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Industrial sand resources of west-central Wisconsin

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- PDF of the report (18 p.)

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Industrial Sand Resources of West-Central Wisconsin

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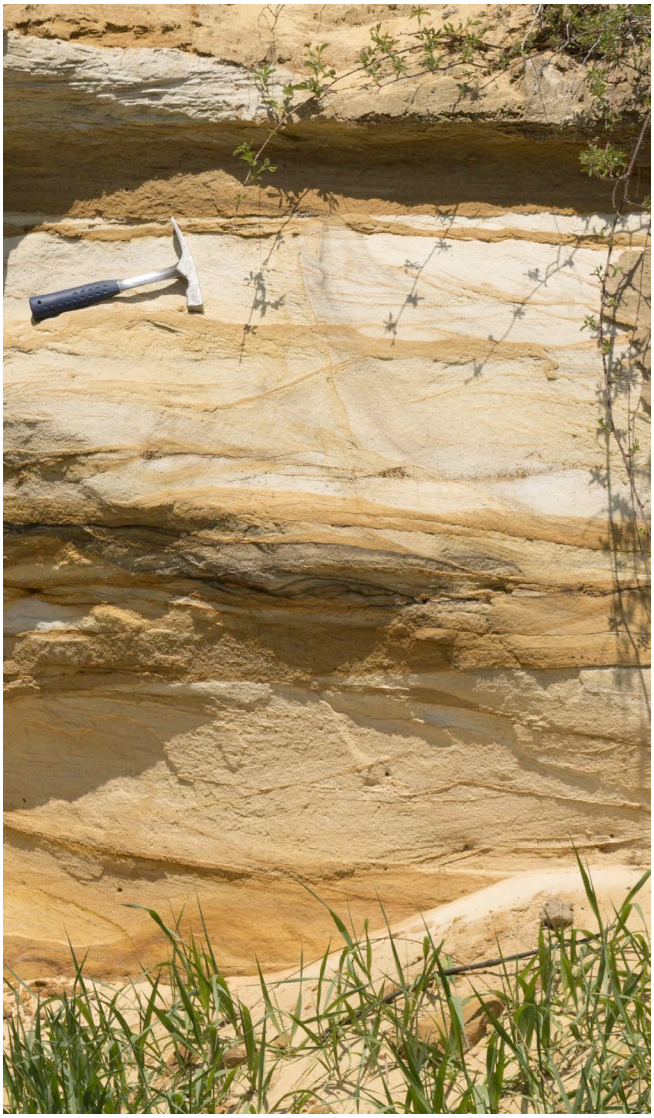

Wonewoc Formation sandstone outcrop northeast of Chapultepec, Trempealeau County, Wisconsin. This sandstone is poorly cemented and readily erodes, as seen by the pile of sand at the base of the photo.

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Acknowledgments

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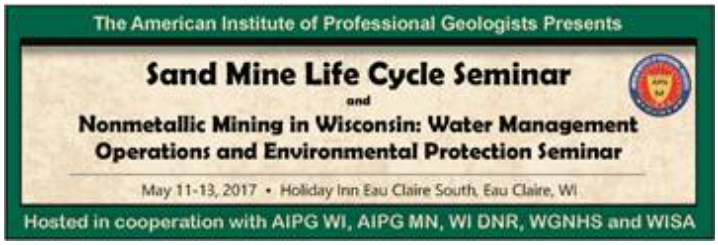

Introduction and regional geologic setting

New advances in extracting domestic unconventional oil and gas using hydraulic fracturing have significantly increased the demand for industrial (frac) sand resources. Wisconsin, the nation's largest frac sand producer, has some of the best frac sand in the country because many of the widespread Early Paleozoic (Cambrian and Ordovician) sandstone formations are near the surface and meet hydraulic fracturing proppant specifications: the grains comprising this sandstone are primarily quartz, well-rounded, spherical, and well-sorted (fig. 1; Zambito and Parsen, 2014a,b). Additionally, these sandstone deposits are close to transportation corridors (primarily rail) for shipping frac sand to unconventional plays in other states. The rapid growth in sand mining in Wisconsin has been accompanied by citizen and local government questions about the distribution of the potential resource as well as possible mining and processing impacts on local groundwater quantity and quality, and future land-use. The WGNHS is developing and distributing objective new geoscientific information— including geologic mapping—that addresses these concerns. We are currently mapping the bedrock geology of Trempealeau County, which forms the basis of this fieldtrip guidebook.

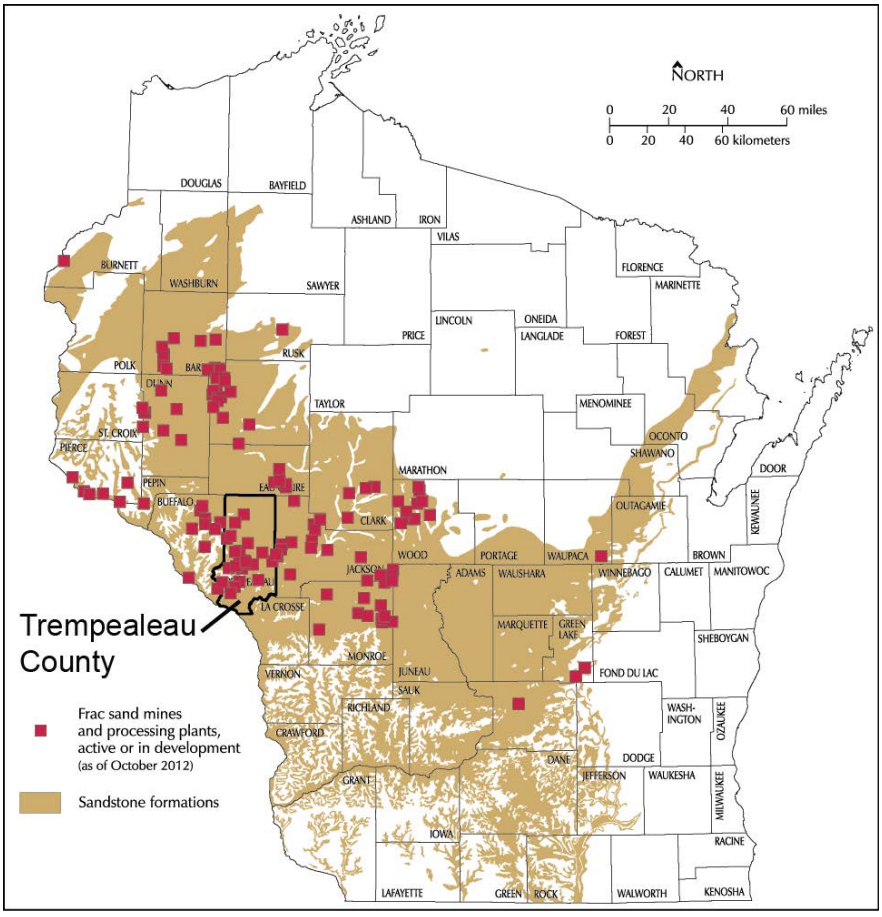

Figure 1: County map of Wisconsin showing the location of frac (industrial) sand mines and processing plants, active or in development (as of October 2012); adapted from Zambito and Parsen (2014a). The extent of sandstone formations includes Cambrian and Ordovician sandstone units that are near the surface (see WGNHS, 2013). Trempealeau County, the focus of this trip and the center of industrial sand mining in Wisconsin, is noted.

