculiar interest to the district; whilst its ruined castles and keeps force a crowd of historical associations on the mind, rarely equalled in so small an area.

(5) THE JUNCTION OF THE PERMIAN LIMESTONE WITH THE UNDERLYING FORMATIONS, AND THEIR UNCONFORMABILITY.

Having thus briefly glanced over the more salient features of the Carboniferous Rocks and those of the Permian, I propose analysing such evidence as may be derived from sections exposed along the Western Escarpment of the Limestone, and deducing therefrom sufficent proof of the unconformability of the two series of rocks, and of the absence of any sandstone which can be considered the equivalent New Red Sandstone, or Rothliegende of the Germans.

There are two principal beds of Sandstone which exhibit a great tendency to assume a red or purple colour when in juxtaposition with the Permian Limestone. One of them occupies a large area in the northern part of the West Riding, stretching from the Moorlands north of Brimham Rocks in an easterly and south-easterly direction, and disappearing beneath the Permian Limestone. The second is in the southern extremity of the county, and known as the Red Rock of Rotherham. Between these localities the Limestone rests on sandstones and shales, which exhibit a much larger proportion of sections, in which the colour is the ordinary grey or white of the rocks where seen away from the Limestone, but which are occasionally coloured red or purple.

The Red Grit in the Brimham and Plumpton district is far from being uniformly red, in many cases it is a grey or whitish colour. Examples in which the red colour is conspicuous may be seen at South Stainley, Scarah, Scriven, Knaresborough, Plumpton Park, Spofforth, and on the banks of the Wharfe (opposite Wood Hall), and in other places.

At Scriven, to the north-west of the village, is a quarry of very thick-bedded purplish grits, about 80 feet thick; near the surface of the quarry is 4 or 5 feet of shaley marl of a deep purple colour. The limestone is not seen resting directly on this sandstone, but about half-a-mile north-east a small quarry exposes the limestone with 10 or 12 feet of quicksand below it. The latter has probably been derived from the disintegration of the grit rocks beneath, anterior to the limestone being deposited above it. The lower beds of the limestone contain sand and pebbles of quartz. The dip of the sandstone is to the north-north-west, whilst that of the overlying limestone, so far as could be ascertained, was slightly north-east. At Knaresborough the river Nidd has carved its channel through the Permian

Limestone Escarpment, and has exposed on its bank some splendid sections; perhaps the finest, and one that proves most conclusively the unconformity of the Limestone, is under the cliff on which the Castle stands. A huge mass of Red Sandstone forms a circular boss over which the limestone is deposited in even beds. Other sections may be found lower down the river which show the same unconformity as the one already mentioned.

At Plumpton and Spofforth the Red Grits make an extensive display, and from the uneven hardness of their constituent parts, the softer portions have weathered away, the more durable parts remaining in all kinds of picturesque or fantastic forms. In Plumpton Park the rocks are surrounded by an artificial lake, which enhances their beauty considerably.

Half way between Spofforth and North Deighton are two quarries, which expose the sandstone and limestone in actual contact. To the left of the road is St. Helen's Quarry, in which 13 feet of coarse quartzose grit, of a red colour, is exposed. In the centre the sandstone forms a hollow, in which 5 feet of shale is deposited. The shales are sandy, and in the lower part red; but towards the top they are a green colour, with spots of deep red. Above the Shale, and resting on the sandstone at each end, are 5 to 8 feet of thin-bedded yellow limestone. A couple of hundred yards further is another quarry, at Newsome Bridge. Here the Limestone is the usual yellowish colour, and rests unconformably on a thick-bedded gritstone, which is in this instance a grey or white colour. The latter presents an uneven surface, on which the limestone is laid, its lower beds being full of grains and pebbles of quartz derived from the lower rocks. Still further south, on the banks of the river Wharfe, a wooded escarpment of red grit rises to a height of about 50 feet; and above this, at a distance of 60 yards, is a second embankment, composed of Permian Limestone, exhibited in a quarry not now used. The lower part of the gritstone is much paler in colour than the upper, and immediately below it is a bed of sandy shale, of which 6 feet are exposed, dipping 26° south-east, which is of a yellow colour.

In all the sections hitherto mentioned, the Grit Rock beneath the limestone is the upper bed of the Third Grits. It is a peculiarity of this rock, throughout its entire extent, that it weathers into blocks and rocking stones; and also that it is a red colour in many localities far away from the influence of the Permian Limestone; as, for instance, on Warley Moor, near Halifax, and in the Cloughs above Holmfirth.

