would be sufficient to melt, under the ordinary pressure of the atmosphere, the hardest rocks. Reasoning from these facts, it would appear that the mass of the globe, at no great depth, must be in a fluid state. But this deduction requires to be modified by other considerations, namely, the influence of pressure on the fusing point, and the relative conductivity of the rocks which form the earth's crust. To solve these questions a series of important experiments were instituted by Mr. Hopkins, in the prosecution of which Dr. Joule and myself took part; and after a long and laborious investigation, it was found that the temperature of fluidity increased about 1° Fahrenheit for every 500lbs. pressure, in the case of spermaceti, bees' wax, and other similar substances. However, on extending these experiments to less compressible substances, such as tin and barytes, a similar increase was not observed. But this series of experiments has been unavoidably interrupted; nor is the series on the conductivity of rocks entirely finished. Until they have been completed by Mr. Hopkins, we can only make a partial use of them in forming an opinion of the thickness of the earth's solid crust. Judging, however, alone from the greater conductivity of the igneous rocks, we may calculate that the thickness cannot possibly be less than nearly three times as great as that calculated in the usual suppositions of the conductive power of the terrestrial mass at enormous depths being no greater than that of the superficial sedimentary beds. Other modes of investigation which Mr. Hopkins has brought to bear on this question appear to lead to the conclusion that the thickness of the earth's crust is much greater even than that above stated. This would require us to assume that a part of the heat in the crust is due to superficial and external, rather than central causes. This does not bear directly against the doctrine of central heat, but shows that only a part of the increase of temperature observed in mines and deep wells is due to the outward flow of that heat."

ADDRESS TO THE GEOLOGICAL SECTION.

By SIR R. I. MURCHISON, D.C.L., LL.D., F.R.S.

Although I have had the honour of presiding over the geologists of the British Association at several previous meetings since our first gathering at York, now thirty years ago, I have never been called upon to open the business of this section with an address; this custom having been introduced since I last occupied the geological chair at Glasgow, in 1855.

The addresses of my immediate predecessors, and the last anniversary discourse of the President of the Geological Society of London, have embraced so much of the recent progress of our science in many branches, that it would be superfluous on my part to go again over many topics which have been already well treated.

Thus, it is needless that I should occupy your time by alluding to the engrossing subject of the most recent natural operations with which the geologist has to deal, and which connect his labours with those of the ethnologist. On this head I will only say, that having carefully examined the detrital accumulations forming the ancient banks of the river Somme in France, I am as complete a believer in the commixture in that ancient alluvium of the works of man with the reliquæ of extinct animals as their meritorious discoverer, M. Boucher de Perthes, or as their expounders, Prestwich, Lyell, and others. I may, however, express my gratification in learning that our own country is now affording proofs of similar intermixture both in Bedfordshire, Lincolnshire, and

other counties; and possibly at this meeting we may have to record additional evidences on this highly interesting topic.

But I pass at once from any consideration of these recent accumulations, and, indeed, of all tertiary rocks; and as a brief space of time only is at my disposal, I will now only lay before you a concise retrospect of the progress which has latterly been made in the development of one great branch of our science. I confine myself, then, to the consideration of those primeval rocks with which my own researches have for many years been most connected, with a few allusions only to metamorphism, and certain metalliferous productions, &c.

There is, indeed, a peculiar fitness in now dwelling more especially on the ancient rocks, inasmuch as Manchester is surrounded by some of them, whilst, with the exception of certain groups of erratic blocks and drifts, no deposits occur within the reach of short excursions from hence, which are either of secondary or tertiary age.

Let us, then, take a retrospective view of the progress which has been made in the classification and delineation of the older rocks since the Association first assembled at York, in 1831. At that time, as every old geologist knows, no attempt had been made to unravel the order or characters of the formations which rise from beneath the Old Red Sandstone. In that year Sedgwick was only beginning to make his first inroads into those mountains of North Wales, the intricacies of which he finally so well elaborated, whilst I only brought to that, our earliest assembly, the first fruits of observations in Herefordshire, Brecon, Radnor, and Shropshire, which led me to work out an order which has since been generally adopted.

At that time the terms of Cambrian, Silurian, Devonian, and Permian were not dreamt of, but acting on the true Baconian principle, their founders and their coadjutors have, after years of toil and comparison, set up such plain landmarks on geological horizons that they have been recognised over many a distant land. Compare the best map of England of the year 1831, or that of Greenough which had advanced somewhat upon the admirable original classification of our father, William Smith, and see the striking difference between the then existing knowledge and our present acquirements. It is not too much to say that when the British Association first met, all the region on both sides of the Welsh border, and extending to the Irish Channel on the west, was in a state of dire confusion; whilst in Devonshire and Cornwall many of these rocks which from their crystalline nature were classed and mapped as among the most ancient in the kingdom, have since been shown to be of no higher antiquity than the Old Red Sandstone of Herefordshire.

As to Scotland where the ancient rocks abound, though their mineral structure, particularly in those of igneous origin, had necessarily been much developed in the country of Hutton, Playfair, Hall, Jameson, and McCulloch, yet the true age of most of its sedimentary rocks and their relations was unknown. Still less had Ireland, another region mainly palæozoic, received any striking portion of that illustration which has since appeared in the excellent general map of Griffith, and which is now being carried to perfection through the labours of the Geological Survey under my colleague Jukes. If such was our benighted state as regarded the order and characters of the older formations at our first meeting, great was the advance we had made, when at our twelfth meeting we first assembled at Manchester in 1842. Presiding then as I do now over the geological section, I showed in an evening lecture how the palæozoic rocks of Silurian, Devonian, and Carboniferous age, as well as those rocks to which I had assigned the name of Permian, were spread over the vast region of Russia in Europe and the Ural Mountains. What, then, are some of the main additions which have been made to our acquaintance with the older rocks in the British Isles since we last visited Manchester?

Commencing with the oldest strata, I may now assume, from the examination of several associates on whose powers of observation as well as my own I rely, that what I asserted at the Aberdeen meeting, in 1859, as the result of several surveys, and what I first put forth at the Glasgow meeting of 1855, is substantially true. The stratified gneiss of the north-west coast of the Highlands, and of the large island of Lewis and the outer Hebrides, is the fundamental rock of the British Isles, and the precise equivalent of the Laurentian system of Canada, as described by Sir W. Logan. The establishment of this order, which is so clearly exhibited in great natural sections on the west coast of Sunderland and Ross, is of great importance in giving to the science we cultivate a lower datum-line than we previously possessed, as first propounded by myself before the British Association in 1855.*

For hitherto the order of the geological succession, even as seen in the Geological Map of England and Wales or Ireland, as approved by Sir Henry de la Beche and his able coadjutors, Phillips, Ramsay, Jukes, and others, admits no older sediment than the Cambrian of North Wales, whether in its slaty condition in Merioneth and Caernarvon, or in its more altered condition in Anglesea.

