III.—*On the Origin of Coal.* By E. W. Binney, Esq.

(Read December 1, 1846.)

The vegetable origin of Coal is now fully established, and the problems remaining to be solved are the following, namely, where did the plants of which Coal is formed grow? and how were the strata in which it is found deposited?

Some years since Sir H. T. De La Beche, in his Researches in Physical Geology, first alluded to the great value of fossil organic remains, especially those of such animals as formerly lived in the ocean, in ascertaining the depth of the ancient seas at the period when such beings existed, and he gives a table of the depths at which some recent shells are met with on the coasts of England. Professor Edward Forbes, in his report of the dredging of the Ægean sea, supplied geologists with a mass of most valuable information as to the habitats of recent shells, and in a paper read by himself and Captain

Ibbotson, on the Tertiary and Cretaceous deposits of the Isle of Wight, at the meeting of the British Association, at York, in 1844, showed how it should be applied in measuring the depths of the ancient seas.

The level of the ocean itself is now assumed by geologists to have been permanent, whatever variations may have taken place in its bottom.

In the present communication it is the author's desire to direct attention to the constant evidence of subsidences in the bed of the ancient ocean, from the commencement of the protozoic rocks, up to and including the new red sandstone formation on the western side of the *penine* chain, and to point out some of the great epochs of repose which have at intervals of time, in particular places, for a period interrupted such subsidences. Every group of fossiliferous strata offers numerous evidences of subsidence interrupted by periods of rest, but the periods of elevation are not so observable, although it is probable that they must have acted on other parts of the earth's surface to counterbalance such subsidences. But geological works have lately been published wherein the earth's crust is not only assumed to have frequently subsided, but to have been again elevated, so as to account for the occurrence of successive seams of Coal, an elevation and a subsidence being necessary for the formation of each seam.* This is a very unlikely hypothesis, when the degradation of pre-existing rocks, and the conveyance of them, by the action of running water, is so evident in all the deposits ; a subsidence of the bed of the present shallow seas would not necessarily require the assistance of any subterranean force to regain its former level, if we allow the action of currents of water charged with sand and silt.

The crust of the globe furnishes us with numerous evidences of the ancient ocean, but the direct evidences of absolutely dry land before the commencement of the Tertiary period are very few. The only instances in England that I am aware of are some in the new red sand stone formation, hereinafter alluded to, and the Portland dirt bed,—and the latter may have been more of a swamp than absolutely dry land. No doubt the existence of tracts of dry land in many of these remote ages, as assumed by some

* Dr. Mantell's Medals of Creation. Vol. i. p. 98.

geologists, and sanctioned by the remains of the Cheirotherium, some insects, the Stonesfield slate, and other animals, is very probable; but positive evidences in support of it, have not to my knowledge been hitherto adduced. At the present time the whole of the dry land upon the face of the globe could be covered by the waters, and a universal sea of considerable depth exist. Great mountain ranges, such as the Himmylaya and the Andes, could easily be buried in the depths of oceans like the Pacific and Atlantic. This is mentioned for the purpose of shewing that it is not necessary to assume the existence of perfectly dry land, in order to account for such seas as those in which most of the beings whose remains we find embedded in the older rocks lived.

The lowest slates of North Wales seem to indicate a sea of considerable depth, the sedimentary deposits at the bottom of which were often disturbed by admixture of volcanic matter in the shape of trappean rocks. It is a difficult matter to state when the first evidence of animal life appeared in the waters of the ancient sea, but there is proof that it existed near Arenig Fawr, where the Asaphus *Buchii* and a few other fossils occur.* The injection of volcanic trap into the sea at some places, no doubt frequently interrupted and destroyed the inhabitants of its waters, but these disturbances being only local would not interfere with the creatures living in distant seas; so that although certain races were partially cut off at particular periods, in some localities, other places existed where the same races of animals escaped destruction, and re-peopled the seas, when such again became fitted for animal life.

The ancient seas, like those of the present day, were doubtless peopled with beings fitted for the conditions under which they lived, and when such conditions changed the animals changed accordingly. Some of these changes were no doubt sudden, and others gradual.

A great irruption of trappean rocks into the sea, the rapid subsidence of its bottom to a great depth, or the elevation of the bottom of the ocean to the surface of the water, would be all equally fatal to animal life in the respective

* See Professor Sedgwick on North Wales. Quarterly Journal of the Geological Society, No. I. p. 8.

localities, where such changes took place; but the cessation of volcanic agency in the first case, the partial filling up of the bed of the ocean in the second, or the subsidence of the surface of the earth in the last, would again fit them for animal life. Again and again the subsidences of the bed of the ocean appear to have taken place, during the formation of the Silurian groups, as the successive bands of fossiliferous rocks testify. Some of these being of great extent, would cause the depth of the waters to be so great as to render them unfitted for animal life; whilst others might for a period be so gradual as to permit the animals to adapt themselves to the altered conditions, or build their way up against the subsiding rocks, like the Zoophytes of the present coral reefs.

At the close of the Silurian system in North Wales, an elevation or a period of repose, it is difficult to say which, of the strata appears to have taken place, as few, if any traces of the old red sandstone are said to be met with in the north eastern counties of Wales; but in the south east of the principality, that deposit is found of great thickness, gradually passing into the underlying Silurian group, thus showing that the subsidence in the latter district was going on during the elevation or period of rest of the former. The whole of its materials, and the few organic remains found in its fossils, as well as the sand of which it is composed, show that it was not deposited in a deep ocean, as these are seldom met with at great depths in our present seas. The grains of sand also indicate considerable currents, which we should not generally expect to find in very deep water. The thickness of this formation is very great, reaching, according to Murchison, (p. 184 of his Silurian System,) to nine or ten thousand feet; a depth of sea which the composition of the rocks and the organic remains found in them, seems to render it next to impossible, but that subsidences of its bottom frequently took place during its formation. From the conformability of the rocks in some positions, it is now generally admitted that the old red sandstone in some places passes upwards into the mountain limestone, as at Stockpole Cliffs, (p. 383 Murchison's Silurian System,) and many other localities. However, in the north east of Wales, this transition is not to be observed, but the mountain limestone reposes on unconformable Silurian rocks.