In the district south of the River Wharfe, as far as Thorner and Bramham, there are several sections which exhibit the relationship of the limestone to the underlying rocks. Near East Keswick there are two or three outliers of Permian Limestone which have been separated from the main mass by the denudation of the intervening valleys. At East Keswick there is a quarry of thin-bedded limestone, close-grained, and separated by marly partings. It is a yellowish colour, full of cavities filled with crystallised Carbonate of Lime, and exhibiting traces of the fossil Axinus. Descending the road towards the village a short distance, a gritstone may be seen forming the sides of the road. The grit in some places had a slightly-reddish tint, but is more commonly of the ordinary colour.

Near Rigton, also, beds of similar limestone occur, having a dip of 5° to the south-east. In the hill-side, just below the limestone quarry, is a quarry of grit rock. A thickness of 25 feet is exposed, of the usual grey colour. It is a thick, falsely-bedded grit, with thin partings of shale. In an adjoining Railway cutting, beds of a similar gritstone may be seen, some of them quite filled with quartz-pebbles, and forming a conglomerate; they have a general dip to the north-west. Though not seen in absolute contact, there can be no doubt the two series of beds do not conform together. Still proceeding southwards about a mile, opposite the situation occupied by the old Pompocali, are the picturesque crags of Etchell. They are formed from the same gritstone already mentioned, are of a yellow colour, and have become much rounded by exposure. A short distance above and beyond the crags, the Permian Limestone is worked for agricultural purposes.

Westward from these points the Gritstone may be traced, and is found to correspond exactly with the various beds of the Third Millstone Grits, already described as stretching from Harewood and Eccup eastward. The great Fault which reaches from Meanwood to Kiddall Hall, and there passes beneath the limestone, has brought the Upper or Rough Rock into apposition with the Coal-measures on the south. The Fault appears to be continued two or three miles still further eastwards along the edge of Bramham Park. North of the Fault, near the park, the limestone has been so much abraded that a considerable expanse of the grit rock beneath is now at the surface. Three or four quarries have been opened in the grit to obtain stone for building purposes. In one, outside the boundary wall of the park, a good section is exposed, showing the limestone superimposed on the grit, with a small bed of fine sand, mostly white and very falsely-bedded, dividing the two. The gritstone, of which about twenty feet are exposed, is white, in thick massive beds. It is quartzose, and contains many rounded pebbles of the same material. In some cases it is very soft, and may be ground into sand between the fingers; usually it is a good building stone. The upper surface is very uneven, and has evidently been subject to the action of water, which has washed away the softer parts, leaving the harder standing in elevated patches jutting up into the limestone overlying it. The limestone, of which about 15 feet are exposed, is yellow, contains numerous sparry cavities, and in its lower beds presents the appearance of a conglomerate, from the great number of pebbles of quartz it contains, derived from the grit rock below.

Near the entrance lodge is another quarry, in which the grit rises quite to the surface. It is similar in composition to the one already described, the white sandstone is occasionally stained yellow by the presence of iron ; the upper part of the right of the quarry is thinner, and somewhat flaggy. It has exactly the appearance that many of the grits present further westwards, where a bed of sandstone, cropping out on a hillside, has been crushed and broken by some lateral pressure. The whole section is evidently Rough Rock. Outside the park gates are other quarries, similar to those described, exposing the sandstone, with limestone above it quite unconformable.

South of Bramham Park, the strata beneath the limestone escarpments are principally composed of shales, a thin bed of sandstone being occasionally present. The thick-bedded quartzose sandstones, so prevalent further north, have disappeared. Remembering that the Fault at Kiddall Hall throws up the Coal-measures against the Rough Rock, the occurrence of a large proportion of shales is exactly what might be expected, and bears evidence to the correctness of the conclusion. Near Barwick-in-Elmete the river Cock and its tributary have cut a deep channel through the limestone, and in several places their beds are composed of shales and thin sandstones of Carboniferous Age. At Potterton Bridge, half-a-mile north of Barwick, the shales are well exposed in the banks of the stream. They vary in colour from a deep purple to the grey colour of the ordinary Coal-shale, which may be seen by tracing the shales in the bed of the stream nearer its source westwards. The shales are sandy, and contain a good quantity of mica.

In the bed of the river Cock, a short distance east of Barwick, beneath beds of thick Yellow Limestone, there is a hard sandstone, close-grained, like Calliard; this is not coloured, but, where the joints occur in the stone, they are often found filled with crystals of Carbonate of Lime. The shales, which also occur near the same place, are coloured a deep purple. The most probable reason why the sandstone is not coloured is its fine, close-grained texture, rendering it impervious, or nearly so, to the passage of water percolating from the limestone. That water-bearing Carbonate of Lime in solution has been present is proved by the lime being crystallised and deposited in the cracks of the stone.

At Garforth, the thin-bedded Lower Limestone rests on about 12 feet of yellow sand, rather pebbly at the base, and very false-bedded. Beneath this are Coal shales, either grey or a reddish colour. Towards the south and south-east the beds of sand thin out and disappear.

