ART. XIX.—*Origin of Formkohle;* by JOHN J. STEVENSON.

A PECULIAR type of brown coal, called Form-, Fein-, Klar- or Rieselkohle, occurs in parts of Sachsen, Brandenburg, as well as in the Cologne region, and similar coal is found in Texas. It is an incoherent brown coal, apparently without cementing material; it may constitute the whole of a bed at one locality, while elsewhere in the same bed only Knabben- or Knorpelkohle, lump coal, is found; or it may be confined to a single bench, even to a portion of a bench. Usually it is converted into briquets for fuel, but in Sachsen it is associated with pyropissite, which is utilized in the paraffin industry. This type of brown coal has acquired new interest to geologists because of recent discussions respecting its origin and mode of accumulation. Potonié* has asserted that it is secondarily-allochthonous in origin, signifying by that term that it must be regarded as an autochthonous coal, removed from its original place of accumulation and redeposited. The transporting agent was running water and the process of redeposition was affected by selective influence of gravity.

Potonié remarks that autochthonous and primarily-allochthonous coals are hard and homogeneous; if they have numerous cracks, they be Rieselkohle, but in that case the fragments fit together as in a mosaic and the clefts are commonly filled with inorganic material, such as calcite. The coal had been Knabbenkohle; he had seen such coal in the Oligocene of Sachsen. The condition is wholly different in coal of secondarily-allochthonous origin, as is seen in the Emma mine, near Streckau in Sachsen. There the individual pieces are less closely united and the larger ones are embedded in fine material, so that, when struck by a pick, the mass falls into a dustlike or crumblike heap. Pebbles of coal are rare in such deposits, because the brittle coal would break into angular fragments during transport. This is proved by the constant occurrence of crumb or dust coal. The farther the coal was transported, by so much finer would be the particles; thus one finds at times, as at the Voss stripping near Deuben, very fine coal throughout, evidently dustlike when deposited. In this connection, Potonié remarks that this specific structure would disappear with increasing age of the coal, as advancing self-decomposition would induce homogeneity.

To determine whether or not a coal is secondarily-allochthonous in origin, one must have an unweathered pile for study, since weathered autochthonous is very similar to the other.

*H. Potonié, "Die Entstehung der Steinkohle," 5te Aufl. 1910, pp. 137–142, 205–211.

Drifted fuel materials necessarily take up mineral substances, which accompany them in the water, and this inorganic matter may be in excess. He has instances from the lower Rhine region, where clay beds intervene in secondarily-allochthonous coal and contain scattered fragments of coal. Similar scattered bits of coal occur in rocks between beds of brown coal in southern Sachsen and in Anhalt, as well as in the underclay at the Emma mine.

Drying-cracks indicate secondarily-allochthonous origin, since autochthonous coals must be compared with moors, which develop under constant cover of water. If a dry period come to these, the humus masses sink together in consequence of their water content, so that extreme drying would be needed to produce the shrinkage cracks. It is very different with unstratified humus, transported by high water and therefore easily carried to areas with only a slight cover of water. So, he knows of drying-cracks, up to this time, only in secondarily-allochthonous coals. It must be recognized also that certain features, which elsewhere indicate autochthonous origin, may occur also in secondarily-allochthonous coals. In study of a particular area, one must not forget that a deposit of transported material, organic or inorganic, can produce in times of quiet an autochthonous vegetation—trees, reed-banks and the rest—and that this in turn may be covered by an allochthonous fuel-material. In illustration, be cites conditions observed by Zimmermann, who stated that in the Culm near Landeshut, between the many meters thick layers of cemented gravel and conglomerate (allochthonous) there occur thinly-layered clay beds (allochthonous) with *Stigmaria* spreading in all directions, therefore the foundation of a coal bed and autochthonous. Zimmermann saw this condition repeated thrice in a single quarry—but the coal beds there are few and thin. Potonié adds that this is a familiar occurrence in all productive coal areas. Erect trees and reed-beds are not always evidence that the coal is autochthonous. The belief that the secondarily-allochthonous coal of Cöln must be autochthonous, because trees grow on it, is absurd. Logically, on the same basis, the North German sands must be autochthonous because firs grow on them. He is inclined to regard bursting bogs as a by no means unimportant agent is causing distribution of the organic material. The great Sumatran bog, described by Koorders, is pulp-like; it could be torn away by high water and redistributed.

