
THE GROWTH AND ORDER OF THE LOWER COAL MEASURES OF OHIO.

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I do not propose a formal discussion. That would require a treatise rather than a paper. What I have to say will rather be in the way of suggestion than of positive statement. I would expressly disclaim dogmatism and controversy. The facts are not in hand, and the time has not yet come for complete and symmetrical theories in regard to the subject involved. I believe, however, that provisional theories, if only held open to change and enlarge-

ment, often serve the student of nature well. They help to formulate his knowledge, they invite discussion and thus tend to clearness and definiteness of view.

Some of the points that I will name are obvious and indisputable, others are inferences in regard to which a wide latitude of opinion must be allowed, to say the least. I will endeavor to distinguish between these several grades of propositions as I proceed.

Without further preface I pass to my subject.

1. The coal measures of Ohio were accumulated around the margin of an ancient arm of the sea, or to give to that sea the name of its diminished but real representative in our own day, around the margin of an ancient arm of the Gulf of Mexico. This fact has been for a long time, universally recognized. The boundaries of this ancient gulf can be traced through Ohio, through several earlier stages with unmistakable distinctness.

The Berea Grit is as plain a shore line as was ever left by a retreating sea. It is characterized by ripple-marks and worm-tracks throughout its entire extent. We can rest assured that it was the western and northern boundary of the old gulf. Other shore lines, interior to this, are disclosed in the remainder of the Waverly system, but I will pass them by.

At the beginning of the coal measures proper, more than half of Ohio was dry land. All of western Ohio and the northern portion of the State, as well, were now above the sea. The land was low and its only relief was produced by the erosion that had already begun its work upon it. There were no mountains, no irregular folds, no fractures of the strata. If they ever existed, there would be evidence of them now, but none has been found. There is not a more orderly portion of the earth's crust than this 40,000 square miles that we call Ohio.

When the earliest coal swamp was in process of formation, the shore of this sea was composed of quite different classes of materials. Long beaches of pebbles, worn on a shore that no man knows, but presumably from the southeastward where the appalachians already existed, transported by an agency that no man understands, though presumably by glacial ice, long beaches of this gravel alternated with the softer beds of the Waverly formation below or with the patches of limestone. The pebbles would seem to have been carried along the lines of deeper water and here from some cause the best conditions for accumulating and preserv-

ing a coal swamp were found. The valuable deposits of our lowest coal are, so far as I know, associated with the pebble deposits. Everywhere else, though the horizon is plain, the accumulation was small. It is necessary to add, however, that coal is not always found where the pebble rock occurs.

2. The deposits of the coal seams, below the Nelsonville coal at least, and including that seam were in the nature of marginal swamps. This is an inference that many will dispute, but I wish to set forth the facts and arguments from which it seems to me to follow.

It is now established that the coal vegetation grew where we find it. A coal seam is literally and truly a buried swamp. A swamp can not exist in deep water. This is a contradiction in terms. Some have claimed that floating islands of vegetation would explain coal seams, but I fail to see how the underclays can be accounted for by this hypothesis.

Swamps around islands in the gulf, if such islands existed, as well as around the main land, would give rise to coal seams under proper conditions. Such islands, I think we find later in the series. The sporadic coals, the jumping seams, I account for in this way. But the earlier seams are characterized by a number of facts that imply the near presence of the sea.

(*a.*) Many of these seams are covered, locally at least, by sharp sandstone, sometimes coarse, sometimes even conglomeratic. Where does this material come from? Surely, from the open sea. Strong currents are required to account for much of it. Mud or shale belongs along quiet and protected shores.

(*b.*) The presence of *marine limestones* through the lower coal measures is conclusive proof that the sea was at hand. Take the lower Mercer limestone, for instance. It is covered with the life of the ancient seas. It stands for moderately pure, salt water as surely as conglomerate stands for strong currents, or as a ripple mark for shoals. We all know scores of cases where this limestone comes directly down upon the coal, making its very roof. The same thing is true of the coal below the Ferriferious limestone, the limestone coal of Jackson County. The limestone makes the roof in many cases. The proof seems perfectly clear and satisfactory to me that in such cases, the swamp was not excessively wide, which terminated the growth of the coal bed. When the slight depression occurred, the *sea*, was at hand to cover the ground.

