DODGE COUNTY

Bedrock geology of Dodge County, Wisconsin

MAP 508–SUPPLEMENT • 2021

Esther K. Stewart

Introduction

The accompanying map is an interpretation of the distribution of bedrock units that are present beneath unconsolidated sediments in Dodge County, Wisconsin. The unconsolidated sediments were mostly deposited by modern and glacial processes during the Quaternary Period and are generally 20–60 feet (ft) thick, though locally they range from absent (where bedrock crops out) to more than 200 ft thick in preglacial bedrock valleys. Bedrock unit contacts are drawn on the buried bedrock surface, which is shown in elevation contours on the base for this map. This map builds on recent mapping in Fond du Lac and Sauk Counties (Batten, 2018; E.D. Stewart and others, 2018; E.D. Stewart and E.K. Stewart, 2020), refines the subdivision of the Precambrian Baraboo interval metasediments (map units XYb, Yw, and XYi; see also Dott, 1983; E.K. Stewart and others, 2016), identifies several low-amplitude folds in the Paleozoic units, and presents new evidence for episodic Paleozoic reactivation of Precambrian structures. A refinement of the bedrock elevation contours and the areas underlain by dolostone bedrock may facilitate identification of those areas that are most susceptible to groundwater contamination from the application of nutrients and pesticides on the land surface. The identification and mapping of subtle folds in the Paleozoic units may also help predict local changes in the physical properties of the bedrock; for example, changes in hydraulic conductivity associated with vertical fracturing near fold axes (E.D. Stewart and others, in press).

Bedrock units include Proterozoic quartzite, schist, banded iron formation (XYb, XYi, Yw), and lesser mafic intrusive rocks and pegmatites (Ypm) nonconformably overlain by Paleozoic siliciclastic and carbonate rocks. Precambrian strata (Waterloo Quartzite) were deposited on the southeastern margin of Laurentia after about 1,630 Ma (mega-annum, or Ma). It is possible that an older unconformable sedimentary succession beneath the Waterloo Quartzite was deposited after about 1,714 Ma, similar to the Precambrian succession in the Baraboo Hills 50 miles to the west (E.D. Stewart and others, 2018; E.K. Stewart and others, in press). Regional events that controlled deformation of these rocks are unresolved (E.K. Stewart and others, in press). Baraboo interval strata show evidence for metamorphism associated with emplacement of the Wolf River batholith at approximately 1,470 Ma (Medaris and others, 2019), and indirect evidence for folding during the Mazatzal event at approximately 1,630

Wisconsin Geological and Natural History Survey
University of Wisconsin–Madison Division of Extension
3817 Mineral Point Road • Madison, Wisconsin 53705
608.262.1705 • WisconsinGeologicalSurvey.org
Kenneth R. Bradbury, Director and State Geologist

Ma (Holm and others, 1998; Romano and others, 2000). The quartzite, schist, and iron formation (XYb, XYi, Yw) are intruded by mafic dikes and pegmatites (Ypm) of uncertain age. Geochemical and geochronologic data suggest pegmatites and associated mafic intrusions are associated with the Wolf River batholith which may be related to the Green Island plutonic belt of the Eastern Granite Rhyolite province (1,400 Ma; Bucholz and others, 2005; Holm and others, 2007; Bickford and others, 2015; Medaris and others, 2019). Some mafic intrusions may be related to the Midcontinent Rift (about 1,100 Ma; for example, Holm and others, 2020). The evidence for these events is from aeromagnetic anomaly data (E.K. Stewart and others, 2016; E.D. Stewart and others, 2018) and an exposure of pegmatites and mafic dikes at a quarry in southwestern Dodge County (Bucholz and others, 2005). Here, the Waterloo quartzite (Yw) is exposed in low-lying outcrops along the western limb of the Waterloo syncline. The overlying Cambrian through Silurian sandstones and dolomites were deposited as nearshore through offshore deposits in a broad, epeiric sea some 510–430 million years ago (for example, Sloss, 1963; Smith and others, 1993; Choi and others, 1999; Runkel and others, 1998, 2007; McLaughlin and others, 2019). Chronologic subdivisions are from Gradstein and others (2012) as well as regional studies. The subdivision of the Cambrian into Middle and Late Cambrian units (Epoch 3 and Furongian; Ꞓe, Ꞓtc, Ꞓt) and the position of the Cambrian-Ordovician boundary are based on Runkel and others (2007). The subdivision of the Ordovician and Silurian units (Opc, Oa, Os, Om, Su) is based on Choi and others (1999), Witzke and others (2010), and McLaughlin and others (2019). The map area overlies the Wisconsin arch, a structural high that was periodically subaerially exposed during the deposition of the Paleozoic units. The Wisconsin dome was elevated to the north and the Paleozoic units dip gently 3–5 degrees toward the Michigan basin to the east.

