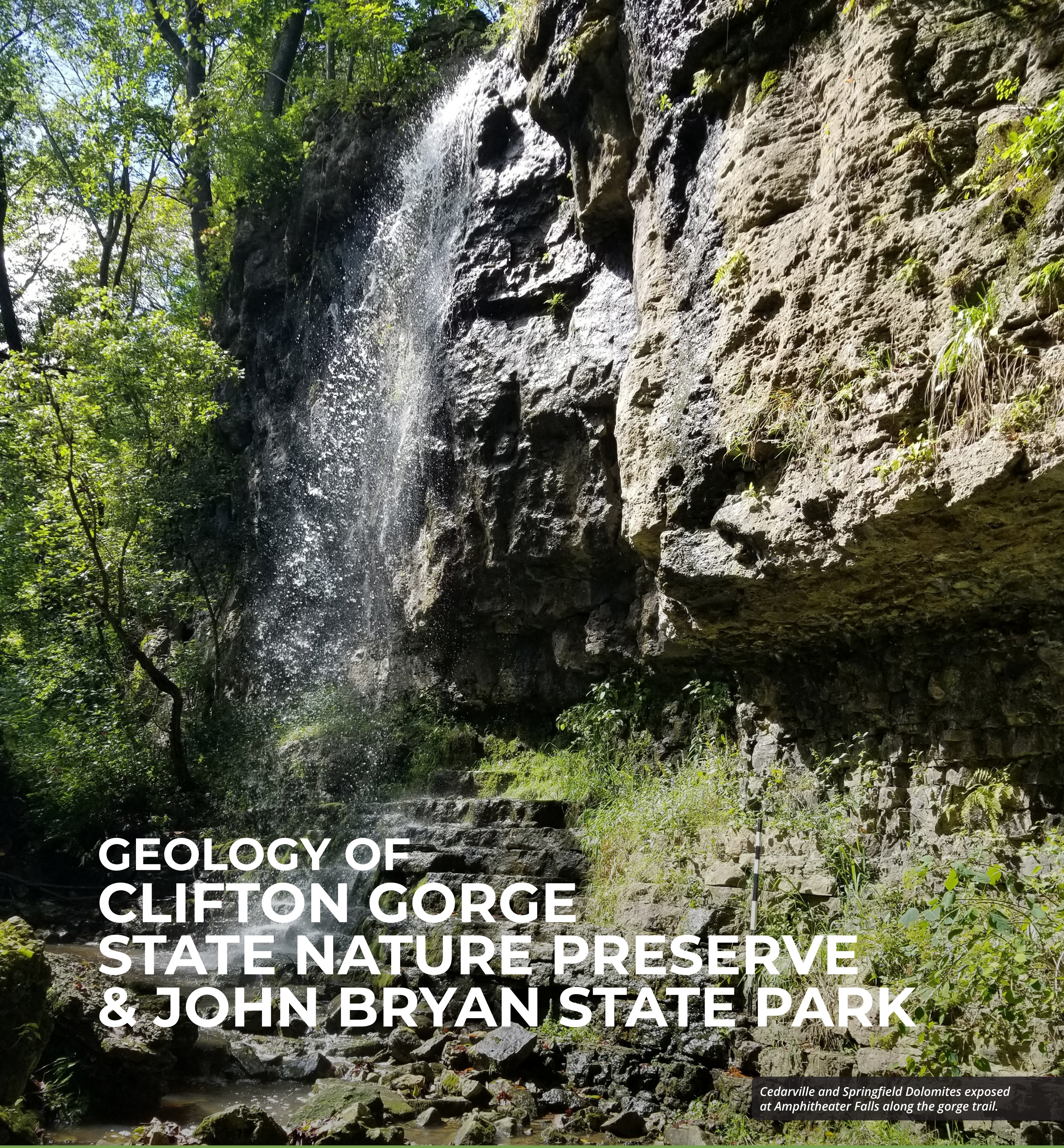

GEOLOGY OF CLIFTON GORGE STATE NATURE PRESERVE & JOHN BRYAN STATE PARK

Cedarville and Springfield Dolomites exposed at Amphitheater Falls along the gorge trail.