Passing Kippax, where the sinking of pits beyond the Limestone Escarpment have shown the limestone to rest on various beds of shale and sandstone, with seams of coal belonging to the Coal-measures, at Pontefract a fine section has been exposed in making the new line of railway from Pontefract to Swinton. A Fault has brought together a thick-bedded, soft, yellow sandstone with red marly partings, and a series of shales with two beds of coal near the top, in the following sequence:—

	Ft.	in.
Shale	—	
Coal	0	6
Blue Shale	2	0
Coal	0	6
Yellow Clay, or Shale	2	0
Sandstone, Ferruginous	8	0
Blue Shale	10	0
Sandstone	8	0

The limestone may be observed stretching above and across both the sandstone on the one side the Fault and the shales and coals on the other.

The sandstone is the same as that on which the castle is built, and, as already stated, the Pontefract and Houghton Common Rocks are undoubtedly members of the Coal-measures, though they were considered for many years, and by eminent geologists, to be New Red Sandstone, or Rothliegende. They are generally of a grey colour, coarse and micaceous, or of a brownish tint, sometimes firm and well cemented, forming a good building stone; at others, only incoherent sand. There are many quarries near the town, and good natural sections beneath the castle. The sandstone extends southwards beyond the river Went, towards Conisborough, and expands westward to the Ackworth and Brierley Moors. It is coarse, thick-bedded, or in some cases micaceous and flaggy, more or less coloured red or variegated, where in conjunction with the limestone, from which it is often distinctly separated by beds of red or purple marls.

Conisborough Castle stands on an eminence composed of an outlying piece of Permian Limestone, capping a hill of sandstone. The latter has been largely quarried for building purposes between Conisborough and Clifton. It is coarse and massive. On the hill-side, opposite the town, a section is exposed at the Ashfield Fire-clay Works, exhibiting the following sequence:—

PERMIAN LIMESTONE.	Ft.	Ins.
Variegated Red Marls	30	0
Sandstone, coloured Red	5	0
Yellow Clay	2	0
Blue Clay	6	0
Yellow Ferruginous Clay	12	0
Yellow Sandstone	14	0
Series of Blue Clays, &c., &c.		

The variegated marls are probably belonging to the

Permian formation, but all below is of the Coal-measures. In the lower part of the marl are numerous fragments of the rock occurring below, which would appear to prove their unconformity, though the beds lay parallel one to the other, so far as can be seen in this section. Still further south we come to the tract of red sandstone, known as the Red Rock of Rotherham. It extends several miles west of the limestone escarpment—to Rotherham and Aston. At North and South Anston, which are on the line of the escarpment, below the yellow limestone, there is a coarse variegated sandstone, which is occasionally a deep red colour, and below that shales and coal. About a couple of miles further, the junction of the sandstone and limestone is well exposed at Harthill, and just outside the boundary of the county, at Barlborough. It is there a coarse, thickly-bedded sandstone in the lower part, becoming finer and thinner in the beds higher up, and is separated from the limestone by beds of marl, all of a red colour. A section through the Limestone, and the strata below it, at Shireoaks, east of Harthill, and on the Permian Escarpment, shows the relation the rocks bear to each other. It is as follows:—

	Ft.	Ins.
Soil and Sand	6	0
Alternations of Light Red Sandstone and Marl	44	0
Magnesian Limestone	90	0
Hard Blue Shale, with thin Limestone bands ...	20	0
Blue Bind, or Shale	30	0
Grey Sand Rock (Quicksand)...	7	0
Fire-clay	2	0
Shale, with Ironstone	4	0
Black Shale, with Ironstone	1	1
Blue Shale	4	0
Grey Sandstone	6	0
Blue Shale, with Ironstone	20	0
Coal	2	0
Fire-clay	0	8
Blue Shale	15	0
Red Rock of Rotherham	200	0

	Ft.	Ins.
Coal	1	4
Blue Shale	13	6
Grey Sandstone	20	0
Shale, with Ironstone	8	0

Below this the pit passes through all the upper Coal-measures to the Barnsley Coal. From this section it is quite evident that the Red Rock cannot be the Rothliegende, as was inferred by Prof. Sedgwick and others, but must be a member of the Coal-measures.

(6) CONCLUSION.