This trip is designed to showcase outcrops, mine sites, and drill core of the major rock units in the industrial sand mining region of west-central Wisconsin. Trempealeau County, in west-central Wiscosin and in the center of industrial sand mining in the state (fig. 1), is an excellent place to observe these rock units and as mentioned above is an area of active WGNHS mapping and research. We also include photographs of nearby core in order to give the reader a complete picture of these rock units in an un-weathered state, as well as the thickness of the units examined, which is integral to determining resource reserves and mapping. These units include the Cambrian Eau Claire Formation shale (fill), Wonewoc Formation sandstone (industrial sand), Tunnel City Group shale and sandstone (fill and potentially industrial sand), St. Lawrence Formation dolostone and siltstone (fill, possibly dimension stone) and Jordan Formation sandstone (industrial sand) which constitute the Trempealeau Group, and the Ordovician Prairie du Chien Group dolostone (aggregate) (figs. 2 and 3). The trip will proceed stratigraphically up-section, showing these rock units from oldest to youngest, highlighting the features that make each stratigraphic unit distinct, unit contacts, classic outcrops (fig. 4), and their natural resource potential (fig. 3).

The bedrock geology of west-central Wisconsin is comprised of a buried Precambrian surface unconformably overlain by upper Cambrian siliciclastics and, at the highest elevations, Ordovician carbonates and siliciclastics deposited near the paleoequator in predominantly shallow water settings (fig. 5). Across the area, Cambro-Ordovician units were deposited on the western slope of the Wisconsin Arch with a facies transition from shallow submarine settings in the northeast to deeper water settings in the southwest toward the Hollandale Embayment depocenter (fig. 5). The strata observed on this trip were deposited at the interface between the offshore, carbonate-dominated Great American Carbonate Bank (dolostone of the Prairie du Chien Group and of the Black Earth Member of the St. Lawrence Formation) and the nearshore, siliciclastic-dominated Inner Detrital Belt (all other stratigraphic units seen in this study). Previous researchers have studied these depositional settings and made sequence stratigraphic interpretations for both siliciclastic units (Ostrom, 1966; Ostrom and others, 1970; Dott and others, 1986; Byers and Dott, 1995; Dott, 2003; Runkel and others, 2007) and carbonate-dominated units (Smith and others, 1993). The reader is also referred to Runkel and others (2012), and references therein, for discussion of the Great American Carbonate Bank and Inner Detrital Belt, as well as the most recent chronostratigraphic summary.

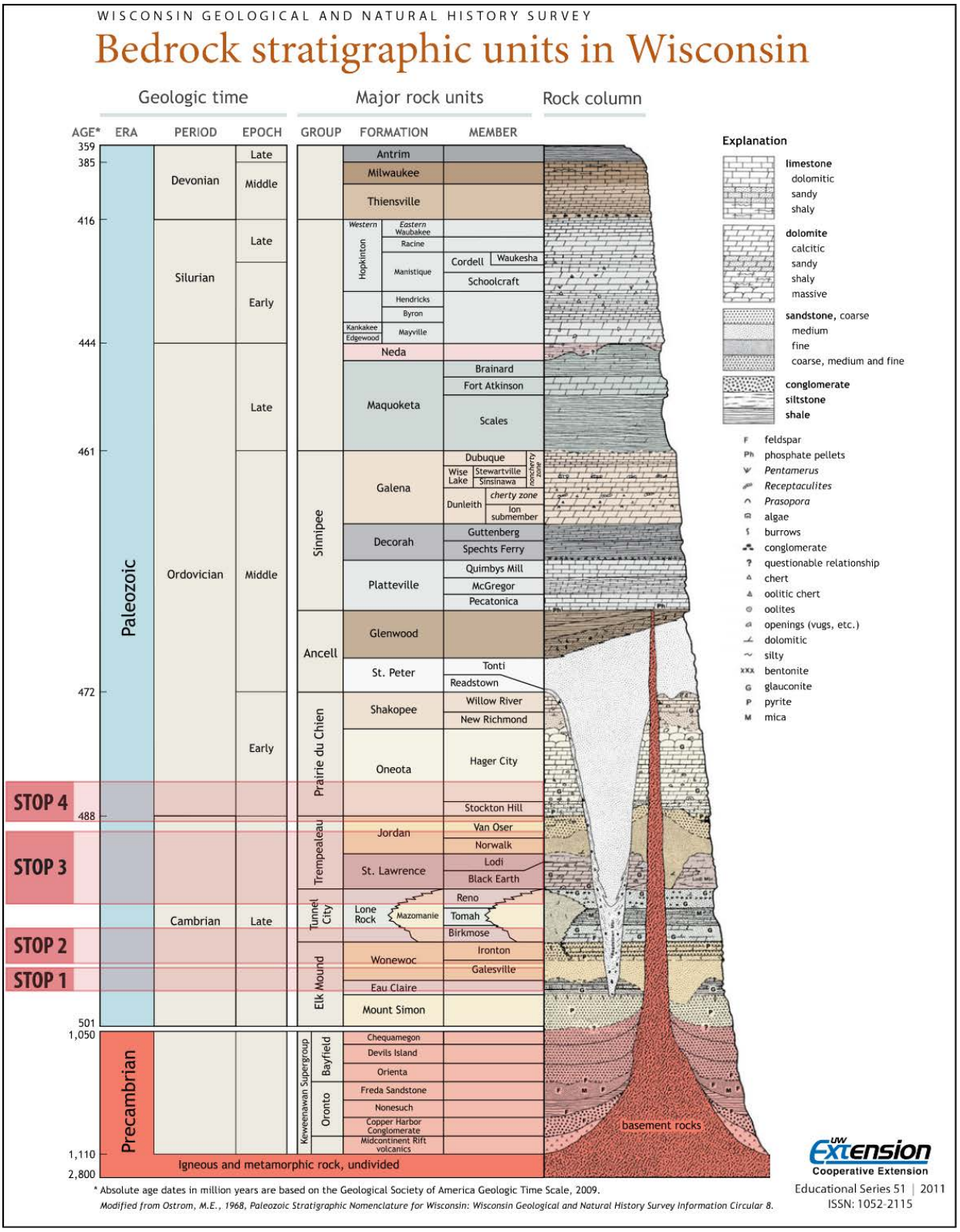

Figure 2: Generalized stratigraphic column for Wisconsin bedrock geology. Stratigraphic successions observed at each stop are shown on left. Adapted from WGNHS (2011).

