Geologic map of Mill Bluff State Park, Monroe and Juneau counties, Wisconsin

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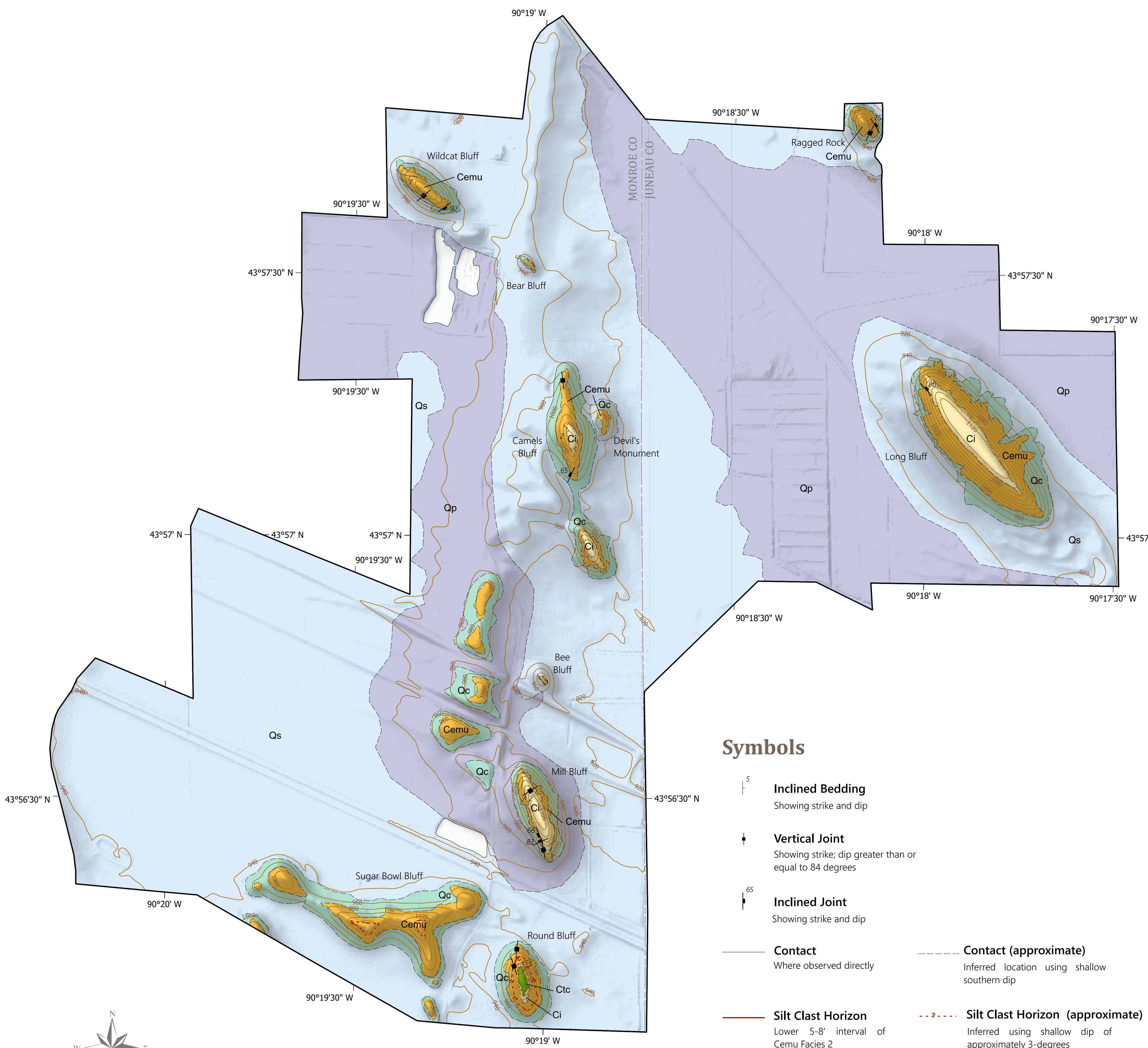
cartography by Shayla M. Barrera-Skibinski with assistance from Caroline Rose

