POTHOLES AND ASSOCIATED GRAVEL OF DEVILS LAKE STATE PARK

*Robert F. Black**

The hundreds of hikers who annually visit the top of the East Bluff of Devils Lake have a unique opportunity to see a geologic situation that is exceedingly fascinating in its connotations. For almost a century the scientific literature has recorded the existence of potholes and associated rounded, polished, siliceous gravel on the higher part of the bluff at its very rim near the Devil's Doorway and "Shortcut Trail" to the south camp ground (Chamberlin, 1874) (fig. 1). (NE ¼, SE ¼, Sec. 24, T11N, R6E and NW ¼, SW ¼, Sec. 19, T11N, R7E). (The polished siliceous gravel is not to be confused with fresh glacial gravel of many igneous and sedimentary rocks that workers have used on parts of the trail and have brought at different times to the rim to make concrete.) The potholes are carved in bedding plane surfaces of the Baraboo quartzite *in situ* and in loose blocks of the quartzite that rest irregularly on the beveled upland surface. Polished chert-rich gravel is associated with some potholes and has been found in them (Salisbury, 1895, p. 657). More than a dozen well developed potholes are known (fig. 2). They range from single circular polished depressions a few inches in diameter and only 1 or 2 inches deep to aggregates of potholes whose individual components may be as much as 3 feet across and equally deep. Water-polished surfaces up to several square yards may be seen along the rim. Striking potholes 6 to 8 inches in diameter and twice as deep resemble artificially drilled holes as their sides are so parallel and smooth (fig. 3). Potholes above the sod are concentrated in an area 50 yds. along the bluff and 30 yds. northward from the rim and also in a narrow zone (fig. 4) for 75 ft. vertically below the rim along the Shortcut Trail; others are scattered in the woods to the north of the Shortcut Trail (fig. 2). Buried potholes and gravel may be more widespread (Salisbury, 1895, p. 655).

Down through the years most writers have attributed the formation of the potholes and associated gravels that are unlike any in the glacial deposits in the valley below to preglacial streams (Cretaceous to Tertiary) that flowed across a continuous upland surface

* The author is Professor of Geology, University of Wisconsin–Madison. This study was supported in part by National Science Foundation Grant GP–2820 and in part by the Research Committee of the Graduate School from funds supplied by the Wisconsin Alumni Research Foundation.

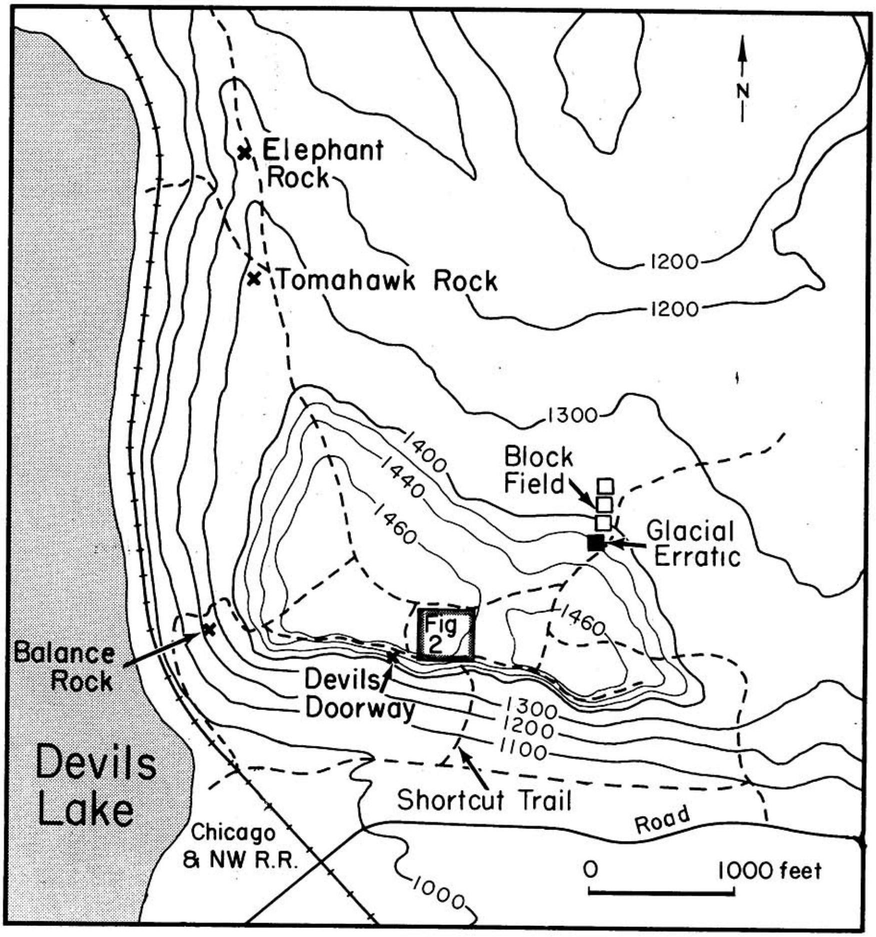

FIGURE 1. Generalized topographic map of East Bluff, Devils Lake State Park. Modified from U. S. Geological Survey Baraboo Quadrangle. Trails in part diagrammatic.