Having passed in review, though hastily and imperfectly, the varied facts relating to the subject of this paper, it appears that in all the rocks to the west, and on which the Limestone is superimposed in this Riding, there is a distinct unconformity in deposition to the Permian series. That after the Millstone Grits and the Coal-measures were formed there was a period of violent upheaval, during which the basin of the Yorkshire Coal Field, as we now know it, was separated by the upheaval of the Pennine Chain from that of Lancashire. This was succeeded by what must have been a long period of denudation, during which the greater part of, perhaps all, Yorkshire was subject to the attrition of the waves, and its eastern part reduced to a tolerably even surface. On this the Permian Limestone has been deposited. Where the bed of the sea, or large lake, as the case may have been, was composed of the coarse Gritstones of the Millstone Series, we find beneath the Limestone, beds of rolled sand and pebbles, derived from and deposited upon the ancient shore before the Limestone was formed; numerous examples of this may be seen along the escarpment, and many have been already mentioned and described. Where, however, the prevailing rock forming the coast or bottom was shale, as throughout the greater portion of the southern half of the escarpment overlying the Coal-measures, there is, in place of the Quicksands, beds of Marl, or hardened mud, of varying colour and thickness, derived from the disintegration of the shale and finer sandstones of the Coal-measures. Where sandstones are prevalent, the Marl is usually found to be sandy and micaceous; where shales, it is finer and more silky to the touch.

The only part of the line of the escarpment where there appears to be the slightest trace of conformability is where the highest strata of the Upper Coal-measures (above the Red Rock of Rotherham) appear to be deposited evenly below the Limestone. But if it be remembered, that they form the uppermost beds in a large trough or basin-shaped area, and in consequence will be far more evenly or horizontally bedded than those composing the outer or deeper rings of the hollow, their seeming conformity will be recognised as only apparent, and that in reality they are quite as distinctly separated as the older members of the series.

Should there at any time be pits sunk in search of coal at sufficient distances east of the Limestone Escarpment, it appears very probable that the lower beds of the Coal-measures will crop up in succession from below these highest measures, and will thus furnish another link in the chain of evidence proving that the whole of the Coal-measures, at any rate in Yorkshire, were formed and subsequently denuded before the advent of the Permian Limestone formation.

JUNCTION OF THE SILURIAN ROCKS WITH THE OVERLYING MOUNTAIN LIMESTONE, AT MOUGHTON FELL, IN RIBBLESDALE. BY THE EDITOR. (SEE PHOTOGRAPH.)

THE photograph issued with this year's volume of proceedings, illustrates an important section exposed in the valley of the Ribble, nearly opposite the village of Horton. The Silurian rocks, composed of grits, slates and limestones, extend over a large area, bounded by the line of the Pennine Fault, running in a north and south direction, and that of the equally important series of Craven Faults which run eastward from Ingleton, their position being indicated by the precipitous Scars of Giggleswick, Attermire, Malham, Yordale and Kilnsey. Bounded on the west and south by these Faults, the Silurian rocks underlie all the highest mountains in Yorkshire, forming a tolerably even base, with a general dip to the north-east. Sections exposing the junction of these rocks with the superincumbent Mountain Limestone may be seen beneath Whernside and Ingleborough, in the Ingleton and Dale Becks, and in Clapdale; underlying Cross Fell and Mickle Fell, they may be seen at High Cup Gill, and as shown by Mr. Dakyns, at the Pencil Mill, near Cronkley Scar. Penyghent, and the extensive Limestone Fells of Malham and Kilnsey also have a basement of Silurian Grits. Perhaps the finest section, showing the junction of the two formations, anywhere exposed, is the one chosen for the subject of this photograph. The Silurian Rocks have long been quarried, and are locally known as the Horton Flagstones; they are a bluish grey colour, rather coarse structure, and can be obtained of very large size. The flags are inclined at a very sharp angle to the horizontal beds of limestone which lie above them, but if traced along the side of the hill, it will be observed that they do not dip uniformly in the same direction, but are doubled into a series of anticlinals. It appears probable, that after the deposition of the bed of sand and mud forming these rocks in the ancient Silurian Sea, they were elevated and subjected to violent lateral pressure, and after this, that there was a long period when the rocks so formed were again beneath the waves, and were ground down by attrition to their present nearly level surface. On this, the coral reefs and shell beds forming the great mass of the Mountain Limestone was gradually accumulated. In many instances, there is between the two series of strata, a layer of pebbles derived from the Silurian Rocks beneath, and rounded by the action of water until all the sharp edges are worn off. Such a mass of pebbly conglomerate may be observed in the section photographed at the point where the water is thrown out, forming a pretty cascade. This conglomerate has been described as a detached mass of Old Red Sandstone, but the probability is that it must be considered as a part of the Carboniferous Limestone series, constituting a good dividing line between these and the Silurians, or as a basement bed to the Limestone.

Minutes and Balance Sheet.

Meeting of Council at the Philosophical Hall, Leeds, on February 28th, 1877.

Prof. A. H. Green, M.A., in the chair. Present—Prof. A. H. Green, Messrs. Davis, Brigg, and Embleton.

The Secretary read the minutes of last meeting, which were confirmed.

The Treasurer read his report; moved by Mr. Davis, seconded by Mr. Embleton, and carried—"That it be adopted."

