FLOTATION OF PEATY ALLUVIAL SOILS.

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ABSTRACT. Peaty soil "boulders" are common along many small streams of the Driftless Area and contiguous parts of Minnesota and Wisconsin. Most are obviously derived from old, dark, peaty alluvial soil horizons exposed in the stream banks. In several instances these peaty "boulders" have been observed to float, and there is at least one eye witness account of extensive "flotation erosion" of peaty alluvium, in 1866. Recent studies suggest that flotation of peaty alluvial soils may have been much more common in the early years of white settlement. This inference provides a logical explanation for several otherwise puzzling anomalies in the nature of the alluvial deposits. Similar processes may have been important also in the selective removal of organic material from the upland topsoils during the early years of white settlement.

INTRODUCTION.

"BOULDERS" of peaty, alluvial soil material often may be seen strewn along minor streams, or their flood plains, in the valleys of the Driftless Area and contiguous parts of Wisconsin and Minnesota. Scores or hundreds may be present within an area of a few acres after a flood or freshet, and it is not uncommon for the larger ones to exceed three feet in greatest dimension. Usually the larger ones are subangular in shape, but those of progressively smaller size tend to be more rounded, and the small particles, ranging down to sand size, may be nearly spherical. Undoubtedly the common stream processes of sliding, rolling, and saltation are important in their transportation, but in some instances, at least, these peaty "boulders" move by floating. The writer has seen this latter phenomenon three times in different places, on the Kickapoo River in Vernon County and Beaver Creek in Trempealeau County, both in Wisconsin, and on a tributary of the Whitewater River in Winona County, Minnesota.

Frequently large boulders of this type are scattered over smooth, grassy flood-plain surfaces after overflows which had not attained a depth as great as the smallest dimension of the boulders. The edges of the larger boulders commonly show very slight rounding, thus indicating that they had not been subject to much rolling. It seems reasonably certain that flotation has been a major factor in transportation of the boulders

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in such instances. Numerous trials have verified that many of the peaty "boulders" will float if dropped in the stream, although their composition is dominantly inorganic. Presumably the buoyant effect of the included vegetable matter is augmented by air trapped within the porous soil, and the buoyant effect aids in transportation even where flotation does not occur. Some of the soil boulders contain embedded pebbles derived from gravel beds underlying the peaty alluvium. Plate 1, Fig. 2, shows such a boulder, which has been transported at least 50 feet before lodging on a gravel bar with its original bedding upside down. Less commonly the soil boulders may acquire an armor of pebbles during their transport, like the mud balls of southwestern arroyos described by Bell.[1]

Floating of peat deposits, especially in swamps or marshes and around the margins of lakes, is a common phenomenon, widely known and readily explained by the low specific gravity of the organic matter comprising the bulk of the peat. The present paper, however, is intended to call attention to the occurrence of similar processes of flotation where the material involved is usually too low in organic content to be properly classified as peat. A large part of the material that appears to be subject to flotation, in the area covered by these observations, certainly is chiefly inorganic. It is not intended to suggest that flotation of such peaty soils is a major factor among erosional and sedimentary processes, but it may deserve consideration among such processes as the natural flotation of sand, as discussed by McKelvey.[2] Recent studies suggest that flotation of these peaty soils may have been more extensive in the past than at present, and that the qualitative effects may be worthy of consideration in several fields of scientific investigation.

RECENT HISTORY OF SOURCE BEDS.

The source of the peaty "boulders" usually can be identified as a dark soil horizon exposed in the stream banks. Under present conditions the peaty soil material usually enters the stream as a result of lateral bank erosion, and flotation occurs

[1] Bell, H. S.: 1940, Armored Mud Balls, Their Origin, Properties, and Role in Sedimentation. Jour. Geol. 48: 1-31.

[2] McKelvey, V. E.: 1941, The Flotation of Sand in Nature. Amer. Jour. Sci. 239: 594-607.

only during the transportation phase. The peaty alluvium is an old topsoil, dark gray when dry or black when moist, of high organic content, but essentially a muck deposit or prairie soil rather than peat. The organic content ranges down to less than five per cent, in the beds which are transitional to ordinary inorganic alluvium, and probably ranges upward to at least 80 per cent. True beds of fibrous peat also are fairly common. At most places the "old soil" horizon is now covered by a deposit of brownish, sandy silt, usually a few feet thick but in some places attaining a thickness of as much as 15 feet. Hundreds of test borings have shown that the same general vertical sequence is present not only where exposed in the immediate stream banks, but also over most of the small valley flood plains.

