Exhumed early Paleozoic landforms on the Baraboo Hills, Wisconsin

Abstract

The Baraboo Hills of southern Wisconsin consist of extremely durable Precambrian quartzite. Some of the well-preserved landforms seen there today were formed during the early part of the Paleozoic, were then buried, and were subsequently exhumed in Mesozoic or Cenozoic time. Valleys in the western part of the South Range were cut in Middle Cambrian time or earlier and buried in Late Cambrian time. Subsummit benches and scarps were cut by marine shore erosion in early Ordovician time and buried soon after. Summit plateaus were cut by subaerial or marine-shore processes, probably in Middle Ordovician time, and buried in late Ordovician time.

The Baraboo Hills of south-central Wisconsin (Fig. 1) contain some remarkably well-preserved Paleozoic landforms. Late Cenozoic landforms are present, but in this paper we conclude that many of the landforms were cut into the Baraboo quartzite early in the Paleozoic, buried soon thereafter, and exhumed in late Mesozoic or early Cenozoic times. These Paleozoic landforms include valleys, subsummit benches and scarps, and summit plateaus.

Although some of these landforms were recognized more than a century ago (Irving 1877, 504–05), they were poorly known until studied by Thwaites (1931, 1935, 1958, 1960). However, some elevations on the topographic maps available to Thwaites are in error by more than 100 m, and some features are misplaced horizontally by as much as 1 km. As a result, Thwaites was unable to adequately document the location and elevation of the landforms or to convincingly demonstrate the relationship between these landforms and the Paleozoic formations of the area.

Accurate topographic maps now exist, and the geology of the region has been mapped in greater detail (Dalziel and Dott 1970; Clayton and Attig 1990; Attig and Clayton 1990; Attig et al. 1990). As a result, we now are able to document the el-
evation and the location of these landforms and relate them more confidently to the Paleozoic stratigraphy of the region. In this paper we reevaluate Thwaites’ speculations about the age and origin of these landforms.

**Description**

**The Baraboo Hills**

The geology of the Baraboo Hills has been outlined by Dalziel and Dott (1970) and Clayton and Attig (1990). In the area surrounding the Baraboo Hills, Paleozoic rock lies on a generally flat unconformity on Precambrian rock. Before the Paleozoic sediment was deposited, the Baraboo Hills rose more than 350 m above the surrounding plain (Fig. 2). Then, as now, the hills were made up of quartzite of the Baraboo Formation, which was more than 1.5 km thick. The quartzite consists of quartz sand that underwent low-grade metamorphism to produce a rock that is highly resistant to erosion. The Baraboo Formation was folded into a doubly plunging syncline, resulting in the oval pattern of hills shown in Figure 1b. The north and south halves of the oval are called the North Range and the South Range, respectively.

The Baraboo Hills then were buried with quartz and lime sand during Late Cambrian and Early Ordovician time. At least the top of the South Range was reexposed by erosion during Middle Ordovician time, and the hills again were buried during Late Ordovician time, beginning with the quartz sand of the St. Peter Formation. By Late Paleozoic time, an additional few hundred meters of marine sediment had probably been deposited on top of the hills. Marine deposition had ceased by late Pennsylvanian time (Shaver et al. 1985). During the ensuing 200 million years, the land surface was lowered to near the level of the top of the Baraboo Hills.

The summit of South Range probably was exposed again just before the fluvial gravel of the “Windrow Formation” was deposited on one of the highest parts of the South Range, above the East Bluff of Devils Lake (Fig. 1c; Thwaites and Twenhofel...
Fig. 2. a: Composite profile of summit plateaus of the South Range (the thin, solid lines at the top of the diagram), viewed from east to west. Vertical exaggeration x 10. The position of the subsummit benches is shown with a heavy dashed line. The thin dashed lines in the Baraboo quartzite indicate dip of the quartzite. The Precambrian, Cambrian, and lowest Ordovician stratigraphy shown at the north and south flanks of the range is based on local information, but the Platteville Formation has been projected from an area 40 km farther south. b: Cross section through a representation plateau, with flanking valleys and valley fills (middle of the South Range; sec. 17, 20, and 28, T11N, R6E).