(c). The *presence of bowlders*, or lost rocks *occurring in the substance of the coal seams*, seems to me to prove the same fact. Such examples are rare to be sure, and yet experienced miners have all met with cases. These bowlders are ice transported blocks, I take it. One in my possession taken from the thick coal at Shawnee, lying upon the second slate, and with the seam normal and regular above it, weighs over 200 pounds. Its outer surface *seems* glaciated. It is a metamorphic sandstone, and to find its fellow, you would be obliged to go to the great ledges of the south Alleghanies. I think it clear that it was floated from there, and ice transport is the most probable. Pushed up over the swamp when the final submergence came, it settled in the seam until the hardening, second slate arrested it. Its presence shows the sea at hand.

Such facts as these, with which we are all conversant, have led me to believe that the lower seams were mainly *marginal* swamps; that they were extended indefinitely from their outer margins, but that a few miles—perhaps a score, perhaps half a score—seldom, I should believe, *two score* miles, would measure the breadth of the swamp. Where the margins approach each other, a greater breadth would *seem* to exist, without, however, necessitating a greater distance from the main land.

3. Another inference that I draw from the facts of our coal measure is, that they were *formed around a contracting sea*. This is a point of great moment. The amount of coal in Ohio is very closely connected with this question, viz: Were the seams formed in an expanding or in a contracting sea? If the land that made the margin of this sea was slowly subsiding, the lowest seams would be in the interior and the highest would reach furthest inland. If the land were slowly rising, the reverse would be true. I need not ask which line of facts we find in Ohio. To guard against misapprehension, let me say here, that *local movements of depression* must have *gone on side by side* with the *general movement of elevation*. In other words, the continued gain of the land to the eastward and southward must have been accompanied by a movement of depression in front of the advancing border. This is established by the clearest of all possible evidence, viz: the presence of the successive beds that cover, for example, the lowest coal horizon. One other condition of the land with reference to the sea, and only one other, is possible, in addition to the two already mentioned.

The land must have been *advancing* during the growth of the coal measures—or it must have been *retreating*—or it must have been *stationary*. If the latter were the fact, then the coal field proper must be bounded by a fault or fracture where the sea met the land, and the coal seams would all be found in one vertical section. It is unnecessary to say that there is not only not the slightest indication of any such fracture, but that there is the clearest and most unequivocal proof that no such fracture ever existed. The steady south-easterly dip of the whole series is one of the first facts that we learn in dealing with this field. This dip is not confined to the coal measures proper, but is shared by them with the shales and limestones that underlie them. Did the lowest coal ever extend across the western outcrop of the Berea Grit that lies 600 feet below it, in geological order? No one has ever claimed this, so far as I know. Every one who has touched the question incidentally or by implication, has taken the contrary view. But the evidence on which we depend to prove that the western margin of the original and oldest coal swamp was approximately where we find the western margin of the coal measures now, is the steady south-easterly dip of the strata to the eastward. Precisely the same order of facts exists in regard to the strata that overlie the lowest coal seam. Take the Cambridge limestone for example. It lies just about as far *above* the lowest coal in geological order as the Berea Grit lies *below* the same horizon. There is no more reason to believe that the limestone originally stretched over the western margin of the coal than there is to believe that the coal originally stretched over the western margin of the Grit. The cases are exactly parallel—in my judgment. Except that some of these formations could have a much wider extension than a coal seam.

The land to the westward seems to have risen to but a slight elevation above the sea, and the same level was reached by each successive addition. The proof of this is the present comparative equality in height of the westernmost outliers of the several strata. In other words, the dry land of Ohio constituted a plain from the first, as it does to-day, (our hill tops are the remnants of the plain), but a plain composed not of horizontal strata, but of strata dipping gently to the south-east. There is no evidence of great rivers in the sub-carboniferous or carboniferous periods.

