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Field trip: Cambrian and Ordovician stratigraphy of southwestern Wisconsin

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Contents:

- Report (23 p.)

Field trip:
Cambrian and Ordovician Stratigraphy of Southwestern Wisconsin

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Silicified domal stromatolite in the Oneota Formation at Shorewood Hills Quarry, Dane County, Wisconsin.

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INTRODUCTION AND GEOLOGIC SETTING

This trip highlights Cambrian through Middle Ordovician rocks of southwestern Wisconsin (fig. 1) in both outcrop and core; these include the primary aggregate and industrial sand resources of the region, as well as serve as primary aquifers and aquitards. We discuss facies and corresponding lithology changes related to the Wisconsin Arch as well as dramatic erosional landscapes that formed during the Paleozoic. Participants will have the opportunity to collect Ordovician fossils and observe well-preserved sedimentary fabrics and microbial structures.

The Cambrian–Ordovician succession in the Upper Mississippi River Valley has long been used as a North American stratigraphic standard, with many rock unit names from Wisconsin used throughout the upper Midwest (fig. 2). The Cambrian and Ordovician strata of the Upper Mississippi River Valley were deposited between 0 and 30 degrees south paleolatitude (fig. 3). This stratigraphic succession records deposition of the inner detrital (sandstone and shale) and carbonate belts (see Runkel and others, 2017). In southwest and western Wisconsin, accommodation space existed in the Hollandale Embayment, which was bordered on its western side by the Transcontinental Arch and to the east by the Wisconsin Arch, a broad feature separating the Hollandale Embayment from the Michigan Basin (fig. 3).

On this trip we will be seeing the transition from nearshore sandstone, to offshore (below storm-wave base) sandstone and shale deposited in a clastic trap, to platform carbonates deposited outboard of the clastic trap (Runkel and others, 2012, and references therein). While the clastic trap existed during the Cambrian, by Ordovician time it was filled and transgressing sea level moved the carbonate depositional belt across Wisconsin. A major Ordovician regression and subsequent transgression, recorded in the high-paleorelief unconformity at the base of the St. Peter sandstone and the deepening upward, non-marine to marine succession of facies observed within the St. Peter, is the local representation of the Sauk–Tippecanoe megasequence (see references below for more details).

The stops on this trip show a range of depositional environments including subaerial silcretes, eolian and shallow marine sandstones, oolitic shoals, siliciclastics and fossil-rich carbonates deposited by storm activity, offshore and tidal-zone microbialites, and quiet water offshore mudstones. For most stops, we include photographs of cores from nearby and/or relevant wells. We include these cores because they are a useful source of geological information in glaciated parts of Wisconsin since bedrock exposure in these areas is typically limited. Cores are also valuable in the Driftless Area, where bedrock outcrops have undergone weathering for millions of years, often resulting in case hardening (mineral precipitation on the outcrop surface that masks the true mineralogy and sedimentary structures). In contrast to outcrops, cores provide useful unweathered sample material and typically include formation contacts which are necessary for mapping.

Readers are referred to the following resources (and references therein) for more detailed information on the Cambrian–Ordovician succession of the Upper Mississippi River Valley:

McLaughlin, P.I., Emerson, N., Witzke, B., Sell, B., and Emsbo, P., 2011, Distal signatures of Late Ordovician oceanic anoxia—New data from a classic epeiric ramp transect, *in* Miller, J.D., Hudak, G.J., Wittkop, C., and McLaughlin, P.I., eds., Archean to Anthropocene: Field guides to the geology of the mid-continent of North America: Geological Society of America Field Guide 24, p. 259–284, doi:10.1130/2011.0024.

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*, vol. 119, no. 7–8, p. 860–881.

Runkel, A.C., McKay, R.M., Cowan, C.A., Miller, J.F., and Taylor, J.F., 2012, The Sauk megasequence in the cratonic interior of North America: Interplay between a fully developed inner detrital belt and the central great American carbonate bank, *in* Derby, J.R., Fritz, R.D., Longacre, S.A., Morgan, W.A., and Sternbach, C.A., eds., The great American carbonate bank: The geology and economic resources of the Cambrian–Ordovician Sauk megasequence of Laurentia: AAPG Memoir 98, p. 1001–1011.

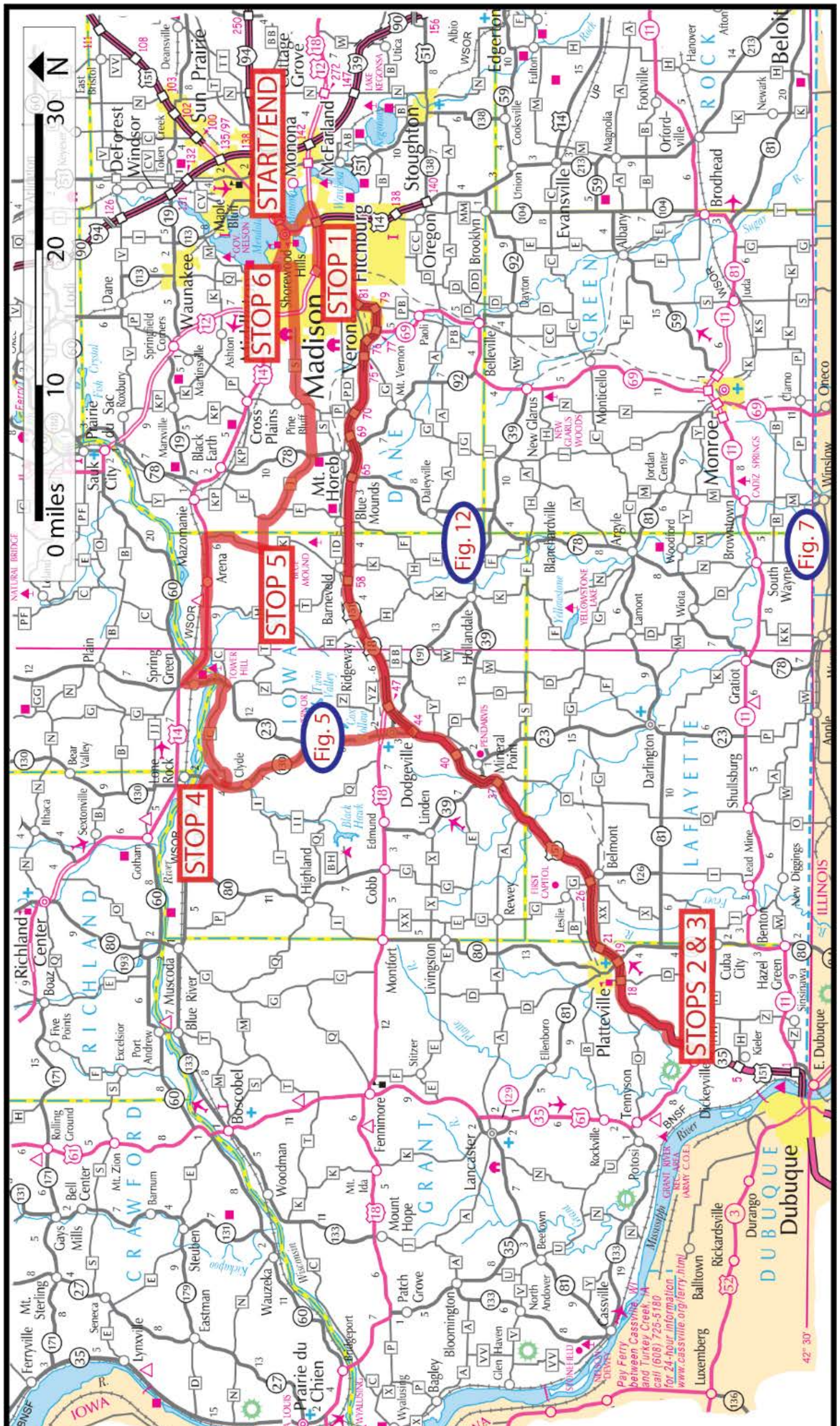

Figure 1: Wisconsin State Highway Map showing the location of Stops 1-6 (red rectangles) and some of the cores discussed in this guidebook (blue ovals). Adapted from Wisconsin Department of Transportation (2017).