Project Outline and Scope

This mapping project builds on previous work and observations by Clayton (1989) through the extent of Wisconsin's Monroe and Juneau counties. Mill Bluff State Park features striking Cambrian sandstone bluffs in the generally flat-lying landscape of Wisconsin's unglaciated Driftless Region and Central Sand Plain (Carson and others, 2023). More than 14,000 years ago, the tallest bluffs in the park stood as islands above Glacial Lake Wisconsin (Black, 1974; Dott and Attig, 2004). The former lake left behind lacustrine sediments which cover much of the flat topography today. Later, local areas were covered by thin aeolian deposits, and colluvial deposits formed at the base of hillslopes. In addition to mapping the geology of Mill Bluff State Park, we investigate factors that may contribute to the pronounced elongated rock bluffs that make this park iconic. Many of the bluffs in the park are aligned in the northwest-southeast direction. Their existence and linear pattern are a result of multiple factors. We introduce the geographic and lithologic variables which affect the resistance of the park's bluffs. These concepts, while pertaining locally to Mill Bluff State Park, can be further expanded to cover similar sandstone bluff features found nearby within the extent of the Glacial Lake Wisconsin basin.

Interpretation

For additional information about the geology presented here, please refer to the report that accompanies this map at: https://doi.org/10.54915/yqay6786.



Symbols

Inclined Bedding
Showing strike and dip

Vertical Joint
Showing strike; dip greater than or equal to 84 degrees

Inclined Joint
Showing strike and dip

Contact
Where observed directly

Contact (approximate)
Inferred location using shallow southern dip

Silt Clast Horizon
Lower 5-8' interval of Cemu Facies 2

Silt Clast Horizon (approximate)
Inferred using shallow dip of approximately 3-degrees

Figure 2. Monroe and Juneau counties.

Map scale is 1:8,000,000

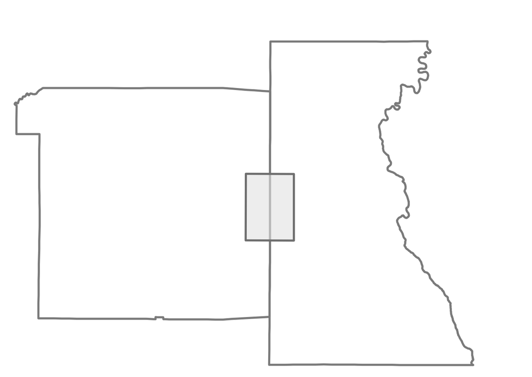


Figure 3. Camp Douglas 7.5-minute quadrangle.

Map scale is 1:1,250,000

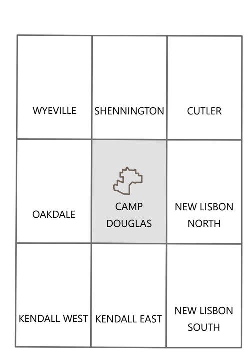


Figure 4. Location of Mill Bluff State Park within the Camp Douglas 7.5-minute quadrangle.

Map scale is 1:800,000

Wisconsin Geological and Natural History Survey
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SCALE: 1:12,000

0.5 0.25 0 0.5
MILES

0.5 0.25 0 0.5
KILOMETERS

CONTOUR INTERVAL 20 FEET

WOFR2024-03

Wisconsin Transverse Mercator Projection, 1991 adjustment to the North American Datum of 1983 (NAD 83/91)

The base map was constructed from U.S. Census Bureau TIGER/Line data (2010 and 2013) and modified by the Wisconsin Geological and Natural History Survey (2014). LIDAR-derived data was provided by the Door County Land Information Office and processed by the Wisconsin Geological and Natural History Survey (2006).