Bedrock surface

The topographic surface of the mostly buried bedrock was interpreted from depth-to-bedrock information from 3,213 well construction reports (WCRs), soils data from the U.S. Department of Agriculture, and observation of land surface topography. The bedrock surface elevation was hand contoured at 20-ft intervals. The bedrock topography closely mimics the present-day surface topography in places underlain by shallow dolostone (depth to bedrock <50 ft). On the basis of this observation, bedrock-surface-elevation contours were interpreted to closely follow the trend of surface topographic contours in areas underlain by dolostone bedrock units, including drumlin fields where WCR data suggest some drumlins underlain by dolostone include a bedrock core (E.K. Stewart, 2021). Bedrock elevation contours more loosely follow the trend of surface elevation contours in areas underlain by sandstone, shale, and quartzite.

Most of the topography on the bedrock surface developed before the deposition of glacial and modern sediments during the Quaternary Period. The variable resistance to weathering and erosion of bedrock units is reflected in the topography of the bedrock and land surfaces. The Precambrian quartzite (XYb, Yw) is most resistant to erosion. Today, the western side of the Waterloo syncline is a mostly buried Precambrian topographic high (Yw); during the Cambrian Period, this topographic high was at the land surface. The Paleozoic dolostone units (Su, Os, Opc) are relatively resistant to erosion and tend to cap elevated ledges or plateaus. In contrast, the softer sandstone and shale units (Om, Oa, Ꞓt, Ꞓtc) are more susceptible to erosion and tend to form slopes that are dissected by preglacial drainage systems. The ledge-forming Silurian dolostone (Su) is present in eastern Dodge County. Bedrock-surface and ground-surface elevations are highest in areas of northeastern and north-central Dodge County that are underlain by Silurian dolostone. To the west, shale of the Ordovician Maquoketa Group (Om) is a slope-forming unit that flanks the Silurian dolostone, and this contact is discontinuously expressed in the land surface morphology as the Niagara Escarpment. The Maquoketa is herein elevated from a formation to a group to more closely follow its usage in Illinois and Indiana. The Maquoketa's subunits are herein elevated from member to formation rank. The Maquoketa Group includes (in ascending order) the Scales Formation (shale), the Fort Atkinson Formation (shaly dolostone), the Brainard Formation (dolomitic shale and lesser shaly dolomite and grainstone), and the Neda Formation (mudstone to oolite). In central Dodge County, dolostone of the Ordovician Sinnipee Group (Os) forms a second broad, relatively elevated ledge. Due to the regional eastward dip, this Ordovician ledge has the highest surface elevation in northwestern Dodge County. The slope-forming sandstone and shale of the Ordovician Ancell Group (Oa) abut the Sinnipee Group to the west. Preglacial drainages dissect western Dodge County west of the Sinnipee Group, exposing dolostone of the Ordovician Prairie du Chien Group (Opc) and underlying sandstone of the Cambrian Trempealeau and Tunnel City Groups (Ꞓt, Ꞓtc).

Two main preglacial drainage systems incised the bedrock surface (see fig. 1). In eastern Dodge County, several east-southeast-trending preglacial tributaries to the ancestral Rock River incised the Silurian dolostone (Su) and shale of the Maquoketa Group (Om). These tributaries flowed either east towards the ancestral eastern branch of the Rock River, or west toward the south-southeast-trending ancestral Rock River that paralleled the Niagara Escarpment and is today partially occupied by Horicon Marsh, Sinissippi Lake, and the modern Rock River in southeastern Dodge County. The ancestral Crawfish River developed over less-resistant Cambrian to Ordovician sandstone (Ꞓt, Ꞓtc, Oa) in western Dodge and southeastern Columbia Counties. It flowed south into Jefferson County to join with the ancestral Rock River. Incision by these drainage systems partially controls the mapped extent of the bedrock units, especially to the east where deep

preglacial valleys cut down into shale of the Maquoketa Group (Om), removing the overlying Silurian dolostone (Su).

Structure

Many previously unrecognized folds in the Paleozoic units are identified and named on the map. Fold geometry aligns with linear aeromagnetic anomalies that previously had been interpreted as Precambrian fold axes and faults (see figs. 2 and 3; E.K. Stewart and others, 2016).

Precambrian

The Precambrian quartzite, schist, and iron formation (XYb, XYi, Yw) are deformed by kilometer-scale folds and may be offset by regional-scale faults (E.K. Stewart and others, 2016). Precambrian rocks (Yw, Ypm) are only exposed in the Waterloo syncline, an east-plunging, kilometer-scale syncline in southwestern Dodge County. An elliptical, canoe-shaped aeromagnetic anomaly in northern Dodge County is likely caused by similarly folded quartzite and iron formation (E.K. Stewart and others, 2016). Beyond the Waterloo syncline, the Precambrian surface is poorly constrained by a few unevenly distributed wells.