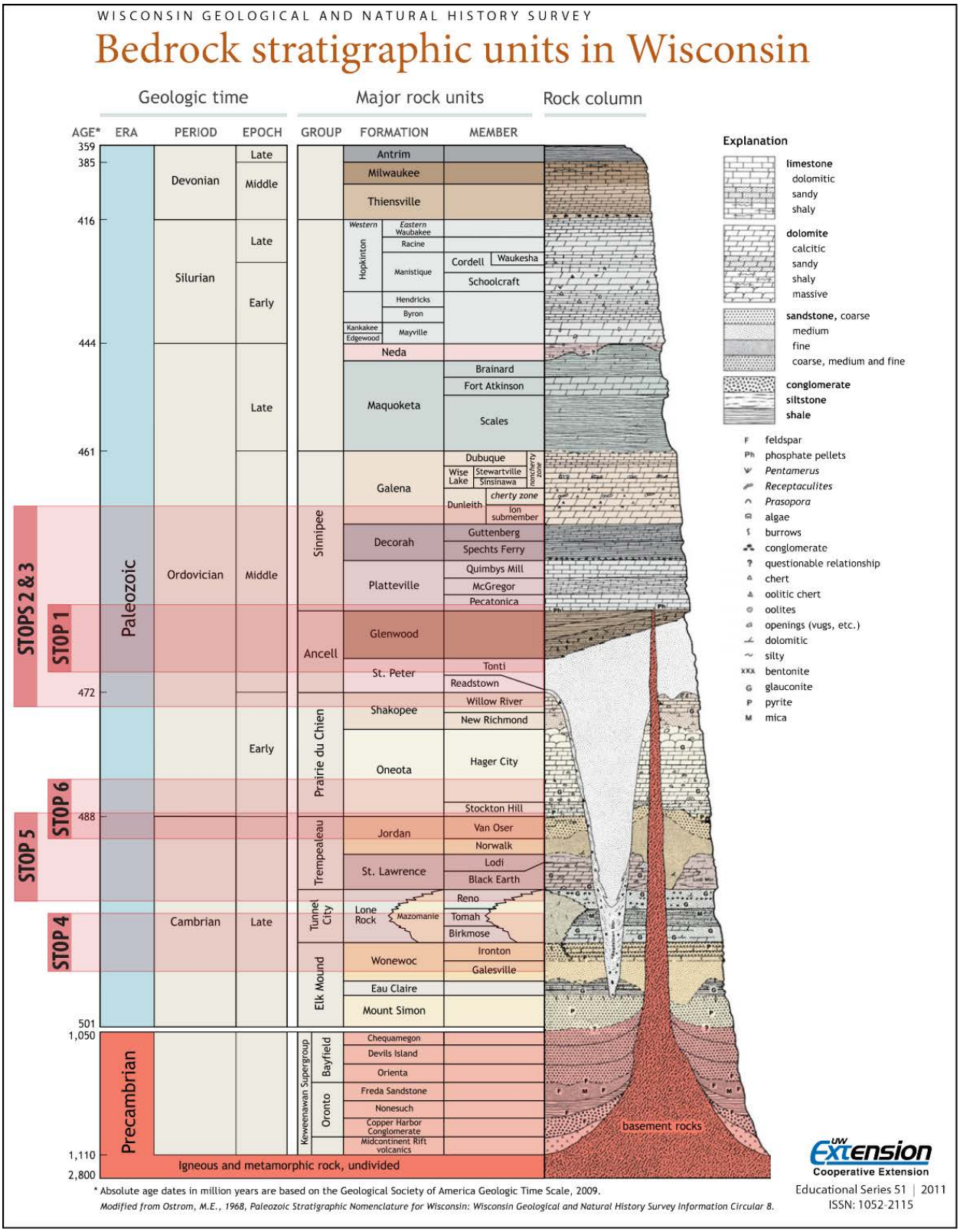

Figure 2: Generalized stratigraphic column for Wisconsin bedrock geology. Stratigraphic successions observed at each stop are shown on left. Adapted from WGNHS (2011).

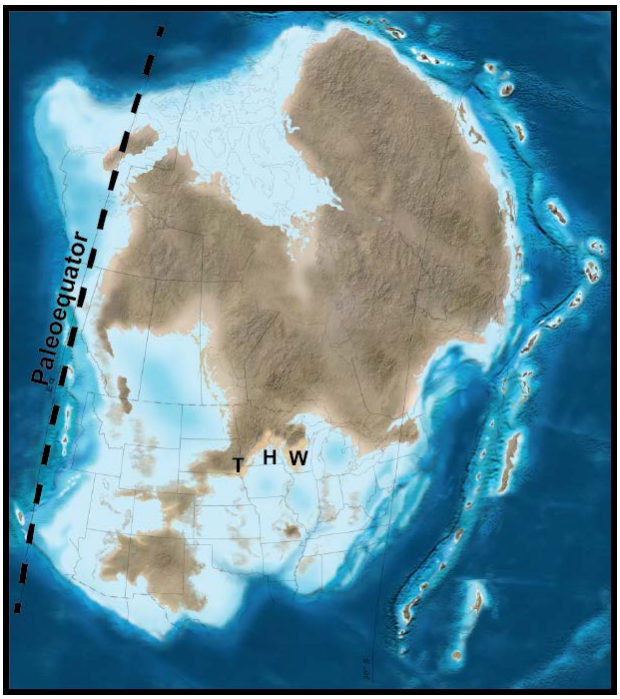

Figure 3: A) Paleogeographic setting for the Cambrian and Ordovician of North America. T, H, and W represent the Transcontinental Arch, Hollandale Embayment, and Wisconsin Arch, respectively. Adapted from Blakey, 2014. © Ron Blakey, Colorado Plateau Geosystems Inc., rblakey@cpgeosystems.com, www.cpgeosystems.com

ROAD LOG

Depart from Monona Terrace Convention Center

-Turn left onto John Nolen Drive.
-Follow John Nolen Drive to US-12/18 W & US-151 S.
-Exit at US-151 S. Follow US-151 S to McKee Rd, turn right on McKee and then left on Nesbitt.
-Turn right on Limestone Lane.