The manner in which pyropissite occurs affords additional evidence to Potonié. He uses this term to designate the clean material, composed essentially of resinous and waxy substances; pyropissite-brown coal is a mixture with fuel coal and

often has marked resemblance to pyropissite; no sharp line of separation exists. Schwelkohle is the technical term for pyropissite-brown coal, which is utilized now in manufacture of oils and paraffin, since the purer material is almost exhausted. Potonié cites v. Fritsch, who regarded coals as allochthonous, to the effect that the flora, providing substance for the brown coals, was very rich in resins; and he looks upon pyropissite as consisting essentially of resinous matter. "Necessarily, the light resin would float and would be set off in special layers, while the somewhat heavier vegetable coal, brown coal proper, was forming its layers." He gives the gravity of brown coal as 1·2 to 1·4, and that of pyropissite as 0·9 or, when pure, even less.

The features observed near Halle in Sachsen agree, in Potonié's opinion, wholly with his conception of origin. Some of the coal is clearly autochthonous, but in chief part it is secondarily-allochthonous. Between Weissenfels and Altenburg, autochthonous coal is mostly in the southeastern part of the area and the other type is in the northwestern part, where pyropissite especially abounds—a fact, which suggests that the transportation was from southeast to northwest; but he feels that closer investigation must be made before the areas can be delimited definitively. It is certain that many mines have autochthonous coal in the Liegende and allochthonous in the Hangende; also that, at times, both kinds appear together, as in the deep works at Preussengrube, which shows that the transporting stream, as in the district west from Cöln, had afterwards filled with coal its channel way through the coal bed.

The autochthonous coal of the region is characterized macroscopically by numerous irregularly mingled larger and smaller pieces of resin (retinite) or by well-distributed pulverized resin. This contradicts the opinion that all the coals of this region have undergone a separation of the humic and resinous constituents, while it makes clear that the brown coals are from a flora rich in resins. These autochthonous coals were attacked, in part, by the waters; in going northwestwardly through the region, one finds more and more abundant that type of brown coal which shows by the finely broken material that it has been transported. During that transport, there occurred through gravity a separation of the constituents; pyropissite increases toward the northwest, where also Rieselkohle and pyropissite-brown coal prevail.

More or less of pyropissite, in layers or smuts, can occur in autochthonous coal; on drier portions decay would take place and there would be corresponding enrichment in resinous materials, just as one recognizes a corresponding similar enrich-

ment in recent peats. When the upper part of an already hard bed of brown coal is so exposed to the atmosphere that a greater decomposition becomes possible and the coal becomes a Schmierkohle, an enrichment of the same kind must occur. But in so far as Potonié has investigated the conditions, evidence favors the belief, that separation of the substances by running water under influence of gravity explains the difference in structure and composition.

Potonié's conclusions were opposed by Raefler,* who based his arguments upon a close study of more than one hundred mines and strippings within that part of Sachsen whence Potonié had drawn his illustrations. He recognizes that when one considers the characteristics of Potonié's typical autochthonous coal and contrasts them with those of that author's secondarily-allochthonous, the temptation to seek different modes of origin is very great; but he maintains that one must not neglect consideration of certain agents which are efficient in causing changes in structure.

The character, constitution and thickness of materials covering the coal are very important. There is one workable coal bed in the district under review, with extreme thickness of 15 to 20 meters and accompanied locally by one or more beds higher in the section. The whole region is covered with Diluvium, which rests now on Lower Oligocene sands and clays, but again directly on the coal. Under clay cover, the coal is Knorpel, i. e., lump coal; under sand, it is Klar or incoherent coal. He gives many instances showing the conditions as shown in a single stripping. The manner in which the roof material originated is important. A thick cover of ice had serious effect on coal separated from it by only a thin layer of Oligocene. Pressure, thrust and the water from melting ice combined to bring about change. The proof is beyond dispute in all mines where the coal directly underlies Diluvium, for there the coal is very different from that in those where Tertiary beds form the roof. Even in the Emma stripping, on which the doctrine of origin was based, coal covered by Tertiary rocks is Knorpel, but under other cover it is not. Following from south to north the gradual disappearance of Tertiary cover in that great open work, one sees the equally gradual passage from lump coal to, in the area of diluvial contact, a typical Rieselkohle. The same condition appears in other mines described by Raefler, whose notes are in such detail as to leave no room for doubt. Even thickness of cover seems to have far reaching influence, for in the old stripping near Fichtenhainichen as well as in

* F. Raefler, "Die Enstehung der Braunkohlenlager zwischen Altenburg und Weissenfels," Jena, 1911, pp. 9, 17-30, 50-70.

several others, the passage from one type of coal to the other coincides with decreasing thickness of cover. Raefler maintains that the relation between character and mass of cover, on one side, and the character of the coal, on the other, is so intimate, that study of maps recently published by the Prussian Landesanstalt should enable one to determine beforehand the kind of coal likely to be found at any given locality. He finds no evidence to support the suggestion that the Formkohle of Sachsen is other than autochthonous.