Paleozoic

The Paleozoic units are offset on the order of tens of feet by small folds that may be underlain or cut by faults. Structures are recognized through the correlation of Paleozoic units identified from well construction reports, cuttings, core, and geophysical logs. A series of low-amplitude anticlines and synclines similar to those recognized in the lead-zinc district of southwestern Wisconsin (for example, Heyl and others, 1959) are apparent on the structure-contour map drawn on the base of the Sinnipee Group (Os; see fig. 2). Descriptions of two representative structures are provided below.

Beaver Dam anticline

The Beaver Dam anticline is a gentle, east-southeast-plunging anticline with a maximum amplitude of approximately 75 ft. The anticlinal trace is sinuous across west-central Dodge County, extending for approximately 17 miles. The inclination of the fold limbs is subtle, reaching as much as 2 degrees, but it is probably less for most of the fold's length.

The Beaver Dam anticline is coincident with a curvilinear, positive aeromagnetic anomaly and an abrupt, slight offset in the gravity data. A drill core collected along the fold axis (drill core name: WGNHS Slinger; WID: 14001388) recovered Precambrian iron formation (XYi) overlain by sandstone of the Cambrian Elk Mound Group (Ꞓe) across a sharp, erosive contact at a relatively elevated 490 ft above sea level. Large (>5 centimeters), angular clasts of iron formation are incorporated into the lowest sandstone of the Cambrian Elk Mound Group. The Ordovician Prairie du Chien Group (Opc) is absent and the overlying Ordovician Ancell Group (Oa) comes into contact with sandstone of the Cambrian Jordan Formation of the Trempealeau Group (Ꞓt) across an unconformable surface. The core shows evidence for greater fracture density and small

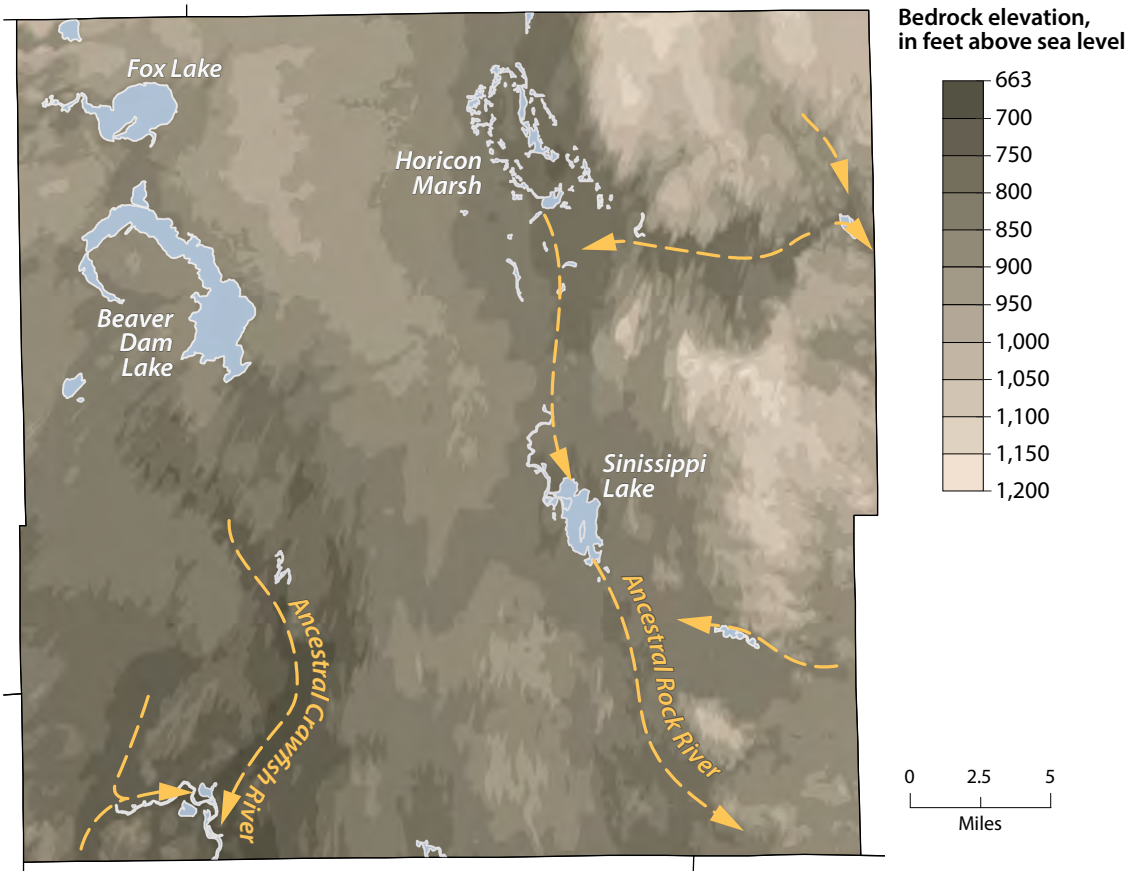

Figure 1. Elevation of the buried bedrock surface, in feet above sea level. Modern lakes are shown in blue and labeled. The approximate locations of ancestral preglacial rivers are shown by the dashed yellow lines, with arrows indicating the downstream direction.

faults compared to cores collected away from the fold axis. Fracturing and faulting is prevalent within the Ancell Group and fractures in the basal Elk Mound Group are heavily mineralized with sulfides.

