

CHAPTER II.

ORIGIN OF COAL.

Common coal is one of the three forms in which free carbon exists in Nature. It is well known that the pure, well crystallized variety of carbon is the diamond; the foliated or massive form which is common in crystalline rocks, graphite; and the ordinary dull, brittle variety, along with various impurities, coal.

No one now doubts that coal is made up in large part of vegetable matter which has accumulated chiefly in swamps, though at the present day the organic nature and structure may be entirely obliterated. It would be possible to arrange a series in which the transitions are more or less complete from peat through lignite, bituminous coal, semi-bituminous coal and other grades to anthracite or even graphite.

It is not the object of the present work to give a systematic summary of the different theories that have been advanced from time to time to explain the formation of coal. Suffice it now to call attention briefly to some of the most notable opinions which have been expressed in regard to the formation of coal in general; and to describe in particular the facts bearing upon the genesis of Iowa coals and of the coals of the great interior basin.

Source of the Materials.—Although the various opinions regarding the formation of coal differ somewhat in

details, the views expressed nearly all agree in ascribing a vegetable origin to the deposit. After plants are dead they rapidly decay and go to enrich the soil, when allowed to stand under ordinary atmospheric conditions. If, however, they are covered with water or prevented from having free access to the air they do not lose their structural characters entirely. Under these circumstances a mass of vegetation subjected to an even temperature and an increased pressure is converted into common mineral coal in a comparatively short time. This conversion is often seen in old mines where the timbers have been allowed to remain under conditions similar to those just mentioned. One of the best known instances of this kind is that alluded to by Hirschwald* in the case of the Dorothea mine near Clausthal in the upper Hartz, where the wooden supports in a deserted chamber of the mine had remained untouched for more than four hundred years. During this time the timber had been thoroughly soaked in water and shut off from the air. When brought to light after its long burial, it was found to be changed into true brown coal, having a characteristic glistening fracture:

The evidence in support of the vegetable origin of coal is derived from a variety of sources. In the layers associated with the coal seams, plant remains are of common occurrence. The white underclays and sandstones just below the coal yield abundant roots of the larger tree-like forms of plants. The overlying layers, whether black shales or soft sandstones, are often crowded with leaves and stems of many species; broad, spreading fronds of delicate ferns; bark and branches of huge lycopods. In the majority of cases the plant remains are spread out between the thin sheets of fissile shale or in the sandstone

* Zeits. d. deutsch. geol. Gesel., Band XXV, 364-366. 1873.

layers, where they are preserved in great perfection. Frequently, however, they are found inside of small concretions of clay ironstone. Sometimes, also, the plants are perfectly preserved by iron pyrite. In the underclay at Ford, in Marion county, as well as elsewhere, the roots of lepidodendrids are found with all the delicate tissues intact. Beneath the pitted bark the woody fibers are plainly visible. Under the microscope all the minute cell structures may be made out as easily as in a living plant. The fibro-vascular bundles are beautifully displayed, while the ducts and scalariform cells with all the minute markings are defined as distinctly as they existed in the original vegetable tissues.

In the coal seams themselves, the vegetable remains are often also well preserved. In nodules of pyrite embedded in the coal, fragments of plants occur in which the microscopical characters of the organisms are as plainly made out as in the cases just mentioned.

Proper preparation of thin slices of all the ordinary coals usually enables the cellular and vascular structures peculiar to plants to be made out with greater or less distinctness when examined under the microscope. The ash left after burning also frequently retains, under favorable conditions, microscopic structures of the different wood cells.

In many coal localities all the stages of bituminization may be made out, from peat or loose plant accumulations to the hard, glistening anthracite. In Iowa the different gradations cannot be traced in all their details, though peat, lignite and various grades of bituminous coal are to be found in the state. The first is abundant in the modern swamp lands of the northern part of the state. Another stage is sometimes exposed in road cuttings where

the old marshes have been covered with drift. Lignite of various sorts is plentiful in the Cretaceous deposits of the Sioux river region. The range of varieties of bituminous coal in the Carboniferous is also very considerable; so that after all, the different stages of bituminization are found to be measurably complete in the state.