Moved by Mr. J. Brigg, seconded by Mr. Embleton, and carried—"That the Papers read during the last twelve months in connection with the Society be published."

Moved by Mr. Davis, seconded by Mr. J. Brigg, and carried—"That Mr. Cash (for Halifax) and Mr. J. T. Atkinson (for Selby) be appointed Local Secretaries."

Moved by Mr. Embleton, seconded by Mr. Brigg, and carried—"That the next meeting be held at Ripon; that the Marquis of Ripon be asked to take the chair; and that the Rev. J. Stanley Tute, B.A., Dr. Parsons, J. R. Dakyns, Esq., M.A., and W. Percy Sladen, Esq., be asked to read Papers at that meeting."

Meeting of the Society in the Mechanics' Institute, Ripon, April 4th, 1877.

The Marquis of Ripon, K.G., F.R.S., in the chair.

The minutes of the last meeting were read and confirmed.

Proposed by Mr. W. Cash, seconded by Mr. Jno. Brigg, and carried—"That Messrs. F. H. Bowman, T. W. Helliwell, F. Smith, G. F. Smeeton, and F. Laxton be elected members."

Proposed by the Rev. J. Stanley Tute, B.A., seconded by Mr. J. W. Davis, and carried—"That Messrs. Thomas Pratt and William Garnett be elected members."

Proposed by Dr. Parsons, seconded by Mr. J. T. Clay, and carried—"That Messrs. Moiser and J. E. Clark be elected members."

Proposed by Mr. Bentley Shaw, seconded by Mr. J. T. Clay, and carried—"That Lieut.-Col. Thos. Brooke and Mr. Thomas Carrington be elected members."

The Chairman addressed the meeting on "Scientific Research."

The following Papers were read:—"The Alluvial Deposits of the Lower Ouse Valley," by H. F. Parsons, M.D., F.G.S.; "Notes on the Glacial Drift near Ripon," by the Rev. J. Stanley Tute, B.A.; "On the Silurian Erratics in Wharfedale," by J. R. Dakyns, M.A. (communicated by the Hon. Sec.). A discussion followed on the three Papers, in which Prof. Miall, Messrs. Davis, Clay, and Dr. Parsons took part. "On the Base of the Carboniferous Limestone in the North of England," by J. R. Dakyns, M.A. (communicated by the Hon. Sec.); "On the Genus Poteriocrinus and other Allied Forms," by W. Percy Sladen, F.L.S., F.G.S. A discussion followed, in which Prof. Miall and Mr. Cash took part.

A vote of thanks to the Chairman and to the readers of Papers, moved by Mr. Bentley Shaw, and seconded by Mr. J. T. Clay, concluded the meeting.

Meeting of Council at the Philosophical Hall, Leeds, June 6th, 1877.

Rev. J. Stanley Tute, B.A., in the chair. Present—Messrs. Davis, Carter, Holt, Reynolds, and the Rev. J. Stanley Tute.

The Hon. Sec. read the minutes of the last meeting, which were confirmed.

A discussion ensued, on the motion of the Hon. Sec., as to the advisability of rescinding the old Rules and adopting new and simpler ones.

Moved by Mr. Reynolds, seconded by Mr. Holt, and carried—"That Prof. Miall, the Hon. Sec., and Messrs. Carter and Atkinson be appointed as a Committee to consider a new set of Rules, to be submitted to the next meeting at Huddersfield."

Moved by Mr. Davis, seconded by Mr. Holt, and carried —"That Malham be selected for the Annual Excursion, and that it take place some Wednesday in July."

Moved by Mr. J. W. Davis, seconded by Mr. Carter, and carried—"That the next General Meeting of the Society be held at Huddersfield early in October, and that Col. Brooke take the chair."

The Annual Meeting was held in the Rooms of the Huddersfield Literary and Scientific Society, South Street, Huddersfield, on Wednesday, October 24th, 1877.

The chair was occupied by THOMAS BROOKE, Esq., J.P., F.S.A.

The Hon. Sec. read the minutes of the last Ordinary Meeting, held at Ripon, which were adopted.

Moved by the Hon. Sec., seconded by Mr. Bentley Shaw, and carried—"That Messrs. H. Ormerod, S. W. North, H. Pocklington, A. Stott, W. Boothroyd, and Leedham Binns be elected members of this Society."

Moved by Mr. J. T. Atkinson, seconded by the Hon. Sec., and carried—"That Mr. R. Wilson Morrill be elected a member of this Society."

Moved by Mr. Sladen, seconded by Mr. Cash, and carried —"That Mr. Jno. Stubbins be elected a member of this Society."

Moved by the Hon. Sec., seconded by Mr. Cash, and carried—"That Mr. C. P. Hobkirk be elected a member of this Society."