Geologic Units

Within the park, Quaternary sediments overlie Late Cambrian siliciclastic rock. Paleozoic stratigraphic names follow those outlined by Ostrom (1967). Descriptions for Quaternary units are modified from Clayton (1989) based on field observations for this project. Paleozoic unit descriptions are described from field observations within the park and sampling performed in Camp Douglas, Wisconsin. Identification of Paleozoic units ties back to previous observations in Juneau County by Clayton (1989) and previously mentioned outcrop descriptions in neighboring counties (Ostrom, 1978a; Ostrom, 1978b).

Quaternary

Qp **Peat**
Organic material overlying and adjacent to wetlands. Heavily vegetated by ferns and tall grass. Primarily deposited during the end of the Holocene (Clayton, 1989). Directly observed in the northeastern areas of the park but primarily inferred using aerial imagery. 3–10 ft (0.9–3 m) thick (Clayton, 1989).

Qc **Colluvium**
Gravity-driven deposits of clay to boulder-sized clasts composed of Paleozoic sandstone units. The deposits commonly surround the bases of bluff structures within the park. Mapped where directly observed and inferred using topography where necessary. The thickness is poorly controlled, but is probably greater than 3 ft (0.9 m).

Qs **Offshore sand**
Offshore lake sand observed directly in relatively flat topographic areas. Commonly covered by dense vegetation of brush and trees. Generally fine to medium, rounded to well-rounded, white to tan grains. Deposited in proglacial Lake Wisconsin, during the Pleistocene. In some areas, overlain by more recent windblown sands and stream-transported sands from Late Cambrian strata (Clayton, 1989). At least 10 ft (3 m) thick (Clayton, 1989).

Cambrian

Tunnel City Group

Ctc **Lone Rock Formation**
Observed only at Round Bluff in the southernmost area of the park. Exposure at Round Bluff was limited to the top 20–25 ft (6.1–7.6 m) of the bluff. Shallow dip is approximated to be 3-degrees south based on map patterns. The dip may explain why the Lone Rock Formation is not found in the north areas of the park.

The Lone Rock Formation of the Tunnel City Group is a tan quartzose sandstone with abundant glauconite. Grains are well-rounded, well-sorted, and medium in size. Commonly bioturbated. The lithologic character of the Lone Rock Formation within the park is similar to observations made in neighboring Juneau County by Clayton (1989) and consistent with the commonly recognized dominant characteristic of abundant glauconite (Eoff, 2014).

The Lone Rock Formation is a well-consolidated unit with considerable glauconite, which differs from lower strata which lack these features. Varying from Clayton's descriptions, the Lone Rock Formation in the park lacks the basal micaceous shale found elsewhere in Juneau County; instead, the contact with the underlying Ironton Member of the Elk Mound Group is marked by mm-scale iron oxide-cemented sandstone bands. Horizons of these cement bands are found where permeability changes between the well-consolidated Tunnel City Group and the more friable Elk Mound Group are likely.

The contact between the Tunnel City Group and the Ironton Member is drawn at the presence of iron oxide bands and onset of abundant glauconite. This unit is representative of a shallow-marine depositional environment (Eoff, 2014).

Elk Mound Group

Ci **Ironton Member of the Wonewoc Formation**
Commonly exposed throughout Mill Bluff State Park. The Ironton Member is the topmost member of the Wonewoc Formation within the Elk Mound Group. Commonly, the Ironton Member caps the tops of bluffs within the park with a unit thickness ranging 20–50 ft (6.1–15.2 m). There is notable variability of thickness within the park's extent, particularly between Round Bluff and Mill Bluff (see figure 1).

The Ironton Member is a quartzose sandstone that is tan in color. This unit can be recognized by several cycles of 1–3 ft (0.3–0.9 m) thick beds of alternating heavily burrowed (both horizontal and vertical) beds and well-cemented, relatively finer-grained beds with subtle decimeter-scale cross-bedding, commonly 3–12 in (7.6–30.5 cm). Burrowed sections are heavily bioturbated and contain very well-rounded, coarse grains which are moderately to poorly sorted. As recognized by Clayton (1989), the Ironton forms a topographic bench which is recognized by the flat tops at bluffs capped by the Ironton Member.

