The Significance of Faulting to the Hydrogeology of the Cambro-Ordovician Aquifer System in Northeastern Wisconsin.

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Introduction

Recent bedrock geologic mapping in Brown County and other parts of northeastern Wisconsin has revealed the existence of numerous large faults in the region that cut across the Paleozoic sedimentary section (Figure 1). These faults may have significant implications for groundwater quality and quantity in northeastern Wisconsin. This article provides a preliminary look at the distribution and character of a few of these structures.

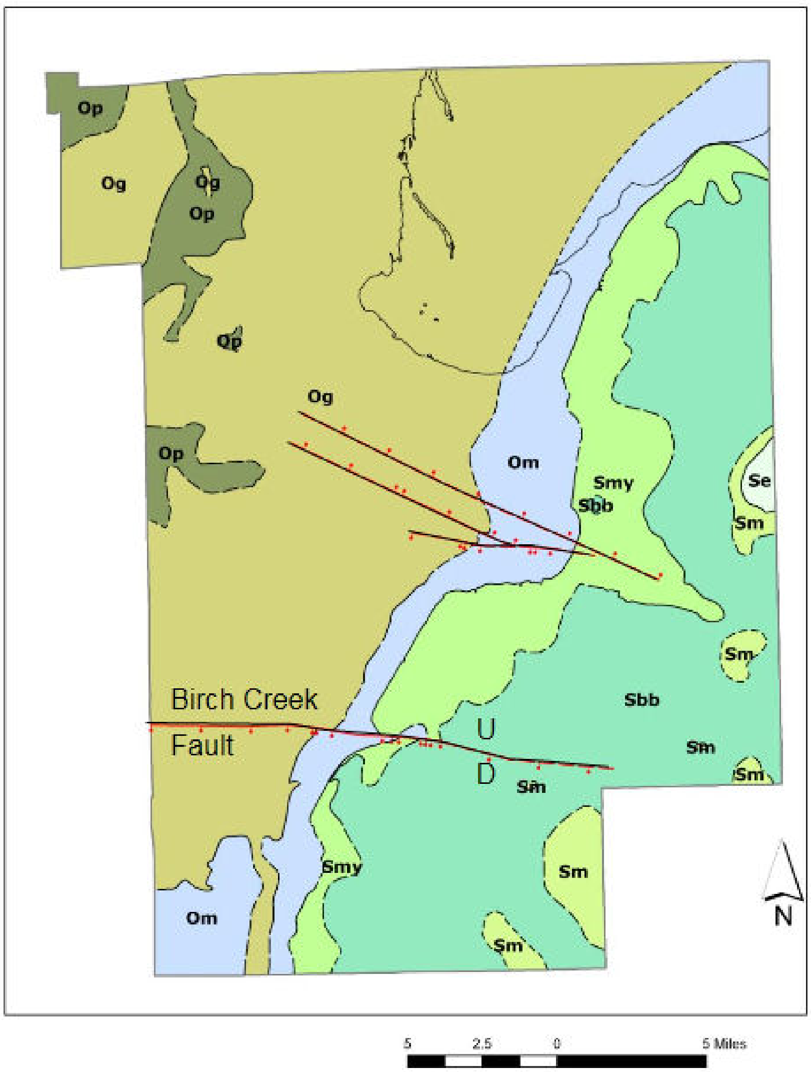

Figure 1. *Preliminary bedrock geologic map of Brown County showing the locations of major dip-slip faults (ball and bar on downthrown side). Op and Og refer to the Ordovician Platteville and Galena formations, respectively. Om is the Maquoketa Shale. Smy, Sbb, Sm, and Se refer to the four principal Silurian units in the region (Mayville Fm., Burnt Bluff Gp., Manistique Fm., and Engadine Fm.,respectively).*

Faults in Parts of Northeastern Wisconsin

Faults cutting the Paleozoic rocks of northeastern Wisconsin were suggested as early as Chamberlin (1877). However, limited work has been done on understanding the distribution and significance of faulting in northeastern Wisconsin due to the extensive cover of Pleistocene glacial drift and lack of abundant data on the deep subsurface. Early work by Thwaites (1931, 1957) suggested the presence of several faults in the region, but the confidence of some of these structures was called into question later by Kuntz and Perry (1976) because of limited data.

The author has recently completed the second year of a 2-year U.S. Geological Survey STATEMAP funded project to map the bedrock geology of Brown County, Wisconsin. The work involved outcrop and subsurface mapping of the geology using available well construction reports, drill cores, and outcrops. While there are some significant changes in the outcrop patterns of major units and the depth to bedrock, perhaps the most significant result is a major advance in our understanding of faulting in the region.