STOP 1: Outcrop just northwest of intersection of Nesbitt Road and Limestone Lane, Fitchburg, Wis. At this outcrop, the contact between the Ordovician St. Peter Formation and overlying Platteville Formation is well-exposed.

-Continue on Limestone Lane to Fitchrona Rd, turn right on Fitchrona and then right on McKee Rd.
-Take US-151 S toward Dubuque, Iowa. The majority of this highway runs along Military Ridge (Platteville-Galena cuesta) that is the drainage divide between the Wisconsin River watershed to the north and the Pecatonica and Rock River watersheds to the south.
-Around Exit 75 you will cross into the Driftless Area of Wisconsin, a region where valleys were cut by streams over the last several million years, instead of by ice during the last 20,000 years, as in the rest of the state.
-Exits 69 and 65 are for Mount Horeb, Wis. The WGNHS has a Research Collections and Education Center in Mount Horeb where the majority of bedrock and glacial core holdings are stored and studied. Tours and research visits are available by appointment.
-Around mile marker 63 you can see the western Blue Mound, which is capped by highly silicified Silurian-age rocks. Caves in this area are in the Galena Formation. This is the northeastern edge of the lead-zinc mining district.
-Around mile marker 58 you will see large road cuts in the Galena Formation exhibiting variable degrees of dolomitization and oxidation.

-From mile markers 55 to 44 are road cuts of the Galena Formation.
-Around mile marker 47 there are old spoil piles from small lead-zinc surface mines to the south of the highway.
-Around mile marker 43, the Belmont and Platte Mounds, capped by Silurian outliers, become visible to the North.
-From mile markers 40 to 37 are road cuts in the Sinnipee Group, including slumping in the Galena that is likely attributed to regional dissolution associated with MVT emplacement and more recent karst development.
-Around mile markers 35 to 33, the highway goes through a valley of eroded St. Peter Formation; coming uphill on the west side of the valley there is a road cut showing the contact between the St. Peter and Platteville Formations.
-Both the Belmont and Platte Mounds are visible to the north at mile marker 28. Although capped by Silurian strata like Blue Mounds, the Silurian of these mounds is not silicified. The large white letter "M" on Platte Mound was completed in 1937 to represent Platteville Miners and the former School of Mines in Platteville.
-At mile marker 10 is the large Dickeyville road cut, our second stop. Proceed to exit 8 and return on US-151 N to examine the road cut along the northbound lanes.

STOP 2: Road cut on both sides of US-151 just northeast of exit 8 (Dickeyville, Wis.) through the Ordovician Platteville, Decorah, and Galena Formations. ***Caution – Traffic is going 70 mph!***

-Continue on US-151 N and in less than a mile, take a left on Church Road. Church Road Quarry is approximately 3,000 feet down this road on the left-hand side.

STOP 3: Church Road Quarry exposing the fossiliferous Ordovician Platteville Formation.
NOTE: This stop is on private property; permission from the landowner is necessary for access.

-Return to US-151 N and head back toward Dodgeville.
-Take exit 44 for WI-23 N through Dodgeville.
-Turn left on WI-130 N shortly after passing the entrance to Governor Dodge State Park.
-Follow WI-130 N to the Wisconsin River, continuing straight onto WI-133 S when you reach the outcrop of the Wonewoc Formation near the bridge to Lone Rock. Continue briefly past the Wonewoc-Tunnel City contact and park at the pull-off just uphill.

STOP 4: Road cut at Lone Rock, Wis., exposing the Cambrian Wonewoc Formation and overlying Tunnel City Group.

-Turn around and take WI-130 S, turning left onto County Hwy C. Down this road is an outcrop of the Trempealeau–Tunnel City contact, which we will see at our next stop. We will also pass Frank Lloyd Wright's house, Taliesin.
-After passing Taliesin, take a left on WI-23 N and a quick right continuing onto County Hwy C past Tower Hill State Park where lead-shot was manufactured in the early to mid-1800s using lead mined from the Mineral Point area 20 miles south. Round lead shot was formed from molten lead as it dropped down a shaft through the 180-ft high cliff of Tunnel City and Wonewoc sandstones seen at Stop 4.
-Turn right on US-14 E.
-After about 5 miles, turn right on County Hwy K continuing past the large outcrop of likely Tunnel City and Trempealeau Group strata.
-After continuing on County Hwy K for about 3.5 miles, pull over at large outcrop immediately after passing Sweeney Road.

STOP 5: Road cut at Vermont, Wis., exposing the Cambrian Tunnel City Group and overlying St. Lawrence Formation. Upper part of outcrop (inaccessible) contains the Jordan Member and is possibly capped by Prairie du Chien Group dolostone.

-Turn around and head north on County Hwy K, taking your first right on Zwettler Road.
-Follow Zwettler Road until it ends and turn right onto County Hwy F.
-In less than a mile, turn left onto County Hwy J.
-Follow County Hwy J to WI-78, turning right and then left at the dogleg to continue on County Hwy J.
-Continue on County Hwy J through the intersection with County Hwy S and P.
-Shortly after the sharp curve in County Hwy J, turn left on Mineral Point Road. Follow Mineral Point Road over the terminal moraine and out of the Driftless Area.
-After about 5 miles, turn left on N. Midvale Blvd.
-Cross University Avenue (becomes Rose Place)
-Take a right on Locust Drive and a left on Highbury Road.
-Disembark at parking lot at the intersection of Highbury Road and Locust Drive, and walk about 300 feet north to the Shorewood Hills Quarry.

STOP 6: Abandoned Quarry at Shorewood Hills, Wis., exposing the Cambrian Jordan Formation and overlying Ordovician Prairie du Chien Group.

-Return to University Avenue, turn left and continue onto Campus Drive then W. Johnson Street.
-Turn right on N. Park Street.
-Turn left on Regent Street continuing onto Proudfit Street and North Shore Drive.
-Turn left on John Nolen Drive. Monona Terrace Convention Center will be just ahead on your right.

Return to Monona Terrace Convention Center.

STOP 1 (43.011747°, -89.478623°)

Outcrop northwest of the intersection of Nesbitt Road and Limestone Lane, Fitchburg, Wisconsin (fig. 4). At this outcrop, the contact between the Ordovician St. Peter Formation and overlying Platteville Formation is well-exposed. The lower portion of the St. Peter here is cross-bedded with abundant Liesegang banding (iron-oxide cements; see fig. 4, C and D). The upper portion is tabular and contains limonitic *Skolithos* burrows indicating a marine depositional environment. The contact with the overlying calcareous Platteville Formation locally forms an angular unconformity. When this outcrop was excavated, varicolored sandstones and red and green shale of the Readstown Member were observed in a ditch across the street. South of this outcrop, across US-151, the Prairie du Chien is quarried at the same elevation. This vertical offset within such a short distance is an indication of the paleorelief on the pre-St. Peter unconformity (Sauk–Tippecanoe cratonic sequence boundary). The St. Peter Formation sandstone has historically been mined for glass making and other industrial uses.