by Mohammad Fakhari, Christopher B. T. Waid, and T. Andrew Nash – 2021

OHIO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES

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Introduction

The Clifton Gorge State Nature Preserve is home to the most notable scenic gorge in western Ohio. While the gorge itself is a sight to behold, the picturesque landscape of this area of southwestern Ohio places it among the top scenic locations in the entire state. The Little Miami River, which flows through the gorge, was designated as the first of Ohio's Scenic Rivers in 1968. Downstream of and adjacent to the nature preserve, John Bryan State Park contains an extensive trail network with exceptional views of the Little Miami River. Together, the park and nature preserve host hundreds of species of trees, shrubs, and wildflowers. In addition to enhancing the natural beauty of the nature preserve and park, the rocks exposed by the Little Miami and the shape of the gorge itself are excellent examples for understanding the geology and landforms of the region.

Bedrock Geology

The sediments and carbonate material that became the rocks exposed along the steep sides of the gorge were deposited (or precipitated) during the early Silurian Period, from roughly 445 to 430 million years ago. During this time, ancestral North America straddled the Equator (fig. 1A). Ohio was situated in a tropical setting south of the Equator and covered by a shallow, inland sea (fig. 1B). The tropical marine setting with clear water (similar to the present-day Caribbean Sea) allowed for calcite-forming, shelly animals such as corals, brachiopods, and crinoids to flourish, leading to extensive limestone rock deposits. Some of the limestone was later altered to dolomite through interaction with magnesium-rich groundwater, a process called *dolomitization.* A mountain range (Taconic Highlands), larger than the present-day Appalachians, existed to the east (fig. 1B). Depending on the sea-level conditions during this time, different depositional environments existed in the region. During times of low sea level, the shoreline along the mountains was closer to Ohio, which allowed muddy sediment eroded from the highlands to be transported to and deposited in southwestern Ohio. This sediment eventually was compacted into a rock known as *shale*. When sea level rose, sediment was deposited closer to the mountains, leaving the water in Ohio clear and conducive to limestone deposition.

Cyclical sea-level rise and fall led to the deposition of alternating layers of limestone, dolostone, and shale, as shown by the different rock units exposed in the gorge (fig. 2). The differing strengths of these rock units contribute to the dramatic landscape of Clifton Gorge. Shale units, such as the Osgood and Massie Shales (fig. 2), are less *competent* (able to maintain a vertical to near-vertical slope), so they generally form the more gently sloping parts of the valley, whereas the stronger dolostone units form steep cliffs.

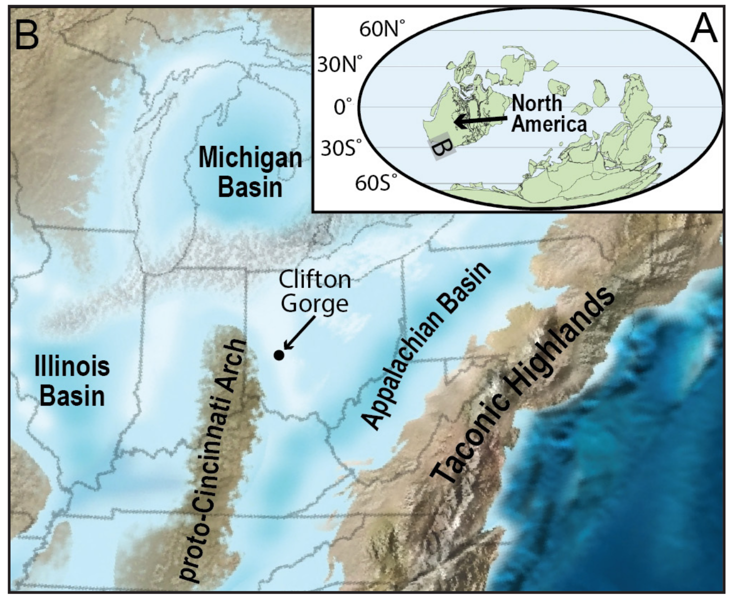


Figure 1. A: Global paleogeographic map of continents during Silurian time. Modified from Torsvik and Cocks (2013). B: Paleogeographic map of eastern North America during the Silurian. Map is modified from Blakey: Key Time Slices of North America © 2013 Colorado Plateau Geosystems Inc.