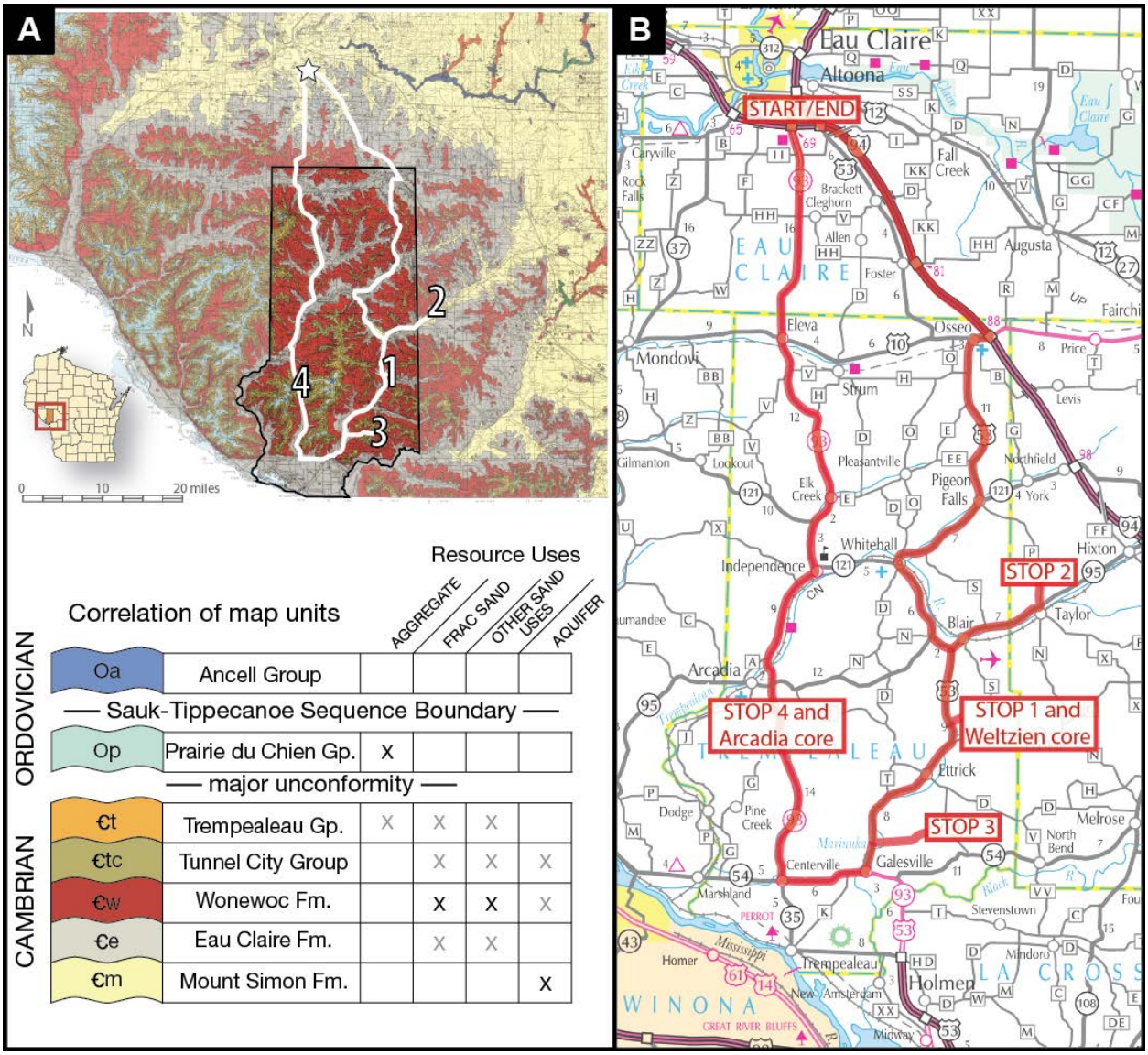

Figure 3: A) 1:250,000-scale bedrock geology map for west-central Wisconsin (Brown, 1988) showing the route (white line), fieldtrip starting point (white star), and fieldtrip stops (white numbers) along with the border of Trempealeau County (black line), the center of large-scale industrial sand mining in Wisconsin. Trempealeau County has abundant industrial sand and ample aggregate resources; black X's indicate common uses and high extraction rates for the designated purposes, gray X's indicate less common uses and lower rates of extraction, such as pits/quarries on farms. B) Wisconsin State Highway Map (showing the location of Stops 1-4 and the WGNHS Weltzien and Arcadia Quarry cores. Adapted from Wisconsin Department of Transportation (2017).

Figure 4: Type section of the Galesville Member of the Wonewoc Formation, High Cliff Park along Beaver Creek in Galesville, Wisconsin. Picture was taken in early spring. The contact between the Wonewoc Formation and the underlying Eau Claire Formation can be difficult to recognize because the bluff is highly weathered and the outcrop surface case-hardened. Ostrom (1966, 1970) and Ostrom and others (1970) observation of ~15 feet relief on this contact is based on exposures to the left of the area shown.