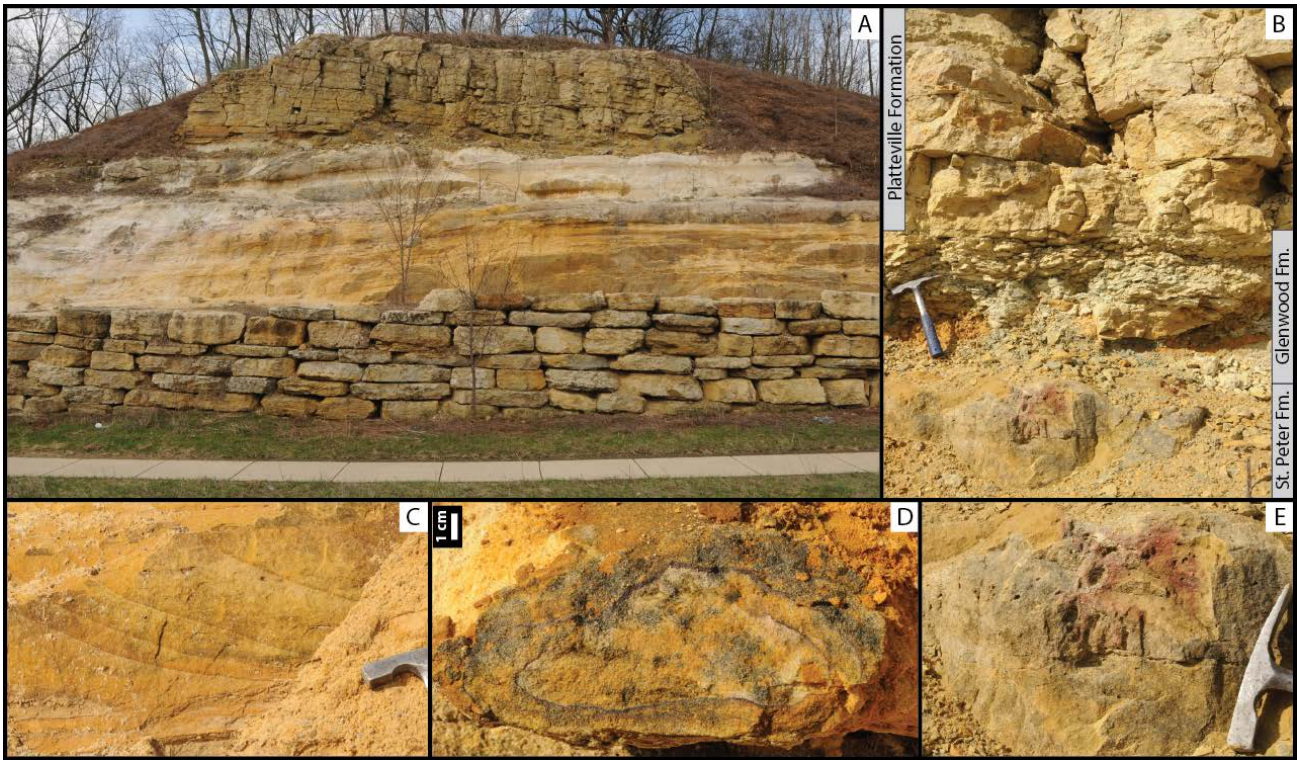

Figure 4: A) Overview of Stop 1 outcrop. B) Close-up of the contact between the Ancell Group (St. Peter and Glenwood Formations) and the overlying Sinnipee Group (Platteville Formation). C, D) Examples of Liesegang bands and rings; both are common features in the St. Peter Formation. E) *Skolithos* burrowed and iron-rich sandstone near the top of the St. Peter Formation at this outcrop.

Figure 5: Contact between the St. Peter and Platteville Formations in the Governor Dodge State Park Core from central Iowa County (WID: 25000505). Note similar presence of iron in the uppermost St. Peter, as well as the dark gray color of the Platteville Formation that is obscured by weathering in the outcrop. Each core box column is about 2 feet long.

STOP 2 (lower: 42.645510°, -90.575720°; upper: 42.637903°, -90.578571°)

Road cuts on US-151 just northeast of exit 8 (Dickeyville, Wisconsin; fig. 6). The southern road cut provides roadside access to the Ordovician Platteville, Decorah, and Galena Formations, as well as four bentonite horizons (Dickeyville, Elkport, Millbrig, and Deicke) that occur within this succession; the northern road cut is stratigraphically lower and provides access to the St. Peter Formation. Nearby drill core demonstrates erosional relief on the Sauk-Tippecanoe mega-sequence boundary exceeding 100 feet (fig. 7). Long considered the archetypical orthoquartzite-carbonate suite of continental flooding, the St. Peter–Galena succession is now known to be chronostratigraphically fragmented, missing multiple interspersed flooding events (figs. 5 and 7).

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Figure 6: A, B, and C) Overview of outcrops at Stop 2, including the position of bentonites within the Platteville–Decorah–Galena succession (Opq – Ordovician Platteville Fm., Quimbys Mill Mbr.; Ods – Ordovician Decorah Fm., Spechts Ferry Mbr.; and, Odg – Ordovician Decorah Fm., Guttenberg Mbr.). D) Picture of the eolian-marine transition in the St. Peter Formation at a nearby quarry (central Iowa County) showing cross-bedded sandstone with slump features overlain by horizontally bedded and *Skolithos* burrowed sandstone. E) Contact between Prairie du Chien Group dolostone and the overlying siliciclastics of the St. Peter Fm. sandstone (Readstown and Tonti Members).

A
eolian St. Peter
marine St. Peter
B
Dickeyville
Odg
Elkport
Ods
Millbrig
Opq
Deicke
C
D
approx. 1 m
eolian St. Peter
marine St. Peter
E
approx. 1 m
Prairie du Chien
Readstown
Tonti

