"PAVEMENT-BOULDERS" AS INTERGLACIAL EVIDENCE.

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ABSTRACT. "Pavement-boulders," either singly or in groups, may indicate major or minor erosional interludes interrupting the progressive accumulation of subglacial till. The interpretation of faceted stones in general is involved and deserves careful consideration. Especially, striae of the pavement-boulder type should be distinguished from striae engraved on a stone during transportation. The common interpretation of true facets as originating largely during transportation is believed to be erroneous. Rarely, a single faceted boulder may afford basis for broad interpretation.

INTRODUCTION.

According to the younger Hugh Miller (1884), Hugh Miller, Sr., widely known for his book "The Old Red Sandstone," originated the term boulder-pavement in 1852 to denote a group of boulders imbedded in till and having glacially faceted and striated upper surfaces lying approximately in a common plane, the striae on the several surfaces being oriented in essentially the same direction. Each stone was called a pavement-boulder. The term boulder at that time apparently denoted a stone of any size, though a boulder-pavement evidently consisted chiefly of cobbles and boulders as now understood. The phenomenon had been known, however, since 1828 when Charles Maclaren ascribed the striae to the action of currents of water. The earliest description of an American locality, near Oxford, Ohio, (Stoddard, 1859) shows that such striae may indicate the direction of glacier movement as accurately as striae on bedrock. Of course the earlier observers had reached the same conclusion, though Stoddard's interpretation seems to have been made independently. In 1898 Gilbert described a well developed boulder-pavement separating tills of slightly different colors in western New York. He concluded that the section recorded a glacial readvance involving some erosion of the earlier till, but he states that the exposed zone of contact contained no evidence regarding the possible duration of the intervening time of recession.

Both Miller and Gilbert believed that boulder-pavements originated by selective erosion of previously deposited till, the finer fragments being removed while the coarser were pressed down into the till matrix. The erosion may have been essentially contemporaneous, as when temporary renewed impetus "... caused the ice to attack its own deposits." (Miller, 1884, p. 173), or, as Gilbert suggests, the erosion may possibly have occurred after the lapse of an interglacial interval. Comparison of the relative concentration of boulders in the pavement and in the subjacent till may afford a general index as to the minimum thickness of till removed, which may exceed the average depth of significant weathering of the supposed earlier till sheet. In that event, however, at least part of the boulders may bear evidence of having been in the weathered zone and may constitute valid evidence of interglacial time

RECOGNITION OF PAVEMENT-BOULDER STRIAE.

Boulder-pavement phenomena may be relatively obvious where the composing boulders are numerous even though the ice may have turned or rotated some of them during the striating process. With fewer boulders interpretation becomes less certain. Many tills contain so few stones of suitable size that true pavements are not likely to occur, although such stones do occur singly and may serve as a guide to further and more positive evidence concerning the conditions of deposition.

Glacially produced facets on stones should be carefully distinguished from flat surfaces originating in other ways and bearing striae in all respects comparable to those on adjacent rounded surfaces. Such striae, originating in transit, are proportionate to the size of the stone and record its frequent and relatively free turning in the ice-and-drift matrix. Plate 1. Fig. 1 illustrates the contrast beween transportational and pavement-boulder striae. The dark limestone cobble, about seven inches in maximum diameter, was collected at Chittenango Falls in Central New York. It was probably rounded by stream wear before it was acquired by the glacier. Fine striae in apparently random orientation were engraved over its surface, the lines conforming easily to the surface irregularities. By contrast, the pavement-boulder striae are coarse and definitely tangential to the rounded surface and are postdepositional. The stone, then firmly imbedded in compact till, formed a part of the floor over which the glacial load moved producing the set of striae shown from upper right to lower left in the photograph. Then a stone in transit impinged upon the cobble in

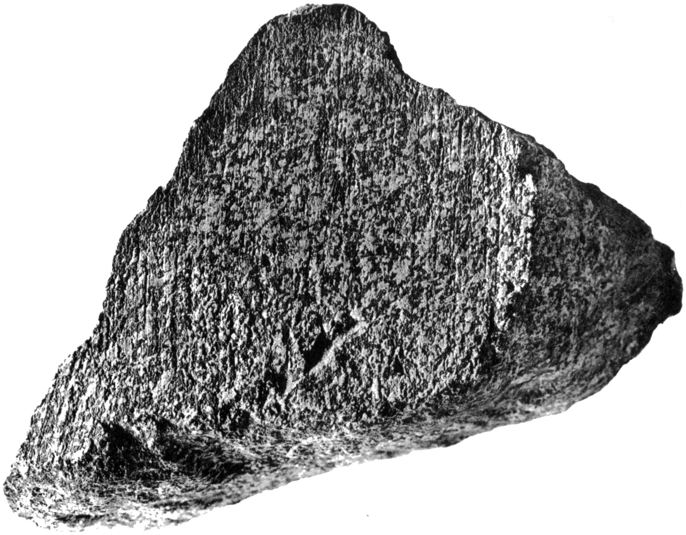

Fig. 2.