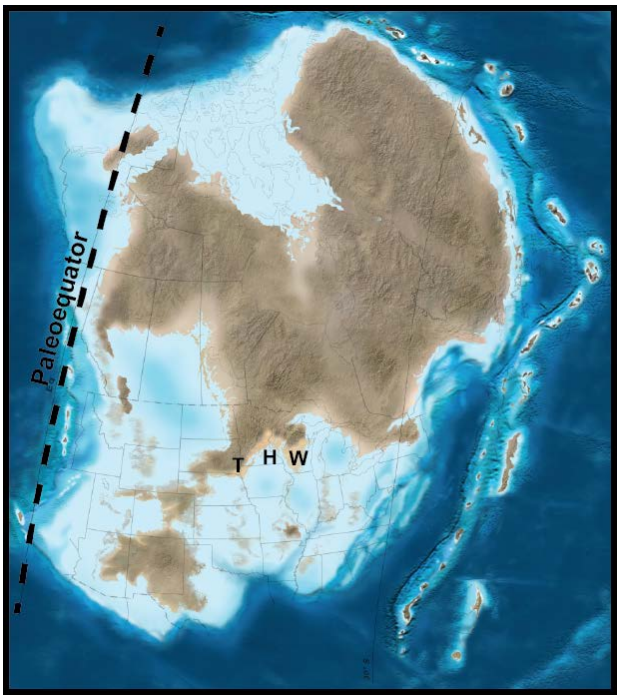

Figure 5: A) Paleogeographic setting for the Cambrian and Ordovician of North America. T, H, and W represent the Transcontinental Arch, Hollandale Embayment, and Wisconsin Arch, respectively. Adapted from Blakey, 2014. © Ron Blakey, Colorado Plateau Geosystems, rblakey@cpgeosystems.com, www.cpgeosystems.com

Road log, in miles (see fig. 3 for fieldtrip stops and fig. 2 for strata observed at each stop)

0.0 Trip begins at Holiday Inn Eau Claire South.
Head northeast on Owen Ayres Court toward Bullis Farm Road.
Turn left onto Bullis Farm Road.
0.3 Turn left onto Keystone Crossing.
0.7 Turn right onto Golf Road.
1.0 Turn right to merge onto US-53 S toward I-94.
2.0 Take Exit 84A for I-94 E toward Madison/Chicago.
18.8 Enter Trempealeau County.
20.0 Take Exit 88 for US-10 W toward Osseo/Fairchild.
21.0 Turn left onto US-53 S/Harmony Street.
26.4 Exposure of the Wonewoc Formation and Tunnel City Group north of Bye-Nelson Road.
26.8 Wayside.
27.7 Exposure of the Wonewoc Formation and Tunnel City Group north of Hagen Road.
28.4 Exposure of the Wonewoc Formation.
29.3 Exposure of the Wonewoc Formation at intersection with County EE.
29.9 Exposure of the Wonewoc Formation.
30.2 Exposure of the Wonewoc Formation at intersection with Arts Road.
32.1 Enter Village of Pigeon Falls.
36.6 Pass through Coral City.
38.6 Intersection with County Road D; road to the Village of Strum.
38.9 Enter City of Whitehall, Trempealeau County seat.
39.0 Cross Trempealeau River, follow US-53 S.
40.2 Exposure of the Eau Claire Formation.
42.1 Exposure of the Wonewoc Formation at intersection with Dubbert Road.
42.9 Industrial Sand Mine (Sand Products of WI) on west side of US-53. Exposures of the Wonewoc Formation and Tunnel City Group.
44.2 Looking to the east, another Industrial Sand Mine is visible (Preferred Sands of Wisconsin).
45.2 Intersection with WI-95.
46.4 Enter City of Blair.
49.2 Exposure of the Wonewoc Formation.
49.3 Exposure of the Wonewoc Formation at the intersection of Lone Star Road.
49.5 Excellent exposure of the Wonewoc Formation and Tunnel City Group strata exposed along 0.8 mile-long road cut.
51.2 Looking to the east, small natural outcroppings of the Wonewoc Formation.
51.5 Turn left onto Bear Creek Road.
52.2 **Stop 1: Bear Creek Road Shale Pit (44.225649°, -91.233921°)**
52.2 Turn around and head back to US-53.
52.7 Turn right onto US-53 N.
57.7 Turn right onto WI-95 E.
58.1 Turn left to stay on WI-95 (drive by lunch stop at gas station).
58.7 Exposure of the Eau Claire Formation along the Trempealeau River.
61.9 Intersection with County Road W, industrial sand mine and transload facility to the south (Hi-Crush Blair/Taylor Frac).
62.2 Enter Jackson County.
64.0 Looking to the north, industrial sand mine (Taylor Frac).
64.7 Turn left onto County Road P.
65.4 Railroad spur for rail cars off to the right.
65.6 Badger Mining Corporation Office.
Stop 2: Badger Mining Corporation Taylor Sand Plant (44.355477°, -91.129706°)
65.6 Return to WI-95 (head South on County Road P) and turn left onto Gilbert Street on the west side of Lake Henry in Blair, and take another left into Memorial Park.
73.2 **Lunch Stop at Memorial Park, City of Blair.**

73.2 Return to WI-95 W and go through Blair to the intersection of WI-95 and US-53.
73.3 Head south on US-53 toward Bear Creek Road.

78.3 Intersection with Bear Creek Road.
78.7 Exposure of the Eau Claire and Wonewoc Formations on west side of road.
79.3 Exposures of the Wonewoc Formation, including natural outcroppings.
82.2 Exposure of the Wonewoc Formation.
82.4 Pass through the Village of Ettrick; the intersection with County Road D.
85.6 Pass through Frenchville; intersection with County Road TT, near T.
88.6 Turn left onto Crystal Valley Road (County Road TTT). *Drive slowly*: this is a windy road with dump truck traffic from the aggregate quarry (Prairie du Chien Group) at the top of Peacock Hill.
91.2 Stay right on Crystal Valley Road at intersection with Cory Road.
91.3 Exposure of the Wonewoc Formation.
92.6 **Stop 3: Crystal Valley Road Shale Pit and road cut (44.116752°, -91.265486°)**
92.6 Return to US-53 (head west on Crystal Valley Road).
96.7 Turn left onto US-53 S toward Galesville.
97.8 Enter the City of Galesville.
98.7 Looking to the east, the type section of the Galesville Member (lower Wonewoc Formation) is exposed in the bluff along Beaver Creek (fig. 4). Ostrom (1966, 1970) and Ostrom and others (1970) observed relief of ~15 feet at the contact between the Galesville Member of the Wonewoc Formation and the underlying Eau Claire Formation at this locality.
99.0 Turn right onto WI-93 N / WI-54 W toward Centerville.
103.9 Enter Centerville.
104.2 Turn right to stay on WI-93 N toward Arcadia.
109.6 Exposure of the Wonewoc Formation at the intersection with German Coulee Road.
112.0 Exposure of the Wonewoc Formation at the intersection with Norway Valley Road.
113.7 **Stop 4: Wisconsin Route 93 road cut (44.198910°, -91.460394°)**
113.7 Continue north on WI-93 N toward Arcadia.
114.7 Scenic overlook.
115.1 Exposure of the Prairie du Chien Group.
115.3 Exposure of the Prairie du Chien Group.
115.6 Exposure of the Prairie du Chien Group (Stockton Hill Member of the Oneota Formation) overlying the Jordan Formation.
116.2 Exposure of the Tunnel City Group and the Black Earth Member of the St. Lawrence Formation to the east; location of the 62000213 WGNHS Lockington core.
116.4 Enter the City of Arcadia.
116.9 Pass by Arcadia Family Restaurant (immediately to the east; excellent diner food) and Draft Horse Inn and Suites (0.5 miles to the west; reasonable rates and friendly owners).
117.5 Intersection with WI-95; continue straight on WI-93 N.
From here to Eau Claire the WGNHS has not yet mapped the outcrops exposed along the roadside; this will be part of the second and final year of mapping Trempealeau County.
125.3 Enter the City of Independence.
126.0 Pass by Bushy's Meat Market (delicious Polish sausage, natural casing wieners, and coffee cake).
126.1 Cross Trempealeau River.
131.0 Enter Elk Creek.
142.7 Enter Village of Eleva.
144.5 Enter Eau Claire County, continue north on WI-93.
155.0 Cross County Road II.
156.5 Intersection with I-94, continue north on WI-93.
157.1 Enter the City of Eau Claire.
157.2 Turn right onto Golf Road.
158.4 Turn right onto Keystone Crossing.
158.6 Turn right onto Bullis Farm Road.
158.9 Turn right onto Owen Ayres Court. Trip ends at Holiday Inn Eau Claire South.