The researches in the Highlands have, however, shown that in our own islands, the older palæozoic rocks, properly so called, or those in which the first traces of life have been discovered, do repose, as in the broad regions of the Laurentian Mountains of Canada, upon a grand stratified crystalline foundation, in which both limestones and iron ores occur subordinate to gneiss. In Scotland, therefore, these earliest gneissic accumulations are now to be marked on our maps by the Greek letter *alpha*, as preceding the Roman *α*, which had been previously applied to the lowest known deposits of England, Wales, and Ireland. Though we must not dogmatise and affirm that these fundamental deposits were in their pristine state absolutely unfurnished with any living things (for Logan and Sterry Hunt, in Canada, have suggested that there they indicate traces of the former life), we may conclude, that in the highly metamorphosed condition in which they are now presented to us in North-Western Britain, and associated as they are with much granitic and hornblendic matter, they are for all purposes of the practical geologist "azoic rocks." The Cambrian rocks, or second stage in the ascending order as seen reposing on the fundamental gneiss of the North-West of Scotland, are purple and red sandstones and conglomerates forming lofty mountains. These resemble to a great extent portions of the rocks of the same age which are so well known in the Longmynd range of Shropshire, and at Harlech in North Wales, and Bray Head in Ireland.

At Bray Head they have afforded the Oldhamia, possibly an Alga, whilst at the Longmynd, in Shropshire, they have yielded to the researches of Mr. Salter some worm-tracks and the trace of an obscure crustacean.

The Highland rocks of this age, as well as their equivalents, the Huronian

* See Reports of British Association for 1855 (Glasgow Meeting). At that time I was not aware that the same order was developed on a grand scale in Canada, nor do I now know when that order was there first observed by Sir W. Logan. I then (1855) simply put forward the facts as exhibited on the north-west coast of Scotland; viz., the existence of what I termed a lower or "fundamental gneiss," lying far beneath other gneissose and crystalline strata, containing remains which I even then suggested were of Lower Silurian age. Subsequently, in 1859, when accompanied by Professor Ramsay, I adopted at his suggestion, the word "Laurentian," in compliment to my friend, Sir William Logan, who had then worked out the order, and mapped it on a stupendous scale. I stated, however, at the same time, that, if a British synonym was to have been taken, I should have proposed the word "Lewisian," from the large island of the Lewis, almost wholly composed of this gneiss.

rocks of North America, have as yet afforded no trace whatever of former life. And yet, such Cambrian rocks are in parts of the Longmynd, and specially in the lofty mountains of the North Western Highlands, much less metamorphosed than many of the crystalline rocks which lie upon them. Rising in the scale of successive deposits, we find a corresponding rise in the signs of former life on reaching that stage in the earlier slaty and schistose rocks in which animal remains begin clearly to show themselves. Thus, the Primordial Zone of M. Barrande is, according to that eminent man, the oldest fauna of his Silurian Basin in Bohemia.*

In the classification adopted by Sir Henry De la Beche and his associates, the Lingula Flags (the equivalent of the Zone Primordiale of Barrande) are similarly placed at the base of the Silurian System. This Primordial Zone is also classed as the Lowest Silurian by De Verneuil, in Spain; by James Hall, Dale Owen and others, in the United States; and by Sir W. Logan, Sterry Hunt, and Billings, in Canada.†

In the last year, M. Barrande has most ably compared the North American Taconic group of Emmons‡ with his own primordial Silurian fauna of Bohemia, and other parts of Europe; and although that sound palæontologist, Mr. James Hall, has not hitherto quite coincided with M. Barrande in some details,§ it is evident that the primordial fauna occurs in many parts of North America. And as the true order of succession has been ascertained, we now know that the Taconic group is of the same age as the lower Wisconsin beds described by Dale Owen, with their Paradoxides, Dikelocephalus, &c., as well as of the lower portion of the Quebec rocks, with their Conocephalus, Axionellus, &c., described by Logan and Billings. Of the crystalline schists of Massachusetts, containing the noble specimen of Paradoxides described by W. Rogers, and of the Vermont beds, with their Oleni, it follows that the Primordial Silurian Zone of Barrande (the lower Lingula-flags of Britain) is largely represented in North America, however it may occupy an inverted position in some cases, and in others be altered into crystalline rocks.

In determining this question due regard has been had to the great convulsions, inversions, and breaks, to which these ancient rocks of North America have been subjected, as described by Professors Henry and W. Rogers.

* I learn, however, that in Bohemia, Dr. Fritsch has recently discovered strata lying beneath the mass of the Primordial Zone of Barrande, and in rocks hitherto considered azoic the burrows of annelide animals similar to those of our own Longmynd.

† In completing at his own cost a geological survey of Spain, in which he has been occupied for several years, and in the carrying out of which he has determined the width of the sedimentary rocks of the Peninsula (including the Primordial Silurian Zone, discovered by that zealous explorer, M. Casiano de Prado), M. de Verneuil has in the last few months chiefly examined the eastern part of the kingdom where few of the older palæozoic rocks exist. I am, however, informed by him, that Upper Silurian rocks with *Cardiola interrupta*, identical with those of France and Bohemia, occur along the southern flanks of the Pyrenees, and also re-occur in the Sierra Morena, in strata that over-lie the great mass of Lower Silurian rocks as formerly described by M. Casiano de Prado and himself. The southern face of the Pyrenees, he further informs me, is specially marked by the display of mural masses of Carboniferous strata, which, succeeding the Devonian rocks, are not arranged in basin shape, but stand out in vertical or highly inclined positions, and are followed by extensive conglomerates and marls of Triassic age, and these by deposits charged with fossils of the Lias.

‡ The Silurian classification was proposed by me in 1835, and in the following year, 1836, Dr. Emmons suggested that his black shale rocks, which he called Taconic, were older than any I described.

§ Nor are the writings of the Professors W. B. and H. D. Rogers in unison with the opinions of the authors here cited.