Glacial Geology

About 28,000 to 15,000 years ago, much of western Ohio was covered by a massive glacier, known as the Laurentide Ice Sheet (LIS). As the LIS initially advanced across western Ohio, it encountered a large hill of Devonian-age (420–360 million years ago) resistant rock, known as the Bellefontaine Outlier, an area of younger rock surrounded by older rock in Logan County. The LIS split into the Miami Sublobe and the Scioto Sublobe as it flowed both around and above the outlier (fig. 3). The LIS began to melt and retreat at the end of the most recent Ice Age, funneling a massive amount of meltwater between the sublobes toward the modern-day village of Clifton. Generally, meltwater carries coarse material away from an ice sheet, creating a geologic deposit known as outwash. Glacial outwash forms as sediment (usually sand and gravel) drop out of the running water and fall to the bed of the meltwater river. The 33-mile-long Kennard Outwash Terrace sits in the former lowland area between the Miami Sublobe and the Scioto Sublobe (fig. 3). It was created by glacial meltwater that was funneled between the two lobes of ice to the south, finally escaping through the Little Miami River. As water drained into the Little Miami River Basin, it eroded downward through the bedrock and created the precursor to the modern Clifton Gorge.

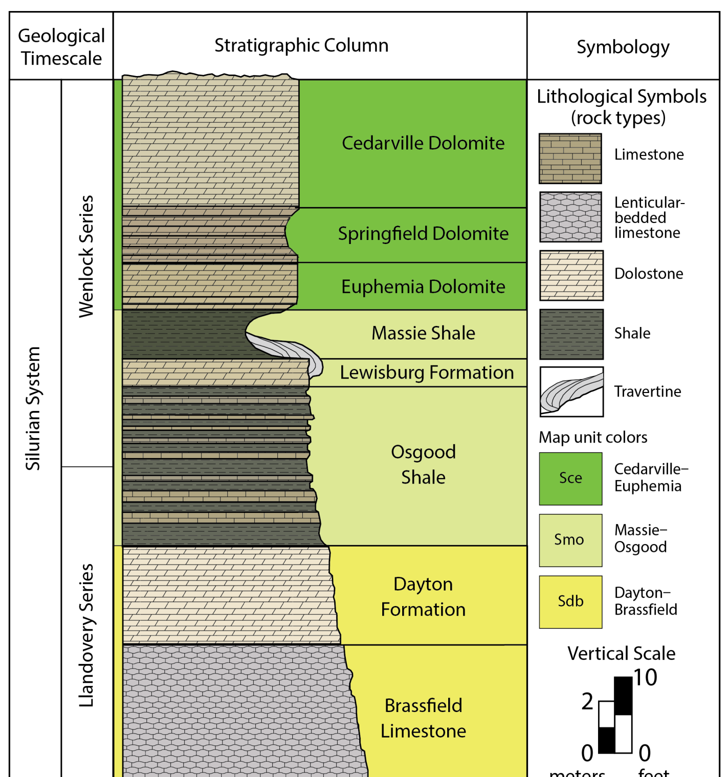


Figure 2. Stratigraphic column of rock units exposed in Clifton Gorge. Adapted from Ausich (1987).