The mountain limestone, or, as it is now generally termed, the carboniferous limestone, may be considered as the base of the profitable Coal-fields of the north of England. Professor Phillips in his treatise on the deposit in Yorkshire, divides it into two parts, namely, the lower limestones and shales, and the Yoredale rocks or limestone shale. Each of these divisions at the greatest points of development reaching to near one thousand feet. The thickness of the lower limestone in Flintshire, I have not been able to ascertain, but the limestone shale in that county does not appear (if at all) to anything like the extent which we find it in Yorkshire and Derbyshire. The organic remains in both deposits, consisting of corals and shells, lead us to suppose that the creatures which belonged to them lived in seas of moderate depth; and that the beds of those seas were gradually subsiding, so as to compensate for their filling up by the deposition of carbonate of lime, sands, and argillaceous beds, brought thither by the water.

Having thus hastily glanced at the deposits on the crust of the globe, which were found prior to the millstone grit, and shown the evidences of continued subsidence in some portions of it compensated for, by continuous sedimentary deposits, let us examine the great Coal-field of Lancashire, now admitted to be the most perfectly developed one in England. Before doing so, however, allow me to direct attention to the errors which have been generally propagated, with regard to carboniferous deposits, by describing nearly all of them as Coal basins. Doubtless, synclinal axes are to be met with in Coal-fields as elsewhere, but not more frequently than in any other equally ancient deposits. The great lines of fault by which Coal-fields are traversed, have all been formed after the deposition of their highest members. But it has been common to suppose a deep basin-shaped hollow in the crust of the earth, of near eight thousand feet deep, having a permanent bottom, which has been gradually filled up by the deposition of limestone, and the *detritus* of ancient lands, occasionally varied by drifts of vegetable matter, so as to form Coal seams. The fossil organic remains, both in the limestones and Coal measures, on being examined, clearly negative any supposition that when alive, the creatures which belonged to them ever lived but at moderate depths; therefore, all the advocates of the different hypotheses of the present day, whether they attribute the origin of Coal to vegetable matter, drifted from adjoining lands;

vegetable matter, which grew on dry land, on the spots where it is now found; or those who merely contend that such vegetable matter grew on the spots where it is now found, without stating whether it grew on dry land or in water must admit of the existence of a subsiding area in their different views.

Different opinions have been held, as to whether the waters which formerly prevailed, during the deposition of the higher part of the carboniferous series were fresh or salt. The authors who take the former view, adduce in support of their hypothesis the remains of a Cypris, and a questionable species or two of Unio; whilst those of the latter adduce shells of the genera, Goniatites, Nautilus, Posidonia, Pecten, Modiola, and Nucula, the great Sauroid and Squaloid fishes, as well as those of the Platysomus, Cælacanthus, Palæoniscus, &c. genera common to the carboniferous, and the magnesian limestone formations. Whether the strata contain the remains of fishes, Pecten, Goniatites or Unio, the remains of such plants as the Sigillaria and its Stigmaria roots are equally present; which would not be expected to be the case if sudden changes of the waters, from fresh to salt, had taken place; for a *Flora* is quite as sensitive of such a change as a *Fauna.* The balance of evidence, therefore, is much in favour of the water having been of *one kind*, and on the whole, probably salt and not fresh.

The materials composing the various beds, known by the term Coal measures, are the main characters that will enable us to judge of the circumstances under which they were deposited. These are to be regarded as true measures of the intensity of the currents of water, which brought them to the places where they are now found, and are, therefore, of great value in ascertaining the physical condition of the globe at that period. They may be conveniently divided into arenaceous and argillaceous beds.* The first, consisting of rough pebbly gritstone, gritstone, fine sandstone, and sandy shale. The last, of shale, bind, soap-stone, fire clay, and indurated silt. Black bass is also an argillaceous deposit, mixed with a considerable proportion of bituminous matter. Probably these deposits may not always occur in the exact order here pointed out, or all of them together; still, in the rich part of a Coal-field they graduate one into another with great

* Beds of limestone are met with in the upper Coal-field, but they are very rare.

regularity, and Coal is found on the deposit showing the greatest quietude of formation, which is nearly in all cases the floor.

Little evidence is at present to be had of the power of moving water, to remove bodies immersed in it, or which obstruct its progress, and further experiments require to be made. In vol. 49, No. I, p. 2, of Professor Silliman's American Journal, Mr. Mather, in a paper on the physical geology of the United States, gives the following table of the transporting power of water:—

POWER OF TRANSPORT.	VELOCITY OF CURRENTS.	
	In. per sec.	Miles per hour.
Wears away fine compact tough clay...	3	0·17
Removes fine sand........................	6	0·34
Sand as coarse as flax seed.	8	0·45
Fine gravel....	12	0·68
Pebbles of an inch in diameter...	24	1·36
Angular fragments, 2 to 3 inches	36	2·14

This last indicates a current, sufficient to move the largest pebbles found in the rough rock, one of the coarsest grained beds of the Coal measures.

Being best acquainted with the Lancashire and Cheshire Coal-field, it may be as well to mention the thickness of its various beds, commencing with the lowest millstone grit and terminating (as far as yet ascertained) by the red clays of Ardwick near Manchester. It is full six thousand six hundred feet in thickness, and contains at least one hundred and twenty different seams of Coal. In a former paper, read before the British Association at Manchester,* it was divided into lower, middle, and higher. This division will be adhered to in the present instance, merely giving the workable seams.

	SEAMS.	THICKNESS.
Lower Coal field	...	2,130 feet.
Workable seams of Coal	6	
Middle Coal field......................	...	2,910 ,,
Workable seams of Coal	20	
Upper Coal field	...	1,560 ,,
Workable seams of Coal	5	
	31	6,600

Now all these seams, whether workable or not, have floors, as beds on which the Coals rest are termed. These consist of fine silt, called by the miners warrant (sometimes warren) earth, fire

* Transactions of British Association, Vol. xii. p. 46; and Sturgeon's Annals of Philosophical Discovery and Monthly Reporter of the Progress of Practical Science, Vol. i.

clay, and rock. In all the floors that I have examined, which are eighty-four in number, remains of Stigmaria *ficoides* have been met with. The floor of the feather edge coal, consisting of a few inches of brown coloured clay resting on rough sandstone, in a former paper read before the British Association in Manchester, was supposed to be the only exception, but latterly numerous instances of the occurrence of the Stigmaria have been found in the floor of that Coal. It is the only Coal in the whole of the Lancashire and Cheshire Coal-field which exhibits evidence of a strong current of water in its roof and floor, and it is a very irregular seam, often found wanting altogether. It presents the only example in Lancashire of the "*Simon*" fault of the Forest of Dean Coal-field. The rest of the floors all indicate great quietude of deposition, indeed, the greatest of any of the beds, and where they are thick and full of Stigmaria, the seams of Coal above them are generally valuable, shewing an intimate relation between the soil and its produce, if the theory of the vegetable matter now forming Coal, having grown where it is found, be true.