The cyclical nature of this unit varies significantly from lower units of the undifferentiated section of the Elk Mound Group. The burrowed sections likely formed during periods with low-sedimentation rate to allow marine creatures to burrow into the shallow marine floor present during the Paleozoic Era. The finer, well-cemented intervals represent the opposing periods of high sedimentation rates. In tandem with crossbedding in these intervals, this deposition could relate to a deep or high energy depositional environment. Prior observations of the Ironton Member recognize it to be deposited in a marine and slow sedimentation environment (Ostrom, 1970).

The contact between the Ironton Member and lower undivided Elk Mound Group is gradational, as noted by Clayton (1989). This contact is marked in Mill Bluff State Park by the onset of burrow cycles in the Ironton Member, which are lacking in the rest of the Elk Mound Group.

Cemu **Elk Mound Group (undivided)**

Abundant throughout Mill Bluff State Park. The rest of the Elk Mound Group, underlying the Ironton Member, consists of the Galesville Member of the Wonewoc Formation, Eau Claire Formation, and Mount Simon Formation. The base and bodies of the bluffs within the park are composed of these units. These units have not been subdivided within the extent of the map due to their similar lithologic character that makes it difficult to distinguish one from the other.

The undivided Elk Mound Group is a light tan to orange sandstone that weathers to a gray buff color. The orange color is due to the presence of iron oxides within the Elk Mound Group. Grains are rounded to well-rounded and range from fine to medium. The unit is friable to moderately well-cemented. It commonly weathers to a vuggy texture and is heavily cross-bedded. Cross-bedding characteristics vary throughout facies.

Four stratigraphic facies are identified within the Elk Mound Group based on detailed observations at two locations within the park: Mill Bluff and Round Bluff. Detailed stratigraphic columns are presented for these two locations in figure 1. Facies 1 follows the cyclical nature observed in the Ironton Member. It consists of indurated planar-apparent beds layered with thin, friable, fine-grained silt layers. These planar-apparent beds are visually planar, likely due to the lack of grain-size variation which would otherwise allow for the recognition of cross bed patterns. The total thickness of this unit as recognized at Round Bluff is approximately 15–30 ft (4.6–9.1 m). This unit is not observed at Mill Bluff.

Facies 2 is defined by cross-beds with lenticular bounding surfaces and basal scouring surfaces. This facies is only recognized at Round Bluff. The upper portion of this unit is 15–20 ft (4.6–6.1 m) thick and composed of white-tan colored quartzose sandstone. The lower portion is a 5–8 foot (1.5–2.4 m) thick primarily white to pink to maroon distinct interval with abundant iron oxides, providing the distinct coloration, and common white mud clasts at the base of cross bed fore sets (mapped as Silt Clast Horizon). These clasts are commonly surrounded by deep maroon oxide staining. This section of facies 2 is reminiscent of the delineating layer observed and described in the Wisconsin Dells State Natural Area (Bojdak-Yates and others, 2023). In addition, it marks a distinct change between the first and second facies represented at Round Bluff.

Facies 3, present at both Mill Bluff and Round Bluff, is characterized by planar, tangential cross beds of less than one inch (2.5 cm) to 4–8 inch (10.2–20.3 cm) scale. These cross beds are laterally continuous on a scale of less than one foot to 3-ft (cm to m-scale) in width. Bounding surfaces are largely planar with rare high-angle surfaces. Cross beds are recognizable from the variation in grain size, which is generally fine to medium, or medium to coarse.

Facies 4 is characterized by the introduction of trough cross beds intermixed in 5–8 ft (1.5–2.4 m) thick planar beds. This is recognized at both Mill and Round Bluffs in the park. These cross beds are laterally continuous on an inch (cm) scale and are bounded by planar surfaces. Rarely, evidence of soft sediment deformation is observed at Round Bluff. This unit is 10–15 ft (3.0–4.6 m) thick, as observed at the two locations.