In an able review of this subject, Mr. Sterry Hunt thus expresses himself: "We regard the whole Quebec group, with its underlying primordial shales, as the greatly developed representatives of the Potsdam and Calceiferous groups (into part of that of Chazy), and the true base of the Silurian system." "The Quebec group, with its underlying shales," this author adds (and he expresses the opinion of Sir W. Logan), "is no other than the Taconic system of Emons;" which is thus, by these authors, as well as Mr. James Hall, shown to be the natural base of the Silurian rocks in America, as Barrande and De Verneuil have proved it to be on the continent of Europe.

In our own country a valuable enlargement of our acquaintance with the relations of the primordial zone to the overlying members of the Silurian rocks, has been made through the personal examination of Mr. Salter, aided by the independent discoveries of organic remains by MM. Homfray and Ashe, of Tremadoc.

It has thus been ascertained, that the lower member only of the deposit, which has been hitherto merged under the name of Lingula-flags, can be considered the equivalent of the primordial zone of Bohemia. In North Wales that zone has hitherto been mainly characterized by Lingula and the crustaceans Olenus and Paradoxides. Certain additions having been made to these fossils, Mr. Salter finds that of the whole there are five genera peculiar to the lower zone, and seven which pass upwards from it into the next overlying band or the Tremadoc slate. But the overlying Tremadoc slate, hitherto also grouped with the Lingula-flags, is, through its numerous fossils (many of them of recent discovery), demonstrated to constitute a true lower member of the Llandeilo formation. For, among the trilobites, the well-known Llandeilo forms of Asaphus and Ogygia range upwards from the very base of these slates. Again, seven or eight other genera of trilobites, which appear here for the first time, are associated with genera of mollusks, and encrinites, which have lived through the whole Silurian series. Such, for example, are the genera Calymene, Illænus, among crustaceans; the Lingula, Orthis, Bellerophon, and Conularia, among mollusks, together with encrinites, corals, and that telling Silurian zoophyte, the Graptolite. By this proof of the community of fossil types, as well as by a clear lithological passage of the beds, these Tremadoc slates are thus shown to be indissolubly connected with the Llandeilo and other Silurian formations above them; whilst, although they also pass down conformably into the zone primordiale, the latter is characterized by the linguloid shells (Lingulella, Salter) and by the genera Olenus, Paradoxides, and Dikelocephalus, which most characterize it in Britain as in other regions.*

I take this opportunity, however, of reiterating the opinion I have expressed in my work, "Siluria," that to whatever extent the primordial zone of Barrande be distinguished by peculiar fossils in any given tract from the prevalent Lower Silurian types, there exists no valid ground for differing from Barrande, de Verneuil, Logan, James Hall, and others, by separating this rudimentary fauna from that of the great Silurian series of life of which stratigraphically it constitutes the conformable base. And if in Europe but few genera be yet found which are common to this lower zone and the Llandeilo formation (though the Agnostus and Orthis are common to it and all the Silurian strata), we may not unreasonably attribute the circumstance to the fact, that the primordial zone of no one country contains more than a very limited number of distinct forms. May we not, therefore, infer that in the sequel other fossil links, similar to those which are now known to connect the Lower and Upper Silurian series—which I myself at one time supposed to be sharply separated by their organic remains—will be brought to light, and will then zoologically connect the prim-

* In the last edition of *Siluria* the distinction was drawn between the lower and upper Lingula-flags, but the fauna of the latter is now much enlarged.

ordial zone with the overlying strata into which it graduates? Let us recollect, that a few years only have elapsed since M. de Verneuil was criticised for inserting, in his table of the Palæozoic Fauna of North America, a number of species as being common to the Lower and Upper Silurian. But now the view of the eminent French Academician has been completely sustained by the discovery in the strata of Anticosti, as worked out by Mr. Billings under the direction of Sir W. Logan, of a group of fossils intermediate in character between those of the Hudson River and Clinton formations; or, in other words, between Lower and Upper Silurian rocks. In like manner, a similar interlacing seems already to have been found, in North America, between the Quebec group, with its primordial fossils, and the Trenton deposits, which are, as is well known, of the Llandeilo age.

I have thus spoken out upon the fitness of adhering to the classifications decided upon by Sir Henry de la Beche and his associates long before I had any relation to the Geological Survey, and which places the whole of the Lingula flags of Wales as the natural base of the Silurian rocks. For English geologists should remember that this arrangement is not merely the issue of the view I have long maintained, but is also the matured opinion of those geologists in foreign countries and in our colonies, who have not only zealously elaborated the necessary details, but who have also had the opportunities of making the widest comparisons.

On the continent of Europe, an interesting addition has been made to our acquaintance with the fauna of one of the older beds of the Lower Silurian rocks or the Obolus green sand of St. Petersburg,* by our eminent associate, Ehrenberg. He has described and figured† four genera and ten species of microscopic Pteropods, one of which he names *Panderella Silurica*; the generic name being in honour of the distinguished Russian palæontologist, Pander, who collected them. It is well to remark, that as the very grains of this Lower Silurian green-sand seem to be in great part made up of these minute organisms, so we recognise, in one of the oldest strata in which animal life has been detected, organisms of the same nature, and not less abundant, than those which constitute the deep sea bottoms of the existing Mediterranean and other seas.

Before I quit the consideration of the older palæozoic rocks, I must remind you that it is through the discovery, by Mr. C. Peach, of certain fossils of Lower Silurian age in the limestones of Sutherland, combined with the order of the strata, observed in the year 1827 by Professor Sedgwick and myself, that the true age of the largest and overlying masses of the crystalline rocks of the Highlands has been fixed. The fossils of the Sutherland limestone are not, indeed, strictly those of the Lower Silurian of England and Wales, but are analogous to those of the calciferous sand-rock of North America. The *Maclurea* is indeed known in the Silurian limestone of the south of Scotland; but the *Ophileta* and other forms are not found until we reach the horizon of North America. Now, these fossils refer the zone of the Highland limestone and associated quartz-rocks to that portion of the Lower Silurian which forms the natural base of the Trenton series of North America, or the lower part of the Llandeilo formation of Britain. The intermediate formation—the Lingula “flags” or “zone primordiale” of Bohemia—having no representative in the North-Western Highlands, there is necessarily a complete unconformity between the fossil-bearing crystalline limestones and quartz-rocks with the *Maclurea*, *Murchisonia*, *Ophileta*, *Orthis*, *Orthoceratites*, &c., and those Cambrian rocks on which they rest.

A great revolution in the ideas of many an old geologist, including myself,

* See Russia and the Ural Mountains.

