Sandstone Caves in Wisconsin

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Abstract.

Sandstone caves account for about 30% of Wisconsin's 250 recorded and mapped caves, yet they are consistently under-appreciated and underestimated. Most are formed in Cambrian aged sandstones in the southwestern part of the state, although others have developed in pre-Cambrian sandstones and by the collapse of Ordovician sandstones into cavities in underlying dolostones. Some of the caves have developed through stream meandering, waterfall undercutting or exterior erosion, but over 40 have formed through dissolution by groundwater, predominantly within the upper Jordan Sandstone where groundwater flow is focused downward through the overlying Oneota dolostone. The transitional Sunset Point member has recently been recognized as an important locus of speleogenesis. Although the longest sandstone cave is nearly 100m in length, most are much smaller, and a large number have not been recorded or mapped. Some are joint-controlled, while others are enlarged along bedding planes. Processes other than dissolution are involved in their development. Many of southwestern Wisconsin's fragile rock formations may also actually be cave remnants. Some of the sandstone caves are significant sites of pre-European Native American artwork, including petroglyphs and pictographs.

Introduction.

Over 77 or about 31% of the approximately 250 caves recorded and mapped in the U.S. state of Wisconsin are developed in sandstones. Despite this, these sandstone caves have received scant attention, except from recreational cavers, and little research into them has been conducted. To date, the most authoritative summary is that by CRONON (1970), whose efforts to stimulate increased attention appear largely to have fallen on deaf ears. Cronon provides a listing of the state's known sandstone caves, grouping them into two broad classes: collapse caves and erosional caves. The former number at least ten and the latter at least 51, with an additional 16 unclassified. Of the erosional class caves, four are classified in a stream meander group, and at least four in an "exterior erosion" group, but the remaining 43 or more are attributed to ground water erosion, or speleogenesis.

Sandstone caves are not numerous in temperate areas, but they have been recorded in several locations (FORD & WILLIAMS, 1989; GILLIESON, 1996; JENNINGS, 1985; MIDDLETON & WALTHAM, 1986). Quartz sandstones are reasonably soluble in natural waters, especially under alkaline conditions (YOUNG & YOUNG, 1992), but insoluble residues often infill developing caves and dolines, with fissure and conduit flow being restricted.

Geological and Geomorphological Contexts.

Wisconsin's sandstone caves are formed within three geologic units. In the northern part of the state a few caves are developed in Precambrian sandstones, but these are not considered in detail here since they are few, small and produced primarily by processes other than dissolution. More significantly, caves in southwestern and central Wisconsin have developed in Paleozoic sandstones, particularly in the Cambrian aged Jordan Sandstone, which underlies the main carbonate cave host rock, the Early Ordovician dolostones of the Prairie du Chien Group, and in the Middle Ordovician St. Peter Sandstone, which overlies the Prairie du Chien Formation. Collapse caves are formed predominantly in the St. Peter Sandstone, and dissolutional caves in the Jordan Formation.

Depositional patterns during the Cambrian reflect the influence of the Wisconsin Arch and adjacent basins, with five rhythmic transgressional sequences of sandstones, dolostones and shales (PAULL & PAULL, 1977). The basal Upper Cambrian formation is the 100-250m thick shallow water Mount Simon Sandstone, which is overlain by the finer-grained impure sandstone of the Eau Claire Formation. Overlying this unconformably is the coarser, better-sorted sandstone of the Wonewoc Formation, which is up to 120m thick, and above this is the Tunnel City or Franconia Sandstone, which is 30-60m thick and lithologically similar to the Eau Claire. The dolostones of the St. Lawrence Formation cap this second transgressive cycle, which was followed by a period of erosion (PAULL & PAULL, 1977).