Extensive studies have led to the conclusion that the overlying brownish deposits are derived from accelerated soil erosion on agricultural lands, and that they have accumulated within less than 100 years, or since white settlement. The evidence supporting this interpretation is much too extensive and too involved to be repeated here in detail, but the main types of evidence are:

(1) Many old residents remember that the bottomland soils were once black where they are now brown, and that the dark, peaty soil horizon now exposed in stream banks and artificial excavations has been covered by flood deposits during the period of their observations;

(2) Occasional presence in the brownish sediment of "modern" artifacts, such as kitchen pans and fence wire, and complete absence of such articles beneath the "old soil" except occasionally where there has obviously been disturbance and artificial burial;

(3) Lateral continuity of the dark horizon with similarly dark surface soils now present on gentle slopes just beyond the margin of the brown deposits, as exposed in many places and verified for many other places by closely spaced test borings; and

(4) Comparisons of recent with old surveys, in several representative areas, show that the surface of the brown deposits is being built up at rates which are in accord with the interpretation that all these brown sediments have accumulated within periods of less than 100 years.

FORMER CONDITIONS CONDUCIVE TO FLOTATION OF ALLUVIAL SOILS.

The interpretation of the dark, peaty soil horizon as having been at the surface at the time of white settlement implies that in the earlier years of agricultural development there would have been much more extensive opportunities than now exist for flotation of such peaty soils from the flood-plain surface. Clearing of native vegetation, and particularly the common practice of cutting the grass of the bottomlands for hay, would tend to cause the alluvial soils to dry out, and hence to become more readily susceptible to flotation during flood inundations. That such processes did occur on a scale of some magnitude is attested by an eye-witness account of an early flood in Beaver Creek valley in Trempealeau County, Wisconsin.

Mr. B. F. Heuston, a pioneer settler of that community, left at his death a manuscript on the history of Trempealeau County, which was printed in part July 4, 1940, in the *Galesville Republican.* This includes an account of a Beaver Creek flood on June 8, 1866, which was noted and brought to the writer's attention by Mr. Howard S. Kunsman. The following extract is of particular interest:

". . . . . Among the remarkable freaks in the way of wash-outs was the lifting of the bogs or turf from their places about and under the small streams. This was most conspicuous along the Goodno Valley and the stream that runs through French's farms. The result was bare channels too deep for a man to see over the banks and as wide as the marshes were, which had furnished hay, between the dry banks of permanent formation. This bog turf or peat appears to have been lighter than the water and to have floated bodily out of its bed. It was lodged along the banks or carried down the current to Beaver Creek, where masses from the latter stream were deposited over the ground which had formed the bottom of the mill-pond and where the black heaps dotted the land until covered by the flow of the later dam."

In the area described by Heuston, a dark, peaty soil horizon occurs beneath several inches to several feet of typical brownish silt. Thus it seems reasonably certain that the conditions described in 1866 help to corroborate both the general interpretation which has been made concerning the age of the deposits, and also the inference that conditions were then conducive to more extensive flotation of such peaty alluvial deposits than is now common. As the flood occurred in June, this evidently was a true case of flotation, on a relatively large scale, of the peaty soil, and not flotation of frozen soil such as has recently been described by Rose from the Susquehanna River Valley in New York.[3] Presumably flotation would have been even more apt to occur at times when the soil was frozen.

The small streams of the Driftless Area are now typically highly turbid, except after prolonged periods of low flow. This turbidity is evidently due to small amounts of very finely divided organic or other coloring matter derived from the prevailingly dark soils. The concentration of inorganic sediment in the streams is generally much less than might be supposed from the turbidity. For example, of 180 samples collected from Beaver Creek between April 1940 and June 1941, taken at irregular intervals but with more frequent sampling during periods of higher flow and greater concentration of sediment, none had an inorganic sediment concentration as great as 3,000 ppm., or 0.3 per cent by weight. Higher concentrations have been known to occur at times on other streams, yet there is considerable data, most of it unpublished, to show that the content of sediment is generally not very high. Thus it appears that material derived from flotation of the peaty alluvial soils may have constituted an appreciable proportion of the total sediment transported during the earlier years, before these original alluvial soils were protected by burial beneath the brownish silt.