† Monats-Bericht d. Königl. Akad. der Wiss. Berlin, 18 April, 1861.

has thus been effected. Strengthened and confirmed as my view has been by the concordant testimony of Ramsay, Harkness, Geikie, James, and others, I have had no hesitation in considering a very large portion of the crystalline strata of the Highlands to be of the same age as some of the older fossiliferous Silurian rocks, whether in the form of slates in Wales, of greywacke-schist in the southern counties of Scotland, or in the conditions of mud and sand at St. Petersburg. The conclusions as respects the correlation of all the older rocks of Scotland have now indeed been summed up by Mr. Geikie and myself in the Geological Sketch-Map of Scotland which we have just published, and a copy of which is now exhibited.* Not the least interesting part of that production is that which explains the age of all the igneous or trappean rocks of the south of Scotland, as well as all the divisions of the Carboniferous formation, and is exclusively the work of my able colleague.

But if, through the labours of hard-working geologists, we have arrived at a clear idea of the first recognisable traces of life and their sequences, we are yet far from having satisfied our minds as to the *modus operandi* by which whole regions of such deposits have, as in the Highlands, been transmuted into a crystalline slate. Let us therefore hope that, ere this meeting closes, we may receive instructions from some one of the band of foreign or British geologists who have by their experimental researches been endeavouring to explain the processes by which such wonderful changes in the former condition of sedimentary deposits have been brought to light, such as that by which strata once resembling the incoherent Silurian clay which we see in Russia, has been hardened into such rocks as the slaty grauwacke of other regions, and how hard schists of the south of Scotland have been metamorphosed into the crystalline rocks of the Highlands. But why are British geologists to see any difficulty in admitting what I have proposed, that vast breadths of these crystalline stratified rocks of the Highlands are of Lower Silurian age? Many years ago I suggested, after examination, that some of the crystalline rocks near Christiana in Norway were but altered extensions of the Silurian deposits of that region; and, since then, Mr. David Forbes and M. Kjerulf have demonstrated the truth of the suggestion. Again, and on a vastly larger scale, we know that in North America all the noted geologists, however they may differ on certain details, agree in recognising that the vast eastern seaboard range of gneissic and micaceous schists is made up of metamorphosed strata, superior even to the lowest of the Silurian rocks. Logan, Rogers, Hall, and Sterry Hunt are decidedly of this opinion; and the point has been most ably and clearly set before the public by the last-mentioned of these geologists,† who, being himself an accomplished chemist, has given us some good illustrations of the probable *modus operandi* in the bringing about of these changes.

The importance of the inquiries to be made by chemical geologists into this branch of our science was not lost upon the earlier members of the British Association. Even in the year 1833, a committee was appointed to endeavour to illustrate the phenomena of the metamorphism of rocks by experiments carried on in iron-furnaces. After a series of trials on various mineral substances, the Rev. W. Vernon Harcourt, to whom we owed so much at our foundation, has, as the reporter of that committee, been enabled to present to the Association that lucid report on the actual effect of long-continued heat which is published in our last volume. In referring you to that document, I must, as an old practical field-geologist, express the gratification I feel in seeing that my eminent friend has, in the spirit of true inductive philosophy, arrived, after much experiment and thought, at the same conclusion at which, in common with Sedgwick, Buckland, De la Beche, Phillips, and others in my own country,

* This map is already on sale in Manchester.

† "American Journal of Science," May, 1861.

and with L. Von Buch, Elie de Beaumont, and a host of geologists abroad, I had long ago arrived in the field. I, therefore, re-echo their voices in repeating the words of Mr. W. Harcourt, "that we are not entitled to presume that the forces which have operated on the earth's crust have always been the same." Looking to the only rational theory which has ever been propounded to account for the great changes in the crust which have taken place in former periods—the existence of an intense central heat which has been secularly more and more repressed by the accumulation of sediment until the surface of the planet was brought into its present comparatively quiescent condition—our first General Secretary has indicated the train of causes, chemical and physical, which resolve some of the difficulties of the problem. He has brought before us, in a compendious digest, the history of the progress which has been made in this branch of our science, by the writings of La Place, Fourier, Von Buch, Fournet, and others; as well as by the experimental researches of Mitscherlich, Berthier, Senarmont, Daubrec, Deville, Delesse, and Durocher. Illustrating his views by reference to chemical changes in the rocks and minerals of our own country, and fortifying his induction by an appeal to his experiments, he arrives at the conclusion, that there existed in former periods a much greater intensity of causation than that which now prevails. His theory is, that whereas now, in the formation of beds, the aqueous action predominates, and the igneous is only represented by a few solfataras, in the most ancient times the action was much more igneous, and that in the intermediate times fire and water divided the empire between them. In a word, he concludes with the expression of the opinion, which my long-continued observation of facts had led me to adopt, "that the nature, forces, and progress of the past condition of the earth cannot be measured by its existing condition."

In addition to these observations on metamorphism, let me remind you that, on the recommendation of the British Association, other important researches have been carried on by Mr. William Hopkins, our new General Secretary, and in the furnaces of our President, Mr. Fairbairn, on the conductive powers for heat in various mineral substances. Although these experiments have been retarded by a serious accident which befel Mr. Hopkins, they are still in progress, and I learn from him that, without entering into any general discussion as to the probable thickness of the crust of our planet, we may even now affirm, on experimental evidence, that, assuming the observed terrestrial temperature to be due to central heat, the thickness of this crust must be two or three times as great as that which has been usually considered to be indicated by the observed increase of temperature at accessible depths beneath the earth's surface.

Of the Devonian rocks or Old Red Sandstone, much might be said if I were to advert to the details which have been recently worked out in Scotland, by Page, Anderson, Mitchell, Powrie, and others; and in England, by the researches of the Rev. W. Symonds, and other members of the Woolhope and Malvern Clubs. But confining myself to general observations, it may be stated, that a triple sub-division of that group, which I have shown to hold good over the Continent of Europe as in our own country, seems now to be generally admitted, whilst the history of its southern fauna in Devonshire has recently been graphically and ably elaborated by Mr. Pengelly, in a paper printed in our last volume.