The formation of mineral coal artificially is very suggestive of the natural processes which may have been at work in certain phases of the metamorphism of vegetable materials on a large scale in Nature. Under high pressures ordinary peat becomes a compact substance like coal in its properties. Daubrée,* by the subjection of wood to the action of super-heated water, has succeeded in producing a substance indistinguishable from ordinary anthracite. The production of brown coal or lignite in the deserted Clausthal mine has already been mentioned. Seeland† also reports an interesting case in which the timbers supporting a steam hammer had been changed completely into lignite within a period of twenty years. Numerous other cases might be mentioned in this connection.

Conditions of Deposition.—The examination of the stratigraphical relations of the Coal Measures of the continental interior has shown that during the Carboniferous period there was a slow, though often interrupted, depression of the land surface over the entire region. This phenomenon is in accordance with the general law which appears to govern depositions of this kind.

In certain localities a prolonged subsidence of the sea bottom is known to have pushed the ancient shore line many miles inland. The movement was manifestly gradual and to some extent intermittent. The seas being

* *Géologie Expérimentale*, p. 464. Paris, 1879.

† *Verh. Geol. Reichs.*, p. 193. 1883.

shallow the conditions were unusually favorable for the formation of extensive coastal swamps which were capable of supporting dense jungles of aborescent plants, together with ferns and other vascular cryptograms. The salt waters could easily and frequently invade the swamps or the tropical vegetation could spread out into the quiet bays or sheltered lagoons of the adjacent seas. This may be inferred from the fact that mingled with remains of the plants are the hard parts of numerous marine animals, which evidently swarmed in countless myriads in the more open places. The effect produced was probably not very unlike that of one of the modern mangrove swamps of southern Florida.

As the subsidence for a brief period suddenly became more rapid currents were allowed to enter bringing in sediments which quickly buried the accumulated masses of vegetation. Other swamps constantly formed landward and the same cycle of changes was repeated.

In other places along the coast, but removed from the immediate influence of the sea, there were doubtless other swamps of a nature somewhat different from that just mentioned. They more nearly resembled the present peat-bogs, that are common in northern Iowa, as well as in Minnesota and other parts of the upper Mississippi valley.

This then is briefly what appears to be the geological history of the coal formations of the continental interior; and there is but little doubt that the basins were formed almost entirely in swampy regions. In this respect they are very similar to the majority of the coal districts of the world. The relations of the coal seams to the rocks lying above and below, the character of the under-clays and the superimposed black shales, the nature of the floras embedded in the strata and the faunal features of

the associated layers, all afford conclusive and independent lines of evidence pointing to the same conclusion.

If it were possible to reconstruct now the state of things that existed at the time the Carboniferous beds were forming over the area of the present upper Mississippi basin there would appear first a long, low shore bordering broad shallow bays, more or less completely sheltered from the direct and destructive influences of the sea. Over the wide marginal lowland, stretching sometimes for many miles, sometimes only for a few hundred yards, would be marshes and peat-bogs, separated from one another by short intervals of dry, elevated land or by low hills rising one after another for long distances. Thus for many hundreds of miles along the shore-line would appear innumerable swamps and marshes, of all sizes and shapes and in all stages of formation, from those just beginning an existence to those about to be silted up or buried. Numberless marsh areas, large and small, some having no connection whatever with one another and often widely separated, others barely coming in contact during their last stages, would exist contemporaneously.

The conditions just described are those which might readily exist on the sheltered coast of any low-land plain. It depends, however, entirely upon the crustal movements, upon a change of level of the land surface of the region, whether or not the accumulated vegetation is favorably situated so as eventually to form carbonaceous deposits to be preserved through the ages.

It is a well known fact that when vegetable matter is allowed to decompose freely in the atmosphere the chemical changes are very different from those taking place where the same material is kept partially or entirely shut off from ordinary air. In the first case the plant remains

usually lose their identity completely, a little inorganic matter only is left behind and is soon blown about by the winds, mingled with the soil, or in rare instances, perhaps, collects in small quantities, locally forming a powdery substance like mineral charcoal. The process is the simple one of oxydation. In the second instance some of the plant fragments can nearly always be recognized, and the entire mass goes through a process of bituminization. Shut off from direct contact with the atmospheric oxygen the elements react chemically among themselves.

In Nature both kinds of changes take place on a large as well as on a small scale. They affect alike the great swamp accumulations and the delicate fern of the darkling glade. The marsh owes its preservation or destruction to the same titanic forces which raise the mountains; the frond withers on its leafy bed in the forest, or falls into a quiet pool to rest.