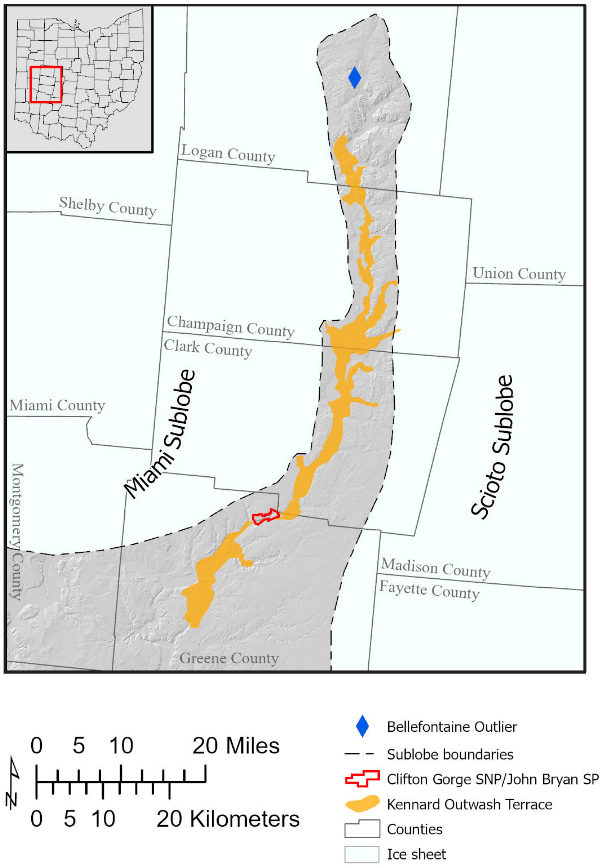


Figure 3. Map showing the relationship between the Kennard Outwash Terrace and John Bryan State Park/Clifton Gorge State Nature Preserve. The boundaries of the Miami Sublobe (west) and Scioto Sublobe (east) wrap around the Bellefontaine Outlier (blue diamond).

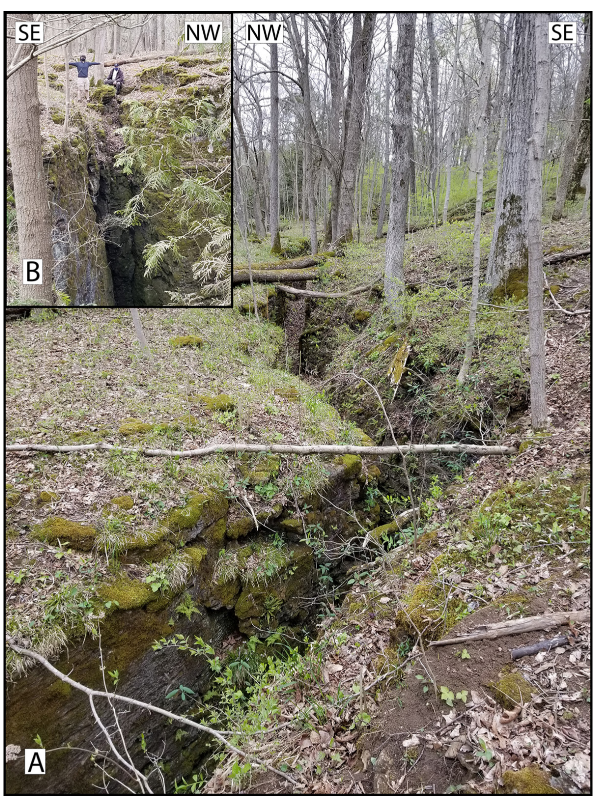


Figure 4. A: Major joints in the Cedarville Dolomite at the east bank of the nature preserve. B: An example of an open joint visible on the east bank of the gorge.

Gorge Evolution

From the historic mills east of the village of Clifton, the Little Miami River begins cutting through hard bedrock and flows westward through the spectacular gorge formed in the massive Cedarville through Euphemia Dolomites. The meltwater from the glaciers at the end of the Ice Age was funneled through limited large, vertical joints (fractures in the bedrock) in the massive Cedarville–Euphemia rock units (fig. 4) and created the deep, narrow gorge (see geologic map, profiles 1 and 2, on back cover). Hard igneous and metamorphic rocks, called *glacial erratics*, transported by glaciers from Canada, helped grind down the relatively softer Cedarville–Euphemia Dolomites along the joints. Potholes carved at different elevations, specifically near the top of the gorge, indicate grinding and erosion of the bedrock by meltwater flowing under the glacier (see geologic map on back cover). The gorge makes sharp turns through the region as it erodes along the regional joint pattern with little resistance to erosion (see geologic map on back cover). In addition to forming a deep, narrow gorge, the joints significantly influenced the downstream morphology of the park where the river cuts into the softer Massie and Osgood Shales.