It is probable that flotation of peaty alluvial soils, such as has been observed in the Driftless Area, may be more important because of certain qualitative effects, than because of the amount of sediment moved by the process. At least five such effects, which have been suggested by the present studies, are believed to be of sufficient importance to warrant consideration by workers in allied fields.

STRIPPING OF SIGNIFICANT ALLUVIAL HORIZONS.

Heuston's account of the 1866 flood on Beaver Creek, as cited above, first attracted attention as a plausible explanation of occasional irregularities encountered in the sequence of alluvial deposits. The flood plains of Beaver Creek and its branches, in

[3] Rose, C. W.: 1941, Flotation Erosion by Ice. Jour. Geomorph., 5: 142-144.

common with those of many other small streams in various parts of the United States, typically have sediment of dominantly brownish color above the dark, peaty, "old soil" horizon, and sediment of dominantly grayish color below that horizon. Where the "old soil" is absent this color distinction is believed often adequate to distinguish between the two bodies of alluvium.

Any one of several possible explanations could account for the failure of the dark, topsoil horizon to be present in any particular place. Hundreds of auger borings have been made. Some penetrated old stream channels, in which the sediment accumulated prior to the beginning of accelerated soil erosion and sedimentation had not been in place long enough to acquire a dark surface horizon; and others penetrated places where the former dark surface horizon had been scoured away by flood currents. Flotation is another erosional process by which the old dark horizon may have been stripped off in many places.

There has long been controversy concerning the relations between floods and the effects of clearing of forests and cultivation of cropland. It is well established that such cultural factors speed up immediate surface runoff, as well as accelerate soil erosion. The relationship between rates of runoff on the ridges and floods in main valleys is complicated by other factors, however. One such factor is the question of relative discharge capacity of small stream channels in their natural condition, and in their present condition. The streams in the small valleys where peat "boulders" are common are in this class. In some places old residents testify that there has been a great increase in the size of the channels within their memory, but in most places no such direct evidence is available. There are also many places, particularly on alluvial fans at the confluence of tributaries with larger valleys, where it is certain that stream channels are filling. The widespread condition of flood-plain aggradation since white settlement naturally suggests the possibility of similar general stream channel filling, which would tend to retard downstream concentration of flood waters. Field studies, largely geomorphic in character, seem to indicate that this has not been the case, yet in most places the evidence is far from conclusive. The record of flotation of peaty soils in the Beaver Creek area in 1866 offers further clues toward solution of this problem.

Many of the small valleys of the Driftless Area, including Beaver Creek and its tributaries, have reaches of relatively wide flood plain and low stream gradient near the upstream end of the Pleistocene, or Post-Pleistocene, alluvial terraces. These are typically areas of poor drainage, with deep, peaty alluvial soils, and often with true peat bogs. Many of these areas have been drained by artificial ditches, but the larger number have natural channels, often intricately meandering. In such places, where the erosive capacity of the streams is apparently relatively low, the condition of the channels is of critical importance, and interpretation of their age and origin would be a significant advance in knowledge of the erosional and sedimentary history. The localities of the peat flotation in the 1866 flood are in just such parts of the Beaver Creek valley system, where the peaty flood-plain soils are now generally buried by one to three feet of "modern", brownish, silty deposits accumulated since the country has been settled.

The 1866 flood occurred only about a decade after white settlement, and the fact that the flotation erosion was then active suggests it may have been an important factor in producing channel enlargement soon after the valleys were first modified by such cultural activities as cutting of hay, and before most of the present flood-plain cover of "modern" sediment had accumulated. It may also be significant that the peaty horizon was described as being present, in some places at least, *beneath* the smaller channels existing prior to the 1866 flood. Remnants of the original flood-plain soil horizon are now exposed in the stream banks, in these localities, several feet *above* the present stream bed. Thus a moderate amount of channel incision is suggested, in places where there has been uncertainty because the "old soil" is found much closer to the stream bed than is the present flood-plain surface. From present appearance it might have been inferred that the banks had been maintained at about the same height, by aggradation of the bed, but if the original condition was that of a very shallow channel above a bed of peaty alluvium, then there may have been channel deepening, at least partly by flotation erosion, even where the flood plain has been aggraded during the modern period.

FOSSIL POLLEN CONTENT OF ALLUVIAL DEPOSITS.