The Hon. Sec. read the Revised Rules, which, after discussion by the Chairman, Messrs. J. T. Atkinson, Bentley Shaw, and others, were adopted on the motion of Mr. J. T. Atkinson, seconded by Mr. G. H. Parke, together with the clause—"That the New Rules be printed and circulated amongst the members."

Moved by Mr. J. T. Atkinson, seconded by Mr. G. H. Parke, and carried—"That the next meeting of the Society be held at Selby in April."

Moved by the Hon. Sec., seconded by Mr. G. H. Parke, and carried—"That the kind expression of feeling of this Society be handed to Dr. Duncan, President of the Geological Society at London, for his generous sympathy with us, and our regret that other engagements will not permit him to be present at this meeting."

Moved by the Hon. Sec., seconded by the Chairman, and carried—"That there shall be Local Secretaries in large towns in the county, who shall be *ex-officio* members of the Council."

The following were elected members of the Council:—

PRESIDENT.

Marquis of Ripon, K.G., F.R.S.

VICE-PRESIDENTS.

Earl Fitzwilliam,
Earl of Effingham,
Earl of Wharncliffe,
Lord Londesborough,
Lord Houghton,
Edward Akroyd, Esq., F.S.A., &c.
W. B. Denison, Esq., M.P.,
Duke of Leeds,
Duke of Norfolk,
Earl of Dartmouth,
Viscount Galway,
Viscount Halifax,
Jno. Waterhouse, Esq., F.R.S.,
W. T. W. S. Stanhope, Esq., M.P.

TREASURER.

Jno. Brigg, Esq., J.P., F.G.S.

HON. SEC.

J. W. Davis, Esq., F.G.S., F.L.S.

COMMITTEE.

Dr. Alexander,
Mr. R. Carter, C.E.,
„ T. W. Embleton,
„ E. Filliter, C.E.,
Prof. Green, M.A.,
Mr. H. P. Holt, C.E.,
Prof. L. C. Miall, F.G.S.,
Mr. R. Reynolds, F.C.S.,
„ Bentley Shaw,
„ H. C. Sorby. F.R.S.,
„ T. W. Tew,
„ W. Sykes Ward, F.C.S.

The following Papers were read:—"On the Occurrence of Vermiculite in England," by Mr. G. H. Parke, F.G.S., F.L.S. Specimens were exhibited; the Chairman and the Hon. Sec. taking part in the discussion which followed upon it. "On Carboniferous Cephalopoda," Part I.; "Structure of Recent Cephalopods," by Mr. Wm. Cash, F.G.S. A recent *spirula*, dredged from the Persian Gulf, together with other recent Cephalopoda, were exhibited. The Chairman and Hon. Sec. took part in the discussion which followed thereon. "On the Unconformability of the Red Rocks of

Central Yorkshire to the Permian Limestone," by Mr. James W. Davis, F.G.S., F.L.S. Messrs. Sladen, Cash, Shaw, and the Chairman took part in the discussion of the Paper.

On the motion of the Chairman, a vote of thanks was given to the lecturers.

On the motion of Mr. Bentley Shaw, seconded by Mr. Sladen, a vote of thanks was given to the Chairman.

Meeting of the Council at the Philosophical Hall, Leeds, November 14th, 1877.

Mr. W. Sykes Ward, F.C.S., in the chair. Present—Messrs. Ward, Davis, Filliter, Carter, Embleton, Atkinson, Lister, Tate, and Dr. Parsons.

The Hon. Sec. read the Balance Sheet, in the absence of the Treasurer.

Moved by Mr. Carter, seconded by Mr. Embleton, and carried—"That it be handed to the Auditors, and if found correct, shall be printed."

Moved by Mr. Atkinson, seconded by Mr. Tate, and carried—"That the same Committee as last year have charge of the publication of Papers."

Moved by Mr. Embleton, seconded by Mr. Carter, and carried—"That the Hon. Sec. be requested to appoint Local Secretaries as soon as possible, in all the principal towns of the county."

Statement of Receipts and Expenditure of the West Riding Geological and Polytechnic Society,

FROM JANUARY 1ST TO SEPTEMBER 30TH, 1877.

Dr. *The Treasurer in Account with the West Riding Geological and Polytechnic Society.* Cr.

Dr.	£	s.	d.	Cr.	£	s.	d.
To Balance	2	7	5	By Cash paid into the Bank	89	2	8
,, Subscriptions	92	4	8	,, Stationery	27	3	4
,, Beckett & Co.	70	18	1	,, Postage and Carriage	4	4	9
,, Reports sold	1	2	6	,, Cost of Photographs	33	14	9
				,, Expenses to Ripon	0	6	2
				,, Salary of Assistant-Secretary (eight months)	10	0	0
				,, Balance in Hand	2	1	0
	£166	12	8		£166	12	8

Dr. *The Treasurer in Account with Beckett & Co.* Cr.