Waupun anticline

The Waupun anticline is a gentle, east-northeast-plunging anticline with a maximum amplitude of approximately 60 ft. The anticlinal trace is discontinuous across northwestern Dodge County, extending for approximately 12 miles. The inclination of the fold limbs is subtle, reaching as much as 2 degrees, but it is probably less for most of the fold's length.

The Waupun anticline is coincident with a strong, broad, linear, northeast-trending set of aeromagnetic anomalies that extends to the southwest (bisecting Columbia County) and to the northeast to the city of Fond du Lac in Fond du Lac County. Geophysical logs and geologic logs generated from the cuttings of several deep wells at the Waupun Correctional Institution indicate that the Prairie du Chien Group (Opc) is locally absent and the Ancell Group (Oa) comes into contact with the lower Trempealeau Group (Ꞓt) (cross section A–A′). The observed offset of the Precambrian surface is about 300 ft, an order of magnitude larger than the offset of overlying Cambrian to Ordovician units.

Interpretation

In Dodge County, observations of drillers' logs, well cuttings, drill core, and geophysical logs demonstrate the deformation of the Cambrian sandstones (Ꞓe, Ꞓtc, Ꞓt) through the Ordovician Ancell Group (Oa). The overlying Ordovician Maquoketa Group (Om) and Silurian dolostone (Su) are likely also deformed (Heyl and others, 1959); however, in Dodge County, the available data constraining such deformation are inconclusive. Observations in Dodge County are consistent with regional observations that indicate several episodes of deformation focused along reactivated Precambrian structures. Craddock and Van der Pluijm (1989) and Van der Pluijm and others (1997) documented the transmission of late Paleozoic plate tectonic stresses from the Appalachian and Ouachita orogenies into the interior of the midcontinental United States, and they suggested these stresses may have caused reactivation of pre-existing structures that were favorably oriented with respect to the plate margin. Paleozoic to Mesozoic reactivation of Precambrian structures likely influenced the source and pathway of the mineralized Mississippi Valley-type fluids in southeastern Wisconsin (Haroldson and others, 2018; Luczaj and Huang, 2018) and a subsequent remobilization of arsenic within the local groundwater aquifer system (E.D. Stewart and others, in press).