1921, 296–97). It is unknown when that event occurred, but guesses have generally ranged from Early Cretaceous to Pliocene (Thwaites and Tewehofel 1921, 307–10; Andrews 1958; Anderson 1988, 255–56). The landscape surrounding the Baraboo Hills since then has been lowered about 60 m at the west end, 250 m at Devils Lake (Fig. 1b; WGNHS Geologic Logs Sk-17 and Sk-39), and 300 m at Portage near the east end of the hills (Fig. 1b; WGNHS Geologic Log Co-634). The stratigraphic relationships summarized here and shown in Figure 2a indicate that the Baraboo Hills are much the same shape today as they were in Middle Cambrian time.

Valleys

The North and South Ranges of the Baraboo Hills are irregular quartzite ridges cut by gorges and valleys. The gorges have been cut completely through the ranges. They had a complex history, including considerable Pleistocene erosion when they functioned as spillways of glacial Lake Wisconsin (Clayton and Attig 1989); they will not be further discussed.

In contrast, the valleys head within the ranges. The largest valleys in the unglaciated part of the South Range are marked by Xs in Figure 1c. These are a few kilometers long, about 1 km wide, and about 100 m deep. They tend to be of uniform width and abruptly terminate at broad, rounded valley heads. The valleys are walled with Baraboo quartzite, but their bottoms are generally underlain by 20 to 60 m of Cambrian sandstone and conglomerate (Fig. 2b).

Subsummit Benches and Scars

Nearly flat benches have been cut into the Baraboo quartzite on the sides of each of these valleys (Fig. 1c, 2a, and 2b). The benches are typically a few tens of meters wide. Above the bench is a scarp with a slope of about 20°. Below the bench, the valley
side typically slopes about 10° to 15°. The benches are about 30 m below the edge of the summit plateaus (Fig. 2a), and are at nearly the same elevation throughout the South Range, descending slightly to the south at about 1 m/km; they are at an elevation of about 402 m (1320 ft) on the north side of the South Range and at about 393 m (1290 ft) on the south side.

The benches are generally covered by forest, but, even so, in many places they are obvious from a distance (Fig. 3a). In addition, they are generally conspicuous in the few places where crossed by roads, especially when leaves are off the trees and patches of snow remain on the bench after a thaw. The benches can be seen where Freedom Road descends from the summit plateau on the south side of Happy Hill (4 km northeast of the community of Denzer) and at the junction of Tower and Denzer Roads (6 km north of Denzer; Fig. 3b).

**Summit Plateaus**

The highest hill tops in the unglaciated part of the South Range are remarkably flat (Fig. 2a, 2b, and 3c). These summit plateaus are typically about 0.5 km wide, with a maximum width of 1.5 km and a maximum length of 7.5 km (Fig. 1 and 2). The middles of the plateaus, at elevations between about 430 m (1410 ft) and 454 m (1490 ft), are horizontal, with slopes increasing to several degrees near the edge, at elevations between about 421 m (1380 ft) and 433 m (1420 ft). The plateaus are quartzite overlain by a few meters of yellowish-brown silt and clay containing quartzite fragments. Thwaites (1935, 401; 1958, 147; 1960, 37–38) reported scattered loose fragments of Paleozoic chert on the plateau surface, as well as a few small exposures of in-place lower-Paleozoic conglomerate along the edge of the plateaus.