These soft, clay-rich shale units are highly erodible. In contact with river water and groundwater, they become an unstable slippery surface under the jointed, massive dolomite layers and cause sliding and collapse of huge slump blocks into the valley. Steamboat Rock and several other bigger blocks (fig. 5) within the river and along its banks are examples of these slump blocks. Without the major joints in the bedrock, the local escarpment could have been resistant to collapse and erosion, and a 35–50-ft (10–15-m)-tall waterfall like Niagara Horseshoe Falls could have formed in the Clifton area instead of the multiple small waterfalls along narrow parts of the gorge. Over time, the older collapsed blocks were crushed and eroded, covering the Massie and Osgood Shales on the riverbed. The famous Blue Hole is created upstream from a pile of crushed slump blocks in the river.

Farther downstream from the Blue Hole, the river has a lower gradient and relatively mature morphology (see profile 3, back cover). The Dayton Formation and Brassfield Limestone underlie the Osgood Shale and are exposed downstream and under the lower trail at the west bank of the river in John Bryan State Park. The northern footbridge is built on the exposed layers of the Dayton Formation. Interpretation of geological features in the park shows that a narrow, deep gorge similar to Clifton Gorge existed within John Bryan State Park in the past. The gorge was widened by erosion and the collapse of the Cedarville–Euphemia Dolomites as the glaciers melted towards the end of the Ice Age.