Coal floors shew no evidence of strong currents of water necessary to drift forests of timber from neighbouring lands, but have every appearance of a hardened mud brought by sluggish water, with scarcely any current.

The presence of the remains of bivalve shells, and fishes, in cannel, clearly prove that it was formed under water; but in the Lancashire coal seams we have, as yet, found no remains either of fishes or shells, although there are frequently found in them regular partings of fine silt and fire clay, evidently deposited from water, full of Stigmaria rootlets, and, like the true floors. A thin layer of an inch of unctuous clay generally intervenes between the bed of Coal and its floor. But there is not any admixture of sand or clay in the Coal itself, to shew that it was drifted, into the places where it is now found, by currents of water. Nearly all the Coal seams, more or less, display evidence of common Coal plants, especially Stigmaria, Sigillaria, and Lepidodendra, pulverulent carbonaceous matter, like charcoal, or shew woody structure under the microscope.

On the other hand, the roofs or strata immediately above the seams of Coal nearly always present some evidence of currents of water.

They are of four kinds, namely, Sandstone, Bind (hardened silty clay), Black Shales (fine clay coloured with bitumen), and Black Bass (bituminous clay approaching to cannel).

Sandstone roofs present exactly such an appearance as a strong current of water flowing over a tract of luxuriant vegetation would now produce, namely, prostrate trees lying in all directions, mingled with sand. The tender and fragile parts of plants are broken and dispersed by the currents that prostrated them, or have since disappeared on the subsequent percolation of water, which first decomposed, and then removed them.

Blue bind roofs exhibit every appearance of a moderate current of water, sufficient to bring the clay, which on ceasing to be suspended in water, although sufficient to weigh down, and bury in fine grained mud, the delicate and small plants found in them, was not able to overthrow the Sigillaria, Ulodendra, Lepidodendra, and other large trees. For it must be remembered, that nearly all the upright specimens of the stems of fossil trees, found in our Coal measures, are large ones.

The black shale roofs indicate even a more quiet and gentle flow of water, than those composed of bind, and show every appearance of having been a long time in formation, as the nearly total disappearance of plants by decomposition, and the dispersion of their carbon throughout the strata, as well as the abundance of shells of the genus Unio in the middle, and of the Pecten, Goniatites, &c. in the lower parts of the Coal-field prove.

The black bass roofs, in the upper Coal-field, afford an evidence of the very long periods of time which must have elapsed during their formation, as many of them are entire masses of bituminous casts of Cyprides, Microconchi, shells and fish bones, and teeth, mingled with decomposed vegetable and animal matter.

In the lower Coal-field, coarse gritstones and black shales abound, but the seams of Coal are few and thin.

In the middle Coal-field, fine grained white sandstones, and light coloured argillaceous deposits are plentiful, and the most numerous and valuable seams are there met with. In the upper field, so long as the rock deposits resemble those of the middle one, the seams are pretty much the same, but as soon as they become red, and are mixed with beds of limestone, the seams become of little value, thus showing that the condition of the waters had some connexion with the production of the seams of Coal; for we find, that the strong currents of the lower Coal field were not favourable to the formation of thick and numerous seams of Coal, but that the tranquil and quiet waters of the middle one were; while the waters of the upper field, although equally quiet and tranquil, having been charged with peroxide of iron, and carbonate of lime, were not favourable to the formation of thick and valuable seams. Rocks highly charged with peroxide of iron, are generally sparingly stored with animal remains, whilst those containing carbonate of lime, are, for the most part, full of them. We thus see, that the distribution of plants and animals varied, according to the state of the waters they lived in. The general absence of fossil plants in limestones of all ages, has never yet, to my mind, been satisfactorily accounted for.

The occurrence of thick seams of Coal lying amidst the most tranquil of aqueous deposits, and the rareness of such seams in the coarse gritstones of the lower field, seem to prove anything but that the vegetable matter now forming Coal was drifted into the places where it is found; else we should expect fully as great, if not a greater, amount of vegetable matter, where we find evidence of a strong current.

As before stated, rough gritstones, containing rounded pebbles of quartz, abound in the lower Coal-field; whilst the middle and upper measures, reaching to a thickness of four thousand four hundred and seventy feet, as far as I know, have never yet afforded a piece of mineral matter in their sedimentary deposits, of the size of a small pea. In two *seams* of Coal, namely, the four feet mine at Patricroft, and a small seam under it, the same mine at Pendleton, I have obtained rounded stones of several pounds in weight, but as both these specimens came from the neighbourhood of great faults, probably they may have been brought to the places where they were found, by other causes than currents of running water. They, however, are interesting, and very difficult to account for, being well rounded. Their composition is the same, though found in different seams and distant places, being of hard crystalline quartz, more resembling Gannister than any other stone in the carboniferous series.

The outsides of both stones are well coated with a covering of Coal, showing that they must have lain long in the places where they were found.

As previously remarked, dry land has been inferred to exist, during the formation of the carboniferous series, from the characters of the fossil plants discovered embedded in it. The true nature of these plants, however, is at present but little understood, and calculated to puzzle the most eminent recent botanists, rather than throw much light upon the soil upon which they grew. Wherever the plants grew, the strata, in which they are found, were no doubt deposited from water, and show no evidence of having been dry land. Had dry land existed during that period, some evidence of it would, in all probability, have been left during the deposition of the flags of the lower Coal-field, as we there find thin beds of fine sandstone, alternating with thin deposits of silty clay. The latter of which, —if exposed to the action of the sun or air for a few hours, even so short a time as the reflux of the tidal wave of our present seas—would have left some evidence of desiccation, and consequent contraction.

In the upper new red sandstone of Weston Bank, near Runcorn, in Cheshire, we have the first positive evidence hitherto discovered of dry land in England.

At Weston, in the rock above named, about thirty-two feet from the surface, and in the higher part of the deposit, there is a thin bed of red clay, from about half to three-quarters of an inch in thickness. This clay affords impressions of the feet marks of the Cheirotherium, Rhynchosaurus, several other reptiles, numerous worm marks, and beautiful lines of desiccation, similar to what a bed of moist clay would undergo, under a hot sun at the present day. The red clay was evidently deposited by water, which afterwards receded from it and left it uncovered. When this deposit was in a plastic state, the animals walked across it and left their tracks, subsequently the sun or air by desiccating the clay, produced wide cracks, and the water, at length returning, again filled both the feet marks and cracks, and made a beautiful cast of them in sand. Thus do these most interesting specimens, not only show us the tracks, left countles ages ago, of some of the most extraordinary animals that ever existed on our globe, but they afford us proofs of a very quiet flow of water that deposited the red clay—the recession of such water—the drying and cracking of the clay by a hot sun or air, and the return of a sharp current of water, bearing along with it the sand that formed the casts of the moulds,—circumstances of great interest, to those who speculate on the physical condition of the globe at that remote period.