Distinction between alluvial or lacustrine sediment deposited during the period of culturally accelerated soil erosion, and other sediment accumulated earlier under conditions of natural drainage and vegetation, is commonly a critical factor in the sedimentation research of the Soil Conservation Service. Recently an effort has been made to determine whether fossil pollen in the sediment can be used effectively as a criterion for this distinction. A considerable number of samples from alluvial deposits of the Driftless Area and adjacent valleys have been studied for this purpose by Professor J. E. Potzger and Mr. Carl O. Keller of Butler University. These studies are still in progress, and present tentative conclusions are subject to change, but as a rule the peaty old soil has a much higher pollen content than the modern sediment.

Some of the "modern" sediment was found to have a pollen content such as would be expected only in the older deposits. Restudy of conditions where these samples were collected revealed a considerable proportion of dark aggregates, or pellets, distributed throughout the brown silt. These dark pellets appear to be derived from older, peaty soils exposed along the stream banks for a half mile or so upstream, and they are of various sizes up to at least two inches in diameter. The fact that they are embedded in much finer-grained silt suggests

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Fig. 1. "Boulders" of peaty alluvial soil strewn on the flood plain of Hardies Creek, about seven miles east of Galesville along State Highway 54, Trempealeau County, Wis. The largest is about four feet in maximum dimension.

Fig. 2. A typical peaty alluvial "boulder" about three feet long, lodged on a gravel bar. It has been moved at least 50 feet, but probably not more than 300 feet. The pebbles embedded in the top were originally part of a gravel stratum underlying the peaty horizon. Below and to the left of the center are pieces of wood more than a foot long, preserved in the fine silty matrix. Trout Creek at the mouth of Frisch Valley, Winona County (Cochrane quadrangle), Minn.

Fig. 3. Stream-bank exposure showing peaty alluvium beneath a black "old soil" horizon. The top of the old soil is indicated by the broken line. Above this is three to four feet of "modern" brown discoherent silt and fine sand in thin layers, but with an obvious large admixture of the older, dark gray material in the lower foot. Bank caving and slumping have caused some distortion of the vertical sequence, and several large chunks of the peaty horizon have fallen into the stream in the foreground. This is typical of the way in which the peaty boulders usually originate under present conditions.

Same locality as Fig. 2.

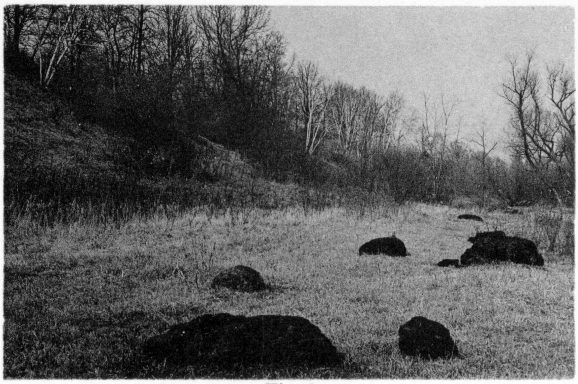

Fig. 1

Fig. 2

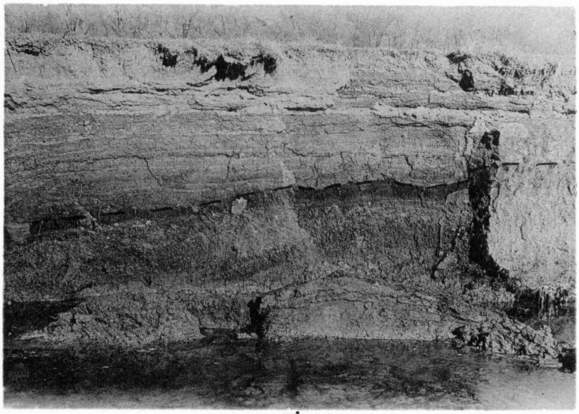

Fig. 3

that these pellets were deposited as a result of flotation. The greatest concentration is near the top of the brownish sediment. In this locality the stream channel is obviously being enlarged by bank erosion, and probably is also being deepened to a moderate extent. Thus floods probably have topped the banks here with decreasing frequency, during accumulation of the brown sediment, and the overbank deposition probably has been from overflows of decreasing depth and velocity. Shallower overflows would contribute less sediment, but would be apt to deposit an increasing proportion of floating material. Thus these local conditions support the suggestion that flotation has been responsible for the distribution of the peaty soil aggregates in the "modern" sediment.