In Herefordshire and Shropshire the passage of the upper members of the Silurian rocks into the inferior strata of the Old Red group, has been well shown by Mr. Lightbody, and the fossils of its lower member have been vigorously collected. Whilst in Scotland Mr. Geikie and others have shown the upward passage of its *superior* strata into the base of the Carboniferous rocks; and Dr. Anderson announces the finding of shells with crustacea in the lower or grey beds, south of the Tay. I may here note, that the point which I have

been for some years endeavouring to establish as to the true position of the Caithness flags with their numerous ichthyolites seems to be admitted by my contemporaries. The lamented Hugh Miller considered these ichthyolites as belonging to the lower member of the group, and had good grounds for his views, since at his native place, Cromarty, these fish-beds appear very near the base. But, by following them into Caithness and the Orkneys, I have shown that they occupy a middle position, whilst the true base of the group is the equivalent of the zone with *Cephalaspis*, *Pteraspis*, and *Pterygotus*.

And here it is right to state, that the Upper Silurian rocks which are clearly represented in Edinburghshire, and which in Lanarkshire seem to graduate upwards into the Lower Old Red or *Cephalaspis* sandstone, are wanting in the Highlands; thus accounting for the great break which there occurs between the crystallized rocks of Lower Silurian age and the bottom beds of the Old Red Sandstone.

Of the Old Red Sandstone of Scotland and Herefordshire I may be permitted further to observe, that its downward passage into the uppermost Silurian rock, and the upward passage of its higher strata into the Carboniferous strata, has been well developed, the one near Ludlow, chiefly through the labours of Mr. Lightbody; the other in Scotland, through the researches of the Government Geologists, Howell and Geikie, as well as by those of Mr. D. Page, and other observers. On this head I may, however, note, what my contemporaries seem now to admit, that the removal of the Caithness flags and their numerous included ichthyolites from the bottom of this group, and their translation to the central part of the system, as first proposed by myself, is correct. In truth, the lower member of this system is now unequivocally proved to be the band with *Cephalaspis*, *Pteraspis*, &c., as seen in Scotland, England, and Russia. The great break which has been traced in the south of Scotland by Mr. Geikie between the lower and upper Old Red, is thus in perfect harmony with the zoological fact that the central or Caithness fauna is entirely wanting in that region, as in England—as it is indeed in Ireland, where a similar break occurs.

It gratifies me to add that many new forms of those fossil fishes which so peculiarly characterize the Old Red Sandstone, have been admirably described by Sir Philip de Grey Egerton in the "Memoirs of the Geological Survey," and I must remark that it is most fortunate that the eminent Agassiz is here so well represented by my distinguished friend, who stands unquestionably at the head of the fossil ichthyologists of our country.

Very considerable advances have been made in the development of our acquaintance with that system—the Carboniferous—which in the North of England—Yorkshire—has been so well described by Professor Phillips, and with which all practical geologists in and around Manchester are necessarily most interested. The close researches of Mr. Binney, who has, from time to time, thrown new lights on the origin and relations of coal, and the component parts of its matrix, established proofs so long ago as 1840, that great part of our coal-fields was accumulated under marine conditions; the fossils associated with the coal-beds being, not as had been too generally supposed, of fluviatile or lacustrine character, but the spoils of marine life. Professor Henry Rogers came to the same conclusion with regard to the Appalachian coal-fields in America, in 1842. Mr. Binney believes that the plant *Sigillaria* grew in salt water, and it is to be remarked that even in the so-called "fresh-water limestones" of Ardwick and Le Botwood, the *Spirorbis* and other marine shells are frequent, whilst many of the shells termed *Cypris* may prove to be species of *Cythere*. Again, in the illustrations of the fossils which occur in the bands of iron ore in the South Welsh coal-field, Mr. Salter, entering particularly into this question, has shown that in the so-called "*Unio* beds" there constantly occurs a shell related to the *Mya* of our coasts, which he terms *Anthracomya*; whilst, as he has stated in

the "Memoirs of the Geological Survey," just issued, the very Unios of these beds have a peculiar aspect, differing much from that of true fresh-water forms. They have, he says, a strongly wrinkled epidermis, which is a mark of the Myadæ, or such burrowing bivalve shells, and not of true Unionidæ; they also differ in the interior, as shown by Professor W. King. Seeing that in these cases quietly deposited limestones with marine shells (some of them indeed of estuary character) rest upon beds of coal, and that in many other cases purely marine limestones alternate frequently with layers of vegetable matter and coal, may we not be led to modify the theory, founded on the sound observation of Sir W. Logan, by which the formation of coal has been rather too exclusively referred to terrestrial and freshwater conditions? May we not rather revert to that more expansive doctrine, which I have long supported, that different operations of nature have brought about the consolidation and alteration of vegetable matter into coal. In other words, that in one tract the coal has been formed by the subsidence *in situ* of vast breadths of former jungles and forests; in another, by the transport of vegetable materials into marine estuaries; in a third case, as in Russia and Scotland (where purely marine limestones alternate with coal), by a succession of oscillations between jungles and the sea; and, lastly, by the extensive growth of large plants in shallow seas.

The geological map of Edinburghshire, prepared by MM. Howell and Geikie, and recently published, with its lucid explanations, affords indeed the clearest proofs of the frequent alternations of beds of purely marine limestone charged with Producti and bands of coal, and is in direct analogy with the coal-fields of the Donetz, in Southern Russia.*

In sinking through the extensive coal-tracts around Manchester (at Dukinfield), where one of the shafts already exceeds in depth the deepest of the Durham mines, rigorous attention will, I hope, be paid to the discovery of the fossils which characterize each bed passed through, not merely to bring about a correctly matured view of the whole history of these interesting accumulations, formed when the surface of our planet was first furnished with abundant vegetation, but also for the practical advantage of the proprietor and miner, who, in certain limited areas, may thus learn where iron-ores and beds of coal are most likely to be persistent. In carrying out his survey-work through the north-western coal-tracts of Lancashire, to which the large, or six-inch, Ordnance-map has been applied, one of the Secretaries of this Section, Mr. Hull, has done good service in accurately defining the tracts wherein the elevated coal deposits are covered by drift only, in contradistinction to those which are still surmounted by red rocks of Permian and Triassic age. In seeing that these are eagerly bought by the public, and in recognising the great use which the six-inch survey has proved in the hands of the geological surveyors in Scotland, our friends in and around Manchester may be led to insist on having that large scale of survey extended to their own important district. By referring to the detailed delineations of the outcrops of all the Carboniferous strata in the cities of Edinburgh, Haddington, Fife, and Linlithgow, as noted by Professor Ramsay and MM. Howell and Geikie, the coal-proprietors of England will doubtless recognise the great value of such determinations.