Stop 1: Bear Creek Road Shale/Sand Pit (44.225649°, -91.233921°)

This stop is in an inactive/abandoned shale/sand pit that shows the contact between the Cambrian Eau Claire Formation and the overlying Cambrian Wonewoc Formation (fig. 6). The upper Eau Claire Formation at this section consists of interbedded mudstone and glauconitic sandstone. Hummocky cross-stratification, burrows, tool marks, and disarticulated lingulid brachiopod shells are common and suggest deposition above storm-wave base. The contact with the sandstones of the overlying Wonewoc Formation appears abrupt, though the red (iron oxide) quartz sandstone sharply overlying the shale and sandstone of the Eau Claire Formation has trace amounts of glauconite. It is not clear if this glauconite was eroded from the underlying Eau Claire Formation and re-deposited as part of Wonewoc Formation sandstone, or if the lowest sandstone is genetically related to the Eau Claire Formation and represents a coarsening-upward, transitional Eau Claire–Wonewoc succession. Approximately 50 centimeters above the shale-sandstone contact is a red quartz sandstone with *Skolithos* burrows and leisegang banding; this bed is certainly within the Wonewoc Formation (fig. 6e). The Wonewoc Formation is a poorly-cemented, well-sorted medium- to coarse-grained quartz sandstone with green and gray shale partings. Large sets of swaley and trough cross-stratification are common suggesting deposition in a nearshore setting above normal-wave base. A core drilled nearby to the south (62000216 WGNHS Weltzien Quarry) and one to the west (62000166 WGNHS Arcadia Quarry) recovered this contact and are shown in figures 7 and 8. In these cores, the contact between the Eau Claire and Wonewoc Formations is abrupt in the WGNHS Weltzien Quarry core (fig. 7), which may not have been recovered completely due to the friable nature of the Wonewoc Formation, and appears more transitional in the WGNHS Arcadia Quarry core (fig. 8). The Wonewoc Formation is up to 150 feet thick in Trempealeau County and is the primary unit extracted for industrial (frac) sand (fig. 3). The Eau Claire Formation is ~120 feet thick in Trempealeau County and serves as the regional aquitard above the Mount Simon Formation aquifer.