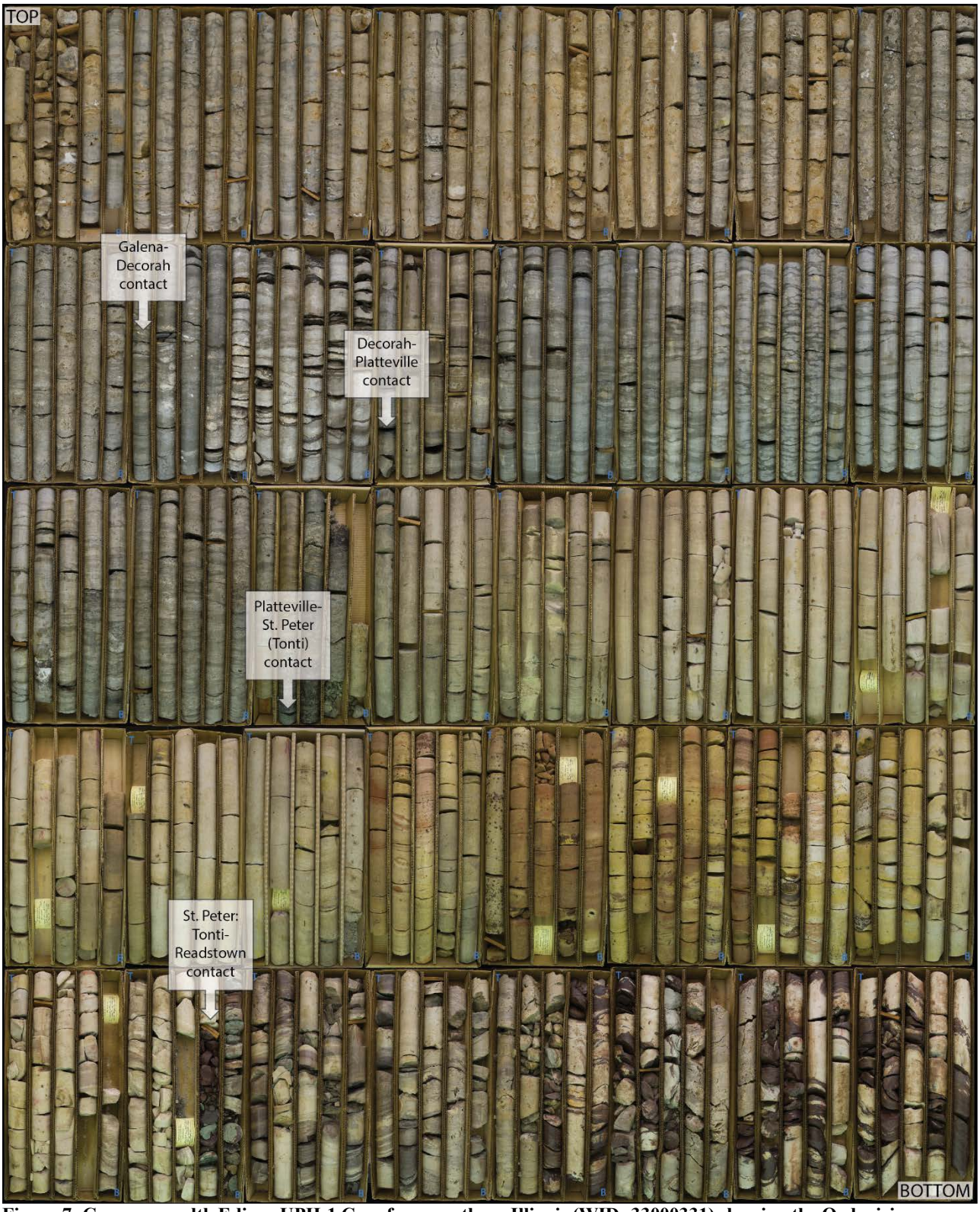

Figure 7: Commonwealth Edison UPH-1 Core from northern Illinois (WID: 33000331) showing the Ordovician St. Peter–Platteville–Decorah–Galena succession. Each core box column is about 2 feet long. Note thickness of the St. Peter Formation relative to what was observed at the Stop 2 outcrop.

STOP 3 (42.667303°, -90.571204°)

THIS IS PRIVATE PROPERTY; ACCESSIBLE ONLY WITH LANDOWNER'S PERMISSION.
PLEASE STAY AWAY FROM THE HIGH WALLS!

Church Road Quarry exposing the fossiliferous Ordovician Platteville and Decorah Formations (fig. 8). This is a similar succession to the nearby Dickeyville road cut, but provides better access to fossils and bedding planes in the rock piles throughout the quarry. The Platteville has been traditionally quarried as a source of aggregate. The Quimbys Mill was called "glass rock" by the early lead miners because it fractures conchoidally. Please wear safety glasses and be aware of sharp edges if collecting from this unit.

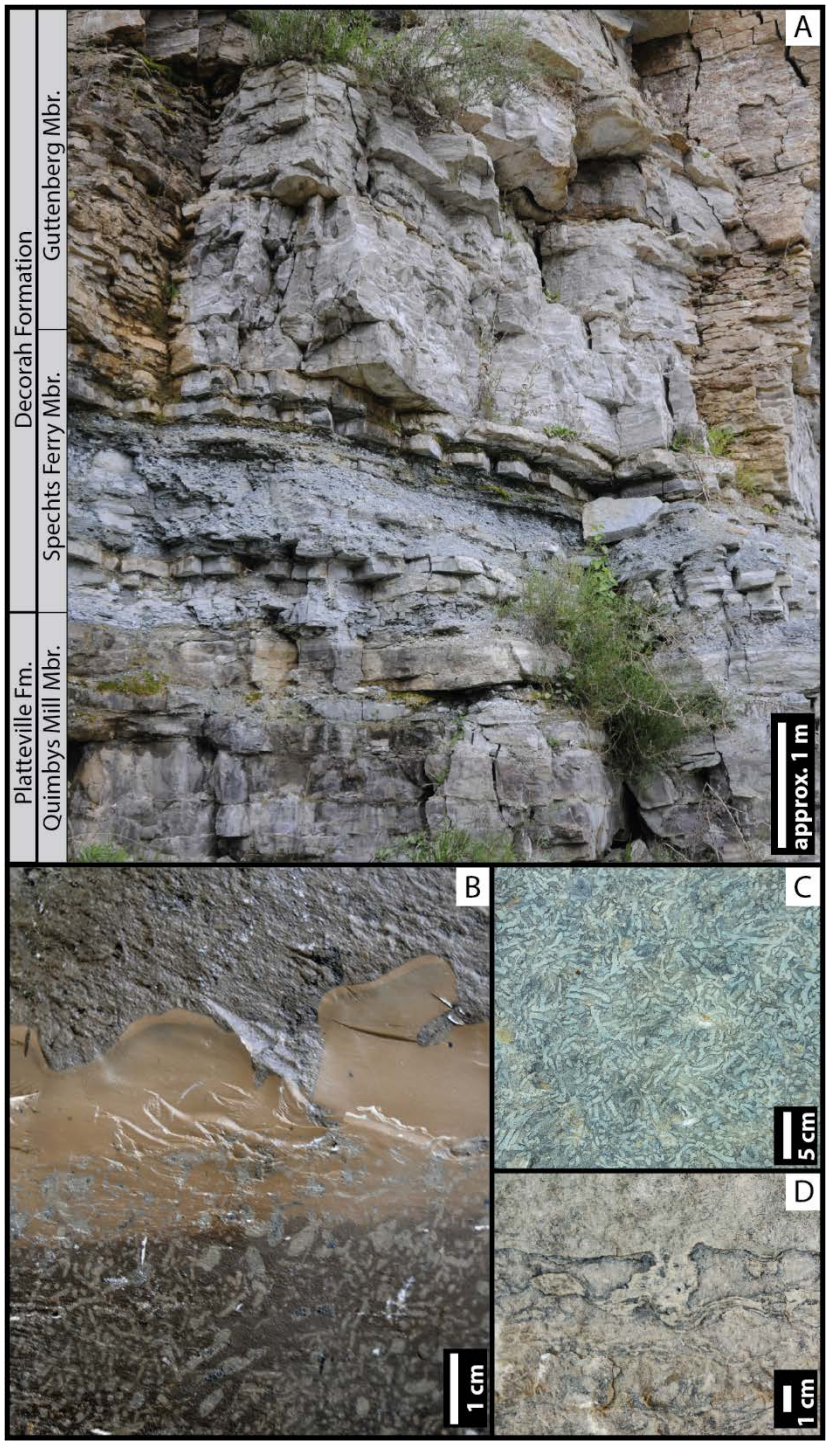

Figure 8: A) Platteville–Decorah succession at the Church Road Quarry. B) Silicified contact between the Quimbys Mill Member of the Platteville Formation and the overlying Spechts Ferry Member of the Decorah Formation. C) Burrows observed in float at the Church Road Quarry. D) Hardground within the McGregor Member.