Numerous such thin beds of clay are to be met with in the Coal measures, alternating with beds of sandstone, formed of grains of different sizes, still no trace of desiccation is to be found like those in the new red sandstone last described. Such may have existed, yet all evidence of them in England has been lost; but Mr. Lyell, in vol. II., No. 4, p. 25, of the second series of the American Journal of Science, states, that he has discovered footmarks of an animal, resembling the Cheirotherium, in the middle of the Coal-field in Unity township, five miles from Greensburg, in Westmoreland county, Pennsylvania. The markings occur on slabs of stone, a few inches thick, between which are thin partings of fine unctuous clay, where casts of the animals' feet in sand are left. Thin cracks filled with sand, also appear in the clay. These seem as if made after the animal had walked. Thus, these American flags present very similar appearances to Weston ones, before described.

Many of the fine beds of flag show very regular depositions of sand, alternating with clays, such as might, on first view, lead us to suppose them the effects of tidal action; but they are of small extent, and the direction of the currents which brought the materials of which they are composed, is often very variable, and much more difficult to ascertain than littoral deposits, by the present ocean, appear to be. Many of these beds of flag exhibit impressions of some body having acted upon them, when in a soft state, as a slab of the upper flag rock from Kerridge shows. (See plate I.) All these marks can be traced downwards, through several successive deposits of one-eighth to one-fourth of an inch each in thickness. In some instances a bed of flagstone, eight inches in thickness, will show impressions of the same size as those in the lithographic plate on its upper surface, and corresponding marks, in relief, on its lower surface; thus showing that

PLATE I.

Portion of Upper Flag containing impressions

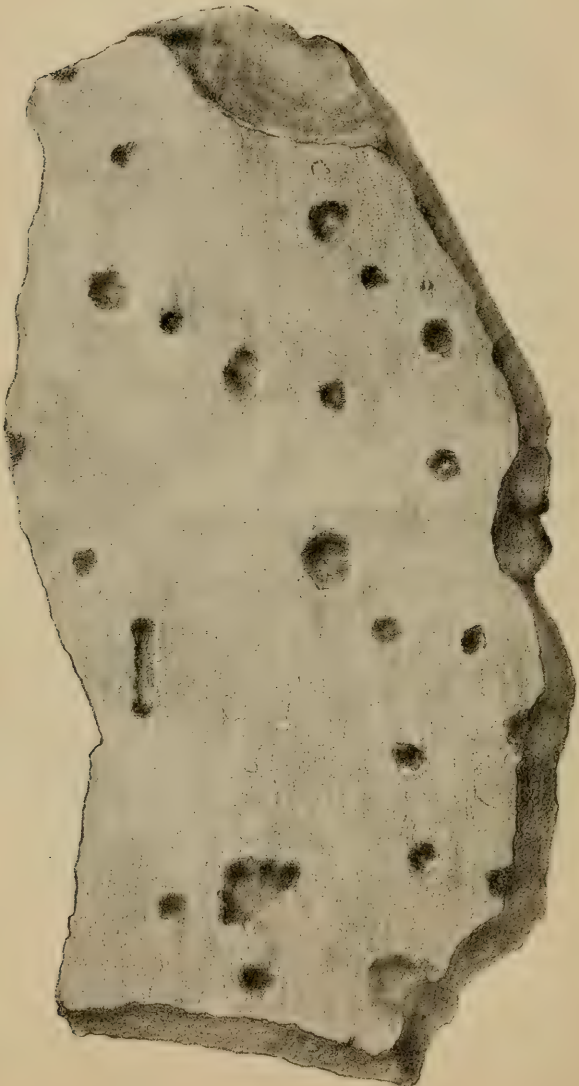


PLATE II.

Portion of Lower Flag from Todmorden showing Casts of Annelide.

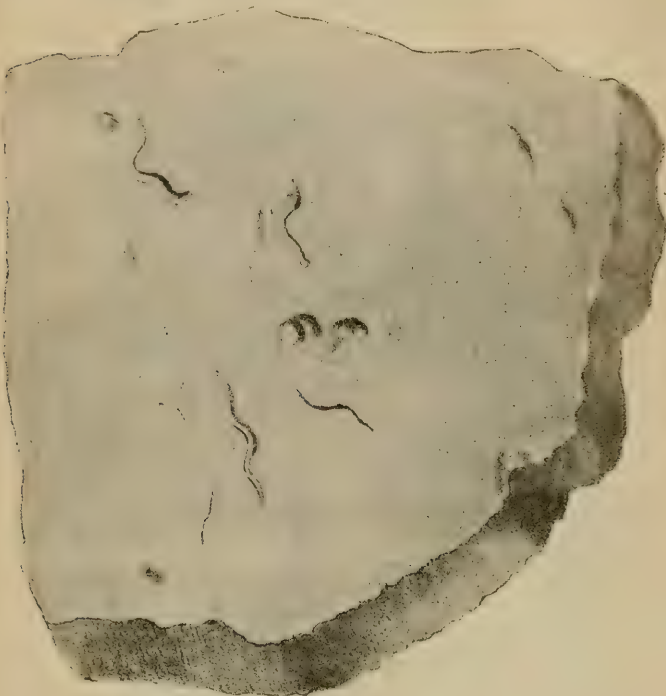


fig 2.

the force had acted throughout several laminæ of the stone.

In the lower bed of flags near Todmorden, I I have met with a specimen of fine grained sandstone, shewing several distinct casts of a small Annelide, described in plate II. fig. 1. And in a nodule of ironstone, presented to me by Mr. Francis Looney, F.G.S., found in one of the Bent mines, at Oldham, there is a beautiful impression of a long-tailed crustacean, resembling the Limulus *trilobitoides.* (See plate II. figure 2.)

The remains of fishes and shells give further evidence of the presence of water.

