ON THE PHYSICAL CONDITIONS UNDER WHICH COAL WAS FORMED.

BY PROF. J. S. NEWBERY.

The mode of formation of coal has been much discussed, and various theories have been promulgated in regard to it; but the peat bog theory, as it is called, has been generally accepted. This is the view that coal is the residual hydro-carbon of plants which have grown where their remains are found, and that it has been formed precisely as peat accumulates in marshes at the present day.

So great has been the harmony of opinion on this subject, that it would at first sight appear unnecessary to renew discussion on a question that has seemed to be definitely and permanently settled. The calm of geological opinion which has prevailed on the coal question has, however, been recently disturbed by a very voluminous and painstaking discussion of the mode the formation of coal by M. Grand Eury, which occupies nearly three hundred pages in "Annales des Mines" for the year 1882. In this discussion the theory is advocated that the carbonaceous matter forming beds of coal has been derived from plants, but plants transported from their places of growth and deposited at a greater or less distance in the bottom of water basins.

We have reports also from time to time, of a system of experiments and observations made by M. Fayol, at Commentry, in the Department d'Allier, in Central France, from which he draws the

same inference, and it is apparent that a formidable attack has been made, all along the line, upon the peat bog theory.

For this reason, and in order that geological truth shall be maintained, I venture to report some facts which I have myself observed in the coal fields of the Mississippi Valley, and which, in my judgment, are incompatible with the conclusions of M. Grand Eury and Fayol.

The opinions presented in the discussion of the chemical and physical history of coal, have been based upon two classes of facts, viz.: (1) those gathered from the study *in the field* of the structure and relations of the coal beds, and (2) those obtained from chemical and physical experiments conducted *in the laboratory*. Now, while there is no doubt that such experiments have contributed much to our understanding of the subject, it is obvious that they have misled observers, through the impossibility of imitating by artificial means the grand processes of Nature. She has, in many instances, left a full and faithful record of her work, but the same difficulties attend the disinterment and translation of this buried record that have been encountered by the students of archæology in their efforts to trace the early history of mankind. Necessarily this is a work of time, and much study is required for the acquisition of a full and accurate knowledge of the language in which it is written, and for the gradual accumulation of the large number of facts required. Yet I claim that so much of Nature's record of the processes pursued in the formation of coal has been submitted to our observation, and this record is so clear, that the truth is within our reach; and further, that this truth is discordant with the results obtained in artificial experimentation, and therefore proves such results fallacious.

In the present communication nothing like a full discussion of the arguments, *pro* and *con*, will be attempted, since the time at my command will permit me to cite only a few of many facts, and to very briefly read their meaning.

For the present, I will confine myself to some of the phenomena presented by one of the Ohio coal beds, with which I am specially familiar. This is our "Coal No. 1," the lowest of the series, sometimes called the Brier Hill coal. As this seam has furnished a fuel of exceptional purity, such as could be used in the raw state for the smelting of iron, and lies nearer the navigable waters of Lake

Erie than any other, it has been very extensively worked. The result of this working has been to show that the coal is confined to a small part of the area it was once supposed to cover, and that it lies in a series of narrow troughs or basins, which were evidently once peat marshes, occupying local depressions in the then existing surface. A large number of these detached coal deposites have been now completely worked out, and the phenomena they present exposed to full view, among these phenomena, I may cite:

First.—Below the coal a fire-clay penetrated in every direction with roots and rootlets of *Lepidodendron*, *Sigillaria*. etc.

Second.—A coal-seam having a maximum thickness of six feet in the bottom of the basins, thinning out to feather-edges on the sides, and containing only two to three per cent. of ash.

Third.—The coal on the margins of a basin rising sometimes times thirty or forty feet above its place on the bottom.

Fourth.—A roof composed of argillaceous shale, of which the lower layers, a few inches in thickness, are crowded with the impression of plants, among which are interlocked prostrate trunks of *Lepidodendra* and *Sigillariæ*, traceable from root to summit, often carrying foliage and fruit, the fronds of ferns—sometimes ten or fifteen feet in length, complete and smoothly spread—*Calamites*, *Cordaites*, etc.