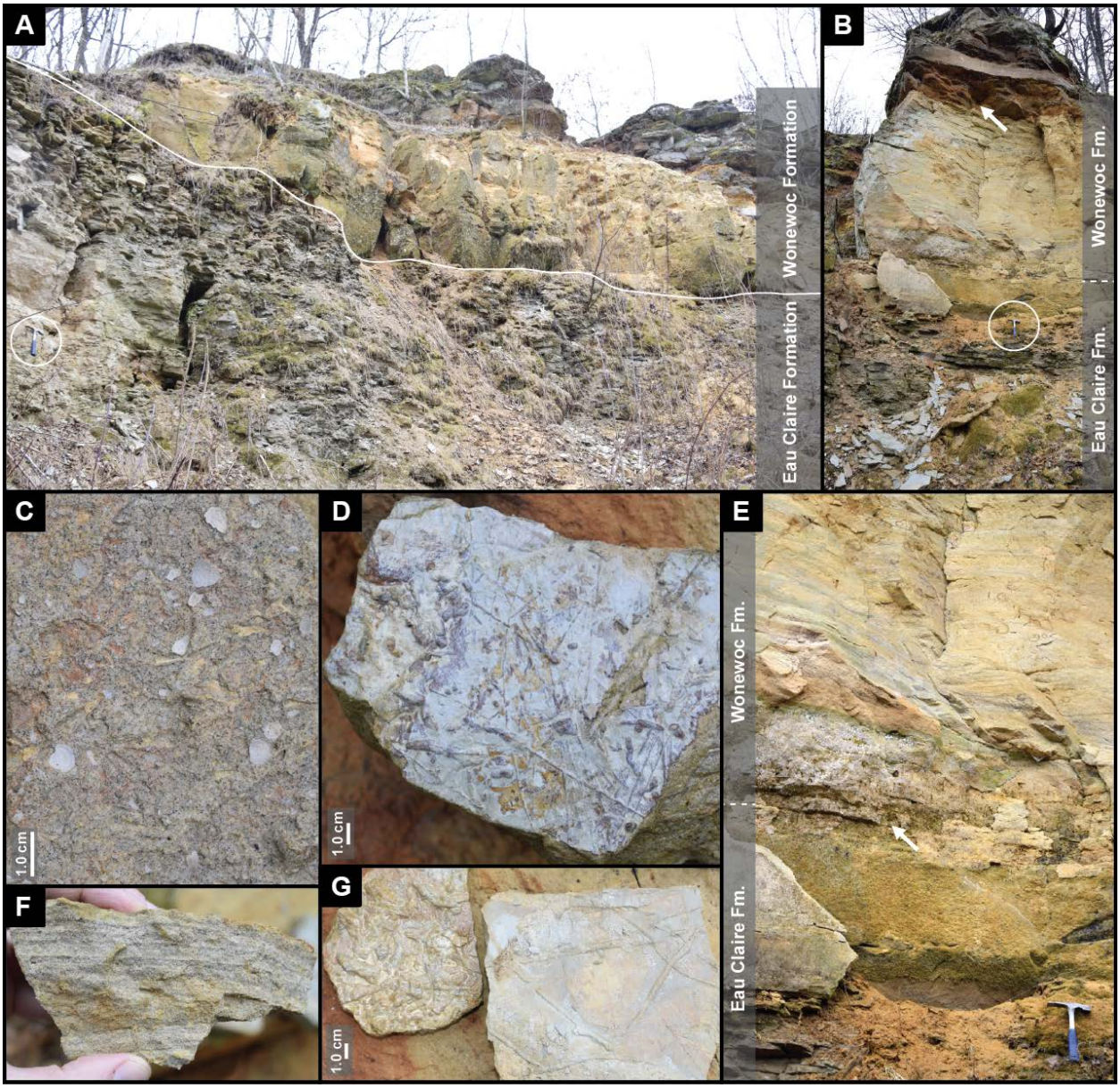

Figure 6: Eau Claire and Wonewoc Formations, Stop #1: Bear Creek Road Shale/Sand Pit (44.225649°, -91.233921°). A) Overview photo showing shale-dominated Eau Claire Formation and sandstone-dominated Wonewoc Formation (hammer in white circle for scale). B) View of same interval shown in part A from another part of the locality (hammer in white circle for scale). Note iron oxide-rich interval near top of outcrop (white arrow), a common feature of the Wonewoc Formation sandstone when near overlying regolith/soil. C) Phosphatic brachiopods in glauconitic quartz sandstone of the Eau Claire Formation (float). D) Tool marks and burrows on the underside of shaly sandstone of the Eau Claire Formation (float). E) Close-up picture of the contact between the Eau Claire and Wonewoc Formations (hammer for scale). The uppermost Eau Claire Formation is a quartz sandstone with rare glauconite grains; we tentatively place the contact at the base of a *Skolithos* burrowed quartz sandstone (white arrow). F) Cross-bedded glauconitic quartz sandstone typical of the Eau Claire Formation (float). G) *Palaeophycus* traces on the base of shaly sandstone-siltstone of the Eau Claire Formation (float).

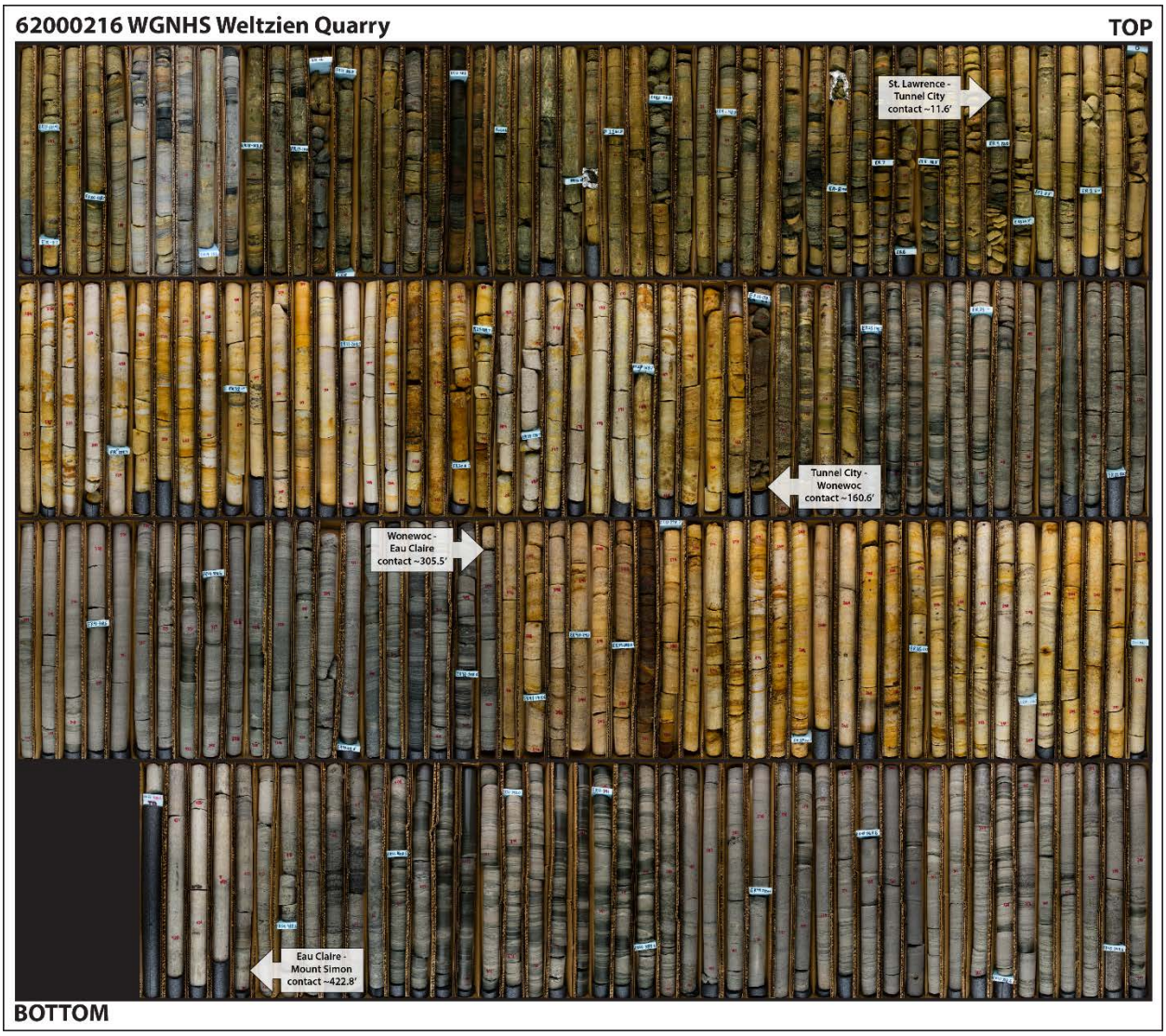

Figure 7: Photographs of core 62000216 WGNHS Weltzien Quarry drilled south of Ettrick, Wisconsin (near Stop 3). Units observed in this core include the basal St. Lawrence Formation (Trempealeau Group), Lone Rock Formation (Tunnel City Group), Wonewoc Formation, Eau Claire Formation, and the uppermost Mount Simon Formation. Each core box column is ~2 feet; blue place holders indicate end runs during drilling.

Figure 8: Photographs of core 62000166 WGNHS Arcadia Quarry drilled south of Arcadia, Wisconsin (near Stop 4). Units observed in this core include the basal Prairie du Chien Group, Jordan Formation and St. Lawrence Formation (Trempealeau Group), Lone Rock Formation (Tunnel City Group), Wonewoc Formation, and the uppermost Eau Claire Formation. Each core box column is ~2 feet; blue place holders indicate end runs during drilling.