This mapping, along with the careful preparation of cross sections, has revealed the existence of several regionally extensive dip-slip faults (Figure 1). Four separate major faults have been mapped in Brown County, and preliminary work in Kewaunee and Door Counties suggests the presence of at least three others. While both dip-slip and strike-slip faults have been observed in quarry exposures in northeastern Wisconsin (Figure 2) (e.g., Luczaj, 2000, 2006), only large offset dip-slip faults are able to be located with confidence using subsurface data from well construction reports. The presence and significance of strike-slip faults in the region is difficult to address in areas of nearly flat lying rocks with significant glacial sediment cover because little or no vertical offset would be produced that could be deduced from well construction reports.

Figure 2. *Exposure of the St. Peter Sandstone near Seymour, Wisconsin illustrating heavily fractured sandstone and a dip-slip fault with about 3 feet (1 m) of vertical offset (right hand side is downthrown).*

One fault, tentatively named the Birch Creek fault, is located approximately 3 miles north of Greenleaf, Wisconsin and is one of the most significant regional faults that cuts the Paleozoic section with about 100 feet of vertical displacement, dropped downward on the south side (Figure 3). Preliminary work suggests that this fault stretches from near Denmark, Wisconsin westward into Waupaca County. Its existence was first suggested in Outagamie County by Chamberlin (1877, pages 280-281), although that literature was only discovered during the later stages of the bedrock mapping investigation after the fault was mapped in Brown County. It is possible that this fault is a reactivated portion of the Spirit Lake Tectonic Zone, which is the Proterozoic suture between the Penokean orogen and the Yavapai orogen in the Precambrian basement (Holm and others, 2007). Two 1.5 mile long reflection seismic surveys were run across this fault in July 2010 by the Kansas Geological Survey. The seismic data are still being processed, and future publications will feature details of the fault zone and the bedrock geology of Brown County.

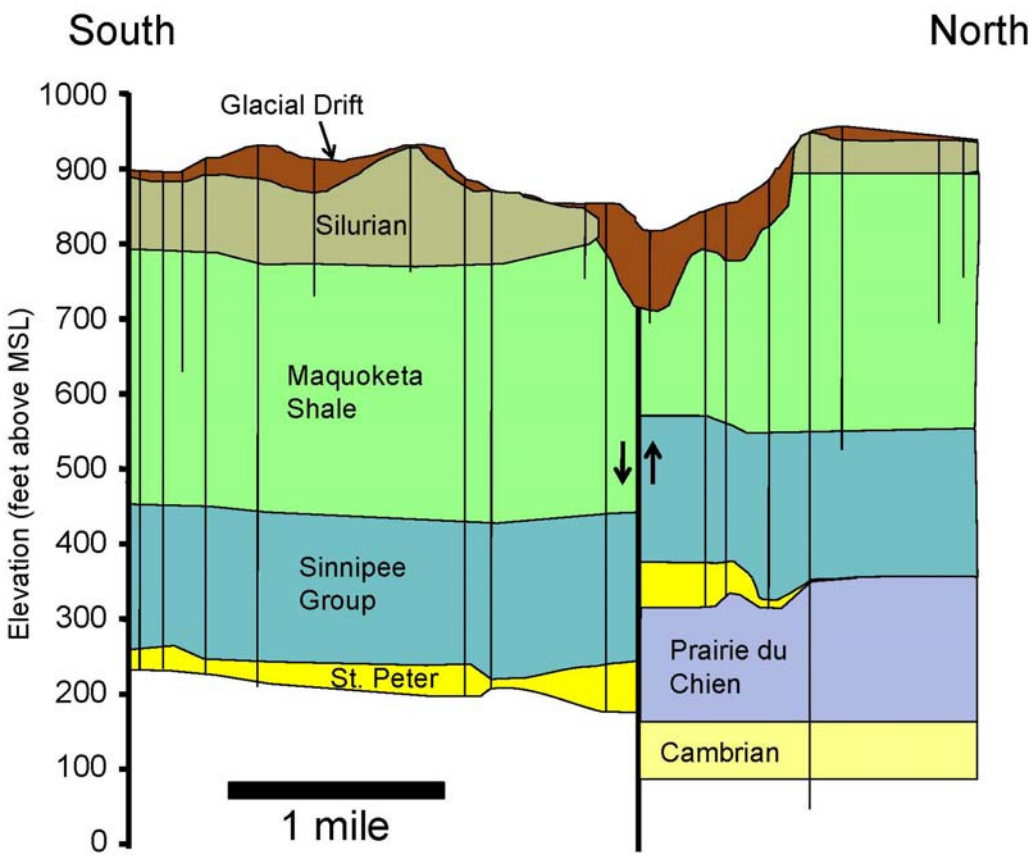

Figure 3. *South to north cross section along the top of the Niagara Escarpment north of Greenleaf, Wisconsin. Thin vertical lines indicate water well locations. Arrows indicate relative offset along the Birch Creek Fault.*