Raefler recognizes that the geographical distribution of liptobiolithic* materials is an important element in the discussion. As the records of only three concerns making Montanwachs were available, he gathered material for direct study from 110 localities, representing all parts of the region. The liptobiolith content was ascertained in part by extraction of the bitumens and in part by determination of the tar-yield. He does not regard distillation as the proper method of determining the quantity of "bitumen," though that was chosen by Potonié and other students. Tar and "bitumen" are not equivalent terms; filter paper yields tar by dry distillation, but it is not a bituminous substance. He prefers Graefe's definition, that "bitumen" is the material extracted by an organic solvent, such as benzol.

One must agree with Raefler in accepting this definition, for it distinguishes sharply between substances actually existing in the coal and those produced by decomposition during destructive distillation. The necessity for this distinction was emphasized long ago by Mulder and by Angus Smith in their study of peats.† Balfour, many years ago, showed that the products of distillation depend very largely upon varying conditions during the process; and the matter has been made abundantly clear in recent years by the studies of Porter and Ovitz,‡ who analyzed gases obtained at different temperatures. Their experiments confirm the conclusions reached by Emerson McMillin and Henry L. Doherty, who have tested all types of coal in their great gas plants in many cities of the United States. They assert that reported results of investigation are not comparable, unless all conditions under which the work was conducted are known. Raefler states that coal, from which the "bitumen" has been removed by benzol, yields

* A term introduced by Potonié to designate "Harz-, Wachsharz- and Wachs-bildungen, die bei ihrer schwerer Zersetlichkeit nach der Verwesung von Pflanzenteilen, die diese Produkte enthalten, zuruckbleiben." ("Entstehung," p. 3.)

† See "Interrelations of the Fossil Fuels, I," Proc. Amer. Phil. Soc., vol. lv, 1916, pp. 103, 104.

‡ H. C. Porter and F. K. Ovitz, "The Volatile Matter of Coal," Bureau of Mines, Bull. I, p. 26.

much tar and even some paraffin. He remarks also that one cannot represent graphically the distribution of bitumens, because the coal of any bed varies in content of tar and "bitumens," both horizontally and vertically; and the composition of those products varies in like manner.

Potonié believed that, in the Zeitz-Weissenfels area, the tar and bitumen content increases from southeast to northwest; but a study of Raefler's map shows that the increase is equally notable from east to west in the basin north from Zeitz (23 miles southwest from Leipzig). At Teuchern, about 10 miles northwest from Zeitz, the coal is very rich, but within 4 miles toward the east, the yield is so small as to be unprofitable. The most important area is a series of small isolated basins, within a space of little more than a square mile, lying west from the Rippach river and north from Teuchern. Here are the well-known properties of Gesterwitz, Granschütz and Teuchern. These patches occupy independent basins, of Pre-Tertiary origin, and their coal is wholly different from that east from the Rippach. Bitumen content of 25 to 30 per cent is by no means rare. In these basins the coal is richest toward the borders, where it contains so great proportion of pyropissite that the monthly yield at the works was from 7·3 to 9·5 kilogrammes of tar per hectoliter.

Aside from deposits on the borders, pyropissite occurs in great isolated nests, mostly in the upper part of the bed; usually, however, Feuer- and Schwelkohle are found in alternating layers. At most localities, the best Schwelkohle is in the lower part of the bed and it is often wanting at the top. Coal from two properties, one near Gaumnitz south from Teuchern, and the other from Webau north from that village, gave the following results of bitumen analysis in successive layers from the bottom upward:

Webau	21·0	27·2	18·1	9·1	21·3	3·5
Gaumnitz.....	19·3	21·4	25·6	6·6	17·9	5·9

the calculation being based on pure coal. The bed is from 15 to 20 meters, extreme thickness. Raefler regards the distribution of liptobioliths, the undisturbed and regular appearance of the pyropissite-brown coal, the stratigraphical relations of the independent basins of the western border as all-important in any discussion respecting accumulation of this material and as wholly antagonistic to the conception of secondarily-allochthonous origin. As the petty basins at the northwest are of Pre-Tertiary age and in all probability always isolated, their pyropissite cannot be regarded as the collected resin of coals at the east. He makes the positive assertion, based on analyses, that Klarkohle, the transported coal of Potonié, is not richer

in tar and bitumen than the adjoining coal, which is recognized by that author as autochthonous. He finds that the alleged separation of original materials according to specific gravity has not taken place, the specifically lighter coal being for the most part in the lower part of the coal deposit. In districts with Klarkohle, bitumen-rich and bitumen-poor coal alternate just as they do in districts containing knorpelig coal. Even in the Emma mine, the pyropissite layers are regular. Still more important is the fact that on the southeastern side of the region, on the outcrop of the beds in that direction, as well as in independent basins, analogous to those of the northwestern side, one finds a bitumen-rich coal with nests of pyropissite.

Raefler believes that wax-producing plants gave the pyropissite material; by decay of cellulosic and other constituents, there would be enrichment of waxy matter, but unless the wax were already present no pyropissite or Schwelkohle could be formed. The careful chemical studies by Graefe* are important in this connection. The prevalent opinion has been that pyropissite is probably a fossil resin; but in consequence of the contrast between that substance and retinite, Graefe cannot regard resin as the source of bitumen. After consideration of the gravity, fusion point, optical conduct, the characteristics of the tar-output and of the acids, he concludes that wax-like secretions were in chief part the original material of pyropissite.

Potonié's hypothesis is an assertion that by structure and composition Rieselkohle—Form- or Klarkohle—is proved to be autochthonous material transported by running water and redeposited, measurably under selective influence of gravity.

Running water, aided by gravity, does exercise selective influence upon transported materials. The process is continuous along streams, and it is so characteristic that one finds no difficulty in recognizing stream-action, even the courses of streams in the older rocks. Particles of coal are like other débris. The writer, in following streams within areas of coal mining, has often seen patches of mud and sand with much fine coal, which had accumulated in the curves. Students of coal-bearing rocks, in every period, have observed fragments of coal in sandstones, clays, even in limestones. But such occurrences have no significance in this connection, for here one has to consider great deposits of commercially clean coal, not patches of sand or clay containing more or less of distinctly transported coal.

The accumulation of Knorpel- and Formkohle was contemporaneous, in the strictest sense of that term, at many places in Sachsen. Both types, at times, are continuous in a bed or bench, passage from one to the other being so gradual that

* E. Graefe, "Bitumen und Retinit," Braunkohle, vol. vi, p. 226.

the continuity is as positive as that in a vari-colored sheet of paper. The coal throughout shows little more than ordinary differences in composition, except that the moisture of Formkohle is apt to be greater owing to the greater porosity; the only positive distinction is in degree of coherence. The profiles by Raefler and the earlier observations by Stohr and Russwurm* confirm these statements.

When one considers the hypothesis of origin by transport, he finds serious difficulties at once. Allusion has been made to relations of the types in a single bench; but a more perplexing condition is the immense mass of the material; Davis† gives a measurement of 328 feet near Cologne; Plettner‡ has shown the great abundance of Formkohle in parts of Brandenburg, while Raefler, Russwurm, Stohr, Laspeyres and others have made certain its prevalence in much of Sachsen and the adjoining region; v. Ammon§ found it the prevailing type in southern Bavaria; and closely allied coal is present in much of the Texas region. The physical character varies; sometimes the mass is a confused intermingling of large and small pieces in a matrix of incoherent, more or less dustlike or crumblike coal; but at others, as at Voss according to Potonié, coarse fragments are absent. Stems of trees, occasionally very large and often very numerous, are found in the Formkohle. The Knorpel- and the Formkohle of a given bed or bench are of the same age throughout, Oligocene or Eocene as the case may be, for the plant remains are the same in both. The important deposits of Sachsen, Brandenburg and the Cologne region are Oligocene and there is no Eocene coal in those areas. The brown coal basins are small and many of them appear to have been wholly independent from their beginning.