Dr.	£	s.	d.	Cr.	£	s.	d.
To Balance at Bank	8	11	11	By Cash from Bank	70	18	1
,, Cash paid to Bank	89	2	8	,, Balance in Bank	26	16	6
	£97	14	7		£97	14	7

Examined and found correct, October 3rd, 1877,

A. H. GREEN.

Summary of Geographical Literature relating to the West Riding, published during 1876.

Compiled by J. W. Davis.

Aitken, John. Observations on the Unequal Distribution of Drift on opposite sides of the Pennine Chain, in the country about the source of the Calder, with suggestions as to the causes which lead to that result, together with some notices of the High Level Drift in the upper part of the valley of the River Irwell. *Quart. Jour. Geol. Soc.*, vol. xxxii., pp. 184-190. (Abridgement.)

Barrois, Dr. Chas. Recherches sur le Terrain Crítacè supérieur dé l' Angleterre et de l' Irlande (English and Irish Chalk). Lille. [Table of twelve zones in British Chalk, with equivalents in Yorkshire and eleven other counties, copied in review of the above.] *Geol. Mag.*, Dec. 2, vol. iii., pp. 516-17.

Bird, Chas. On the Red Beds at the Base of the Carboniferous Limestone in the N. W. of England. *Proc. of Geol. and Polyt. Soc. of W. Rid. of York.* New Series. Part 2, pp. 57-67.

Clark. J. E. Glacial Deposits at York. *Geol. Mag.*, Dec. 2, vol. iii., p. 384.

Clough, C. T. The section at the High Force, Teesdale. *Quart. Jour. Geol. Soc.*, vol. xxxii., pp. 466-471. Two woodcuts.

Davis, J. W. Erratic Boulders in the Valley of the Calder. *Proc. of Geol. and Polyt. Soc.* of W. Rid. of York. New Series. Part 2, pp. 93-101.

Green, A. H. On the Geology of the Central Portion of the Yorkshire Coal Fields lying between Pontefract and Bolton-on-Dearne. *Proc. of Geol. and Polyt. Soc. of W. Rid. of York.* New Series. Part 2, pp. 108-112.

——— A. H. Geology for Students and General Readers. Part 1. Physical Geology, pp. 27-552. Numerous woodcuts. Demy 8vo. (London.)

——— A. H. On the Variation in Character and Thickness of the Millstone Grit of North Derbyshire and the adjoining parts of Yorkshire, and on the probable manner in which these changes have been produced. *Brit. Asso. Rept.* for 1875, *Sections*, p. 65. *Abstract* also, in full, in *Geol. and Polyt. Soc. of W. Rid. of York.* New Series. Part 2, p. 68.

Huddleston, W. H. The Yorkshire Oolites. Part 2. Middle Oolites. *Proc. Geol. Assoc.*, vol. iv., p. 353.

Jones, Prof. T. R. The Antiquity of Man, Illustrated by the contents of the Caves and the Relics of the Cave Folks. *Geol. Mag.*, Dec. 2, vol. iii., pp. 269-272. [Abstract of Lecture to the Croydon Microscopical Club.]

Marr, J. E. Note on the occurrence of Phosphorised Carbonate of Lime at Cave Ha. (near Settle), Yorkshire. *Geol. Mag.*, Dec. 2, vol. iii., p. 268.

Miller, Hugh. Northumberland Escarpments and Yorkshire Terraces. *Geol. Mag.*, Dec. 2, vol. iii., p. 23.

Mortimer, J. R. The Distribution of Flint in the Chalk of Yorkshire. *Quart. Jour. Geol. Soc.*, vol. xxxii. Proceedings, p. 131.

Plant, J. On a Submerged Forest near Holmfirth. *Trans. Manch. Geol. Soc.*, vol. xiv., p. 71.

Rance, C. E. de. First Report of the Committee for investigating the circulation of the underground waters in the New Red Sandstone and Permian Formations of England, and the Quantity and Character of the Water supplied to various towns and districts from these Formations. *Rep. Brit. Assoc.* for 1875, *Sections*, pp. 114-141. Yorkshire Notes by J. C. Ward, pp. 126-128.

SPENCER, JAS. Geology of the Halifax Hard Bed Coal. *Naturalist* (New Series), vol. i., Nos. 11-12, pp. 163-164, 182-184.

TATE, RALPH, and Rev. J. F. BLAKE. The Yorkshire Lias. 8vo. (London.)

TATE, THOMAS. On the Glacial Deposits of the Bradford Basin. *Proc. of Geol. and Polyt. Soc. of W. Rid. of York.* New Series. Part 2, pp. 101-107.

TIDDEMAN, R. H. Third Report of the Committee appointed for the purpose of assisting in the Exploration of the Settle Caves (Victoria Cave). *Rep. Brit. Assoc.* for 1875, *Sections*, pp. 166-175. Two photographs.