The coal measures share this structure with the rest of the series and important consequences follow from this fact. The most ob-

vious of these consequences is that the earlier and later seams are not to be looked for in the same section. It is certainly safe to say that the swamp from which the Pittsburgh coal was derived never extended over the swamp of the lowest coal. I *think* it safe to say that the swamp of the Nelsonville seam very seldom extended, if it did in any single instance, over this lowest coal. I have yet to learn of a single workable deposit of this lowest coal beneath the horizon of coal No. 6, so-called, though bore-holes that would reveal it if it were present, can be counted by the hundred. But just how far this law is to be applied, is of course not a matter of theory, but a question of observation. The most prominent exceptions that I know to the general rule are in the case of the Freeport coals and the upper Kittanning (our Nos. 7–6*b* & 6*a*). The buff limestones that go with these seams give us a clue to the history, I believe. These limestones are fresh water or brackish-water formations, as appears from their obscure fossil contents. They did not grow in the open sea, but the gulf had become largely filled at the time when they were growing. Islands at least, dotted the brackish water that occupied wide areas next the main land. Around these islands, as around the border of the shore, coal swamps were formed while in the shallow waters at hand, limestones, earthy and ferruginous, were being deposited. So, I think, we must account for the extremely unsteady and uncertain beds that overlie the Nelsonville seam within one hundred feet. These are the coals that oftenest come into the section below the Pittsburgh seam, as I believe.

Each portion of the field would have its own history in this, as in all other respects. On the eastern margin of the gulf, quite different conditions prevailed from those found in Ohio. There is greater disturbance of the strata, larger intervals between the vital elements of the scale and a much larger number of workable coals in a single vertical section, than occur in our series.

The intervals in Eastern Ohio are twice or thrice as great as at some other points around the border—and this has increased the difficulty in holding the series. Finally, *oscillating* borders, upward, downward, etc. coal seams formed in stages of depression.

4. Again, I infer from various lines of facts in our coal measures that the formation of coal and also of limestone and flint, was confined to certain definite portions of the period to which these coal measures belong. Coal was not formed at *any* time in the period,

but only at certain definite times. It was not geographical conditions that were lacking, when it did not accumulate, but conditions of climate. There were always shores around which swamps could exist, but there were not always swamps. It was only at particular seasons of the long period that vegetation would thrive on the land, and limestone would grow in the adjacent seas.

There were *times, seasons,* for coal to grow. These seasons were separated from each other by approximately equal intervals. They recur with an astronomical sort of regularity and quite likely they had an astronomical cause. The barren intervals are approximately equal between the different seams in any one part of the field. We have all observed that when one clear and well defined interval is measured, the same measure is likely to come again. It may be twenty feet, it may be forty feet, but whatever we begin with is repeated again and again. I do not hold to the parallelism of coal seams in any theoretical way. I believe that the intervals between two coal seams vary to a considerable extent in the same field. Such a difference would result from the intervals being filled with different materials at different points, Shale is compressible, but sandstone is much less so. A ledge of sandstone between two beds of coal would make the measure larger than a stratum of shale, though both originally held the same thickness. A stigmaria bedded in shale is always flattened and compressed. In sandstone, it retains its cylindrical form. I have calculated from these examples that the shale frequently loses from one-half to one-third of its thickness by the compression it has endured.

The intervals in different portions of the field are found to vary quite widely. These differences must result from unequal rates of subsidence. They increase from the middle point of our field, both to the east and to the south. The series is shortest in its lower portions, about Hocking, Perry, Muskingum and Coshocton counties.

I believe in *coal horizons.* When the time came for the growth and proper accumulation of coal, there was a tendency, all around the border and around every island of the gulf, to form a coal seam. The conditions would often be wanting and no large accumulation could take place.

Out of this fact comes the very important conclusion that the coal *horizons,* and to some extent, the *seams,* are continuous, all around the margin of the gulf. There was the same number of

coal-making stages on each side of the arm of the sea that we have been considering. Absolute continuity may be rare at the present time, for erosion has come in to complicate the facts, but I do not believe it is wanting in all instances. Certain horizons, at least, can be traced around the entire border. The correspondence between the Pennsylvania and the Ohio side of the gulf is coming to be seen as wonderfully close in this regard.

In 1877, I published an order of coal seams as I found them in Vinton county and adjacent territory. Beginning with the lowest coal which I followed Dr. Newberry in calling coal No. 1, there comes in coal No. 2, at about 75 ft. to 100 ft. interval. At 50 to 100 feet above that, coal No. 3, with the lower Mercer limestone is found. Coal No. 4, is placed by Newberry under the Gray limestone. There is some ambiguity, I acknowledge, as to this limestone, in eastern Ohio, but as to Dr. Newberry's intent, I think there can be no real question.