at and above the level of the rim (Salisbury, 1895; Alden, 1918, p. 99–102; Trowbridge, 1917, p. 352; Thwaites and Twenhofel, 1921, p. 296; Thwaites, 1958, p. 149; Andrews, 1958; and Thwaites, 1960, p. 38). No one seriously has considered them to be glacial, yet to the writer such an origin seems at least as plausible. It is hoped that this note will attract attention to these common features and their odd surroundings. Optimistically they will intrigue others into looking for additional evidence on their past history.

The writer in examining the locality at different times during the last several years has been struck particularly by the presence of rounded, water-polished boulders of chert and quartzite (fig. 5) 2 feet and more in diameter associated with the gravels and haphazardly lying among angular quartzite blocks without water-polished surfaces (several are shown by ▲'s in fig. 2), by the presence of potholes in loose boulders that unquestionably have been moved

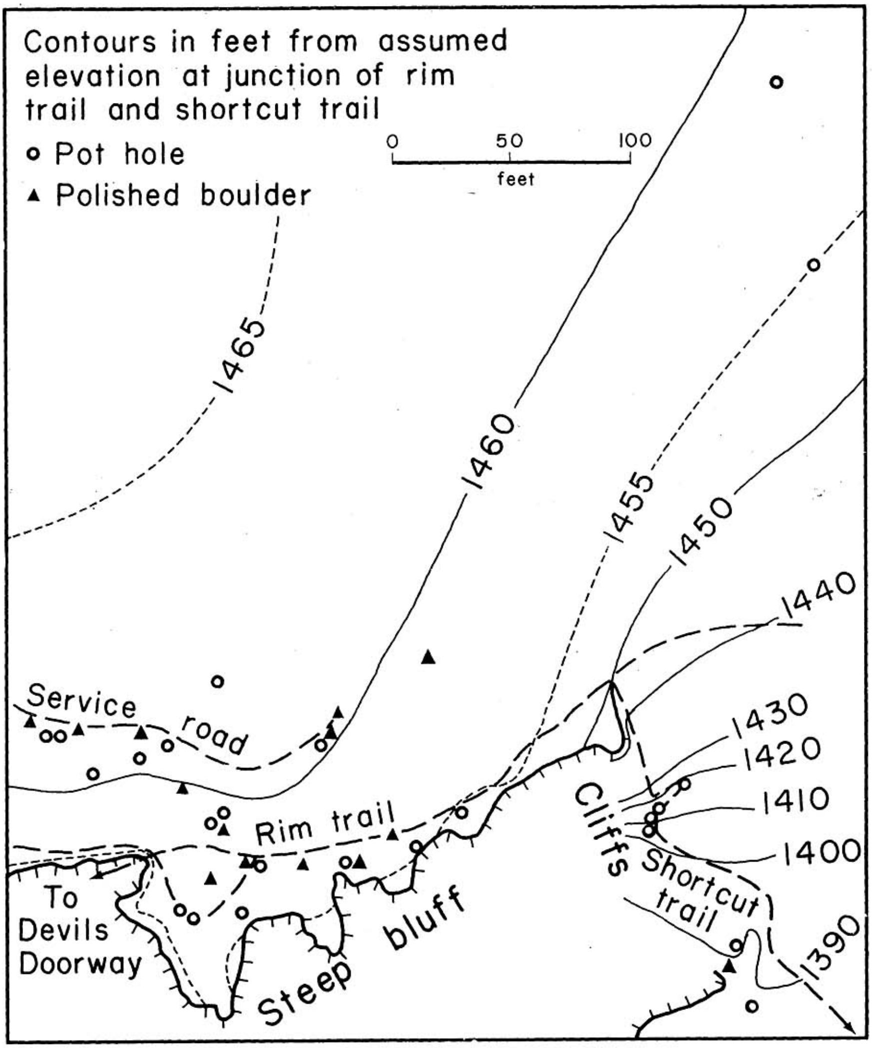

FIGURE 2. Sketch of pothole area, East Bluff, Devils Lake State Park.