As before stated, it is from the remains of plants that dry land has been supposed to have existed during the carboniferous epoch. Such large trees as Sigillariæ, Ulodendra, Lepidedendra, and many other fossil remains, were considered to have grown on an insular spot; and it has been plausibly argued that hard wooded trees, like the genera Pinites and Pitus of Witham, were located on higher and drier grounds, while the numerous remains of ferns, and other small plants, were attributed to low marshy land.

No reason was assigned for the rarity of specimens of ferns, showing remains of fructification,—although it is well known that, in the oolitic Coal-field, such plants are frequently met with in that state,—except that the floods swept down the plants at a period of the year when their fructifications were absent. The long processes radiating in quincuncial order from the Stigmaria, to a considerable distance, did not allow of its being so easily drifted, therefore it was allowed to have grown in the position where it is found, and called an aquatic plant. As it was always met with in the Coal floors, it was supposed to have been a kind of harbinger of dry land, filling up, by its rapid growth, the swamps, until a bed of soil was formed for the growth of the larger trees, like the Sigillaria, &c. This view was taken by many authors, who represented the vegetable matter, now forming coal, to have grown on the spots where it is now found on dry land. The parties who advocated the drift hypothesis, carried by currents of water the Stigmaria with all the rest of the plants into their *Mare Carboniferum*, where they formed all the Coal seams. The various arenaceous and argillaceous deposits of the Coal measures were thus accounted for, but no sufficient reason was assigned for the Coal seams themselves containing so little of transported matter.

As before stated, the seams of Coal are generally found lying upon a fine deposit of hardened clay or silt, indicating great quietude in its formation, and scarcely any trace of a current. In fact, we have in the floor a fine rich soil, well calculated to have produced a luxuriant crop of vegetation, full of immense numbers of Stigmaria *ficoides*, now proved by the trees of St. Helens and Dukinfield, to be nothing more than the roots of Sigillaria.* So their presence under the seams of Coal, is now fully accounted for, being merely the roots *in situ* of the forests of Sigillaria, that have chiefly formed the beds of Coal found lying above them. These fossils are of great value in accounting for the true formation of Coal seams, and must for ever do away with the drift hypothesis, so far as concerns those seams in which they are found in the floors,

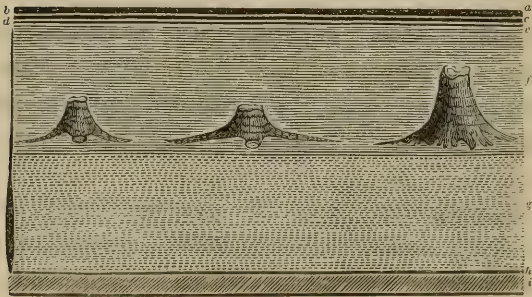
* Phil. Mag. for March, 1844, and October, 1845; also, Quarterly Journal of the Geological Society, for Nov. 1846.

and establish the rival theory, which attributes the formation of Coal seams to vegetable matter, grown upon the identical places where it is now found.

In most of the Coal seams of Lancashire, some evidence is found of upright stems of trees, for the most part Sigillariæ, standing upon the roof of the Coal. Professor Ansted, in Vol. I. p. 262, of his Treatise on Geology, in speaking of Sigillaria, says, " The great abundance of the large stems, referred to this genus, is a fact which seems to show that it was one of those to whose presence much of the solid matter of the Coal is due. Many instances are known, in which trunks or stumps of large trees of this kind are found close together, in an erect or highly inclined position ; and this, not only in England, but also in the continental Coal-fields, and more particularly in that of St. Etienne, where a remarkable group has been described by M. Brongniart. It must not be supposed, however, that the trees grew upon the spot where they are thus singularly arranged ; it is more probable that they may have been caught, and stopped in their passage down a rapid stream, and, like the *snags* on some of the great American rivers, have been detained till the lower portion was firmly embedded in the rapidly forming sandstone." Whatever evidence of *snags* the fossil trees examined by the above learned author may have presented, most of the specimens found standing erect in Lancashire, show every appearance of having grown where they are now found. Remains of Sigillaria can also be generally found in the coal itself.

Although the stems of Sigillaria have been generally noticed in the roofs of Coal seams, it is by no means to be inferred that they are not to be found in other portions of the carboniferous strata. They no doubt have been found more frequently in the roof than other places; but that part can be better examined than other strata in a mine. The fossil trees at St. Helens, all Sigillaria, were four in number, and occurred in a deposit of gray indurated silty clay, lying about eighteen yards two feet above a foot coal, and fourteen yards one foot under a yard seam. The bases of the stems lying about eight feet above a white gritstone rock, and the stems proceeding upwards in the warren, which was completely traversed, as far as it could be traced, by Stigmaria *ficoides*; so if the whole of the rock had been on in the quarry, the stems would probably have reached up to the Roger seam of Coal.

Fig. 1.*



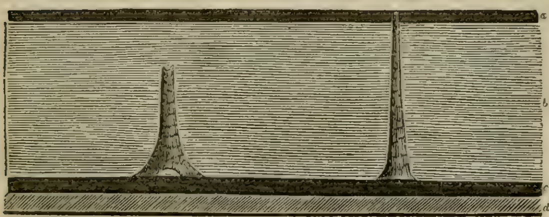
			yds.	ft.	in.
ROGER MINE.	*a*	Coal	0	2	0
	b	Dirt	0	1	0
	c	Coal	0	0	9
	d	Dirt	0	0	6
	e	Coal	0	1	0
	f	Warren containing the fossil trees	17	0	0
	g	White gritstone	16	0	0
	h	Coal and dirt	0	1	0
	i	Floor full of Stigmaria *ficoides*.			

In the Duchess of Lancaster mine at Pendleton, near Manchester, have been observed a great number of fossil trees, most of which exhibited undoubted characters of Sigillaria. They stood

* The seams of Coal and fossil trees in all the three wood-cuts, are drawn upon a scale of double the size of the other strata, and are merely for the purpose of showing the *position*, and not the *characters* of the fossils.

erect on the seam of Coal there, seven feet in thickness, some of them showing small portions of their roots, whilst others rested with their stems upon the Coal. These trees I measured twenty-five feet upwards in the Blue bind, but Mr. Ray, the intelligent engineer of colliery, had traced one which went through the floor and into the seam of the Albert Coal. A portion of this stem, converted into Coal, is now in the museum of the Manchester Geological Society. In the strata near the bases of the stems occur plenty of Pecopteris *nervosa.*

FIG. 2.