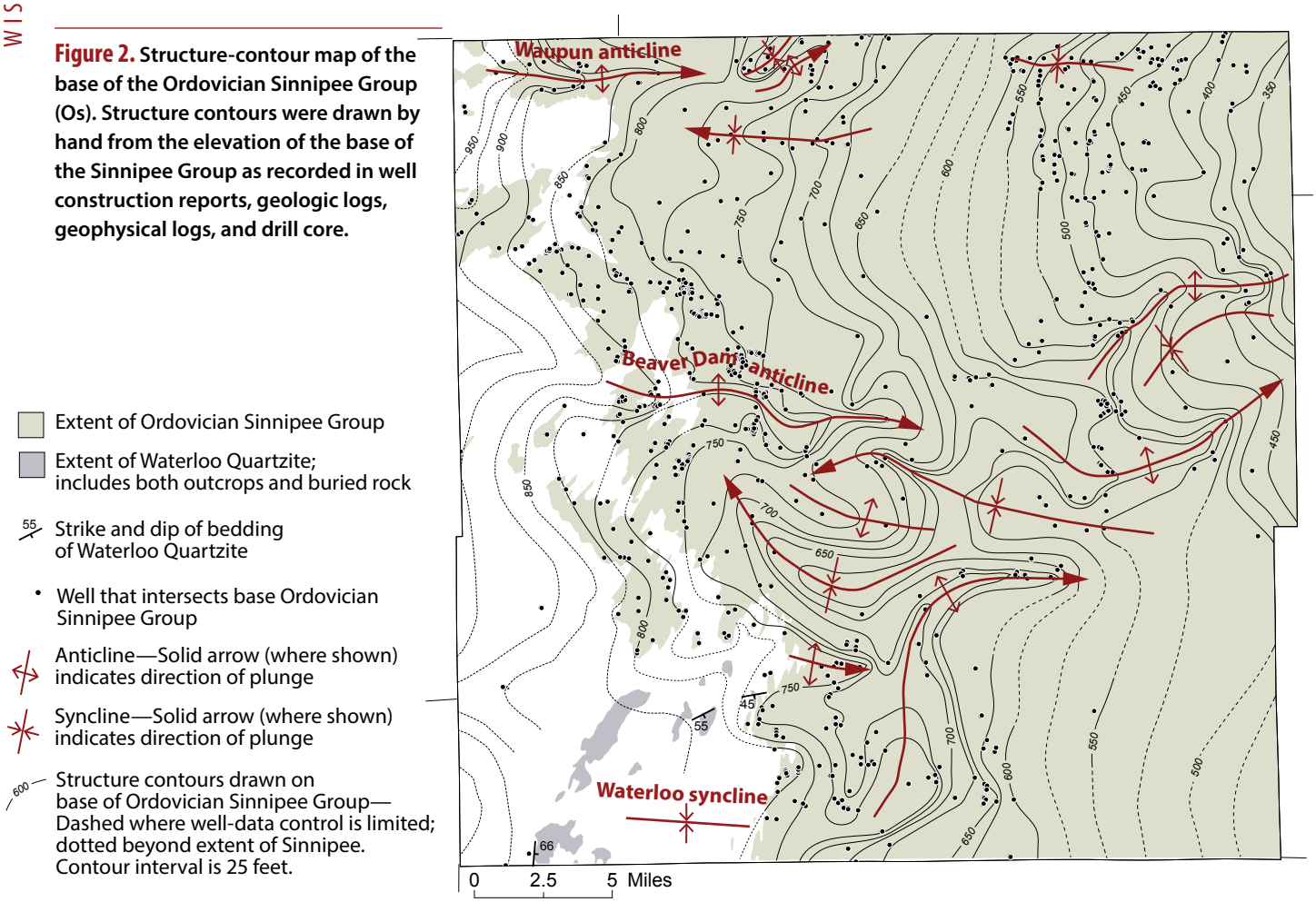

Figure 2. Structure-contour map of the base of the Ordovician Sinnipee Group (Os). Structure contours were drawn by hand from the elevation of the base of the Sinnipee Group as recorded in well construction reports, geologic logs, geophysical logs, and drill core.

The fold axes interpreted from the structure contours drawn on the base of the Sinnipee Group (fig. 2) tend to align with geophysical anomalies that likely reflect structures in the underlying Precambrian rocks (fig. 3; Holm and others, 2007; E.K. Stewart and others, 2016). The coincidence of Paleozoic folds with Precambrian faults is observed in the Baraboo Hills, some 40 miles west of Dodge County (E.D. Stewart and E.K. Stewart, 2020). In Dodge County, the large offset of the Precambrian surface relative to the offset of the overlying Paleozoic units observed along the axes of the Beaver Dam and Waupun anticlines may be attributed to Precambrian deformation, which supports the interpretation that older structures were reactivated during the Paleozoic.

An early period of uplift may have developed during the Middle Cambrian, shortly before or during the deposition of the Mount Simon Formation (Ꞓem) of the Elk Mound Group (Ꞓe). The evidence for this uplift is mostly from the observation of large, angular clasts of iron formation incorporated into the base of the Elk Mound Group in the WGNHS Slinger drill core along the axis of the Beaver Dam anticline. The size and angularity of these soft, poorly resistant clasts indicate they were exposed at the land surface shortly before their incorporation into the basal Elk Mound Group detritus. The overall coarse grain size of the Elk Mound Group in Dodge County suggests the Wisconsin arch was subtly expressed as a topographic high by Middle Cambrian time. The fine-grained fraction that is characteristic of the Eau Claire Formation (Ꞓee) elsewhere in Wisconsin is minimal to absent in all but perhaps eastern Dodge County, likely due to the winnowing of the finer grains in a slightly higher-energy, more proximal setting over the Wisconsin arch. The overlying Cambrian Tunnel City Group (Ꞓtc) and Trempealeau Group (Ꞓt) maintain their thicknesses, indicating potential Cambrian deformation did not persist much longer beyond the deposition of the Elk Mound Group.

An important period of deformation developed by the end of Early Ordovician time, resulting in a more pronounced uplift of the Wisconsin arch (Heyl and others, 1959). This Early to Middle Ordovician deformation likely caused the localized uplift and erosion of the Prairie du Chien Group (Opc) before the deposition of the overlying Ancell Group (Oa). Mapping in southeastern Minnesota is consistent with these observations and further documents the changes in thicknesses within the Prairie du Chien Group that are interpreted as evidence for syndepositional tectonism (Steenberg and others, 2015, 2018). Closer to Dodge County in the Baraboo Hills