Concerning the Permian Rocks, which were formed towards the close of the long palæozoic era, and constitute a natural sequel to the old Carboniferous deposits, it is to be hoped that we shall here receive apposite illustrations from some of our associates.

When Professor Sedgwick, thirty-four years ago, gave to geologists his excellent Memoir on the Magnesian Limestone of our country, as it ranges from Durham, through Yorkshire, into Nottinghamshire, he not only described the numerous varieties of mineral structure which that rock exhibits, noting at

* See Russia in Europe and the Ural Mountains. Vol. I.

the same time its characteristic fossils, but he also correlated it, and its underlying beds, with the Zechstein, Kupferschiefer, and Rothe-todte-liegende, of Germany. But whilst this is the true order in both countries, there is this considerable difference in England, that along the zone where the Magnesian Limestone exists as a mass, and where Sedgwick described it, the inferior member of the group is a thin band of sandstone, usually of a yellow colour (the Pontefract rock of William Smith), which in its southern extremity, near Nottingham, is almost evanescent. In many parts of Germany, on the contrary, and notably in Thuringia and Silesia, the same lower band, with a few intercalated courses of limestone, swells out into enormous thicknesses and even constitutes lofty ridges.

In Russia the series of this age puts on very different mineral arrangement. There the calcareous bands, containing the very same species of shells as the magnesian limestone of Germany and Britain, are intercalated with pebble-beds, sandstones, marls, and copper-ores, so that, although the same lithological order does not prevail as in the Saxon or typical Permian country of the elder German geologists, the group is, through its fossil types, unquestionably the same. It was from the observation of this fact, and from seeing that these deposits, so mixed up, yet so clearly correlated by their animal and vegetable relics, and all superposed to the Carboniferous system, occupied a region twice as large as the British Isles, in which the varieties of structure are best seen in the government of Perm, that I proposed in 1841, that the *whole group* should have the name of "Permian."

Of late years various British authors, including King, Howse, and others, have ably described the fossil shells of this deposit as it exists on the eastern side of the Penine chain; and recently Mr. Kirkby has produced a carefully written and well-considered memoir, showing the relations of the whole group, by comparing its structure and palæontological contents in Durham with those in South Yorkshire. Whilst, in addition, my associates of the Geological Survey, particularly Mr. Aveline, have been carefully delineating the area of these beds in their northern range from Nottingham through Yorkshire, much yet remains to be done in correlating the Permian rocks lying to the west of the Penine ridge, or where we are now assembled, with their eastern equivalents.

Already, however, great strides have been made towards this desirable end. Thus, Mr. Binney has indicated the succession in the neighbourhood of Manchester, and has shown us that there some of the characteristic fossils of the eastern magnesian limestone exist in red marl and limestones subordinate thereto, and that these are clearly underlaid by other red sandstones, shales, and limestones, which he terms Lower Permian. He has further followed these Lower Permian beds to the west and north-west, and finds them expanding into considerable thicknesses at Astley, Scarisbrick, and other places where they overlie the coal-measures, and he has also traced them into Westmoreland, Cumberland, and Dumfries-shire. In the last case he went far to prove that which I suggested many years ago, that the red sandstones of Dumfries-shire containing the large footprints of chelonians, as described by Sir W. Jardine, are of Lower Permian age.

This view of the relations of the Permian rocks of the north-west has been also taken by Professor Harkness, and this summer he has successfully worked it out, and has definitely applied the Permian classification to large tracts in Cumberland, as explained in a letter to myself. He finds that the breccias and sandstones of Kirby-Stephen and Appleby, which at the latter place have a thickness of three thousand feet, extend northward on the west side of the Eden (the breccia being replaced by false-bedded sandstones with footprints), and attain near Carlisle the enormous thickness of about five thousand feet. These beds he classes unhesitatingly as Lower Permian, because he finds them

to be overlaid (near Ormsby) by a group of clays, sandstones, and magnesian limestones, containing peculiar plant remains and shells of the genus *Schizodus*, representing in his opinion the marl-slate and magnesian limestone of Durham. These again support beds equivalent to the Zechstein, and the last are covered by the Triassic sandstone of the Solway.

A very striking fact, noticed by Professor Harkness, and corroborative of earlier researches made by Mr. Binney, is the existence of foot-prints, in the Lower Permian of Cumberland, similar to those of Corncockle Moor, in Dumfriesshire, where, from my own observations, including those of last year, these Lower Permian sandstones have, I am convinced, a greater thickness even than that which is assigned to them in Cumberland.

Notwithstanding these discoveries, we have still to show the continuous existence of the Lower Red Sandstone of Shropshire, Worcestershire, and Staffordshire, which I have classed as the lower member of the Permian rocks, and to decide whether it be really such lower member *only*, or is to be regarded as the equivalent of the whole Permian group, under differing mineral conditions. With the extension of the Geological Survey this point will, doubtless, be satisfactorily adjusted, and we shall then know to what part of the series we are to attach the plant-bearing red beds of Coventry and Warwick, described as Permian by Ramsay and his associates. We have also to show that, in its northern course, the lower red sandstone of the central counties, with its calcareous conglomerates, graduates into the succession exhibited at Manchester, thence expanding northwards. Already, however, we have learned that in our own little England, which contains excellent normal as well as variable types of all the palæozoic deposits, there exists proofs that the Permian rocks, according to the original definition of the same, present to the observer who examines them to the west as well as to the east of the Penine chain, nearly as great diversities of lithological structure, in this short distance, as those which distinguish the strata of the same age in Eastern Russia in Europe from the original types of the group in Saxony and other parts of Germany.

Geological Survey and Government School of Mines, Mineral Statistics, and Colonial Surveys.—As I preside for the first time over this Section since I was placed at the head of the Geological Survey of Britain, I may be excused for making an allusion to that national establishment, by stating that the public now take a lively interest in it, as proved by a largely increased demand for our maps and their illustrations—a demand which will, I doubt not, be much augmented by the translation at an early day of many of our field-surveyors from the south-eastern and central parts of England, where they are now chiefly employed, to those northern districts where they will be instrumental in developing the superior mineral wealth of the region.

The Government School of Mines, an offshoot of the Geological Survey, is primarily intended to furnish miners, metallurgists, and geological surveyors with the scientific training necessary for the successful pursuit and progressive advancement of the calling which they respectively pursue; but at the same time, the lectures and the laboratories are open to all those who seek instruction in physical science for its own sake, or by reason of its important application to manufactures and the arts. The experience of ten years has led the professors to introduce various modifications into their original programme—with the view of adapting the school as clearly as possible to the wants of those two classes of students; and at present, while a definite curriculum, with special rewards for excellence is provided for those who desire to become mining, metallurgical, and geological associates of the school; every student who attends a single course of lectures may by the new rules compete, in the final examination, for the prizes which attach to it only.