Further to the north, three east-west and southeast-northwest trending dip-slip faults in the Green Bay to Bellevue region appear to converge along a southeast-trending buried bedrock valley located south of Bellevue, Wisconsin (Figure 1). One of the blocks caught between two of these faults appears to be a horst, although the dip on the faults is unknown. These faults appear to have between 60 feet (18 m) and 100 feet (30 m) of vertical offset based on preliminary cross sections and structure contour maps. Although the faults are unnamed at present, one of these faults was plotted on hydrogeologic cross-sections constructed by Kammerer et al. (1998) as the “Dutchman Creek Fault”.

Hydrogeologic Significance

These faults are important for hydrogeologists working in the region for several reasons including groundwater quality and quantity issues, as well as a better understanding of the hydrostratigraphy for those who wish to model flow in the region's deep aquifer system.

It is well known that faults may exhibit enhanced permeability or may serve as barriers to subsurface fluid flow, depending upon a number of variables related to host rock/sediment lithology, fault zone diagenesis, and faulting mechanisms (Rawling et al., 2001). Previous hydrogeologic and modeling studies in northeastern Wisconsin (e.g., Krohelski, 1986; Conlon, 1998) did not address how faults would affect flow in the region because there was little or no information known about them at that time. However, the next generation of models for the Northeastern Groundwater Management Area should include these fault zones early in the development of the models, as models for southeastern Wisconsin have with the Waukesha fault (SEWRPC, 2005).

Faults have been shown to compartmentalize aquifers and hydrocarbon reservoirs under certain circumstances (Rawling et al., 2001). This is especially true where clay smearing along fault surfaces or abundant mineralization can significantly limit cross-fault flow. The extent to which this occurs in northeastern Wisconsin has not been evaluated but should be considered in future studies. There is, however, anecdotal evidence to suggest that this might indeed happen along some parts of these faults. Abundant white clay has been observed in fractures near one of the mapped faults in Ashwaubenon near the Dutchman Creek Fault (Troy Simonar, personal communication). Other boreholes in areas near suspected faults have yielded anomalous amounts of cement in the quartz sandstones that has limited the production potential of planned municipal wells.

Even if there is not a significant change in cross-fault permeability, one might expect to see significant decrease in well yields due to the large amount of offset on some of these faults. For example, the Birch Creek fault has had approximately 100 feet of vertical displacement (Figure 3). Because the Cambrian sandstones are typically about 400 feet thick, this results in only about 200 feet, or 50%, of the original formation thickness of sandstone to transmit water flowing perpendicular to the fault. Furthermore, there might be complete isolation of the St. Peter Sandstone aquifer on either side of the fault in places where offset is greater than the thickness of this unit. While it may be a coincidence, it is interesting to note that the Birch Creek Fault occurs near the groundwater divide on the potentiometric surface between the two prominent cones of depression in the northeast Groundwater Management Area (Luczaj and Hart, 2009).

Other data show that sulfide mineralization can be focused along faults and fracture systems (e.g., Luczaj, 2006), but exposures of these in outcrops and quarries are limited. However, increased dissolved arsenic concentrations in formation waters near an extension of the Birch Creek fault in Outagamie County was documented by Dave Johnson of the WDNR (Dave Johnson, personal communication). The abundant sulfide mineralization in these structures is interpreted to be the result of precipitation along faults and fracture systems that acted as conduits of enhanced permeability during the Middle and/or Late Paleozoic Era when regionally extensive hydrothermal brine migrations occurred along the margins of the Michigan and Illinois basins in Wisconsin (Luczaj, 2006).

Recommended Future Work:

Additional bedrock and structure mapping should be completed in northeastern Wisconsin, especially in areas with potential groundwater quality and quantity concerns. Future hydrologic investigations that focus on improving our understanding of the permeability of the host rock and fault gouge along these structures would be quite valuable to future modeling efforts in the region.

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