STOP 4 (43.164181°, -90.196250°)

Road cut at Lone Rock, Wisconsin, exposing the Cambrian Wonewoc Formation and overlying Tunnel City Group (fig. 9). The Wonewoc Formation is the prime target for recently opened industrial sand mines in Wisconsin because its sand grains have the right size(s), hardness, roundness, and mineralogy (quartz) to meet the specifications for use as a proppant in the hydraulic fracturing process. The overlying Tunnel City Group is notable for its abundant glauconite (an iron potassium phyllosilicate) that gives the rock its green color. The Wonewoc–Tunnel City contact is unconformable and locally shows up to 10 inches (25 cm) of relief; the core in figure 10 shows reworked clasts of Wonewoc Formation at the unconformity, which are difficult to see at the highly weathered and overgrown outcrop of Stop 4. Trough cross-stratification, a paucity of fossils, green mud stringers, and reworked mud balls in the Wonewoc Formation suggest a nearshore (probably shoreface to tidal) depositional environment. Hummocky cross-stratified sandstones and flat-pebble conglomerates in the Tunnel City Group suggest deposition in deeper water, but above storm wave base. The upper part of the Tunnel City Group is accessible at the next stop.

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Figure 9: A, B) Overview photos of the contact between the Wonewoc and overlying Lone Rock Formations at Stop 4 (the contact interval was power-washed shortly before these pictures were taken). Contact is at the level of the hammer, just below the vegetation line. Dark green color of the Wonewoc is due to overgrowth by moss. C) Close-up of the contact (white dashed-line), showing iron-stained Wonewoc overlain by a dolomitic pack to grainstone comprised of what appears to be recrystallized pelmatozoan material. D) Green mud stringers and a reworked mud ball within the Wonewoc Formation.

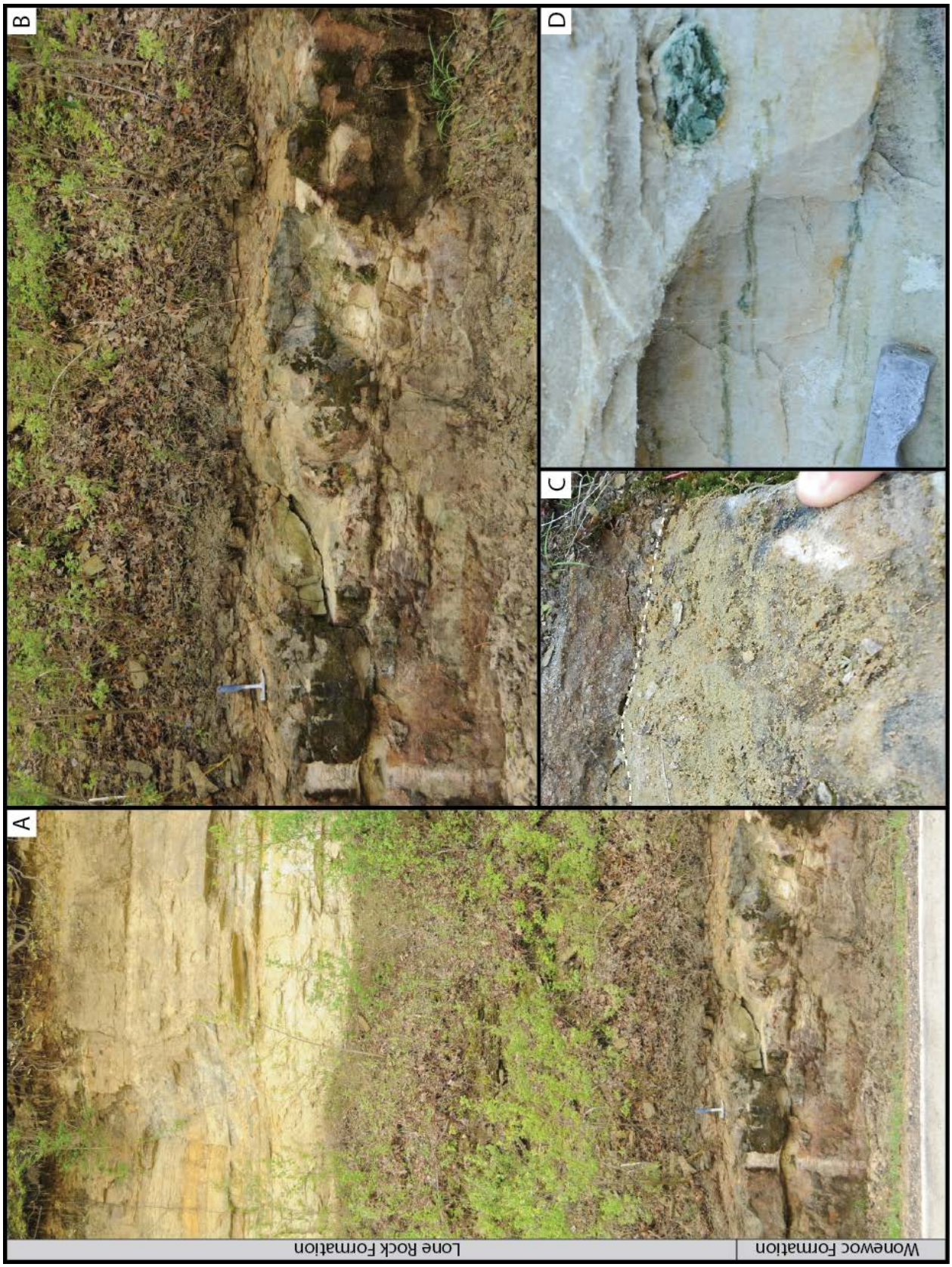
B
D
C
A
Lone Rock Formation
Wonewoc Formation

Figure 10: Triemstra Quarry Core from northcentral Columbia County (WID: 11005900) showing the erosional contact between the Wonewoc Formation and overlying Tunnel City Group. Each core box column is about 2 feet long.

STOP 5 (43.094455°, -89.867585°)

Road cut at Vermont, Wisconsin, exposing the Cambrian Tunnel City Group and overlying St. Lawrence Formation (fig. 11). The inaccessible upper part of the outcrop contains the Jordan Formation and is possibly capped by Prairie du Chien Group dolostone—both are better exposed at Stop 6. Similar to the previous stop, the Tunnel City Group here was deposited above storm wave base as evidenced by the exceptionally preserved trace fossil suite and the presence of flat-pebble conglomerates. The Black Earth Member of the St. Lawrence Formation is accessible on the first landing. The Black Earth Member is a thrombolitic (clotted fabric that is microbial in origin) dolostone that was deposited below fair-weather wave base based on a lack of subaerial exposure features and some intraclastic (tempestite) beds (fig. 12). The Black Earth Member, at this locality, appears transitional (coarsening upward) to the Jordan Formation; the intervening interbedded dolostone and fine-grained sand to siltstones may be the Lodi Member of the St. Lawrence Formation.