In a number of other places similar dark soil aggregates or pellets are concentrated chiefly toward the base of the brown sediment. This is probably the most common distribution, and presumably is due to the fact that much more of the dark peaty soil was subject to erosion, including flotation, during the earlier years of accumulation of the brown deposits. It is suggested that the relative ease with which peaty soils can be moved by flotation leads to larger admixture of older pollen-bearing material in later deposits than would be expected if only ordinary stream transportation were effective.

FLOTATION OF BEAVER DAM DEPOSITS.

Flotation erosion may also deserve special consideration in the interpretation of the effects of beaver dams on fluvial processes. Ruedemann and Schoonmaker[4] and more recently Ives[5] have called attention to the considerable importance of beaver as geomorphic agents. Undoubtedly beaver dams have been important in the history of sedimentation in many of the small valleys of the Driftless Area. Most of the peaty soils are believed not to be beaver-meadow deposits, however, for they extend far up into steep minor valleys and swales where conditions probably have not been favorable for beaver because of inadequate surface water supply, and traces of beaver dams are not common in the alluvium exposed in stream banks. In

[4] Ruedemann, Rudolf, and Schoonmaker, W. J.: 1938, Beaver-Dams as Geologic Agents. Science 88: 523-525.

[5] Ives, R. L.: 1942, The Beaver-Meadow Complex. Jour. Geomorph. 5: 191-203.

somewhat larger valleys, not those of major streams, beaver dams probably were more important and they must have played a rôle in the alluvial history.

In Colorado mountain valleys, where the thickness of post-glacial alluvial deposits evidently is similar to that in many small valleys of the Driftless Area, Ives estimated the present rate of valley aggradation due to beaver dams as 25 to 80 times the rates indicated by the entire thickness of alluvium. This apparent discrepancy he suggested might be most plausibly explained by assuming that the beaver had not been continuous occupants of these mountain valleys, but had migrated up and down the streams in response to climatic changes. This explanation is plausible, unquestionably, but the process of flotation erosion suggests an alternative possibility. If any considerable part of the beaver-meadow deposits have an organic content as high as that of the peaty alluvial soils of the Driftless Area, they may have been removed by flotation from time to time. Local beaver migrations and drying of the ponds and meadows may have exposed the deposits to this process. Thus the rate of progressive valley aggradation might be reduced. The same reasoning presumably would apply to the interpretation of beaver-pond accumulations in the Driftless Area, or elsewhere.

EROSION OF HUMUS LAYERS FROM UPLAND SOILS.

Under natural conditions the soils of large parts of the United States seem to have been covered and partially protected from surface erosion by accumulations of organic matter. Such layers of forest "duff" may yet be seen in protected areas. That this was a common or general condition throughout large parts of the country has been attested by many old accounts and the recollections of living people. For example, Dr. Paul Bartsch[6] of the United States National Museum states that in 1882, when he went to the White River country of southern Missouri, as a boy, it was almost entirely forested, with white oaks attaining a diameter of four feet, and very little underbrush. He recalls having seen his father thrust a walking stick into the forest litter, or humus layer, to a depth of two feet or more. These conditions were general throughout the forested hills, and were not confined to the valleys or swales. In 1907 when he revisited the country the forest had been entirely

[6] Personal communication.

removed and replaced by scattered scrub oak and other brush. The humus layer had disappeared, and in its place the hillsides were strewn with boulders where none had been visible before. Rock ledges were common on the slopes, protruding through the soil, but the valley bottoms, which probably had received much of the upland humus, were good corn lands.

With the cutting of trees, and the resulting natural drying out of the soil, much of the finer duff and humus may well have become subject to removal by flotation during occasional periods of high-intensity rainfall and consequent strong surface runoff. Flotation would increase the rapidity of erosion of surface soil, and it would be a factor tending to counteract the erosion-resisting effect of the higher humus content of the natural soils during the early years of accelerated erosion. It is not yet practicable to make any estimate of the quantitative importance of flotation in sheet erosion, but it should be recognized in any efforts to apply data from short-term studies on erosion plots to interpretations of natural processes which occur over a longer period.

CONCLUSIONS.

Flotation of aggregates or boulders of peaty alluvial soil is common in valleys of the Driftless Area in Wisconsin and Minnesota. Recent studies suggest it may have been much more important in the earlier years after white settlement. This provides a reasonable explanation for apparent anomalies in the alluvial deposits, and may help clarify other questions in the fields of hydrology, paleobotany and soil erosion. Flotation erosion of alluvial soils thus seems sufficiently important, at least qualitatively, to deserve consideration in future studies of erosion and sedimentation.

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