Fifth.—In many places the roof marked with circles one to two feet in diameter, called by the miners *pot bottoms*. These are sections of the bases of the upright trunks of *Sigillaria* or *Lepidodendron*, which rise *perpendicularly*, sometimes many feet, into the overlying shales. They consist of hollow cylinders of coal, perhaps a half inch in thickness, the interiors of which are filled in with shale laminated horizontally, and some containing remains of plants and animals which must have been introduced when they were hollow stumps standing where they grew.

Sixth.—In certain circumscribed areas part of the coal seam is cannel, bituminous shale, or black band iron ore; and in all cases of this kind the cannel, shale, and black band contain the remains of aquatic animals, crustacea, fishes, or mollusks; the normal or cubical coal never including anything of the kind.

Seventh.—The boundries and bottoms of the channels and basins which hold the coal composed of the Waverly shales, or the Carboniferous conglomerate.

Eighth—The normal or cubical coal laminated by alternate layers of a bright, black, pitchy substance, and those which are dead black, non-caking, and composed largely of mineral charcoal. The cannel and black band containing more earthy matter and not laminated.

From these facts I translate the following history, which I am sure will be accepted as true by every geologist who has had sufficient experience in field work to make his judgment of such phenomena trustworthy.

I. At the beginning of the formation of the Coal measures, Northeastern Ohio was a land surface underlain by the Waverly shales, or beds of gravel, now the Conglomerate. This surface was furrowed by valleys of streams and pitted by local basins similar to those which mark the present surface.

II. With a slow subsidence which continued with interruptions throughout the Coal-measure epoch, the drainage was checked and lakes and marshes were formed in the depressions of the surface. In these basins a fine sediment was deposited—the "fire-clay"—like the clay now found under some of our peat beds. When overgrown with vegetation the roots of plants, penetrating this silt, drew out of it iron, potash, soda, etc., leaving it nearly pure silicate of alumina and specially refractory, whence its use and name.

III. The marshes and lakes were ultimately filled with peat, which rose to a general level, near the water-line, and was sometimes thirty or forty feet deep in the deepest parts of the basins.

IV. In places water basins remained such through a considerable portion of the time occupied in the accumulation of the peat, and sluggish streams flowed through the marshes, connecting these basins, and transporting to them fine mechanical sediment, iron, etc., which mingled with completely macerated vegetable tissue, formed cannel coal, black band iron ore, and bituminous shale. After a time these basins also were filled with peat growing from the margins, just as our lakelets are now filled and converted into peat marshes.

V. After ages had passed with the physical conditions described, a subsidence caused a submergence of the peat marshes, which first resulted in the destruction of the generation of growing plants which covered them. These drooped in succession, leaves, twigs, and branches, and finally most of the tree-trunks also fell. Some,

however, continued longer to maintain an upright position, while the fine argillaceous sediment suspended in the water was slowly deposited to form the roof shale, of which the lower layers are charged with the debris of the plants growing on the marsh, the upper layers, deposited when these were all buried, nearly barren of fossils.

VI. The weight of the superincumbent mass pressed down the bed of peat, which, consolidated by that process and undergoing internal chemical changes, ultimately became a bed of coal, thickest in the deepest part of each basin, thinning and raising on each side up to its edge, which remained to mark the original level of the surface of the peat marsh.

VII. The laminated structure of the normal coal is apparently due to seasonal or secular variations in the conditions under which it was formed; variations likely to occur in a marsh accumulation, hardly possible in a lake deposit. Wet seasons, by producing more surface water and more complete preservation of the soft tissues of the marsh vegetation, would promote the formation of the pitch layers, richer in hydrogen. Dry seasons or cycles may be credited with the formation of the sheets of woody tissue and mineral charcoal, the result of partial oxidation through long exposure to the air.

The homogeneity and more abundant ash of the cannel and black band are the natural consequences of their deposition as carbonaceous mud at the bottom of water which carried some earthy matter of foreign origin.

The presence of the remains of fishes, crustacea, and mollusks in cannel and black band, is sufficient evidence of their aquatic origin; their complete absence from the cubical is an equally good argument in favor of sub-aerial origin.

I have elsewhere discussed the formation of cannel coal, and as the facts there cited have a bearing on the question now raised, I would refer the reader for a full presentation of these facts to the *American Journal of Science*, second series, vol xxiii., 1857, p. 212; and to the *Geological Survey of Ohio*, vol. ii., *Geology*, p. 125.