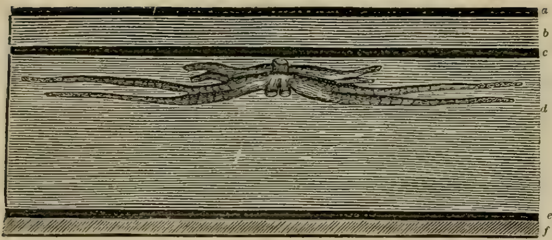


		yds.	ft.
a	Coal Albert Mine	1	0
b	Blue Bind and Shale (fossil trees)	19	0
c	Coal, Duchess of Lancaster	2	1
d	Floor, full of Stigmaria *ficoides.*		

Lately has been discovered in the floor of the Victoria mine, Dukinfield, near Manchester, at the depth of eleven hundred feet from the surface, a magnificent specimen of Sigillaria, which exhibits in the stem the respective characters of the species *pachyderma*, *reneformis*, and *organum*, and true Stigmariæ traced eighteen or twenty feet as its roots. The stem was about two feet high, and could not be traced into the Coal and Cannel seam above. Four main roots appeared to have proceeded from the base, but only one has been preserved entire and lodged in the museum of the Manchester Geological Society. This, after proceeding some distance, divides into two roots, and each of these latter into two more, which run in a horizontal direction as Stigmaria, at a depth of two feet under the Coal. Their extremities have not been reached, although they were traced upwards of twenty feet.

The matrix in which they occurred was a dark coloured fire clay, which contained so much carbonaceous matter as to prevent the rootlets of Stigmaria or any other fossil remains from being easily traced in it; but it was very evident that the destruction of an immense number of these bodies had caused the dark colour of the clay, as they could be distinctly seen on dividing the moistened clay with a penknife.

Fig. 3.



		yds.	ft.	in.
a	Coal, Stone Mine	0	2	6
b	Black Shale, &c	4	0	0
c	Canal or Two Feet Mine	0	2	2
d	Tender Metals, containing the fossil tree, Black Bands and Rock	22	0	0
e	Coal, Peacock Mine	0	2	4
f	Floor full of Stigmaria *ficoides.*			

The above trees have been alluded to for the purpose of showing the different positions which they are met with, and not as the only instances of upright specimens which have been found in the Lancashire Coal-field. For after eight years' observation, I am led to believe that most mines of any considerable thickness, if carefully examined, will give some evidence of upright trees.

The resemblance of seams of Coal to beds of peat, has long been advanced as a proof that Coal was formed from vegetable matter, grown upon the places where it is now found. All the early advocates of this theory, comprising Jamieson, De Luc, Brongniart, and others, gave strong evidence in support of their views; but their supposition, of raising and depressing the surface of the earth so as to have it alternately land and water for every seam of Coal, was not borne out by any such similar changes of position now observed on the crust of the globe. Mr. Bowman's paper on the origin of Coal, published in the 1st volume of the transactions of the Manchester Geological Society, is unquestionably the most valuable treatise on forming Coal by subsidence; and satisfactorily accounts for the dividing, thickening, and thinning of seams of Coal, and was the most useful memoir on the origin of Coal which had then appeared.

It was owing to the observations of Mr. Charles Darwin, on the coast of Patagonia, that geologists were first presented with a series of phenomena of the gradual rising of land, it then being in a state of repose, for a considerable period, and again rising. This alternation of elevation and repose being repeated many times. Upon first reading his work, I immediately saw a series of phenomena, the reverse of which, I had long been convinced, had taken place during the formation of our beds of Coal, and that, in all probability, they were the opposite of what was taking place on other parts of the earth's crust at that time.

Direct evidence of the subsidence of land is difficult to obtain, but Mr. Darwin, at p. 475, of the second edition of his Journal, states, "Nevertheless, at Keeling Atoll, I observed on all sides of the lagoon of cocoa-nut trees, undermined and falling, and in one place the foundation posts of a shed, which the inhabitants asserted had stood, seven years before, just above high water mark, but was now daily washed by every tide. On enquiry, I found that three earthquakes, one of them very severe, had been felt here during the last ten years." In addition to the mass of evidence previously known, as to the subsidence of land, Mr. Darwin, at page 171, observes, "Every thing in this southern continent has been effected on a grand scale; the land from the Rio Plata to Tierra del Fuego, a distance of twelve hundred miles, has been raised in a mass, (and in Patagonia, to a height of between three hundred and four hundred feet,) within the period of the now existing sea shells. The old and weathered shells, left on the surface of the upraised plain, still partially retain their colours. The upraising period has been interrupted by at least eight long periods of rest, during which, the sea ate deeply back into the land, forming, at successive levels, the long line of cliffs or escarpments, which separate the different plains as they rise like steps one behind the other. The elevatory movement and the eating back power of the sea, during the periods of rest, have been equable over long lines of coast; for I was astonished to find that the step-like plains stand at nearly corresponding heights, at far distant points. The lowest plain is ninety feet high, and the highest which I ascended, near the coast, is nine hundred and fifty feet, and of this, only relics are left in the form of flat gravel capped hills. The upper plain of Santa Cruz slopes up to a height of three thousand feet, at the foot of the Cordillera. I have said, that within the period of existing sea shells, Patagonia has been upraised three hundred to four hundred feet. I may add, that within the period when icebergs transported boulders over the upper plain of Santa Cruz, the elevation has been at least fifteen hundred feet. Nor has Patagonia been affected only by upward movements; the extinct tertiary shells from Port St. Julian and Santa Cruz, cannot have lived, according to Professor E. Forbes, in a greater depth of water, than from forty to two hundred and fifty feet; but they are now covered with sea-deposited strata, from eight hundred to a thousand feet in thickness; hence, the bed of the sea, on which these shells once lived, must have sunk downwards several hundred feet, to allow of the accumulation of the superincumbent strata. What a history of geological changes does the simply constructed coast of Patagonia reveal!"

In the early part of this paper, the evidences of periodical subsidences, and periodical rests in those subsidences, as exhibited by the beds of fossil shells, were brought before your notice; they showed great regularity of motion in the earth's crust, extending during vast periods of time. Is it likely that such a series of phenomena should at once change? No.—It is much more philosophical to suppose that it continued on during the whole period of the formation of the carboniferous strata, and the successive forests of fossil trees entombed in them, standing on the exact spots where they grew and flourished, to most minds must satisfactorily prove it. The evidences of the periodical states of elevation and repose of the Patagonian coast, are but the reversed action of what has taken place during the deposition of our Coal seams. Every seam of Coal indicating a period of rest of the earth's crust, which allowed the growth of a forest of trees; whilst the sandstones, shales and binds, give us a correct measure of the rate of subsidence, and the force of the currents caused by such changes of the surface of the globe. As before stated, there are, in the Lancashire Coalfield, one hundred and twenty beds of Coal, which would require as many epochs of rest, and the same number of subsidences, to account for their origin, a period of time, vast to our ideas, but small in the history of the earth.