**Age and Origin**

**Valleys**

Most large valleys in the South Range are known to have formed before Late Cambrian time, because there is Late Cambrian sandstone and conglomerate in the valley bottoms (Fig. 2b; Dalziel and Dott 1970). The valleys are known to have been at least 20 to 60 m deeper at the beginning of Late Cambrian time than they are today, because the Late Cambrian fill is that thick, and the interfluvies may have been considerably higher, if the summit plateaus were eroded in Orдовician time, as will be discussed. Otherwise, the general shape of the valleys probably has changed little, because thin patches of Cambrian rock occur in a few places high on the valley walls (Thwaites 1935, 401; Thwaites 1958, 147; Thwaites 1960, 38).

Most large valleys in the unglaciated part of the South Range are shaped like typical stream valleys. They require no explanation other than hillslope and stream erosion through Early and Middle Cambrian time and perhaps also during latest Precambrian time.

**Subsummit Benches and Scars**

The subsummit benches on the South Range are not structural terraces, because they slope only about 1 m/km (less than 0.1°) but are cut in quartzite that dips 10° to 40° (Fig. 2). These are not fluvial terraces because they slope to the south, whereas the valleys slope north and south on either side of the range. Thwaites (1935, 401; 1958, 147–48; 1960, 38–39) concluded that these benches and the scars above were cut into the quartzite by marine shore erosion. We agree, because no other explanation seems
plausible. However, the scarsps clearly have been rejuvenated in places by mass movement when permafrost was present during the Pleistocene (Clayton and Attig 1990).

Although there is no direct stratigraphic evidence, these shore benches were most likely cut during the Ordovician. Patches of early Paleozoic conglomerate occur locally.
on the slope just below the benches (Thwaites 1958, 147; Thwaites 1960, 38). The formations present on either flank of the South Range can be projected into the range (dotted lines in Fig. 2a), using the stratigraphic and structural information of Clayton and Attig (1990, Plates 1 and 2, Fig. 13 and 14); the contact between the Jordan Formation (Late Cambrian) and Prairie du Chien Formation (Early Ordovician) is about 30 m below the benches. The original thickness of the Prairie du Chien here is unknown, but it is 60 m thick 40 km to the south (WGNHS Geologic Log Dn-993) and may have been that thick across the South Range. If the Prairie du Chien dolomite was deposited near sea level on the Baraboo Hills, the benches would have been cut before the upper Prairie du Chien was deposited, during Early Ordovician time, as suggested by Thwaites (1935, 401; 1958, 147; 1960, 38). This conclusion is corroborated, in a general way, by the dip of the benches; as shown in Figure 2a, the benches slope southward about 1 m/km, about the same as the regional dip of the Prairie du Chien Formation in the Baraboo area (Clayton and Attig 1990, Fig. 14).

If the benches were eroded at that time, much eroded quartzite would be predicted to occur in the upper part of the Prairie du Chien Formation. However, we know of no sedimentological evidence for increased erosion and deposition of quartzite around the Baraboo Hills at that time, because appropriate exposures are unavailable—no more than about the lower 25 m of the Prairie du Chien Formation is exposed in the Baraboo region.

Other less conspicuous benches and scarp occur at lower elevations on both the North and South Ranges. Wanenmacher (1932, 75–76) and Raasch (1958) interpreted these as marine shore terraces formed in Late Cambrian time, and we agree with this interpretation.

**Summit Plateaus**

If the top of the South Range had been rounded or marked by a series of hogbacks over harder layers in the northward-dipping quartzite, the shape of the range would require little explanation other than normal subaerial erosional processes operating over a long period of time. However, the summit plateaus, crosscutting the dipping quartzite, require some special explanation. Before Thwaites studied them, the summit plateaus were considered the remnants of a peneplain, or at least of a subaerial erosion plain.

Martin (1916, 68) and Smith (1931, 128), and others, thought this was a peneplain cut in Precambrian time. Thwaites (1935, 398; 1958, 141; 1960, 37), however, thought the plateaus were cut after Precambrian time, doubting that the Precambrian surface surrounding the Baraboo Hills could have been lowered 350 m without destroying the erosion-surface remnants on the hills. Furthermore, the summit plateaus seem to slope southward at about the same inclination as the subsummit benches and the Prairie du Chien Formation (1 m/km; Fig. 2a); if the summit plateaus were cut before the Precambrian plain surrounding the Baraboo Hills, they should slope south at least as steeply as that plain (2 to 4 m/km; Thwaites 1957).