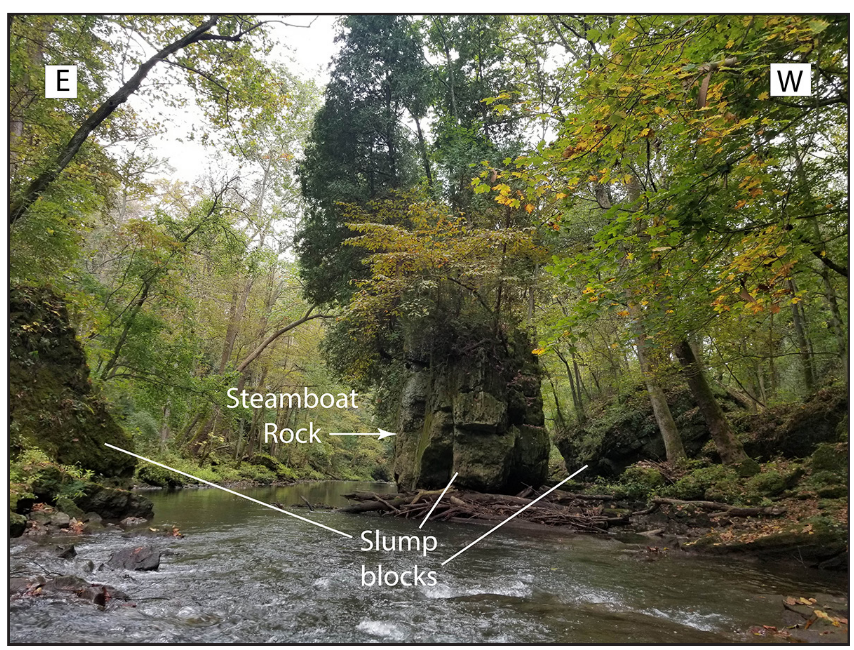
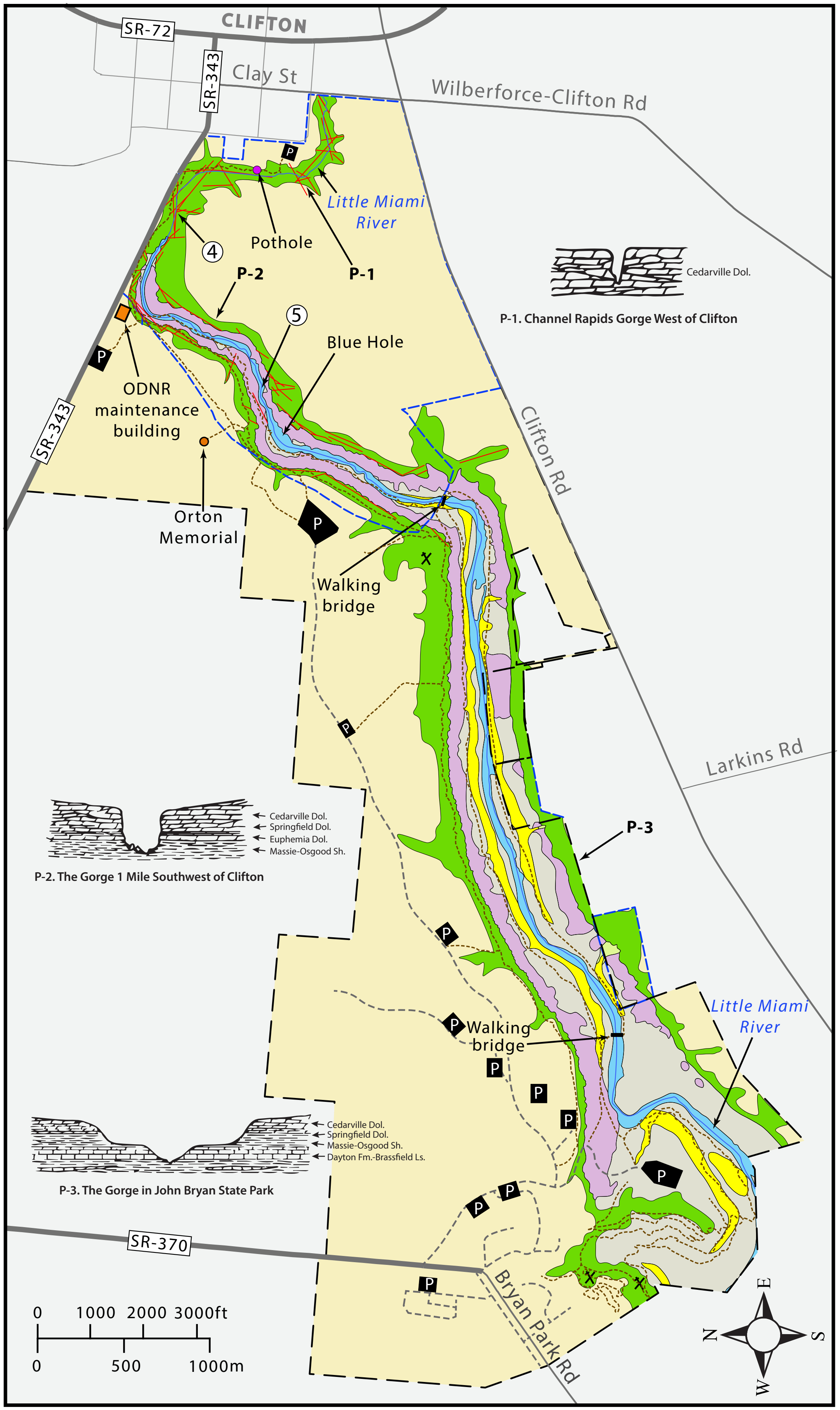
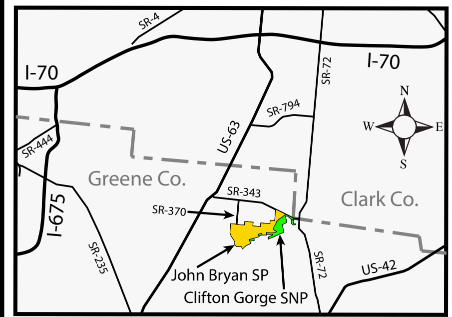


Figure 5. Cedarville Dolomite blocks and the famous Steamboat Rock (Carman, 1946) in the river. See geologic map on back cover for location.

Clifton Gorge State Nature Preserve & John Bryan State Park

GEOLOGIC MAP





LEGEND

Quaternary
- Qsc — Scree / terrace
- Qtl — Till*

Silurian
- Sce — Cedarville - Euphemia Dolomites*
- Smo — Massie - Osgood Shales*
- Sdb — Dayton Formation and Brassfield Limestone*

- Slump blocks
- Little Miami riverbed/gravel
- Joint
- Trail
- Abandoned quarry
- Pothole
- ④ Figure location/number
- Clifton Gorge State Nature Preserve boundary
- John Bryan State Park boundary
- Park roads
- P Parking

* Partially covered by scree.

P-1, 2, 3. Schematic gorge and bedrock profiles modified from Carman (1946).

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