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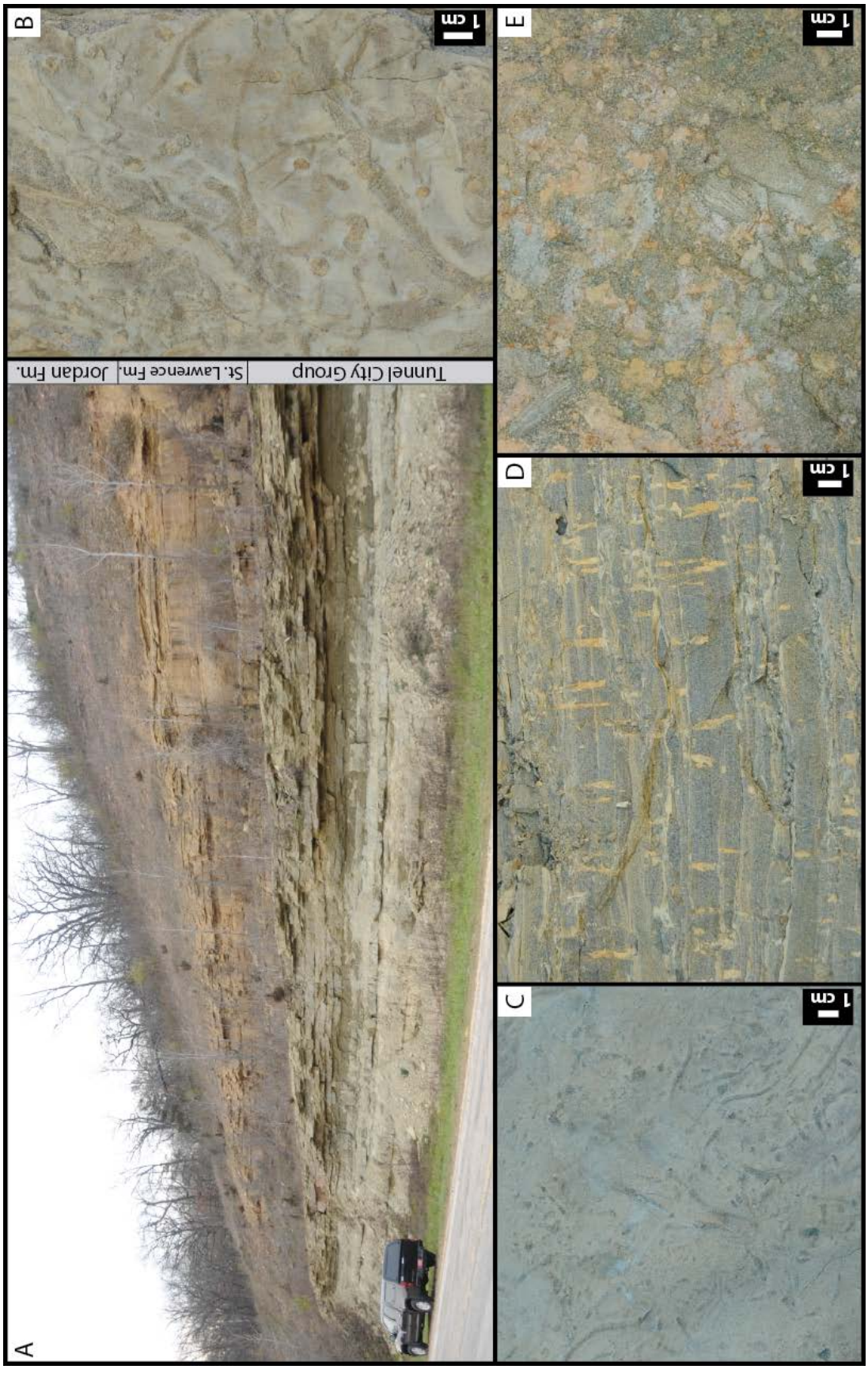
Figure 11: A) Overview of the outcrop near Vermont, Wisconsin, of the Tunnel City Group and the St. Lawrence and Jordan Formations of the Trempealeau Group. B, C) Trace fossils preserved on the base of beds in the Tunnel City Group. D) *Skolithos* burrows in the Tunnel City Group. E) Flat-pebble conglomerate from the Tunnel City Group.


A
Tunnel City Group
St. Lawrence Fm.
Jordan Fm.
B
1 cm
C
1 cm
D
1 cm
E
1 cm

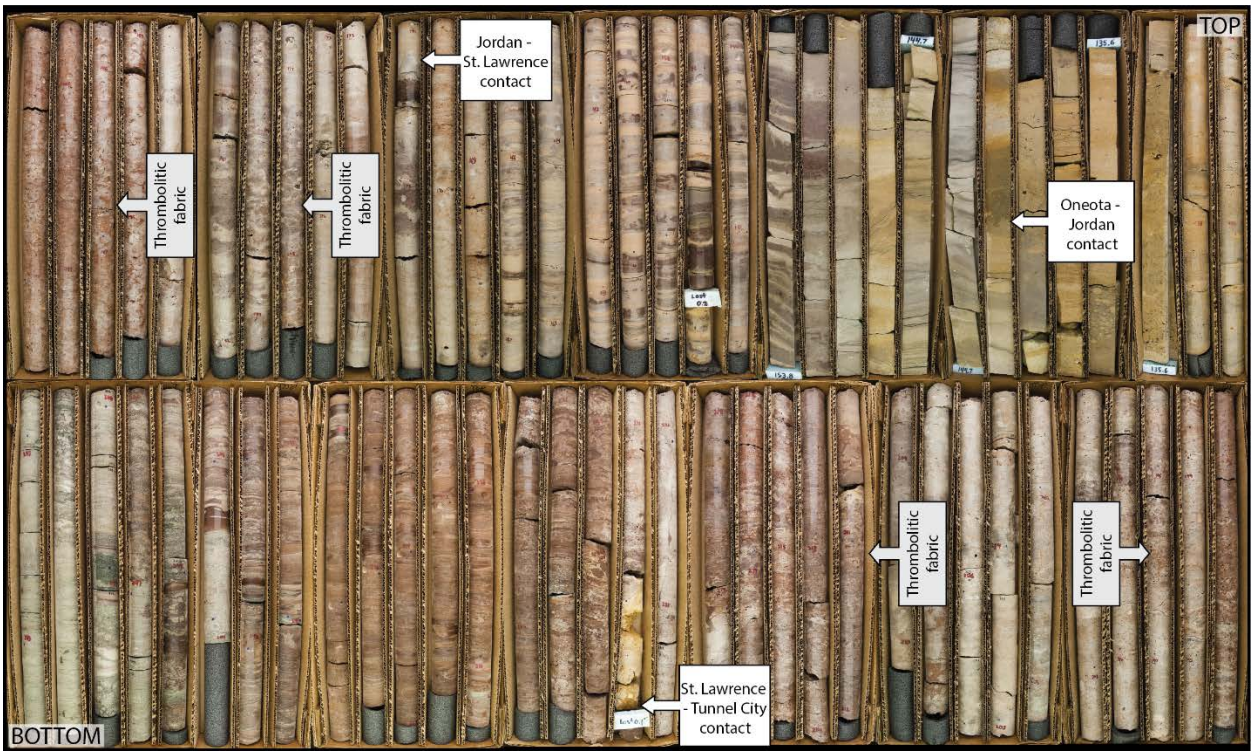


Figure 12: Hwy A #2 Core from southeastern Iowa County (WID: 25000529) showing the Tunnel City–Trempealeau–Prairie du Chien succession. Note the thrombolitic (microbial), clotted fabric throughout the St. Lawrence Formation (Black Earth Member dolostone) which is not apparent in the weathered outcrop (fig. 11). Each core box column is about 2 feet long.