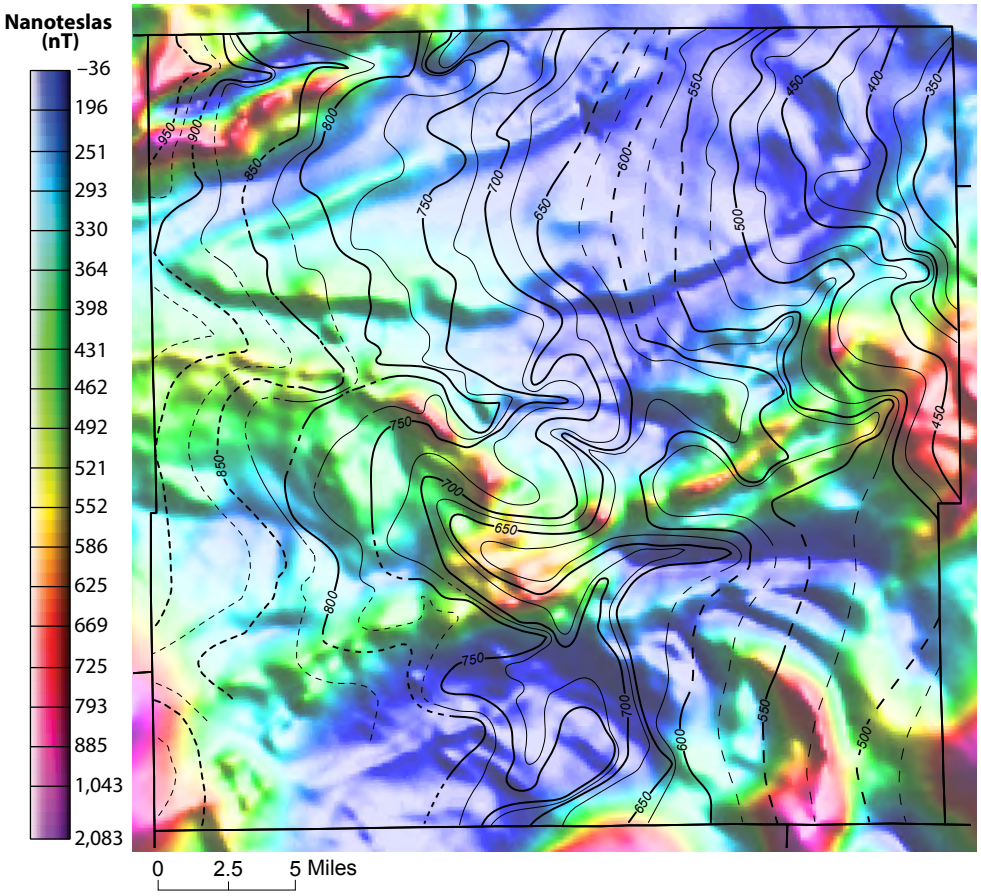

Figure 3. Structure contours drawn on the base of the Ordovician Sinnipee Group (from fig. 2) overlain on reduced-to-pole (RTP) aeromagnetic anomaly map. Aeromagnetic anomalies reflect magnetic contrast in the upper crust; in Wisconsin, this data responds to variations in the Precambrian basement because the overlying Paleozoic rocks and Quaternary sediments are mostly magnetically transparent. Paleozoic fold axes closely align with linear aeromagnetic anomalies (compare with fig. 2), supporting the interpretation that Precambrian structures were reactivated during the Paleozoic. See Daniels and Snyder (2002) and E.D. Stewart and others (2018) for a description of the aeromagnetic dataset.

of Sauk County, outcrops of the Prairie du Chien Group are gently folded (E.D. Stewart and E.K. Stewart, 2020).

Subtle deformation continued after the deposition of the Ancell Group (Oa), resulting in the folding of the overlying Sinnipee Group (Os) and localized fracture development and mineralization. Subsurface mapping of the base of the Ordovician Maquoketa Group (Om) and overlying Silurian dolostone (Su) indicates subtle folding of these units, though less conclusively than for underlying units (see cross sections A–A′ and B–B′).

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References

Batten, W.G., 2018, Bedrock geology map of Fond du Lac County, Wisconsin: Wisconsin Geological and Natural History Survey Map M505, 2 plates, scale 1:100,000, https://wgnhs.wisc.edu/pubs/000963/.

Bickford, M.E., Van Schmus, W.R., Karlstrom, K.E., Mueller, P.A., and Kamenov, G.D., 2015, Mesoproterozoic-trans-Laurentian magmatism: A synthesis of continent-wide age distributions, new SIMS U-Pb ages, zircon saturation temperatures, and Hf and Nd isotopic compositions: Precambrian Research, v. 265, p. 286–312.

Bucholz, T.W., Falster, A.U., and Simmons, W.B., 2005, Mineralogy of pegmatites and spatially associated metasomatized zones, Michels Materials Quarry, Waterloo, WI [abs.], in Easton, M., and Hollings, P., eds., Institute on Lake Superior Geology, 51st annual meeting, Nipigon, Ontario, May 24–28, 2005, Proceedings, Part 1—program and abstracts: Institute on Lake Superior Geology, v. 65, p. 8–9.

