

Apr 16th, 11:00 AM - 2:00 PM

Glacial Origin of Massie Creek Gorge, Greene County Ohio

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McKevitt, Dylan J., "Glacial Origin of Massie Creek Gorge, Greene County Ohio" (2014). *The Research and Scholarship Symposium*. 32. http://digitalcommons.cedarville.edu/research_scholarship_symposium/2014/poster_presentations/32

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Objectives

- Observe and record the geomorphological characteristics of Massie Creek Gorge in Greene County, Ohio.
- Determine the probable gorge-forming processes.
- Possibly compare/apply findings to Martian analogs.

Methods

Preliminary reconnaissance of the surrounding area was conducted through field observations (driving and hiking) and literature review of the area's history and previous studies. Within Massie Creek Gorge, joint orientations were recorded with a Brunton compass, number of rockfalls and their approximate dimensions were paced out, boulder bar and bedrock island dimensions were measured using a Jacob's staff and Google Earth, and pot-holes were located by GPS, photographed, and measured with a Jacob's staff. Patterns and morphological features similar to those observed were then searched for in studies on ter-restrial and Martian geomorphology.



Figure 5. Potholes, Rockfalls, Spring Deposits (photos taken by R. T. Gustafson)
Scale bar = 2 m in all photos. Numbers refer to locations in Fig. 4.

Vertical/plunge potholes: 1A) South side of river. 1B) Same large pothole, with smaller one closer to water (can circled at bottom of large hole is about 15 cm long). 2) Partial pothole on side of rockfall. 4) Lower pothole section visible, upper section in another rockfall block to right of picture. 5A) Along river's north side. 5B) Pothole in bedrock, center of river. 6A) Along south cliff face. 7) Near base of dry valley's cliff face. 9) Pothole well above water level along north cliff face.

Stacked lateral/trough potholes: 3A) Pair, angled downstream about 30° below horizontal. 6B) Located just west of 6A on same cliff face.

The eroded nature and location of potholes suggest formation contemporaneous with that of the gorge and evidence previous flow elevations. They represent either suspended sediment leading to vortex abrasion or toolless cavitation. The differing pothole types observed (vertical, plunge, trough) suggest changes in joint-controlled drainage resulting in "rip-up" clasts and rapid headward erosion and gorge cutting. For most potholes located higher up, plunging water likely from an overlying and retreating glacier may have initiated formation. Large pothole sizes and similar morphologies suggest common formation in a single or multiple rapid, massive-flow events. (Wang et al., 2009; Zen and Prestegard, 1994)

Rockfalls: Rockfalls in the upper gorge, before the dry valley, average 733 m³ in volume (n=17). Rockfalls downstream from the dry channel are more numerous (n=23) but only average 238 m³. Rockfalls along either side of the dry valley average 191 m³ (n=17). Six rockfalls are larger than 1000 m³ (max ~1800 m³), and 26 are smaller than 100 m³. 3B) Large rockfalls along south side of river.

Numerous and large rockfalls resulted from relief jointing due to mass gorge erosion and rapid undercutting by stream erosion. Overall joint orientations correlate with the orientations of Massie Creek Gorge and its side channels, along with regional southwesterly drainage. Joint-controlled glacial outflow may have formed the present drainage network. (Waren, 1988)

Spring deposits: Multiple travertine and tufa spring deposits up to 5 m³ in volume occur at the contact between Massie Creek Shale and the Euphemia Dolomite, accumulating as groundwater flows out from the top of the less permeable Massie Shale. Present-day accumulation of spring deposits testify to decreased erosion rates compared to the past, showing Massie Creek Gorge is a relic landscape, and thus past gorge-forming processes are not presently observed. 8) Large travertine/tufa spring deposits along base of north cliff face, extending downwards from Springfield Dolomite to Massie Creek Shale. Some blocks have broken off.