FIGURE 3. Small upland-type pothole in loose block. Part of side and base are missing.

since the potholes were formed (fig. 3), by the considerable vertical range of potholes on the upland—some being several feet above the apparent bed of the postulated ancient stream, by the lack of coincidence of the flow of water with the slope of the ridge (fig. 2), and by the wide distribution of potholes on the upland but the narrowness and limited discharge of the small cascade that must have plunged over the side of the bluff along the route of the Shortcut Trail. The large chert and quartzite boulders seem identical in composition, surface polish, percussion fractures, and rounding to the small gravel in the vicinity. A continuous size range from sand to 2 foot boulders may be seen but has never been recorded in the literature. The cascade that descended the bluff at the Shortcut Trail is too small to correlate with the broad area of potholes on the upland unless they were cut at different times by a migrating stream whose course was not controlled by the bedrock beneath. Alternatively evidence of greater discharge off the upland elsewhere is not now available. The vertical range of isolated potholes on the upland suggests rather deep water, but it is difficult to explain how many potholes could get started where they are now found. In short the potholes and rounded and angular boulders of the upland are not in a normal stream channel (fig. 2) although the potholes on the south-facing slope are.

In February, 1964, while searching the woods north and east of the pothole locality (fig. 1), a block of quartzite 3 by 3.5 by 4 yds. (fig. 6) was seen tilted over another smaller block of quartzite. The large block weighs about 85 tons. It rises conspicuously above the general level of the rounded summit of the upland and is immediately uphill from an area of large joint blocks of quartzite bedrock that have moved down slope enough to create a jumbled chaos or block-stream. (The erratic is reached by following the fire road south and east from the north shore (fig. 1) or by going west and

FIGURE 4. Cascade-type pothole along the Shortcut Trail.

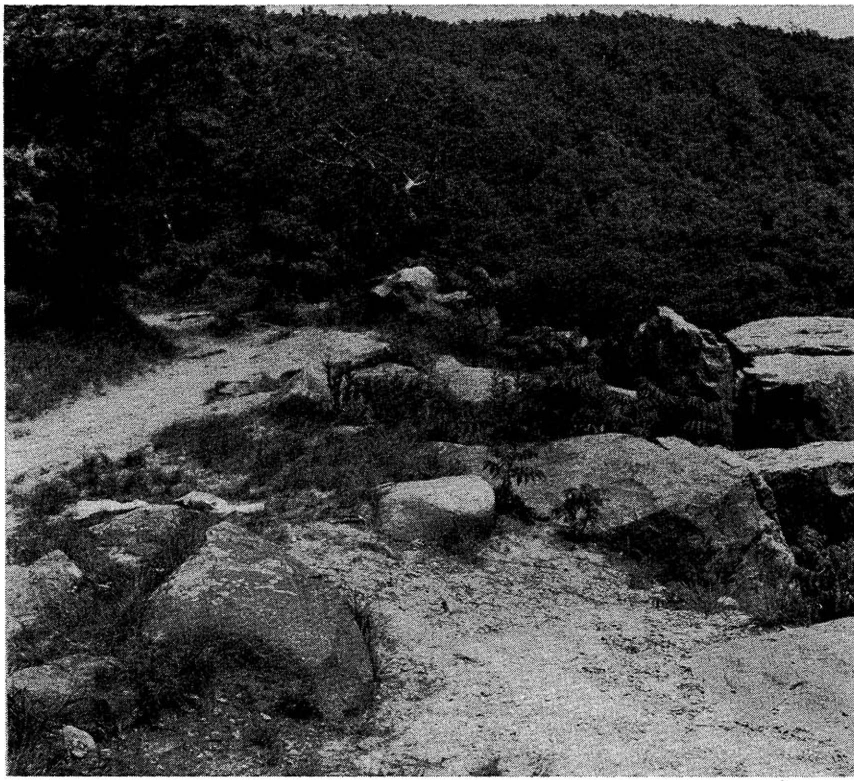

FIGURE 5. Rounded, polished quartzite boulder with percussion fractures among loose angular, unpolished quartzite boulders on the rim of East Bluff. View east. Highest block of quartzite in background has a pothole on top.

north on the service road at the potholes to that fire road and then east about 120 yds.) (fig. 2). Many smaller angular blocks are scattered over the upland. Hundreds of millions of years ago marine erosion of the Baraboo Range beveled the dipping strata (Thwaites, 1960, p. 37–38). However, such processes could not leave behind an isolated fresh, very angular block of quartzite to rise above the general level nor mix the rounded boulders with the angular blocks. No apparent outcrop exists above the block that is large enough to produce it. It does not seem feasible to pluck it out of the smooth upland and move it by gravity to its resting place. The block has sharper corners and less weathering effects than quartzite exposed on the west-facing bluff of Devils Lake. A convenient steep slope with just such large angular blocks lies immediately below, but how is an 85-ton block to be moved upslope? Man surely is not to blame. No conceivable force other than glacial seems possible to explain its existence. However, all previous researchers except Weidman (1904, p. 102), whose evidence has been discredited (Trowbridge, 1917, p. 357), have stated unequivocably that the location is outside the limits reached by any glacial ice.