In a former paper (p. 178, Vol. i. of the Transactions of the Manchester Geological Society) I have stated, that the Coal measures presented some appearance of having been deposited in an estuary; but further observations, and the great superficial extent of the formation, now lead me to believe that they must be considered more of a *marine* character, and that the currents which brought the *debris*, did not altogether proceed from rivers running into the sea, or by tidal action, but were chiefly produced by the subsidence of the bottom of the ocean itself. The occurrence of the Cypris and the Unio, in the upper Coal measures, has been considered indicative of the fresh water origin of those strata; but when these fossils are found in company with remains of the Megalichthys, Holoptychius, Cælacanthus, Platysomus, Palæoniscus, and other genera, heretofore considered as of decidedly marine origin, their diagnostic value ceases, even if all these genera were confined to fresh water; but it is well known that such is not the case, but that many are found in salt water.

Independently of this, we must take into consideration the vast extent of the true Coal-fields of Europe, all of which have, most probably, been once united and formed under similar conditions; and the evidence they present of the action of currents of water, is very different from what we now witness at the mouths of estuaries or on beaches, for we find no deposits in them resembling those of the latter. Professor H. D. Rogers, in his admirable paper on the origin of the Appalachian Coal strata, at p. 469, states "that it may fairly be questioned whether any sensible proportion of river silt could spread itself to the distance of one hundred and fifty or two hundred miles seawards." The extent of this immense Coal deposit, as well as its accompanying strata and organic remains, like our European field, seems to require an ocean for its formation. This ocean would be of a very different character to any now known to cover the surface of the globe, exhibiting an uniformity and shallowness unknown at the present time ; and such circumstances would doubtless influence the tidal wave and produce phenomena unlike those observed at this day.

As the present ocean and its tides will not, therefore, account sufficiently for the different deposits of the Coal measures, allow me to direct your attention to vertical sections of those strata, and show the materials of which they are composed, and how they change and graduate into one another.

The size and nature of the particles composing the different beds give us some idea of the currents of water that brought them. I propose to ascertain the rate of subsidence from the same source, and to attempt to show that the currents are but the effects of such subsidences.

The diagram, plate III, figure 1, represents a section of part, and the richest portion, of the lower Coal-field at Staly-bridge, near Manchester, proved in sinking Mr. Woolley's shaft. It commences a little under the Gannister Coal, and terminates with a portion of the upper Flag Rock, and is interesting from the circumstance of the roof of the upper seam of Coal containing an abundance of Goniatites, Pecten, Posidonia, and other marine shells. The vertical black line indicates by its varying thickness the degree of rapidity of the subsidence of the bottom of the sea, at the particular period when the part of the deposit at which it is opposite was forming, as well as the strength of the current produced by such alteration in level.

The Sandstones, Rock Binds, Shales, Metals and Binds, and Floors, indicate diminishing rates of subsidence, and the breaks in the line are periods of absolute rest, during which the vegetable matter, now forming Coal, grew.

The diagram, plate III, fig. 2, shows a section of the St. George's Colliery, near Manchester, the property of Edmund Buckley, Esq., M.P. It commences with the upper portion of the middle Coal-field, and terminates upwards with the lower and richest part of the upper division. This section is remarkable for the number of

Coal seams occurring in a short distance, from the compound nature of some of the seams, and from the abundance of casts of a Cypris, mingled with the remains of large fish. The black line here also marks the rate of subsidence of the crust of the earth, and the velocity of the water, as in the other section.

Both sections are taken for the purpose of proving the hypothesis, that the currents of water which carried the arenaceous, argillaceous, and calcareous deposits of the coal measures, were caused chiefly by subsidence of the bottom of the sea, and that seams of Coal indicate periods of rest, during which such currents ceased to flow, and thus allowed of the growth of vegetable matter, sufficient for their formation.

The first section (see plate III, fig. 1,) commences with the floor of the "Parson's Mine," which is composed of a crystalline stone, known by the name of Gannister. It is formed of a fine grained silt, cemented together by a silicate of lime or alumina, and contains an abundance of tree roots, (Stigmaria *ficoides*) evidently *in situ*. When these trees grew, the soil which supported them could not have been deeply covered with

SECTIONS SHEWING THE INTENSITIES OF SUBSIDENCE AND CURRENT

and the periods of rest during the formation of the COAL MEASURES

FIG. 1.

Section of part of Mr. Woolley's Colliery

STALYBRIDGE

Scale. 1 INCH = 12½ YARDS

Fossils	Name of Strata	Thickness
	Gorse Hall Rock	9 . . 6
	Rock Bind	1 . 2 . .
	Dk. Gray Soapstone	8 . . 6
	Blk. rocky Metal	3 . . .
	Soft Blk. Clay	. . . 4
	Blk. Shale	4 . . 2
Posidon. Goniatites & Bed	LITTLE COAL	. . 1 . 3
Roots of Trees	Fire Clay	1 . 1 . .
Roots of Trees	L. COAL Floor Dirt	. . . 6
	Dk. Gray Soapstone	3 . 1 . 6
	White Rock	11 . 2 . .
	Black Bind & Rock Bind	7 . 2 . .
	Black Shale with Bullions	28 . . .
	Rabbit Hole Rock	9 . 1 . .
	Black Shale	4 . 1 . 9
Parson Mine	COAL	. . 2 . .
	Gannister Floor	. . 1 . 3
Roots of Trees	White Earth	1 . 2 .

FIG. 2.

