Proceedings of the Iowa Academy of Science

Volume 59 | Annual Issue Article 35

1952

The Origin of Fusain

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Introduction

Fusain has been described by various workers as a black, dull, fibrous, friable charcoal-like material which readily breaks down to dust and exhibits a cellular structure when examined microscopically.

According to White (1926, p. 267) fusain or as it has been known to others; mother of coal, mineral charcoal, carbonized wood, fusit, or faserkohle is composed of all kinds of woody material and occurs in post-Devonian coals and in sediments of all kinds.

Fusain is most frequently found in coals and is a detrimental constituent. According to Stutzer (1940, p. 108) the greater friability of the fusain increases the amount of dust in mines or makes coking and briquetting difficult. Although friable, fusain can resist pressure for long periods of time and survives with its woody structure intact.

Basically there are two schools of thought concerning the origin of fusain; the char theory and origin by chemical methods. The char theory proposes that fires in peat bogs or in the surrounding forests provided the charcoal to the coal swamp before the coalification of the other constituents began. The proponents of the chemical method believe that some kind of decomposition, which as yet is unexplained, achieved the result.

According to Stopes (1924, p. 254) the presence of mineral charcoal in coals has interested observers since 1826 when Karsten after a study of German coals believed that a selective volatilization of oxygen and hydrogen led to the fusinization of some fragments and not of others bringing about the occurrence of mineral charcoal as layers and scattered fragments in the more indurated coal. His work began a long series of investigations of the origin of this material. Daubrée (1846, p. 155) was the first exponent of the char theory. He noted in his study of fibrous coal from Saarbruck that the structure of the mineral charcoal resembled that of coniferous wood and further that the product was very much like commercial charcoal in appearance. He reasoned that since it resembled commercial charcoal and had a different structure and volatile content than coal, it could not be the result of spontaneous decomposition but rather a product of forest fires. He indicated that in a forest fire near Saint Leon in 1844 charcoal was produced.

White and Jeffrey have been the foremost contemporary American authorities on the chemical and char theories of origin respectively.

White (1908, p. 302) first believed that a partial dry rot under subaerial conditions before immersion in the coal swamp produced fusain. However he abandoned this idea in favor of one which postulated little or no decay prior to immersion. Ulmo-humic decomposition products deposited on these fragments during time of low water level impregnate and dry on the surface of the woody material providing a repellant covering inhibiting the action of bacteria during later submergence (White, 1925, p. 21).

White and Thiessen (1913, p. 32) as the result of their study of the coals of Exeter, Illinois concluded that slender rodlike fragments in the charcoal were either resin or putrefaction paste fillings of secretory ducts or vessels. In their opinion neither of these materials could survive the heat of a forest fire. Those favoring the char theory of origin have not been able to satisfactorily explain the presence of resin.

According to Jeffrey (1913, p. 715) hydrolitic action does take place in wood if it is continuously submerged for periods of hundreds and even thousands of years but that this reaction produces lignite and not fusain.

Bode (1928, pp. 487-492) defending the char theory of origin stated that although he has examined many specimens of fusain there was no evidence of the ulmic films which White believed impregnated the woody tissue. Fusain was not produced by coalification but was present in the swamps before the process began. Since fusain is resistant to everything but combustion it could survive coalification while the other material was being converted to coal.

Occurence in The Newcastle Sandstone

Fusain occurs in the Newcastle sandstone of the Black Hills region intimately mixed with the shale, bone coal and sandstone facies of the unit. Occasionally fragments of the magnitude of 15 mm. are found which have no relation to the bedding of the host rock, but the most frequent occurrence is that of particles of 1 mm. and less in size deposited along bedding planes. The amount of the material is so widely divergent that graduations ranging from absence to 10% are found. Characteristically a small amount of the fusain has the ability to impart a dark color to the rock leading the observer to believe that it is present in much greater quantities.

Psysical characteristics

The fusain occurs as black, fibrous fragments, worn and fresh,

with a dull to silky luster. It is brittle and easily split to its constituent fibers. Two types are present: the first with a specific gravity of less than 1 found with fragments of pine tar in sandstones and the second with a specific gravity of more than 1 associated with resin, vitrain and rarely with pine tar in bone coal and bituminous shales.

The resin ranges in color from amber to deep red and volatilizes at from 278 to 320 degrees centigrade and gives off aromatic fumes. After the volatiles have been driven off the residue is the black, shiny, brittle pine tar.

Present Investigation

Since the origin of fusain is in doubt with opinion divided between the proponents of the char theory and those favoring some method of decomposition the observations made during the study of the Newcastle sandstone were examined to see how they coincided with the hypotheses presented in the literature.

The occurrence of fossil resin with fusain was mentioned earlier. One of the most important objections to the char theory is that resin could not survive a forest fire because of the high temperatures reached in burning. The presence of resin according to White and Thiessen (1913, p. 32) indicates another origin. They also maintained that forest fires due to natural causes could not provide sufficient sediment to the depositional area.

With this in mind the writer sampled the creek beds and banks of the drainage system in the area of Crystal Cave, 19 miles northwest of Rapid City, South Dakota, where 6630 acres burned in August 1949. The sediment collected from the creeks contained fusain, quartz grains, uncharred vegetable material and fragments of pine tar. Resin was not found in the sediment.