STOP 6 (43.078379°, -89.449673°)

Abandoned quarry at Shorewood Hills, Wisconsin, exposing the Cambrian Jordan Formation and overlying Ordovician Prairie du Chien Group (fig. 13). The majority of the Jordan Formation exposed at this outcrop is a dolomitic fine-grained feldspathic and quartz sandstone with abundant *Skolithos* burrows called the Sunset Point Member (not shown in fig. 2, occurs above the Van Oser Member). The upper 3 feet of the Jordan Formation at this locality is silicified, presumably during subaerial exposure related to the unconformable surface separating it from the overlying Oneota Formation of the Prairie du Chien Group. An additional silicified bed, interpreted as a silcrete, is present within the lower portion of the Oneota Formation and comprised of chalcedony. Silicification in the uppermost Jordan Formation is a common feature throughout Wisconsin, and the silcrete bed in the lower Oneota Formation can be traced regionally on the Wisconsin Arch (fig. 14). This bed has not been observed in western sections, which were presumably deposited in deeper water associated with the Hollandale Embayment. Up-section in the larger portion of this abandoned quarry, accessible by a trail to the south of the Jordan Formation outcrop face, the Oneota Formation is dominated by microbial and oolitic dolostones. Brecciation shortly after deposition (possibly tepee structures?) are common and suggest the presence of evaporites in the primary depositional environment. A common feature of the white, chalky silica in the upper part of the Oneota Formation exposed here is that algal laminations and oolites are well preserved, more so than the dolomitized host rock. This suggests that the silicification was an early diagenetic feature, possibly related to the depositional environment.

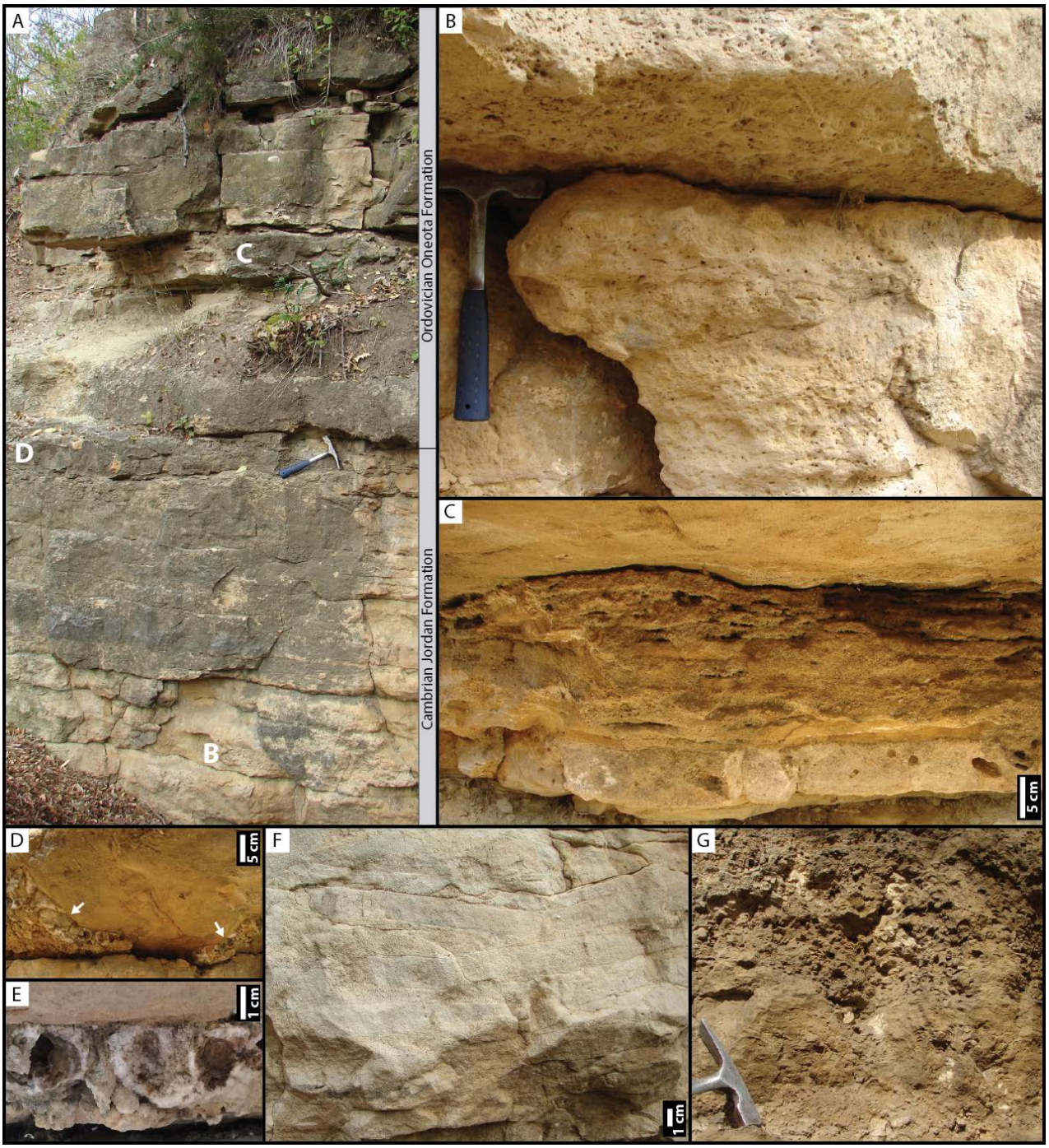


Figure 13: A) Contact between the Cambrian Jordan Formation and the Ordovician Oneota Formation (Prairie du Chien Group) is at the bedding plane immediately above the hammer. White letters refer to the stratigraphic position of other parts of this figure. B) *Skolithos* burrowed sandstone of the Jordan Formation. C) Silcrete within the lower part of the Oneota Formation (Stockton Hill Member) consisting of a mix of silicified quartz sandstone and oolite. D, E) Silica that precipitated in fractures just below the Jordan-Oneota unconformity (denoted by arrows in part D; shown in detail in part E). F) Brecciated oolitic dolostone within the Oneota Formation. G) Domal stromatolites overgrown by digitate stromatolites within the Oneota Formation.

Figure 14: Rio #2 Core from central Columbia County (WID: 11005903) showing the contact between the Cambrian Jordan and the Ordovician Oneota Formations. Similar to the outcrop at Shorewood Hills Quarry, the upper Jordan contains silica nodules (SN) and a reworked silcrete bed (RSB) is present in the lower portion of the Oneota Formation. Each core box column is about 2 feet long.

Additional references cited in text:

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