The hypothesis of secondarily-allochthonous origin appears to require as a basal postulate that the coal had become hard prior to removal. One is told that the large fragments are all angular, as they ought to be, because rounded pebbles are not to be expected, for coal is brittle. But the cutting and transportation must have been done while the Knorpelkohle was still exposed, for the statement is made that channels in the coal bed were filled with transported coal. This certainly involves the conception that the coal was already hard before it had received a cover of inorganic material, since there is no coal of earlier age in the districts. The question respecting the time

* E. Stohr, "Das Pyropissit Vorkommen in den Braunkohle bei Weissenfels und Zeitz," Neues Jahrb., Jahrg. 1867, pp. 407-409: P. Russwurm, Zeitschr. f. prakt. Geologie, Jahrg. 17, 1909, pp. 93. 94.

† C. A. Davis, U. S. Bureau of Mines, Techn. Paper 55, 1913, pp. 5, 6.

‡ Plettner, Zeitschr. d. d. geol. Gesell., IV Band, 1852, pp. 249-483.

§ L. v. Ammon, "Bayerische Braunkohlen und ihre Verwertung," München, 1911.

required for conversion of peat into hard coal may still be open to debate; but in this case the speed of conversion exceeded that conceived by the most earnest advocate, since the change must have been complete before the bog ceased to grow.

But the author of this hypothesis is not wedded too firmly to a belief that the coal was already hard. On page 142 of his work, one finds two paragraphs which seem to represent an after-thought. It would appear that bursting peat bogs might give material for a layer of coal; the great bog of Kampar river in Sumatra, described by Koorders, is pulpy, so that its material could be removed by high water and be deposited elsewhere. But the difficulties are no less along this path.

The basins, in which Formkohle occurs, are small and many of them seem to have been isolated throughout their existence as coal basins. Their distribution suggests conditions such as exist in some of our northern states, where one finds swamps, large and small, scattered over the several areas. As these basins of Sachsen cannot be brought into relation with any general system of Oligocene drainage, it would seem that one who asserts the doctrine of transport must seek the source of the material as well as an explanation of the phenomena within the area of local drainage—which, in some cases, was much less than 30 or 40 square miles, including the space now occupied by the coal itself. It is possible that enough vegetable matter might accumulate on the low hills surrounding the present coal area; enough to give, for example, the lower or Formkohle division of the bed at Orebkau, described by Russwurm. There would still remain the difficulty of accounting for the uprooting and transferring of the more or less forested bog to the lower forested part of the basin. The extreme toughness of recent peat and its strenuous resistance to eroding agents are among the most familiar facts—and one must emphasize anew that only bog material can be considered in this connection, as there are no Eocene coals in the districts under consideration. To remove the mass of peat there would be required a series of cataclysmic cloudbursts, possessed of more than ordinary discrimination, so as to end their destructive work with removal of the peat and to carry out none of the underlying inorganic matter.

The importance assigned to shrinkage cracks seems to be excessive, for it is not clear that the crevices are actually shrinkage cracks. If the transported material were coal and deposited under even the slight cover of water imagined by the author, drying cracks would be insignificant. If the material were still peat and there were a similar thin cover of water, the probabilities are almost certainties that the peat would become a living bog. In any case, there is no reason

for supposing that pulpy peat, when transferred and kept under a water cover, would undergo changes so different from those which would have occurred on the original site as to give pulverulent coal instead of solid coal. If there were no cover of water, the saturated peat would dry on the surface, would be oxidized and would be blown away. This condition of wasting would be the same if the material were a powdery imperfect brown coal.

There is little evidence of selection by gravity in deposits of Formkohle. Some beds have incoherent coal in the upper bench and lump coal in the lower, while in others the positions are reversed. Raefler has shown that passage from one type to the other is gradual and within a space so small as to render the hypothesis of selection incompetent. Indeed, the relation is so indefinite that miners use the terms arbitrarily, coal from one mine being called Knorpel-, which in adjacent mines would be called Formkohle. The presence of logs in the fine coal is evidence that there was little selection, for those are often large and very numerous.

Pockets, even layers of sand, gravel and clay are not evidence that the mass consists of transported matter. Such pockets and layers occur in peat deposits generally and one can see them on the surface of growing bogs, where their origin is evident, and where no one would dream of utilizing them to prove that the peat is allochthonous.

The distribution of pyropissite and Schwelkohle gives no support to the hypothesis. Pyropissite material is supposed to have been carried farther than that of the brown coal and to have reached the place of deposition at the northwest. Raefler's study, not of a single property but of the whole region, has shown that the concentration is certainly notable in the northwest, but not in such way as required by the hypothesis. The richest localities are several small basins, independent and probably always so, in which the concentration is along the borders, not in the central portion. Pyropissite occurs in nests, streaks and layers within Knorpelkohle (autochthonous) as it does in Formkohle (secondarily-allochthonous). Stohr and Fiebelkorn* have shown that the Schwelkohle is confined to no particular position in the bed. It is certain that the coaly material must have been in advanced stage of conversion so as to make possible separation of pyropissite from other substances borne by the moving water; but whether the material were well advanced or not, one cannot well conceive how the pyropissite could be deposited by a current, slow or swift, since its gravity is less than that of water. Deposition could come only through evaporation.