——— The Work and Problems of the Victoria Cave Explorations. *Proc. of Geol. and Polyt. Soc. of W. Rid. of York.* New Series. Part 2, pp. 77-92.

LIST OF MEMBERS.

AKROYD, Col., Bank Field, Halifax.

ALDAM, W., Frickley Hall, Doncaster.

ALEXANDER, Dr., Halifax.

ATKINSON, J. T., The Quay, Selby.

BAILY, WALTER, M.A., 176, Haverstock Hill, London, N.W.

BAINES, EDWARD, St. Ann's, Burley, Leeds.

BALME, E. B. W., Cote Hall, Mirfield.

BARBER, F., Castle Hill, Raistrick, near Brighouse.

BARTHOLOMEW, CHAS., Castle Hill House, Ealing, Middlesex.

BEDFORD, JAMES, Woodhouse Ridge, Leeds.

BINNS, LEEDHAM, Grove House, Oakenshaw, Bradford.

BIRD, C., B.A., Grammar School, Bradford.

BOOTH, EDWIN, Barnsley.

BOOTHROYD, W., Brighouse.

BOWMAN, F. H., Halifax.

BRADLEY, GEORGE, Aketon Hall, Featherstone.

BRIGG, JOHN, Broomfield, Keighley.

BROOKE, ED., Jun., Fieldhouse Clay Works, Huddersfield.

BROOKE, Lieut. Col. THOMAS, Armitage Bridge, Huddersfield.

BROWN, HENRY, Daisy Hill, Rawden, near Leeds.

BROWN, JAMES, Rossington.

BUSTARD, JOHN, Engineer, Barnsley.

BUTLER, J. O., Kirkstall.

Carr, J. O., Mining Engineer, Barnsley.

Carrington, Thomas, High Hazels, Sheffield.

Carter, R., Barnsley.

Cash, W., 2, Elmfield Terrace, Halifax.

Chadwick, Wm., Arksey, Doncaster.

Charlesworth, J. B., Hatfield Hall, Wakefield.

Childers, J. W., Cantley, near Doncaster.

Childers, Mrs. Walbanke, Gloucester Lodge, St. Leonard's-on-Sea.

Clark, J. E., Friends' School, York.

Clayton, F. G., Ousecliffe, near York.

Dartmouth, Earl of, Patshull House, Wolverhampton.

Davis, J. W., Chevinedge, Halifax.

Day, Rev. Henry J., Barnsley.

Denison, W. B., M.P., Meanwood Park.

Durham, Machin, Thorne, near Doncaster.

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Effingham, Earl of, The Grange, Rotherham.

Embleton, T. W., The Cedars, Methley.

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Farrer, James, Old Foundry, Barnsley.

Ffooks, John, Elliot's Terrace, West Tarring, Worthing.

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Filliter, E., East Parade, Leeds.

Fraser, J., Grove House, Headingley, near Leeds.

Fraser, H. J., Grove House, Headingley, near Leeds.

Galway, Viscount, Serlby Hall, Bawtry.

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Hardcastle, John, Jun., South Milford.
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Hirst, John, Tadcastle, Dobcross, Saddlesworth.
Hobkirk, C. P., Huddersfield.
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Holmes, John, Methley.
Holt, H. P., Cavendish Road.
Houghton, Lord, Fryston Hall.
Hutchinson, John, Barnsley.

Jeffcock, John, Cowley Manor, Sheffield.

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Kell, Geo., Barnsley.
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Laurance, Jno., Barnsley.
Lancaster, Ed., Barnsley.
Leeds, Duke of, Hornby Castle, Bedale.
Leather, J. T., Leventhorpe Hall
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Mammatt, J. E., Barnsley.

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MARSHALL, ARTHUR, Headingley House.
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NORFOLK, Duke of, The Farm, Sheffield; Arundel Castle, Sussex.

OXLEY, HENRY, Weetwood.
ORMEROD, HANSON, Brighouse.

PEACOCK, W. H., Thornhill Collieries, Dewsbury.
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PRATT, THOMAS, Ripon.
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Shaw, Thomas, Allangate, Halifax.
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Sladdin, W. H., The Mount, Brighouse.
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Stott, Alfred, Brighouse.
Stott, W., Greetland, near Halifax.
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Tate, Thomas, Thornbury, Bradford.
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Ward, Christopher, Halifax.
Ward, W. Sykes, Denison Hall, Hanover Square, Leeds.
Ward, J. Whiteley, Halifax.
Warrington, John, Worsbro', near Barnsley.
Waterhouse, John, F.R.S., Well Head, Halifax.
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Wharncliffe, Earl of, Wortley Hall, Sheffield.
Wheatley, Charles, Sand House, Mirfield.

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