Oscillations of the shore-line, even though slight one way or the other, may be, then, of the greatest import to the future history of the coastal swamp lands. So long as the level of the neighboring country remains the same with respect to the sea-level and the shore-line practically stationary, the marsh growths may continue to flourish indefinitely. When, however, the land rises, or the shore-line moves seaward from its old position, the swamp begins to be drained, finally becomes dried, and the accumulated masses of vegetation brought under the influences of the open air. In a comparatively short time all traces of the once extensive marsh are lost completely. On the other hand, if the sea invades the land, the great body of decomposed and partially decayed plant remains is soon covered by sediments which, after a brief interval

of time, greatly retard further dissolution of the organic matter, and finally the process of decay practically ceases.

In general, then, it may be concluded that with the same vegetable accumulations along a sheltered shore a rising of the land does not afford the proper conditions for preserving intact the plant mass; [while a constant sinking of the surface previously above water is conducive to the permanent preservation of a great part at least of the organic deposit. These influences are in perfect harmony with the facts deduced from observations made on the old Carboniferous swamp lands of Iowa.

Under circumstances which are favorable to the preservation of vegetable tissues, there is a constant addition of sediments above, increasing the superincumbent weight until it frequently becomes something enormous. The temperature of the mass at the same time gradually rises. The heat and pressure, aided at times by other agencies perhaps, may continue to be operative for long periods; the vegetable mass in the meanwhile going successively through all the stages of bituminization to the hardest anthracite or even to graphite. In the process, through the loss of water and various gases, and through certain chemical reactions of the various component elements or compounds among themselves, the bulk of the vegetable mass is very greatly reduced, the amount of reduction of course depending upon the nature of the swamp materials, the degree of bituminization, and method by which the loss of carbon is effected. According to the estimates of Maclaren in one of the Scottish coal-fields it would take nearly 2,000 acres of forest to produce an acre of coal three feet in thickness. In case of the average Iowa coal bed it has probably taken upwards of thirty feet of closely compacted material of the original woody growth to

produce a seam of coal having the thickness of four and one-half feet — the mean measurement of the veins mined in the state. Ordinary anthracite probably shrinks to less than one-tenth of its original bulk in the course of its formation; so that a bed twenty-five feet thick may represent between two hundred and fifty and three hundred feet of the original mass.

In the diminution of bulk in a great lenticular deposit of vegetation the change in dimensions is chiefly in a vertical direction. Providing the surface of the marsh was originally nearly horizontal, as is probably usually the case, the margins would remain stationary while the cen-

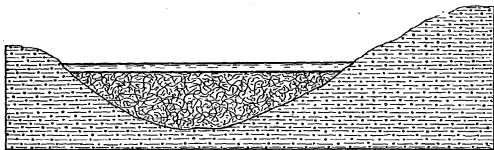


Figure 1. Section of Peat Swamp in Northern Iowa.

ter of the mass where the contraction is naturally greatest would be depressed below the level of the borders, producing, when fully compressed, a shallow saucer-shaped sheet of coal. This fact is also well exhibited in the coal deposits of Iowa, especially in the case of the smaller basins. The six-foot coal vein displayed at the top of the Redrock sandstone quarry in Marion county is a good example.

The original conditions of deposition of the Iowa coal beds appear in many respects to be not very unlike those observed at present in the peat swamps of the northern part of the state, the most noticeable difference being, perhaps,

that in Carboniferous times the marshes were largely maritime. The peat bogs of northern Iowa, or "lakes," as they are often called, occupy shallow saucer-shaped depressions in the drift. A cross-section is represented in figure 1. In size the "lakes" may vary from a few hundred yards to a dozen or more miles in extent. The bottoms of the marshes are commonly covered by matted masses of vegetation in a more or less advanced state of decomposition. The waters are always shallow, for the greater part only a few feet in depth. Most of the "lakes" seem to be gradually filling up their basins with dead vegetation, each year's growth falling into the water, then, only partially decaying, contributes some increment to the accumulating mass which for centuries has been slowly augmenting season after season. The process differs considerably from that of the silting up of an open lake in that the depth of the water appears to remain the same each year, each accumulation of plant remains on the bottom merely allowing, to all appearances, the level of the water to annually rise a little in the swamp. The extent to which the vegetable matter is accumulated in the peat swamps is shown in a number of places where railway lines have attempted to cross the marshes. In the effort to secure a firm road bed piles have been driven down fifty to one hundred feet, without obtaining sufficient support. The same is true in many Minnesota localities. In several instances piling was driven down nearly two hundred feet without reaching bottom, and finally large quantities of brush and trees were cut down and placed along the line surveyed through the swamp. Upon this gravel and clay were placed and the grade established as in an ordinary filling. The matted vegetable matter below was everywhere firm enough

to bear the weight of all the trains passing over the road, with no inconvenience to traffic.