This leaves us on the horns of a dilemma. Obviously we either lack sufficient information to explain the phenomena or previous interpretations of existing evidence are incorrect. As the smaller gravel associated with the potholes is considered the type section of the East Bluff member of the Windrow Formation (Andrews, 1958) which in turn is correlated widely in the upper Mississippi Valley with deposits of Cretaceous or Tertiary age (Austin, 1963; Frye, William, and Glass, 1964), it behooves us to look more closely at the criteria that have been used for explaining and dating them. Many of our concepts of the evolution of the land surface in the upper Mississippi Valley are at stake.

It is readily apparent to the observer that the small stream that cascaded down the south face of the East Bluff did not exist on a peneplained surface. Even with 200 feet of relief on the postulated peneplain (Trowbridge, 1917, p. 352) boulders over 2 feet in diameter seem unduly large and such cascades should not exist. Moreover,

FIGURE 6. Quartzite erratic northeast of pothole area. For location see figure 1.

the haphazard mixing of rounded and angular boulders is not normal to a stream valley. Was the stream on the upland the same one that produced the cascade on the bluff? They have been so correlated, but this is an assumption that is difficult to prove. If true, the stream hardly flowed on a peneplained surface. Moreover, how do we relate the potholes in loose blocks on the upland to those in the bedrock *in situ?* It is difficult to have beautiful holes drilled so symmetrically into a loose block that rises several feet above the bed of the stream. Why isn't the block moved during cutting? From where were the coarse stones obtained for cutting? It would be easier to have the blocks *in situ* during cutting and subsequently moved. This must have occurred to many blocks in which the sides or bottoms of potholes are missing (fig. 3), and the void is now partly occupied by a sharp unpolished corner of another block; others are turned on their sides with no rock adjacent to the void. Some of the loose blocks with potholes are on the very edge of the bluff. In figure 5 the most distant block to the right of the trail has just such a pothole. They are on the highest surfaces and surely were not cut there by any normal stream flowing on a peneplain, nor have they been moved downslope by gravity to their resting place. Moreover, it seems difficult to explain the potholes as having been produced by streams of considerable velocity running off a higher surface held up by Paleozoic rocks now removed (Thwaites, 1960, p. 38) or by an ancestral Wisconsin River (Irving, 1877, p. 508) without calling for subsequent movement of the blocks and the mixing of rounded and angular boulders. What moved them?

Because the potholes are above and outside the marked terminal moraine of Late Wisconsin (Cary) ice that existed perhaps 13,000 to 16,000 years ago and are in the classical Driftless Area of southwest Wisconsin, any thought that glaciers were involved has been in the past unthinkable. Hence, it was only logical to attempt to reconstruct substitute situations. These have not been entirely successful. Glaciation of much, if not all, the Driftless Area is called for by Black (1960) on the basis of a variety of evidence that cannot be detailed here. It includes many definite erratics, deposits stratigraphically up out of place, boulder trains, absence of old loess and residuum, reconstruction of ice surfaces, etc. Can glacial action, which directly and indirectly could easily account for the phenomena we see, be substantiated locally? At least is it unreasonable?

The Cary ice left thick coarse deposits up to about 1600 ft. in elevation in the vicinity of the radio tower (WWCF) about 3.5 miles east-northeast of the potholes, a prominent moraine up to 1450 ft. about 1.5 miles east-northeast, and the well-developed terminal moraine whose upper surface approaches 1100 ft. in the valley directly below the potholes. The potholes on the rim are about 1450–1460 ft. in elevation; the large quartzite block northeast is about 1420 ft. (Note, these elevations are derived by altimeter and from the new quadrangle maps, Baraboo and North Freedom, which replace the older Baraboo and Denzer quadrangle maps used by many earlier workers).