Choi, Y.S., Simo, J.A., and Saylor, B.Z., 1999, Sedimentologic and sequence stratigraphic interpretation of a mixed carbonate-siliciclastic ramp, midcontinent epeiric sea, Middle to Upper Ordovician Decorah and Galena Formations, Wisconsin, in Harris, P.M., and Simo, J.A., eds., Advances in carbonate sequence stratigraphy: Application to reservoirs, outcrops, and models: SEPM Society for Sedimentary Geology Special Publication 63, p. 275–289.

Clayton, L., and Attig, J.W., 1990, Geology of Sauk County, Wisconsin: Wisconsin Geological and Natural History Survey Information Circular 67, 68 p., 2 plates, scale 1:100,000, https://wgnhs.wisc.edu/pubs/000317/.

Craddock, J.P. and van der Pluijm, B.A., 1989, Late Paleozoic deformation of the cratonic carbonate cover of eastern North America: Geology, v. 17, 416–419.

Daniels, D.A., and Snyder, S.L., 2002, Wisconsin aeromagnetic and gravity maps and data; a web site for distribution of data: U.S. Geological Survey Open-File Report 2002–493, https://pubs.usgs.gov/of/2002/of02-493/.

Dott, R.H., Jr., 1983, The Proterozoic red quartzite enigma in the north-central United States: Resolved by plate collision? in Medaris, L.G., Jr., ed., Early Proterozoic geology of the Great Lakes region: Geological Society of America Memoir 160, p. 129–141.

Haroldson, E.L., Beard, B.L., Satkoski, A.M., Brown, P.E., and Johnson, C.M., 2018, Gold remobilization associated with Mississippi Valley-type fluids: A Pb isotope perspective: Geological Society of America Bulletin, v. 130, p. 1583–1595.

Gradstein, F.M., Ogg, J.G., Schmitz, M.D., and Ogg, G.M., 2012, The geologic time scale 2012: Oxford, U.K., Elsevier, 1,176 p.

Heyl, A.V., Jr., Agnew, A.F., Lyons, E.J., and Behre, C.H., Jr., 1959, The geology of the upper Mississippi Valley zinc-lead district: U.S. Geological Survey Professional Paper 309, 310 p., 24 plates

Holm, D., Schneider, D., and Coath, C.D., 1998, Age and deformation of Early Proterozoic quartzites in the southern Lake Superior region: Implications for extent of foreland deformation during final assembly of Laurentia: Geology, v. 26, p. 907–910.

Holm, D.K., Anderson, R., Boerboom, T.J., Cannon, W.F., Chandler, V., Jirsa, M., Miller, J., Schneider, D.A., Schulz, K.J., and Van Schmus, W.R., 2007, Reinterpretation of Paleoproterozoic accretionary boundaries of the north-central United States based on a new aeromagnetic-geologic compilation: Precambrian Research, v. 157, p. 71–79.

Holm, D., Medaris, L.G., Jr., McDannell, K.T., Schneider, D.A., Schulz, K., Singer, B.S., and Jicha, B.R., 2020, Growth, overprinting, and stabilization of Proterozoic provinces in the southern Lake Superior region: Precambrian Research, v. 339, 106687.

Luczaj, J., and Huang, H., 2018, Copper and sulfur isotope ratios in Paleozoic-hosted Mississippi Valley-type mineralization in Wisconsin, USA: Applied Geochemistry, v. 89, p. 173–179.

McLaughlin, P.I., Emsbo, P., Brett, C.E., Bancroft, A.M., Desrochers, A., and Vandenbroucke, T.R.A., 2019, The rise of pinnacle reefs: A step change in marine evolution triggered by perturbation of the global carbon cycle: Earth and Planetary Science Letters, v. 515, p. 13–25.

Medaris, L.G., Jr., Malone, D.H., Hill, G.C., Singer, B.S., Jicha, B.R., Van Lankvelt, A., Williams, M.L., and Reiners, P.W., 2019, The Wolf River orogeny: Geon 14 magmatism, sedimentation, and deformation in the southern Lake Superior region [abs.], *in* Puumala, M., ed., Institute on Lake Superior Geology, 65th annual meeting, Terrace Bay, Ontario, May 8–9, 2019, Proceedings, Part 1—program and abstracts: Institute on Lake Superior Geology, v. 65, p. 64–65.

Medaris, L.G., Jr., Singer, B.S., Dott, R.H., Jr., Naymark, A., Johnson, C.M., and Schott, R.C., 2003, Late Paleoproterozoic climate, tectonics, and metamorphism in the southern Lake Superior region and Proto–North America: Evidence from Baraboo interval quartzites: Journal of Geology, v. 111, p. 243–257.

Romano, D., Holm, D.K., and Foland, K.A., 2000, Determining the extent and nature of Mazatzal-related overprinting of the Penokean orogenic belt in the southern Lake Superior region, north-central USA: Precambrian Research, v. 104, p. 25–46.