It is possible that the lower region of facies 2 could be representative of subaerial stream deposition. This marine interpretation is challenged by the lack of observed trace fossils typically recognized within a marine depositional environment. Previous work on the depositional environment of the Wonewoc Formation found it to be primarily aeolian with minor shallow marine reworking (Dott and others, 1986).

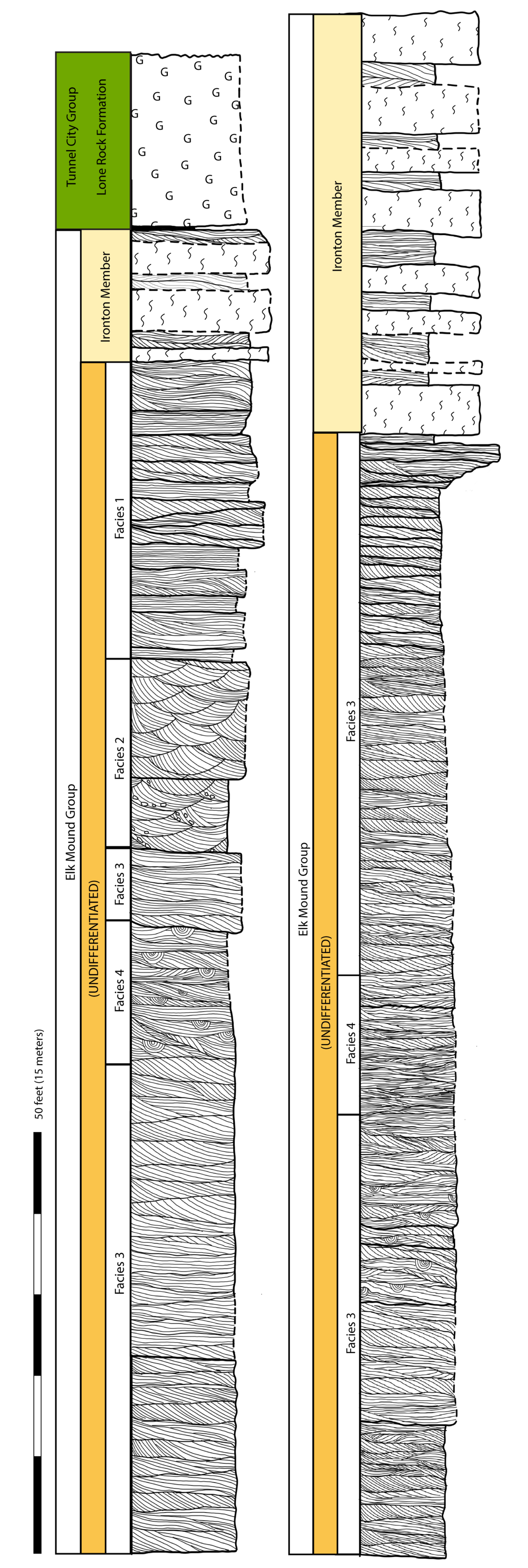
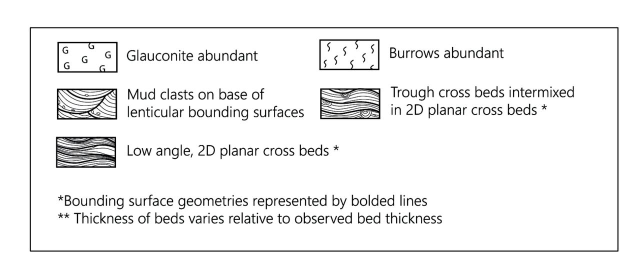


Figure 1. Stratigraphic columns of Round Bluff (left) and Mill Bluff (right).

STRATIGRAPHIC COLUMN LEGEND



Correlation of Map Units

Unlithified Sediments

Qc, Qp	Holocene	Quaternary	CENOZOIC
Qc, Qs	Pleistocene		

Supracrustal Rocks

Ctc, Ci, Cemu	Late	Cambrian	PALEOZOIC

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Acknowledgments

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