Others, such as Trowbridge (1917, 352–53), suggested that the summit plateaus are remnants of a plain (the "Dodgeville peneplain") cut by subaerial processes when the South Range was being exhumed in Mesozoic or Cenozoic time. Thwaites (1935, 403; 1958, 149; 1960, 37) argued that if subaerial erosion was capable of planing the extremely
resistant quartzite, erosion should also have been capable of planing the much weaker Paleozoic dolomite and shale of Blue Mounds (40 km south of the Baraboo Hills), one of which is 70 m higher than the South Range. Thwaites argued further that scattered loose blocks of Paleozoic chert on the plateaus are an indication of much less erosive activity than would have been required to plane the quartzite from the top of the South Range. The patches of lower-Paleozoic conglomerate on the plateaus also indicate they could not have been formed in Mesozoic or Cenozoic time.

As indicated in the discussion of the subsummit benches, the formations on either side of the South Range are projected into the range (Fig. 2a), the position of the middle Ordovician unconformity (at the base of the St. Peter Formation) is unclear, but it may be near the level of the edges of the summit plateaus. This suggests the possibility that the summit plateaus were cut by subaerial erosion during this hiatus, which lasted about 25 million years (Shaver et al. 1985). This possibility suffers from none of the objections listed for Precambrian and post-Paleozoic subaerial erosion plains, but much less time was available. In addition, the summit plateaus seem too flat to correspond to the middle Ordovician unconformity, which is known to have considerable local relief near the Baraboo Hills; in some places the unconformity is as low as or even below the base of the Prairie du Chien Formation (suggested in left-hand side of Fig. 2a; Clayton and Attig 1990).

Thwaites (1931, 745; 1935, 401-02; 1958, 145-47; 1960, 36-38) suggested that the summit plateaus on the South Range are the result of marine shore erosion rather than subaerial erosion. Thwaites favored this interpretation for the following reasons. If subaerial erosion is ruled out, marine erosion is the only reasonable alternative, and marine shore erosion seems more capable of eroding the quartzite than any other process. Once the subsummit bench had been interpreted to result from shore erosion, it was reasonable to extend this interpretation to the summit plateaus. However, a shore plain might be expected to be even flatter than the plateaus on the South Range, although Thwaites suggested that sea level gradually rose as the plain was cut.

The age of the summit plateaus, if in fact they are marine shore terraces, is less clear than that of the subsummit benches. Thwaites (1935, 401; 1958, 147; 1960, 37) suggested that if the Paleozoic formations farther south are projected into the South Range, the summit plateaus would coincide with the base of the Platteville Formation (Late Ordovician). Our projection (Fig. 2a) shows this also, but because the original thickness of the Ordovician units is uncertain here, this projection could be in error. No sedimentological evidence is available for increased Platteville erosion and deposition around the Baraboo Hills, because there are no Platteville outcrops in the area.

**Conclusion**

The Baraboo Hills retain early Paleozoic landforms that have undergone little change since they were exhumed in Mesozoic or Cenozoic time. The large valleys in the South Range (except Devils Lake gorge) are normal stream valleys that formed before the Late Cambrian. The subsummit benches and scarp are almost certainly a marine shore terrace, which probably formed during the Early Ordovician. The summit plateaus are remnants of a plain formed by marine shoreline erosion or by subaerial erosion, possibly during either the Middle or Late Ordovician.
Acknowledgments

We wish to thank David M. Mickelson, W. N. Melhorn, and Thomas W. Gardner for reviewing an earlier version of this paper.

Works Cited


Lee Clayton is a Professor and John W. Attig is an Associate Professor of the University of Wisconsin (Extension) at the Wisconsin Geological and Natural History Survey in Madison.