Runkel, A.C., McKay, R.M., and Palmer, A.R., 1998, Origin of a classic cratonic sheet sandstone: Stratigraphy across the Sauk II-Sauk III boundary in the Upper Mississippi Valley: Geological Society of America Bulletin, v. 110, p. 188–210, https://doi.org/b4wp8v.

Runkel, A.C., Miller, J.F., McKay, R.M., Palmer, A.R., and Taylor, J.F., 2007, High-resolution sequence stratigraphy of lower Paleozoic sheet sandstones in central North America: The role of special conditions of cratonic interiors in development of stratal architecture: Geological Society of America Bulletin, v. 119, p. 860–881.

Schwartz, J.J., Stewart, E.K., and Medaris, L.G., Jr., 2018, Detrital zircons in the Waterloo Quartzite, Wisconsin: Implications for the ages of deposition and folding of supermature quartzites in the southern Lake Superior region [abs.], *in* Stewart, E.K., ed., Institute on Lake Superior Geology, 64th annual meeting, May 15–18, 2018, Iron Mountain, Michigan, Proceedings, Part 1—program and abstracts: Institute on Lake Superior Geology, v. 64, p. 93–94.

Sloss, L.L., 1963, Sequences in the cratonic interior of North America: Geological Society of America Bulletin, v. 74, p. 93–114.

Smith, G.L., Byers, C.W., and Dott, R.H., 1993, Sequence stratigraphy of the Lower Ordovician Prairie du Chien Group on the Wisconsin Arch and in the Michigan Basin: American Association of Petroleum Geologists Bulletin, v. 77, p. 49–67.

Steenberg, J.R., Bauer, E.J., Chandler, V.W., Retzler, A.J., Berthold, A.J., and Lively, R.S., 2018, Geologic atlas of Hennepin County, Minnesota: Minnesota Geological Survey, County Atlas Series C–45, part A, https://conservancy.umn.edu/handle/11299/200919.

Steenberg, J.R., Retzler, A.J., and Runkel, A.C., 2015, Evidence for Early Ordovician reactivation of Mesoproterozoic rift structures within the Prairie du Chien Group: Washington County, Minnesota [abs.]: Geological Society of America, Abstracts with Programs, v. 47, no. 5, p. 81.

Stewart, E.D., and Stewart, E.K., 2020, Geologic map of the 7.5-minute North Freedom Quadrangle, Sauk County, Wisconsin: Wisconsin Geological and Natural History Survey Map 506, scale 1:24,000, https://wgnhs.wisc.edu/pubs/000973/.

Stewart, E.D., Stewart, E.K., Bradbury, K.R., and Fitzpatrick, W., in press, Correlating bedrock folds to higher rates of arsenic detection in groundwater, SE Wisconsin, USA: Groundwater.

Stewart, E.D., Stewart, E.K., Walker, A., and Zambito, J.J., IV, 2018, Revisiting the Paleoproterozoic Baraboo interval in southern Wisconsin: Evidence for syn-depositional tectonism along the south-central margin of Laurentia: Precambrian Research, v. 314, p. 221–239.

Stewart, E.K., 2021, Depth-to-bedrock map of Dodge County, Wisconsin: Wisconsin Geological and Natural History Survey Open-File Report 2021-01, scale 1:100,000, https://wgnhs.wisc.edu/pubs/wofr202101/.

Stewart, E.K., Stewart, E.D., and Bradbury, K., 2020, New bedrock mapping of Dodge County improves the geologic framework for understanding and managing southeast Wisconsin's groundwater resources [abs.]: Madison, American Water Resources Association, Wisconsin Chapter Annual Meeting.

Stewart, E.K., Brengman, L.A., and Stewart, E.D., in press, Revised provenance, depositional environment, and maximum depositional age for the Baraboo (<ca. 1714 Ma) and Dake (<ca. 1630 Ma) quartzites, Baraboo Hills, Wisconsin: Journal of Geology, https://doi.org/10.1086/713687.

Stewart, E.K., Stewart, E.D., and Lamb, M., 2016, Discovering hidden folds and faults in the Precambrian: New insights into Baraboo-interval stratigraphy and deformation in southern Wisconsin [abs.], *in* Schardt, C., and Miller, J., eds., Institute on Lake Superior Geology, 62nd annual meeting, May 4–8, 2016, Duluth, Minnesota, Proceedings, Part 1—program and abstracts: Institute on Lake Superior Geology, v. 62, p. 143–144.

Van der Pluijm, B.A., Craddock, J.P., Graham, B.R., and Harris, J.H., 1997, Paleostress in cratonic North America: Implications for deformation of continental interiors: Science, v. 277, p. 794–796.

Witzke, B.J., Anderson, R.R., and Pope, J.P., 2010, Bedrock geologic map of Iowa: Iowa Geological and Water Survey Open File Map OFM2010–01, scale 1:500,000.