As an example of what took place during the period when coal was forming a case may be assumed somewhat similar to that just mentioned. Let there be imagined a swamp one-fourth to one-half a mile in diameter and two hundred feet in depth; let the swamp be filled to within a few feet of the water level with half decayed vegetation; let the region after this stage is reached become one of slow subsidence, and let it be so situated as to allow the introduction into the swamp of currents which sweep in sediments of different kinds; and the conditions of the

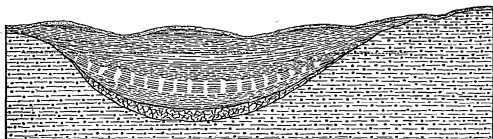


Figure 2. Ideal Section of Peat Swamp after being covered by Sediments and Compressed.

old coal marshes are practically reproduced. If the superincumbent sediments should continue to accumulate and the peat-like mass be compressed to one-tenth or less of the original bulk the process would be almost identical with that which seems to have taken place in connection with many of the coal beds of Iowa. It being possible for the compression and diminution of bulk to take place only in one direction—that is vertical, on account of the weight of the overlying beds—there results a broad sheet of pressed vegetable remains, thickest centrally and becoming gradually attenuated toward the margins. During the process of compression the central part of the

upper surface, which, just prior to the influx of sediments when the swamp had reached its greatest development and expansion, was on a level with the margins, is little by little depressed or bent downward as the plant remains are more and more compacted. (Figure 2.) At the end of the process the upper surface of the vegetable mass at the center of the basin will be from one hundred and seventy-five to one hundred and eighty-five feet below its original level. In the particular case assumed this would be a slope of about one to thirteen in all directions towards the center, or a dip of five degrees nearly. Conceiving this area to be covered to a considerable depth with other beds the phenomenon becomes practically identical with what is now observed everywhere in connection with the coal beds. The areas are numerous throughout the Iowa coal field where the veins of coal have been opened in a hill-side, for instance, showing a considerable dip inward as the entry was driven forward, the coal at the same time rapidly increasing in thickness. After progressing some distance the inclination has become nearly horizontal and soon has changed in the opposite direction. With this change in dip the coal becomes thinner and thinner until mining in that particular seam is no longer profitable. Basins of this kind have been noticed in nearly every county of the Iowa area. At the Redrock quarry, in Marion county, an excellent illustration is to be seen. (Figure 3.)

Associated Beds.—So many references are made to the different layers found in connection with the coal beds that little needs to be said here. Attention may be called to the great similarity of vertical sections of Coal Measure strata taken in various parts of the world; and to the fact that the common sequence of beds observed in

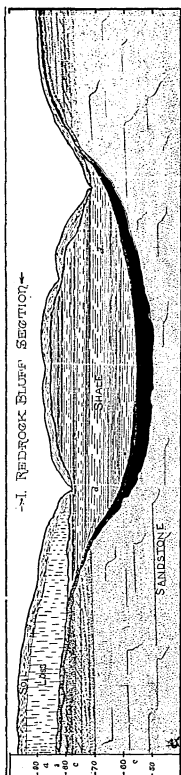


Figure 3. Section of small Coal Basin in Redrock Quarry, Marion County.

different places is indicative of the same gradual succession of physical conditions. Beginning at the bottom of the series there are : (1) fire-clay ; (2) coal ; (3) dark, bituminous clay - shale ; and (4) sandstone or shale. These beds are naturally closely related. The first named, being the soil upon which grew the coal flora, may be, in its formation, entirely independent of the underlying strata, and may even rest upon them unconformably. The third stratum mentioned may be extremely thin, owing to local conditions, but being simply mud deposited directly upon the old vegetable remains it has become more or less impregnated with bituminous matter. The fourth group of layers is dependent entirely upon chance currents of water and really is not closely related to the other beds. The strata may be shales, sandstone, or calcareous deposits, or an alternating succession of these. This sequence may be a few or many feet in thickness before another repetition of the coal series occurs.