Fig. 1.

such a way as to cause slight rotation counterclockwise, and a second set of coarse, tangential striae followed. With further uncovering, the ice tended to divide and to flow around the stoss side, and the large scars from impinging stones testify to the firm grip of the inclosing till although ultimate dislodgement may have occurred. Had the glacial load which moved across the cobble contained only smaller stones and abundant sand, faceting probably would have developed rapidly.

At least one drift-filled interglacial gorge occurs at Chittenengo Falls (Holmes, 1935), but the stone shown in Plate 1, Fig. 1 is believed to represent only Wisconsin glaciation.

PAVEMENT-BOULDER AS INTERGLACIAL-HORIZON MARKER.

Plate 1, Fig. 2 shows a fragment (maximum dimension five inches) from a diorite boulder about two feet in diameter. The specimen was collected at Gillaspie School, four miles northeast of Columbia, Boone County, Missouri, and came into the writer's possession through the courtesy of Prof. Donald L. Blackstone, Jr. The exposure where the boulder was found is slumped, and although it was suspected to include the contact between the Nebraskan and Kansan drifts, the boulder fragment is the only ascertained evidence that both drifts are actually represented there. Nebraskan gumbotil was known a few miles to the northwest and was identified later at a nearby locality at approximately the same elevation. Thus the testimony of the fragment was substantiated, but the fragment itself merits consideration for the completeness of its testimony.

The striated surface shown by the photograph, Plate 1, Fig. 2, is a portion of a glacially cut facet that formed the top of the boulder, the ice having moved from left to right. Relatively unaltered rock comprises the center of the facet as shown, and is bordered on the left and on the near end by a kaolinized zone nearly an inch wide that marks the outer part of the boulder. The upper and lower margins represent two of the many intersecting fractures that divided the boulder into irregular pieces, though along most of the fractures complete separation had not occurred naturally at the time of collection. Oxidation of iron in the mafic minerals had extended through a quarter-inch zone on either side of the joints and is well developed on the fragment.

Interpretation of the beveled stone may be stated as follows: The nearest possible source of the diorite erratic is a few hundred miles to the north. Chemical alteration since the facet was cut has been practically nil, the surface of the unaltered part still retaining the high polish imparted to it by the Kansan glacier. The weathered, fragile condition of the boulder with its inch-thick kaolinized zone intact except at the facet definitely indicates that the weathering took place at the locality where it was discovered, and not at its place of origin. Therefore Nebraskan ice brought the boulder to the locality, where it became much weathered during Aftonian time. The degree of alteration corresponds to that observed on other similar stones slightly below the base of the gumbotil. The Kansan glacier evidently eroded the overlying drift and beveled the top of the weathered boulder. The upper left corner of the fragment as illustrated shows a second set of striae indicating some disturbance of the boulder, though actual removal of the boulder from its place in the Nebraskan till is unlikely. Kansan drift then shielded the stone from further alteration until the present.

GENERAL INTERPRETATION OF FACETS.

The expression "faceted and striated" has been used somewhat loosely in the literature describing glacial deposits. Original flat surfaces on stones from jointing, stratification, or fracture may persist even after considerable glacial wear and are not properly called facets, as the word facet in this connection implies shaping or cutting. However, glacially faceted stones are reasonably common. They are popularly supposed to have been frozen fast in the bottom of the glacier while the latter moved over a rock floor whose hardness was equal to (or greater than) that of the stone being faceted. This may be true of the relatively rigid carapace of a valley glacier, but at least two objections are offered to the general interpretation. First, recent studies (Demorest, 1938, 1942) indicate that the basal ice in glaciers is too plastic to hold a stone thus in a constant position through the necessary distance. Secondly, as in northern Missouri, the drift contains many sharply faceted granites and quartzites in areas where the bedrock is predominantly shale and weak sandstone which would not have produced the facets. Moreover, much of the floor must have consisted largely of till subglacially deposited.

The pavement-boulder concept seems to meet all the requirements of glacial faceting. Unfrozen, clayey till compacted beneath a glacier is believed adequate to hold a stone with sufficient firmness while the passing ice, laden with sandy drift and stones of moderate size, constitutes an ideal abrasive mechanism. The faceted stone may or may not remain permanently imbedded at that place. Hugh Miller (1884, p. 182) evidently had this process in mind when he wrote: "I have frequently seen little bits of shale, not more than 1/10th of an inch deep, of which the upper surface was well rubbed, while the lower surface was almost untouched. *The sole of the boulder*, as Robert Chambers used to term their flatter side, seems generally, in fact, to have travelled uppermost."

CONCLUSION.

Stones having a true facet of appreciable dimensions record a time of glacial erosion which may be equivalent to a major unconformity or to an insignificant hiatus. Rarely a single faceted stone may indicate the former, while a well developed boulder-pavement may afford evidence only of the latter. Numbers are not necessarily significant. A shift in glacier activity from deposition to erosion may well indicate renewed movement following temporary stagnation and may thus relate to minor substages of glaciation. Though the time value of the erosion surface as seen in section may not be readily apparent, the occurrence may be suggestive of further evidence to be sought.

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