Stop 2: Badger Mining Corporation Taylor Sand Plant (44.355477°, -91.129706°)

This stop will focus on the industrial sand mine north of Taylor that is operated by Badger Mining Corporation. Because of proprietary information, we do not discuss this stop herein in detail. More information can be found at: http://badgerminingcorp.com/. The units present at this site include the Wonewoc Formation, mined for its compositionally and texturally uniform quartz sand, and the Lone Rock Formation (Tunnel City Group).

Stop 3: Crystal Valley Road Shale Pit/Quarry and Road Cut (44.116752°, -91.265486°)

At this stop, the Lone Rock Formation (Tunnel City Group) and the Trempealeau Group (St. Lawrence and Jordan Formations) are accessible (fig. 9). This succession is typically not exposed and rarely quarried in west-central Wisconsin so this exposure is a rare window into this portion of the Paleozoic succession. The uppermost Lone Rock Formation is exposed at the level of Crystal Valley Road. These rocks consist of interbedded glauconitic medium- to coarse-grained sandstone, tan and green mudstone, and flat pebble conglomerates (fig. 9b). Hummocky cross-stratification is common, and similar to the Eau Claire Formation the depositional setting was above storm-wave base. The overlying St. Lawrence Formation is composed of the interbedded lithologies of the Black Earth Member (green and buff to tan glauconitic and thrombolitic – clotted texture from microbialites – dolostone) and the Lodi Member (buff to tan thin planar-bedded siltstone and sandy dolostone) as shown in figure 9a and b, deposited in offshore 'moat' settings marginal to the 'Great American Carbonate Bank' facies. The Jordan Formation is present at the top of this outcrop but poorly exposed; it is better exposed and discussed in detail at Stop 4. Pieces of the overlying Prairie du Chien Group were found in float. In Trempealeau County the Lone Rock Formation is ~150 feet thick; the Trempealeau Group (St. Lawrence and Jordan Formations) is ~125 feet thick. The core 62000216 WGNHS Weltzien Quarry was drilled just to the northeast of this outcrop (fig. 7).

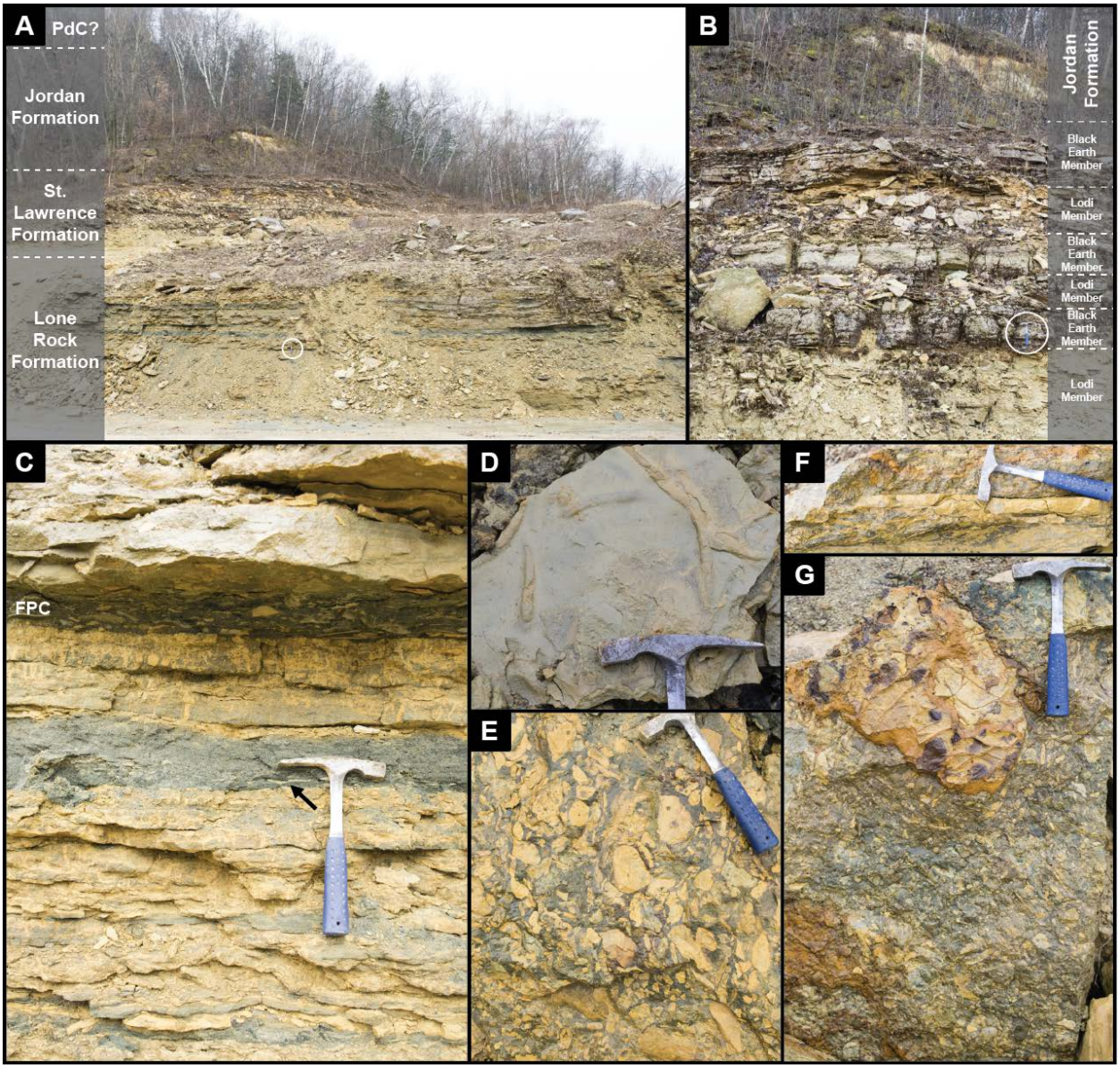

Figure 9: Lone Rock, St. Lawrence, and Jordan Formations, as well as possibly the Prairie du Chien Group (inaccessible), Stop #3: Crystal Valley Road Shale Pit/Quarry and Road Cut (44.116752°, -91.265486°). A) Overview photo (hammer in white circle for scale, PdC = Prairie du Chien Group). B) Picture of the St. Lawrence Formation showing interbedded dolostone of the Black Earth Member and dolomitic silty sandstone of the Lodi Member (hammer in white circle for scale). C) Typical Lone Rock Formation lithologies (hammer for scale) including bioturbated glauconitic sandstone (throughout; abundant immediately above hammer), flat pebble conglomerate (FPC), and rip-up clasts (black arrow). D) *Palaeophycus* burrows on the base of a piece of shaly glauconitic sandstone of the Lone Rock Formation found in float (hammer for scale). E) Fresh, bedding-parallel face of a flat pebble conglomerate (float) showing tan-colored mudstone chips within a matrix of glauconitic sandstone (hammer for scale). F,G) Flat pebble conglomerate (float) shown perpendicular to bedding (F) and parallel to bedding (G); presence of large re-worked clasts suggest high-energy (storm) conditions during deposition (hammer for scale).