* M. Fiebelkorn, Zeitschr. f. pr. Geol., Jahrg. 1895, pp. 360, 403, 404.

The hypothesis that Formkohle is transported coal or peat appears to be a generalization based on conditions in portions of a few mines. It is supported merely by a priori reasoning dependent on postulates, which themselves are hypothetical. No evidence is presented to show that the supposed process of removal and redeposition is probable, though such evidence is necessary; since this supposed process is not only unlike anything known in the present era but also is contradicted by all that is known. The author appears to have been so convinced by his logic as to suppose that nothing was essential beyond mere assertion in order to secure immediate acceptance. But one should be grateful for the delicate reminder that sand is not necessarily autochthonous when it happens to be covered by a forest of firs.

There are features in Formkohle that are perplexing and no one explanation, thus far, seems to be sufficient. But it is certain that some are explicable by the well-known process of weathering, which is protean in manifestations. Potonié well says that for determination one must have a pile of freshly mined coal, since exposure to the weather changes lump to fine coal. Weathering may be induced by change in character or thickness of cover as well as by disturbance, which by crushing increases the porosity and aids access of surface water. The Emma mine in the Zeitz district is that on which the transport hypothesis had its birth; but even there the influence of changing cover and of increasing disturbance is distinct. Where the cover is only slightly pervious clay, the coal is lump; but pulverulent coal appears in greater and greater proportion with change of roof to pervious diluvium and with increasing disturbance. The relations are exposed fully in that extensive stripping. Stohr's section is equally to the point. The upper bench is lump coal and has a roof of clay to sandstone; it is best under the clay. The lower bench, separated by a parting, is fine coal. Its cover is very thin and represents a period during which the underlying coal or peat was exposed to the action of leaching waters. Heusler,* in describing the Cologne area, says that the coal often has a diluvial cover, through which pluvial waters gain access and pass even to the bottom of the mass, affecting the quality. In that region, the top portion of the deposit has been converted into Schmierkohle, a soft, greasy substance, which is said to yield a greater proportion of distillation products than is obtained from the underlying coal. Potonié has suggested that this Schmierkohle is allied to Schwelkohle; but it is unquestionably due to weathering and the ash as well as moisture content decreases

* C. Heusler, "Beschreibung des Bergreviers Brühl-Unkel und des Niederrheinischen Braunkohlen-beckens," Bonn, 1897, pp. 149, 163.

below it. Potonié recognizes the efficiency of weathering upon peat and explains by it the nests and streaks of pyropissite in lump coal, though he does not apply the same explanation to the similar nests and streaks in Formkohle.

The cementing substance of brown coal, related to the dopplerite of peat, can be removed by solution, as Pishel* has shown. In describing the conditions on an Indian reservation in North Dakota, he says that much "hydrocarbon" can be removed during the lignite stage and that a great quantity is carried out from lignite beds by springs. The larger springs are but slightly discolored but those of less size are decidedly dark. The substance is dissolved, it is not in suspension, for water in pools becomes darker on evaporation and leaves no precipitate until wholly removed, when some dry scales remain. The water of this region contains some alkaline matter. Wilder† states that sometimes the upper part of a lignite bed is "slacked" and does not improve away from the outcrop. The condition is such as would result from exposure of the upper portion while the lower portion was protected. At times the whole bed has been reduced to "slack" or pulverulent coal. The change in structure, judging from Wilder's descriptions, may have begun before the deposit was covered.

While in some districts weathering appears to have been the cause of change, still there are others in which there is no proof that it was the sole or even the dominant cause. But whatever the cause may have been, the hypothesis of origin by transport fails to offer an adequate explanation. As presented, the supporting arguments are contradictory, while the basal postulates are inconsistent with all known existing conditions.

* M. A. Pishel, "Lignite in the Fort Berthold Indian Reservation," U. S. G. S. Bull. 471-C, 1912, pp. 9–11.

† F. A. Wilder, "The Lignite Coals of North Dakota," Econ. Geol. vol. i, 1906, pp. 676, 677.