The question of providing sufficient material for a sediment arises but there is no difficulty in this instance. The burned area had been providing sediment for two years under increased runoff yet the sediment in the creek beds and banks was a maximum of 6 inches thick.

It has been the opinion of those opposing the char theory that the majority of fires during historic time have been caused by man and therefore the incidence of natural fires was too small to leave its impress on the geologic column. It is true that natural fires form a small average percentage of the yearly total but Brown, Chief of the Fire Research Branch of the Forest Service (1951) stated that although the overall percentage for the country is 10% some areas have a higher incidence. For example in 1950 in the Black Hills

40% of the fires are caused by lightning and in Arizona and New Mexico during a bad year there were as many as 600 fires from natural causes in the Coconino Forest alone.

Another important consideration usually overlooked is that present day forests are under constant surveillance and that if fires do occur there are trained men with the necessary equipment to prevent the fire from spreading. In the geologic past the fires once started would burn until all the timber was consumed or until they were extinguished by natural causes.

The key to the solution of the problem of the origin of fusain in the Newcastle sandstone is the presence of fossil resin and pine tar. White has repeatedly stated that resin could not survive a forest fire. The volatilization point of the Newcastle resins ranges from 278 to 320 degrees centigrade yet according to Brown (1951) fire temperature up to 704 degrees centigrade have been recorded by the Forest Service. It is probable that discrete particles of resin would not survive the high temperature reached during forest fires but would volatilize and leave residues of black pine tar. However resin does occur in some parts of the shale and bone coal of the Newcastle sandstone accompanied by worn and fresh fragments of fusain and vitrain and rarely with pine tar.

The additional constituent vitrain may provide a possible solution for the occurrence of the resin with fusain. Resin is a common constituent of coal. Stone (1912, pp. 8-63) in his report on coal in the Black Hills region stated that it contained mineral charcoal and resin and was found in the Lakota formation, predominantly in Wyoming.

If during Newcastle time the coal was present in the Lakota formation and exposed to erosion it could have supplied sediment to the site of deposition and since fusain and resin are common in coal it seems likely that these materials would be carried as sediment along with the clastics derived from other sources.

The question arises concerning the origin of the fusain in the coal. It has been shown that it is doubtful if resin could survive a forest fire but resin is frequently present with fusain in quantities up to 3%. According to White (1913. p. 65) resin resists the coalification process and survives with its characteristics unimpaired. Therefore it is possible that resin survived coalification while the woody tissue from which it was derived was converted to vitrain.

However, pine tar is present with fusain, resin, and vitrain in the bone coal and shales but in very small amounts. Since pine tar is not a coalification product of resin it must have been derived

from resin in the high temperature of a forest fire. The limited amount of pine tar is understandable since the loss of volatiles would cause a corresponding loss of volume. This fact coupled with the loss of fragments in transport from the source area to the site of deposition would further limit the quantity of pine tar found in the sediments.

It is possible that the discrete particles of resin originated as normal constituents of coal while fusain and pine tar resulted from forest fires and were transported to the coal swamp before coalification began.

According to Report 466 of the Forest Service (1950, p. 2) pine tar is derived in the charcoal industry along with charcoal. If resin is in the presence of high heat but not in contact with the flame the volatiles will be driven off and pine tar will result. The writer heated samples of canada balsam and Newcastle resins until volatilization ceased and the result, pine tar, was remarkably similar to the material from the burned area and from the Newcastle sandstone. The color ranged from brownish-black to black, the fragments were brittle and exhibited conchoidal fracture. Although most of the material was opaque, the powdered fragments were isotropic and had indicies of refraction of from 1.56 to 1.61. Some of the fragments of fusain from the Newcastle sandstone and from the burned area still had pine tar coatings on their exteriors.

Twenhofel (1950, p. 48) stated:

> It might be thought that the incident of fire would be shown by charcoal, but such would not be likely as the specific gravity of the charcoal permits it to float and thus pass onward as the inorganic sediments are deposited. No proof has yet been presented that there are any parts of the geologic column for which fire is responsible (the burned coal beds of Montana and Wyoming are not considered), yet it can hardly be doubted that there are sedimentary features due to fires in parts of the column.

It appears that special conditions must exist for the entrapment of the charcoal for unless it was incorporated in the sediment soon after it arrived in an area of deposition, it would be carried away by currents and dispersed, the individual particles being deposited as soon as they became water-logged. In order to get well-defined deposits of fusain such as are found in the Newcastle sandstone, the writer believes that action such as takes place along a beach or bar swept by waves and currents could provide the necessary conditions for entrapment and in the writer's opinion the Newcastle sandstone represents such a body. As soon as the streams draining the area contributed their sediments to the sea the charcoal would be carried by the long shore currents along the seaward face of the bar where

the waves would carry it up on the bar and when covered by sediments, out of reach of further wave action. In this manner fusain would be deposited along the bedding planes.

Conclusion

Since charcoal and pine tar are derived by high temperatures it is highly probable that when this assemblage is encountered in rocks forest fires were responsible. Therefore it is likely that the large proportion of the fusain found in the Newcastle sandstone has a char origin. However the fusain associated with the resin may be the product of decomposition but the presence of pine tar makes this doubtful.

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