Stop 4: Wisconsin Route 93 Road Cut (44.198910°, -91.460394°)

This road cut exposes the Cambrian Jordan Formation and the overlying Ordovician Prairie du Chien Group (fig. 10; see also stop description in Ostrom and others, 1970). The upper Jordan Formation is an orange and white coarse-gained sandstone with abundant trough cross-stratification indicative of inner detrital belt deposition; silica cements are common near the top of this unit as are calcite-cemented concretions ranging from centimeters to decimeters (fig. 10c and d). The lower Jordan Formation is poorly exposed, is finer-grained, and appears transitional with the underlying St. Lawrence Formation in drill core (fig. 8). Prairie du Chien Group strata exposed at this stop include the Stockton Hill Member and the Hager City Member of the Oneota Formation. The interbedded dolostone, friable white quartz sandstone, and green mudstone of the Stockton Hill Member sit unconformably on the well-cemented sandstone of the uppermost Jordan Formation. The overlying Hager City Member is a buff to tan-colored stromatolitic thin- to thick-bedded sandy dolostone with white to cream-colored silica (chert) nodules. A core (62000166 WGNHS Arcadia Quarry) drilled within the aggregate quarry immediately to the east of this road cut also contains these units (fig. 8). The Jordan Formation is ~50 feet thick in this area and is typically only present where the overlying Prairie du Chien Group occurs. Although it is a coarse-grained quartz sandstone, silica and carbonate cements and the relative thinness of this unit locally make this a less suitable sandstone for industrial sand uses; however, it is an important source of industrial sand to the west along the Mississippi and in Minnesota.

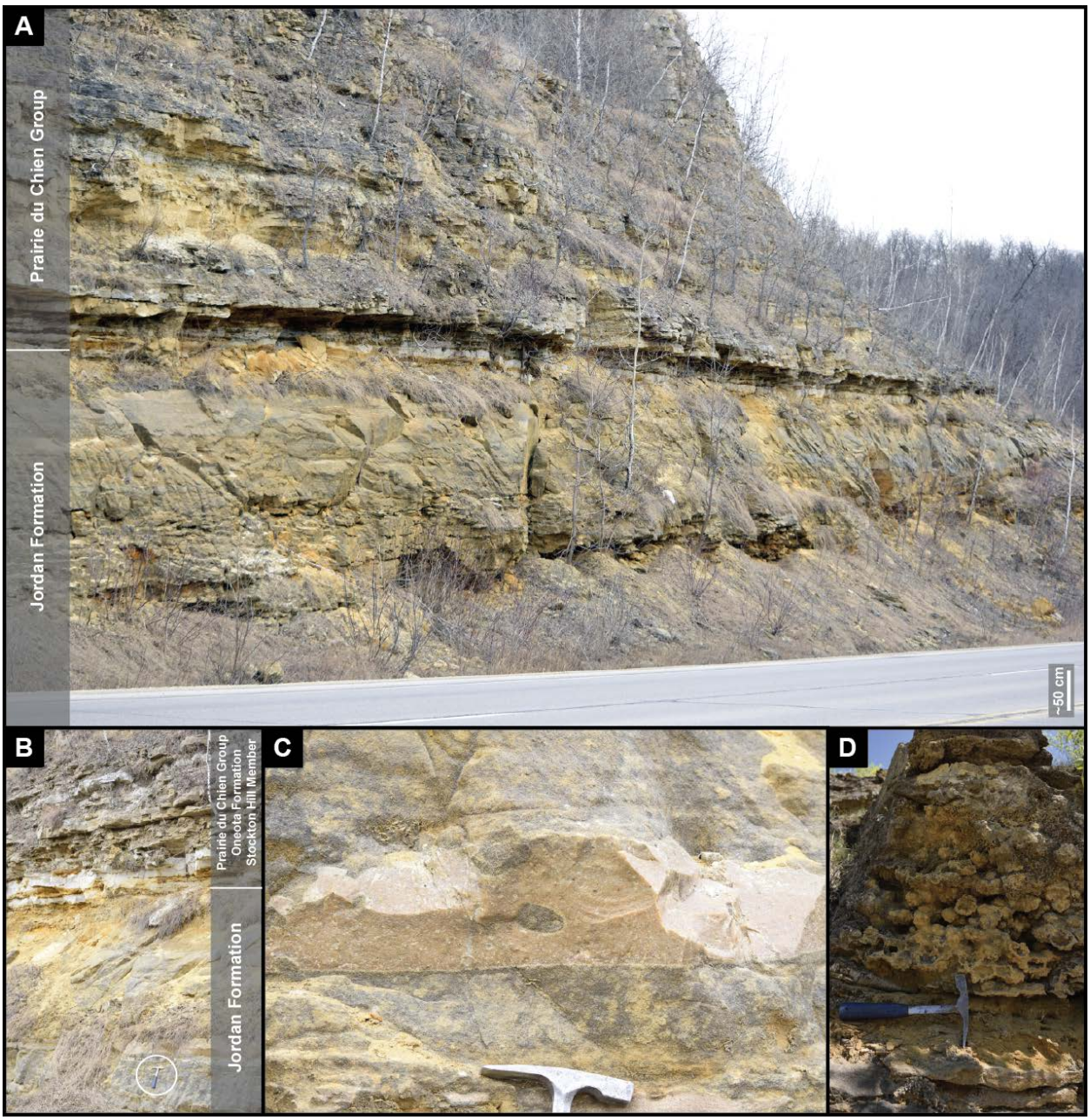

Figure 10: A, B, C) Outcrop of the contact between the Jordan Formation and the Prairie du Chien Group, Stop #4: Wisconsin Route 93 Road Cut (44.198910°, -91.460394°). A) Overview photo. B) Close-up of contact showing orange quartz sandstone of the Jordan Formation overlain by interbedded white quartz sandstone and buff dolostone of the Stockton Hill Member, Oneota Formation, Prairie du Chien Group (hammer in white circle for scale). C) Photo of silica nodule (chert, note conchodial fracturing) cementing quartz sand grains in the Jordan Formation (hammer for scale). D) Calcite concretions in the Jordan Formation, south of Hegg, Wisconsin (hammer for scale).

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