The Jordan Sandstone is the youngest of the sequence of Cambrian sandstones and is a clean, well-sorted, white, medium-grained, high-energy sandstone about six to 46 meters thick that was deposited during a third marine transgression onto the Wisconsin Arch (PAULL & PAULL, 1977). As the transgression continued, increasing marine depths favored carbonate deposition and the Jordan graded into the overlying Oneota dolostone, which is the youngest of the Prairie du Chien Group. Regional uplift at the end of the Early Ordovician was followed by two further transgressions, during the second of which the St. Peter Sandstone was deposited. The St. Peter is typically a white, massively bedded, medium-grained, well-sorted quartz sandstone, 12 to 107m thick, in places cross-bedded and in part of aeolian origin (PAULL & PAULL, 1977).

The sandstones are integral components of the northernmost of the three westward-dipping cuestas that dominate Wisconsin's western uplands (MARTIN, 1965). North of the Wisconsin River, the Jordan Sandstone typically forms 10m high laterally extensive vertical cliffs beneath a Prairie du Chien dolostone caprock; further south and west the St. Peter outcrops above the Prairie du Chien. Further north and east the older Cambrian sandstones outcrop, with the Tunnel City forming particularly extensive valley-side cliffs. Regional dip is slight, typically one or two degrees to the west or southwest. The landscape is fluvially dissected, with broad alluviated main valleys tributary to the Wisconsin and Mississippi Rivers flanked by narrow

interfluvial ridges. Karst is a significant component of the upland landscape of southwestern Wisconsin's Driftless Area, with a wide array of dry valleys, sinkholes, caves and springs (DAY *et al*, 1989). Although dissolution of the dolostone is sluggish (DAY, 1984), the area was spared the ravages of Pleistocene glaciation (MICKELSON *et al*, 1982), which has allowed the persistence of the spatially restricted, essentially relict karst.

The Sandstone Caves.

The only exhaustive discussion of the sandstone and sandstone-carbonate contact caves in Wisconsin has been by CRONON (1970, 1980), who has catalogued at least 77 individual examples, representing over 30% of Wisconsin's 250 recorded and mapped caves. The sandstone caves are consistently under-appreciated and underestimated in the cave and karst literature, perhaps because their speleologic pedigree is not appreciated, although they are well-known to recreational cavers. The caves occur in two distinct geological contexts, being formed both within the Cambrian sandstones, particularly the Jordan and the Tunnel City, and in the Ordovician St. Peter Sandstone.

Caves in the St. Peter Sandstone.

The caves in the St. Peter Sandstone represent subjacent karst development, since they have developed essentially by the collapse of the sandstones into cavities in the underlying Prairie du Chien dolostones. Although not numerous, these are some of the most interesting caves in the state (CRONON, 1970).

The progression of cavity migration from the dolostone into the overlying sandstone is outlined by CRONON (1970:85) and results in a variety of sinkhole and cave morphologies with variable carbonate-sandstone ratios. Most of these caves are single rooms entered through sinkhole bases, and they are generally symmetrical, with circular plan profiles and ceilings arching upward toward the center. There is often a central pile of sand and sandstone rubble, and the floors typically slope downward toward one of the edges. At least 10 of these collapse caves are catalogued by CRONON (1970), and several more are known.

Several of southwestern Wisconsin's best-known caves, including Star Valley Cave and Viroqua City Cave, have exposures of the St. Peter Sandstone in their ceilings, and their sandy floors attest to gradual upward migration. In other cases, the upward migration has been such that the caves are now entirely within the overlying sandstone. Several pit caves occur in this category, including E-Pit, Jones Cave and Bridgeport Cave, which contains the largest cave room in Wisconsin.

Caves in the Jordan and Other Cambrian Sandstones.

Some of the better-known and more accessible caves within the Cambrian sandstones have developed through stream meandering, waterfall undercutting or exterior erosion (MARTIN, 1965; CRONON, 1970), but at least 43 have formed through dissolution by groundwater, and are thus of true speleogenic origin. These occur throughout the Cambrian sandstone sequence where the sandstones have higher carbonate contents, such as in the upper Tunnel City and Jordan Formations. They occur particularly within the upper Jordan Sandstone where groundwater flow is focused downward through the overlying fractured and karstified Oneota dolostone. The vertical continuity of the carbonate-clastic aquifer has been documented by the tracing of agricultural contaminant flushes to caves, springs and wells within both lithologies (REEDER, 1992; REEDER & DAY, 1993).