Throughout the whole period of the existence of the school, the professors have given annual courses of evening lectures to working men, which are

always fully attended, as a part of their regular duty; and during the past year, several of them have delivered voluntarily courses of evening lectures, at a fee so small as to put them within the reach of working men, pupil-teachers, and schoolmasters of primary schools. The professors thus hope to support to the utmost the great impulse towards the diffusion of a knowledge of physical science through all classes of the community, which has been given through the Department of Science and Art by the Minute of the Committee of Privy Council of the 2nd June, 1859.

A body like the British Association for the Advancement of Science should, I conceive, not be unaware of a step of such vast importance, and tending so entirely towards the same goal as that to which its own efforts have been and still are constantly directed.

Now, inasmuch as I can trace no record of the teachings of the Government School of Mines in the volumes of the British Association, and as I am convinced that the establishment only requires to be more widely known, in order to extend sound physical knowledge not merely to miners and geologists, but also to chemists, metallurgists, and naturalists, I have only to remind my audience that this School of Mines which, owing its origin to Sir Henry De La Beche, has furnished our colonies with some of the most accomplished geological and mining surveyors, and many a manufacturer at home with good chemists and metallurgists, has now for its lecturers men of such eminence that the names of Hoffman, Percy, Warington Smyth, Willis, Ramsay, Huxley, and Tyndall are alone an earnest of our future success.

In terminating these few allusions to the Geological Survey, and its applications, I gladly seize the opportunity of recording, that in the days of our founder, Sir Henry De la Beche, our institution was greatly benefited in possessing, for some years, as one of its leading surveyors, such an accomplished naturalist and skilful geologist, as the beloved Assistant General Secretary of the British Association, Professor Phillips, who by his labours threw much new light on the palæontology of Devonshire, who, in the Memoirs of the Survey, has contributed an admirable monograph on the Silurian and other rocks around the Malvern hills, and who, by his lectures and writings, is now constantly advancing science in the oldest of our British universities.

There is yet one subject connected with the Geological Survey to which I must also call your attention, viz., the Mineral Statistics of the United Kingdom, as compiled with great care and ability by Mr. Robert Hunt, the keeper of the Mining Records, and published annually in the memoirs of our establishment.

These returns made a deep impression on the statisticians of foreign countries who were assembled last year in London at the International Congress. The Government and members of the Legislature are now regularly furnished with reliable information as to our mineral ore produce, which, until very recently, was not obtainable. By the labours of Mr. Robert Hunt, in sedulously collecting data from all quarters, we now become aware of the fact that we are consuming and exporting about eighty millions of tons of coals annually (a prodigious recent increase, and daily augmenting). Of iron ore we raise and smelt upwards of eight millions of tons, producing 3,826,000 tons of pig iron. Of copper ore we raise from our own mines 236,696 tons, which yield 15,968 tons of metallic copper; and from our native metallic minerals we obtain of tin 6,695 tons; of lead, 63,525 tons; and of zinc, 4,357 tons. The total annual value of our minerals and coals is estimated at 26,993,573*l.*, and that of the metals (the produce of the above minerals) and coals at 37,121,318*l.*

When we turn from the consideration of the home survey to that of the geological surveys in the numerous colonies of Great Britain, I may well reflect with pleasure on the fact that nearly all the leaders of the latter have

been connected with, or have gone out from, our home Geological Survey and the Government School of Mines.

Such were the relations to us of Sir William Logan in Canada, of Professor Oldham in India, with several of his assistants; of Selwyn in Victoria, of my young friend Gould in Tasmania, as well as of Wall in Trinidad; whilst Barrett, in Jamaica, is a worthy pupil of Professor Sedgwick. Passing over the many interesting results which have arisen out of the examination of these distant lands, we cannot but be struck with the fact, that whilst Hindostan (with the exception of the higher Himalayan mountains) differs so materially in its structure and fossil contents from Europe, Australia, and particularly Victoria, presents, in its palæozoic rocks at least, a close analogy to Britain. Thanks to the ability and zeal of Mr. Selwyn, a large portion of this great auriferous colony has been already surveyed and mapped out in the clearest manner. In doing this he has demonstrated that the productive quartzose veins, which are the chief matrix of gold, are merely subordinate to the Lower Silurian slaty rocks, charged with Trilobites and Graptolites, and penetrated by granite, syenite, and volcanic rocks, occupying vast regions. Mr. Selwyn, aided in the palæontology of his large subject by Professor M'Coy, has also shown how these original auriferous rocks have been worn down at successive periods, one of which abrasions is of pliocene age, another of post-pliocene, and a third the result of existing causes. All these distinctions, as well as the demarcation of the carboniferous, oolitic, and other rocks, are clearly set forth. Looking with admiration at the execution of these geological maps, it was with exceeding pain I learnt that some members of the Legislature of Victoria had threatened to curtail their cost, if not to stop their production. As such ill-timed economy would occasion serious regret among all men of science, and would, I know, be also deeply lamented by the enlightened governor, Sir Henry Barkley, it would at the same time be of lasting disservice to the material advancement of knowledge among the mining classes of the State; let us earnestly hope that this young House of Parliament at Melbourne may not be led to enact such a measure.

Whilst upon the great subject of Australian geology, I cannot avoid touching on a *questio veauta* which has arisen in respect to the age of the coal-fields of that vast mass of land. Judging by the fossil plants from some of the carboniferous deposits of Victoria, Professor M'Coy has considered these coaly deposits to be of the oolitic or jurassic age, whilst the experienced geologist of New South Wales, the Rev. W. B. Clarke, seeing that where he has examined these deposits, some of their plants are like those of the old coal, and that the beds repose conformably upon and pass down into strata with true Mountain-limestone fossils, holds the opinion that the coal is of palæozoic age. As Mr. Clarke, after citing a case where the coal-seams and plants were reached below Mountain-limestone fossils, expresses a hope that Mr. Gould may detect in Tasmania some data to aid in determining this question, I take this opportunity of stating that I will lay before this meeting a communication I have just received from Mr. Gould, in which he says that in the coal-field of the rivers Mersey and Don, one of the very few which is worked in Tasmania, he has convinced himself that the coal underlies beds containing specimens of true old carboniferous fossils. Remarking that these relations are so far unlike those which he observed on the eastern coast of the island where the coal overlies, yet is conformable to, the carboniferous limestone, he adds that in Tasmania, at least, the coal most worked is unquestionably of palæozoic age.