In southern Ohio, however, I found three distinct seams between No. 3 and No. 4, as thus construed. These were termed No. 3*a*; 3*b*; 3*c*. They are all actual and frequently workable seams. At McArthur, No. 4, No. 3*c*, and No. 3*b* are actually mined in the same hill. As to the two seams that come next in order, there is no question. They are Nos. 5 and 6 of Newberry's scale. Above these, come the three uncertain seams to which I have previously referred, viz: Nos. 6*a*, 6*b* and 7. To count each we should have 1, 2, 3, 3*a*, 3*b*, 3*c*, 4, 5, 6, 6*a*, 6*b*, 7. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, or twelve seams in all.

The Pennsylvania series, as reported by Lesley, White, and others, matched very closely with this; it was, in fact, identical with it for a number of intervals, but I never could find exact agreement as to the upper coals of the section. Last October, however, at the meeting of the American Institute of Mining Engineers, Dr. H. M. Chance, of the Pennsylvania Survey, in a paper of merit and interest, presented a section that corresponds exactly, according to my readings, with the Ohio series. He had recently found a seam not heretofore recognized as distinct, apparently corresponding to our No. 6*a*, which also escaped recognition for a long while, and now all was in harmony.

His series, as at present held, is as follows:

Lower productive and conglomerate coal measures.

- Freeport Upper,
- Freeport Lower,
- Kittanning Upper (new),
- Kittanning Middle,
- Kittanning Lower,
- Scrub Grass,
- Clarion,
- Brookville,
- Mercer Upper, } Conglomerate Coals.
- Mercer Lower, } Conglomerate Coals.
- Quakertown, } Conglomerate Coals.
- Sharon. } Conglomerate Coals.

in all twelve seams, showing the same number of coal forming epochs on each side of the gulf.

It is obvious that our system of numbers was applied too early. The facts were not in, and great confusion results from the present arrangement. Our resources are belittled by the system and the numbers are really misleading. Some change must be made at some time.

The Pennsylvania Survey discards numbers entirely and depends on the geographical designation of the several seams.

When the facts, however, are fully in hand, it seems to me that a numerical system is both natural and helpful. The order in reality is an order of time. We demand this order and are never satisfied until we reach it. When we come to this, the Nelsonville seam will be known by as high a number as 9, and the Pittsburgh seam by as high a number as 16 or 17.

I have touched incidentally upon the *quantity* of our lower coals. If my inferences are sound, there is very *much less coal* in these measures than many of our earlier calculations asserted or implied. In any case the quantity is vast. A great deal of work must be done in Ohio before we can make even an approximate calculation of the total amount.

This is well illustrated in Dr. Chance's paper to which I have already referred.

In Pennsylvania, according to older methods of estimation, an average thickness of a seam was assumed, apparently for a solid or unbroken area.

In the new survey, the geographical outlines of the several coals were mapped, and the thickness for each county, or smaller area, was carefully given. Coals above 2 feet and under 3 feet in thick-

ness, were traced no further than to the water level. Seams ranging from 3 to 5 feet were run down to 150 feet below drainage, and seams of over 5 feet were calculated to 400 feet below drainage.

The estimate of Dr. Chance gives to the lower coal measures of western Pennsylvania about 35,500,000,000 tons. The earlier figures ranged from 180,000,000,000 tons to 300,000,000,000 tons. In other words, the last measurement is somewhat more than 1-10 of the earlier calculation. From this amount a large deduction must be made and there will remain 15,000,000,000 to 20,000,000,000 tons that can be reached by ordinary outlay in ordinary methods which would supply the world, at present rates of consumption, for about 800 years. The rate is however steadily increasing.

Whatever views are held as to the extent of our coal resources, no one can be blind to the duty of husbanding them with all care. They are the stores of buried power upon which very largely the future development of the nation turns.

Prof. Orton's paper was discussed by Mr. Jennings, Mr. Hazeltine, Mr. Head, Mr. Akley and Mr. Roy.