In continental glaciers or ice sheets that surmount the topography, debris is carried typically in the basal units of the ice and is moved up in the terminal areas through complex flow that cannot be discussed here. Nonetheless, the uppermost ice is invariably free of debris acquired from its base until such time as downwasting removes the clean ice down to the level reached by the debris. Many situations are known where a particular ridge may be crossed by an ice sheet without the basal ice reaching the top of that ridge. The debris at the terminus of a glacier then never reflects the uppermost level attained by clean ice. Hence, it seems entirely reasonable, though not proved, for clean ice to have stood on the uplands when the potholes were formed and prior to the main building of the prominent moraines nearby. If true, such ice would have access only to the residual materials on that surface. These need be only the highly siliceous material capable of surviving long weathering and the local quartzite. However, drilling reveals at least 8 feet of pebbly, sandy clay beneath the angular blocks of Baraboo quartzite that cover the surface of the upland. The pebbles are identical to those at the potholes in the type section of the Windrow formation and the clays are expandable type—not kaolin that characterizes the Windrow formation elsewhere.

Siliceous terrace gravels in many places in the Driftless area are subdivided into two groups (Thwaites, 1928) and the younger correlated with moraine in central Wisconsin that is now considered about 30,000 years old (Black, 1962) and certainly not older than the Wisconsin glacial stage (Hole, 1943). However, the actual material is composed of siliceous metamorphic rocks of Precambrain age and chert residuum with fossils from the Paleozoic dolomites (Andrews, 1958). They have been thought to have been concentrated initially during the Cretaceous or Tertiary—as far back as the last 135 million years of geologic time. It seems clear that many particles are multigenetic or have been worked and reworked at different times. The big question is when were they last reworked?

As it seems possible to have ice over the area, it remains to determine when. This cannot now be done. The absence of loess in the joints in the chaos by the large quartzite block (fig. 6) implies movement in post-Cary times. The unstable perched blocks in the block field also imply youthfulness. Igneous rocks outcropping west of Devil's Lake are fractured but not chemically altered as they would be if exposed to weathering for many millions of years. They indicate very recent exposure to weathering, possibly by glaciation which is not older than late Wisconsin. The well-jointed quartzite along the bluffs of Devils Lake lends itself to movement by frost action so great antiquity or absence of glaciation cannot necessarily be ascribed to such nearby features as Devil's Doorway and Balance Rock (fig. 1) (Salisbury and Atwood, 1900, p. 65). Features of similar size are known to have been produced in well-jointed igneous rocks since the Cary glaciation elsewhere (e.g., Devil's Chair, St. Croix River, Martin, 1932, pl. 28). Moreover, ancestral Devils Lake reached the level of the divide between the north branch of Messenger Creek (on the west side of Devils Lake) and Skillett Creek at about 1150 feet (Trowbridge, 1917, p. 366). This is about the elevation of Elephant Rock and the base of many vertical cliffs. Frost action along the shore likely was intensified at that time and would help produce some cliff features. If the clean Cary ice were not present, the Rockian ice of about 30,000 years ago surely must have been for it went well beyond the Cary limit everywhere else in the state.

Were ice to stand over East Bluff and downwaste, the highest part would be exposed first. Crevasses would open first probably along the axis of the ridge allowing meltwaters to plunge to the bottom. Thin slow-moving ice should not have removed all the residuum or pebbly, sandy clay on the quartzite, and the remainder would then be subjected to water working. The deposits of clay with chert and other siliceous materials could again be reworked in part by the ice and in part by the glacial waters. The odd distribution horizontally and vertically of potholes on the upland could be explained readily by such waters flowing off the ice into the crevasses at various times and places. So too could the movement of blocks after pothole drilling was completed, the mixing of rounded and angular blocks, and the irregular distribution of angular blocks of Baraboo quartzite on the upland, on top of the pebbly sandy clay.

Thus, in summary, the large quartzite block is interpreted as a glacial erratic that has been moved some yards upslope by clean ice that merely reworked and mixed old residuum or an ancient glacial deposit with rounded boulders and angular quartzite blocks on the upland of East Bluff. A late Wisconsin age is assigned tentatively to the glaciation mainly because of the absence of loess in the vicinity. Further it is believed possible that pothole drilling occurred by glacial waters reworking that pebbly, sandy clay whose initial concentration according to lithologies and possible other affinities in the upper Mississippi Valley may have been in Tertiary or Cretaceous times. The coarseness of the rounded boulders and the wide range horizontally and vertically of the potholes belie the existence of a peneplain across which a meandering stream flowed. The mixing of angular quartzite fragments of many sizes with the well-rounded and polished gravel and boulders must have taken place after the rounding of much of the gravel. This is considered possible only by glaciation. Certainly the East Bluff of Devils Lake is not a good type section for the Windrow Gravel.

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