Some caves in the Cambrian sandstones are joint-controlled, with tall narrow passages, while others are enlarged into gently sloping "pancake" passages and rooms along bedding planes. Overall, their morphology and orientation is similar to that of regional carbonate caves (CRONON, 1970; DAY, 1986; DAY *et al.*, 1989; TERLAU & DAY, 1997). In particular, they slope generally downwards toward their entrances, indicating water egress (CRONON, 1970). One notable difference, however, is that the sandstone caves contain very little of the silt-clay sediment infill which characterizes the dolostone caves (DAY, 1988), presumably because the sediment has been retained within the latter rather than transported down into the underlying sandstones.

Notable caves in the Cambrian sandstones include Anderson's, Grunt and Hummel's Caves in Richland County (PETERSON, 1968). Although the longest cave in the Cambrian sandstones, Autograph Cave, in Juneau County, attains nearly 100m in length, most are much smaller, and a large number have not been recorded or mapped. For example, there are numerous small caves in the Jordan Sandstone cliffs flanking the Kickapoo River Valley north of Viola, but only one, Mount Nebo Cave, is catalogued by CRONON (1970).

The development of these caves involves processes additional to dissolution, notably granular disintegration, the mechanical flaking of interior wall and ceiling surfaces and the development of breakdown. Freeze-thaw may play an important role around entrances, where sand piles and vegetative debris accumulate, and cavities may be initiated or expanded by tree root growth or animal burrowing. Mass wasting of slopes, for example through rock toppling or rockfall (LYDEN, 2001) may further disrupt entrances.

Archaeological Significance.

Several of the sandstone caves in southwestern Wisconsin have proven to be valuable archaeological sites yielding a variety of pre-European Native American artifacts, and a comprehensive survey is now underway to determine if other caves may provide additional evidence (G. HUPPERT, pers. comm., 2000). Much of Wisconsin's pre-European rock art is associated with sandstone caves and rockshelters in southwestern Wisconsin (SALZER, 1987a, 1997; BIRMINGHAM & GREEN, 1987; STILES-HANSON, 1987). In particular, Arnold Cave contains an impressive array of recently documented pictographs (G. HUPPERT, per. comm., 2000) and a famous petroglyph was discovered in the Gottschall Rock Shelter (SALZER, 1987b).

Natural bridges and other fragile rock formations.

The absence of Pleistocene glaciation has permitted the development and persistence within the sandstones and dolostones of the Driftless Area of numerous fragile rock formations, some of which have at least a partial speleogenic origin. Two natural

bridges occur in the Upper Cambrian Franconia or Tunnel City Sandstone, one at Pier Natural Bridge Park in Richland County, the other at Natural Bridge State Park in Sauk County. The former is essentially of fluvial origin, but the latter may have originated as a cave. Fragile rock formations in the St. Peter Sandstone include Elephant Trunk Rock, Monument Rock, Maiden Rock and the Three Chimneys, none of which have been the subject of detailed geomorphological study. Rock castellations in the Jordan Sandstone are numerous, especially at the tapering extremities of the interfluvial ridges, but these too have not been studied in detail.

One particularly striking rock formation is Five-Column Rock, in Vernon County (DAY & KUENY, 1999). The rock is formed at the transition from the Jordan Sandstone to the overlying Oneota dolostone, and has a basal sandstone plinth, a set of columns enclosing "windows", and a tabular dolostone summit, the entire structure being over 6m high. The morphology of the feature, its stratigraphic context and its juxtaposition to extant cave passage all point to a speleogenic origin, which may have broader significance for the development of similar features throughout the region. In particular, the columns are developed within the transition Sunset Point Member of the lower Prairie du Chien Group, which may represent a significant locus of speleogenesis adjacent to the sandstone-carbonate contact.

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