Now, as Australia is so vast a region, may not much of the coal within it be of the age assigned to it by Mr. Clarke: and yet may not Professor M'Coy be also right in assigning some of the mineral coal to the same oolitic age as the coal of Brora and the eastern moorlands of Yorkshire? In his survey of

Tasmania, Mr. Gould has also made the important discovery of a resinous shale, termed Dysodile, and which, like the Torbane mineral of Scotland, promises to be turned to great account in the production of paraffine.

There are, indeed, other grounds for believing that coal, both of the mesozoic as well of the old carboniferous age, may exist in Australia. Thus putting aside the fossil evidences collected in Victoria by M'Coy and Selwyn, we learn from the researches of Mr. Frank Gregory in Western Australia, that mesozoic fossils (probably cretaceous and oolitic) occur in that region; whilst the Rev. W. B. Clarke informs me in a letter just received, that he is in possession of a group of fossils transmitted from Queensland, 700 or 800 miles north of Sydney, which he is disposed to refer to the age of the Chalk; there being among the fossils Belemnites, Pectacrinites, Pectens, Mytili, Modiola, &c. Again, the same persevering geologist has procured from New Zealand the remains of a fossil Saurian, which, he thinks, is allied to the *Plesiosaurus*.*

It would therefore appear that in the southern hemisphere there is not merely a close analogy between the rocks of palæozoic age and our own, but further, that, as far as the Mesozoic formations have been developed, they also seem to be the equivalents of our typical secondary deposits.

This existence of groups of animals during the Silurian, Devonian, Carboniferous, and even in Mesozoic periods in Australia and New Zealand, similar to those which characterize these formations in Europe, is strongly in contrast with the state of nature which began to prevail there in the younger Tertiary period. We know from the writings of Owen that at that time the great continent at our Antipodes was already characterized by the presence of those marsupial forms which still distinguish its *fauna* from that of any other part of the world.

In relation to our Australian colonies, I must also announce that I have recently been gratified in receiving from Messrs. Chambers and Finke, of Adelaide, a collection of the specimens collected by McDouall Stuart, in his celebrated traverse (the first one ever made) from South Australia to the watershed of North Australia. Having had occasion to address the Royal Geographical Society on this point, and to award its gold medal to that most adventurous and successful explorer, with observations on the main geographical results of his labours, including the discovery of trees and plants unknown in other parts of that continent, I may here say, in addressing myself to geologists, that a collection of rocks has been submitted to me which may tend to illustrate the structure of the interior of that great continent.

These specimens are soft white chalky rocks, with flints, agates, saline, and ferruginous incrustations, tufas, breccias, and white quartz rocks, and a few specimens of quasi-volcanic rock, but with scarce a fragment that can be referred to the older stages of Lower Silurian age like those of Victoria.† Again, the only fossil shells collected by Mr. Stuart (though the precise latitude and longitude is unknown to me), are Mytiloid and Mya-like forms, seemingly indicating a Tertiary age, and thus we may be disposed provisionally to infer that large tracts of the low interior between East and West Australia have in very recent geological periods been occupied by the sea.

Conclusion.—In concluding this address, I may assure the section that, as one of the original members of the Association, it gives me infinite satisfaction to return to my old friends in this great and thriving centre of our national industry. In common with many of my associates who come from a distance, well do I remember how cordially we were received here in the year 1842;

* In another part of this Number we give the paper of Professor Owen, describing this interesting fossil as *Plesiosaurus Australis*.

† It must, however, be noted that the collection sent to me consists of small specimens of rock forming an imperfect series.

and never can I forget how admirably we were presided over by a nobleman* as distinguished by his ability and learning as he was beloved for his philanthropy and public spirit, and who had upon his right hand the illustrious Dalton. Looking to the character and influence of that philosopher, I may truly say that, as he was one of our founders when we first met together at York, we owe through him a deep debt of gratitude to Manchester; for Dalton was one of the few eminent men who at our birth stood sponsor for our future career, and who supported us at many a subsequent meeting.

In our present visit we are most happy to see placed at our head one of the scientific men of Manchester, who exhibits in his own person the cheering example of the great success which can be attained by the steady and judicious application of science to the improvement of our manufactures. And if England is to hold her own lofty position in great measure through the superior strength of the metal derived from inexhaustible masses of iron-ore which occur in many of her geological formations, we cannot but regard William Fairbairn as the individual who, united at first with the late Eaton Hodgkinson, through a long series of ingenious experiments, as detailed in the volumes of this Association, not only laid the basis for the erection of the Menai Bridge, and such tubular constructions, but who is now directing the manufacture of those iron plates which may best resist the most powerful artillery, whether in casing our ships, or in strengthening our fortresses.

I need not re-affirm that all the men of science who have flocked hither from distant places rejoice with his townsmen in serving under such a man.

Lastly, let me say that we of the Geological Section, who are gathered together from remote parts, have solid grounds for satisfaction in being greeted here by so many good and active brother workmen of the Geological Society of Manchester, who have done such honour to their town, not only by the establishment of a rich and instructive Museum, in which many of the subjects we are met to discuss are thoroughly illustrated, but who have also, by their publications, contributed much to advance our science.

GEOLOGY OF THE NEIGHBOURHOOD OF MANCHESTER.

Mr. E. W. Binney, F.R.S., F.G.S., described the several beds of gravel, sand, and till, forming the superficial covering of the district:—1st. The valley gravel, with its successive terraces; 2nd. The widely-distributed upper sand and gravel; 3rd. The great deposit of boulder-clay or till, which is at some places ninety feet thick; 4th. A lower bed of gravel. The underlying rocks known chiefly by boring operations, were—1st. The trias, or upper red series, about five hundred feet thick; 2nd. The lower new red or Permian series, six hundred feet. These overlie the coal measures, and have been pierced in search for coal at Medlock Vale and elsewhere to the lower Permian beds of Yorkshire. The lower bed of conglomerate is found to thicken out northward in Cumberland and Scotland to some thousand feet in thickness. 3rd. The coal measures of the Manchester coal field, as proved by borings, and by the few local exposures at Ardwick and elsewhere. All of these are exceedingly dislocated, one fault having certainly a down-throw of one thousand and fifty yards.

* Lord Francis Egerton, afterwards the Earl of Ellesmere.