Section of part of St. George's Colliery

MANCHESTER

Fossils	Name of Strata	Thickness
	Soapstone	15 . 2 .
	Rock & Binds	6 . . .
	Clay & Ironstone	2 . 1 . .
Roots of Trees	COAL	. . . 2
	Blk. Soapstone	3 . . 6
	Rock & Binds	9 . . .
Shells Cypris & Fish	Blk. Soapstone & Ironstone	4 . 2 . 11
Three Quarters	COAL	. . 1 . 5
Roots of Trees	Floor	1 . . .
	Binds & Rock	8 . 2 . .
Roots of Trees	COAL	. . . 6
Four Feet	Dirt	. . 1 . .
	COAL	. . 4 . .
Roots of Trees	Dirt	. . 2
Roots of Trees	COAL	. . . 2
	Floor	3 . . .
	Soapstone	4 . . .
	Binds & Rock	8 . . .
	Black Bass	2 . 1 . 4
	- - - - - - - -	. . 1 . 6
Roots of Trees	Floor	3 . . .
	COAL	. . . 3
Roots of Trees	Floor	3 . 2 . 2
	COAL & Bass	. . . 4
Roots of Trees	Floor	1 . . .
	Binds & Rock	3 . 2 . 8
	Blk. Soapstone	. . 2 . 5
Shells Cypris & Fish *Yard*	COAL	1 . 8
Roots of Trees	Floor	2 . 8
	Soapstone Rock and Binds	9 . . .
Roots of Trees	COAL	. . . 3
	Floor	

water, and it must have remained in a state of repose for a long period, so as to allow of the growth of sufficient vegetable matter to form the two feet of Coal. After the production of this Coal seam, the surface slowly and gradually subsided, and the vegetable matter being partially decomposed, a portion of its carbon mingled with the fine clay composing the Black Shale, brought by a current caused by such slow and gradual subsidence.

The subsidence then increased, and caused a quick current, which brought the sand now constituting the "Rabbit-hole Rock." Again the subsidence diminished during the formation of the Black Shale with ironstone nodules, and then gradually increased during the formation of the Black Bind, Rock Binds, and White Rock. The dark gray Soapstone indicates a period of approaching rest. The Floor-Dirt was then formed, on which grew the vegetable matter composing the six-inch seam of Coal. A slight and partial subsidence then appears to have taken place, and formed the four feet of Fire clay whereon grew a fresh crop of Sigillariæ that formed the one foot three inches of Coal. The subsidence then appears to have been very gradual, so as to allow of the decomposition of vegetable and animal substances, and thus colour with their carbon the Black Shales, and the existence of a bed of Pecten, Posidonia, and Goniatites, now found lying in them. According to Sir H. De La Beche's table, p. 403, in the appendix to his Geological Researches, the Pecten is now found in sands, sandy mud, and mud at depths from 0 to 20 fathoms; so it is fair to assume that these creatures lived in about 10 fathoms of water. A gradually increasing rate of subsidence then appears to have been in action during the formation of the dark gray Soapstones, Rock Bind, and Gorse-Hall Sandstone Rock.

The section of St. George's colliery, plate III, fig. 2, presents nearly similar dynamical and statical conditions of the earth's surface to that last described; but the periods of repose appear to have been more frequent, and the subsidences more gradual, than in the former instance. The phenomena, however, are, on the whole, so similar that it will be unnecessary to go through all the changes of the earth's surface, at the period they were made, a second time, except by noticing the Black Basses over the yard and three quarters mines. These strata, by the immense mass of casts, Cyprides, and disjointed teeth, scales, and bones of sauroid and other fishes, scattered throughout them, as well as by the occurrence of the Unio—a shell resembling the Modiola—and the Microconchus, prove that a considerable period of time was requisite for their formation.

The fossils, in the first case, occur over a space of about two feet, in a bass, which is composed of fine clay, mixed with bituminous matter, resembling the indurated black mud which we now find at the bottom of stagnant pools, in which there is much decomposing vegetable matter. After the growth of the vegetables constituting the yard Coal, the subsidence must have been very slow and gradual, so as to allow time for the complete decomposition of all the vegetable matter, and the existence of the animals whose remains are now found there. From the fragmentary state of the portions of fish, mixed with the casts of Cyprides, there is every reason to believe that their edible parts were consumed by the Cyprides, in a similar manner to the removal of decomposing animal matter by the small crustaceæ of our modern waters.

The Bass, over the three quarters seam of Coal, resembles that over the yard mine, in the nature and condition of the organic remains found embedded in it; but the under portion of it, nine inches in thickness, is a rich iron ore. The whole mass of the Bass and ironstone, like the Bass above the yard Coal, teems with remains of Cypris and Microconchus, detached bones, scales, and teeth of fishes of the genera Megalichthys, Holoptychius, Cælacanthus, Platysomus, Palæoniscus, Diplopterus, Ctenoptychius, and shells of the genera Unio and Modiola, all mingled together.

The three sections of strata containing fossil trees, heretofore referred to, may also be brought as proofs to show the change of level and condition of the earth's surface, at the period of their formation; but their changes in structure, especially those of the two last, are so regular and slow, as to show but little variation in the rate of subsidence. The St. Helen's section commences with a mass of vegetation now forming the foot coal, grown during a period of repose of the area on which it is found. It then subsided, at first slowly, but gradually increasing. The subsidence was at length rapid enough to prevent the growth of plants, so long as the White Sandstone Rock was in the process of formation. When this was done, however, it became gradually slower, so as to allow of the formation of the Warren, and the growth of the Sigillariæ found in it.

All these instances prove the existence of *land covered by water*, but no *dry land*, and confirm Brongniart's opinion, formed from the examination of Stigmaria, that the Sigillaria was an *aquatic* plant.

Sufficient evidence has not been adduced to prove that the various other plants found in the coal measures were grown on the places where they are now found, for we have not been able to detect their roots *in situ*. This remains to be done.

With respect to the Sigillaria, there can scarcely be a doubt but that it grew in water, on the deposits where it is now discovered, and that it is the plant which in a great measure contributed to the formation of our valuable beds of Coal.

In this, my first attempt to connect the currents which existed during the deposition of the Coal measures, with the rate of subsidence of a portion of the earth's crust, I have adduced evidence to prove that the subsidences during the period under review were of such a character, in general, as to cause slow and gradual movements, similar to what Mr. Babbage avers would arise from the contraction of the earth's crust by the radiation of heat, rather than paroxysmal disturbances, similar to those which dislocated the carboniferous series, at intervals, long after its formation.

Whatever the cause of the numerous subsidences that have evidently taken place in the crust of the globe, it must certainly have been *deep seated*, and acted at intervals over vast periods of time, commencing long before the formation of the Protozoic rocks, extending over the whole of the Palæozoic rocks, and up to the latest Tertiary deposits.

We are at present in want of a correct vertical section of the earth's crust, showing the materials composing its various beds, and the nature of their organic remains. When this is supplied, we shall be enabled to trace back the physical history of our globe, and furnish the mathematician with data from which to calculate, with absolute certainty, the changes which have taken place in the solid particles of our planet, and to determine whether some of the most important of them have not been effected by the slow and silent process of the radiation of heat, rather than by more actively energetic causes.