Origin of Massie Creek Gorge, Greene County Ohio

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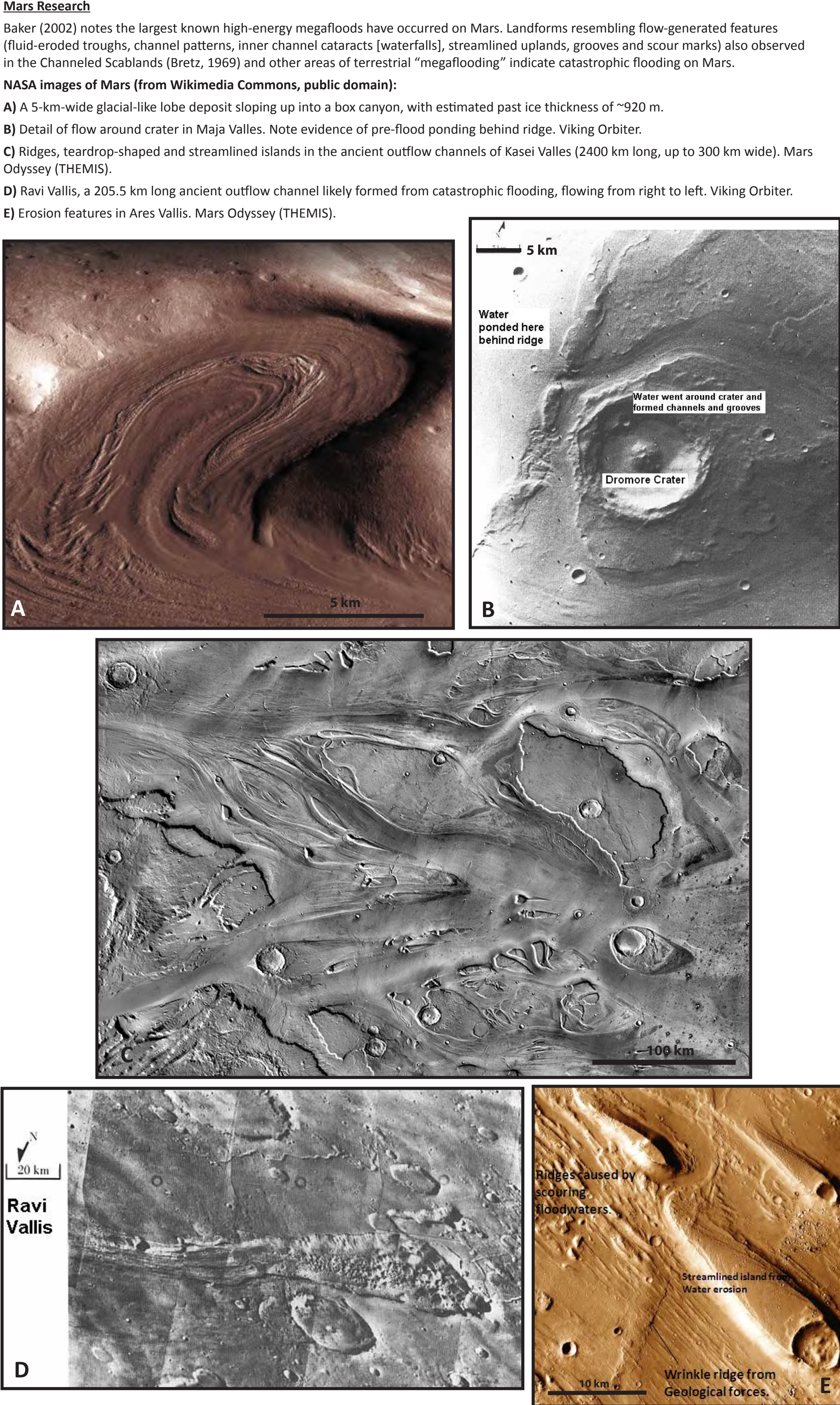
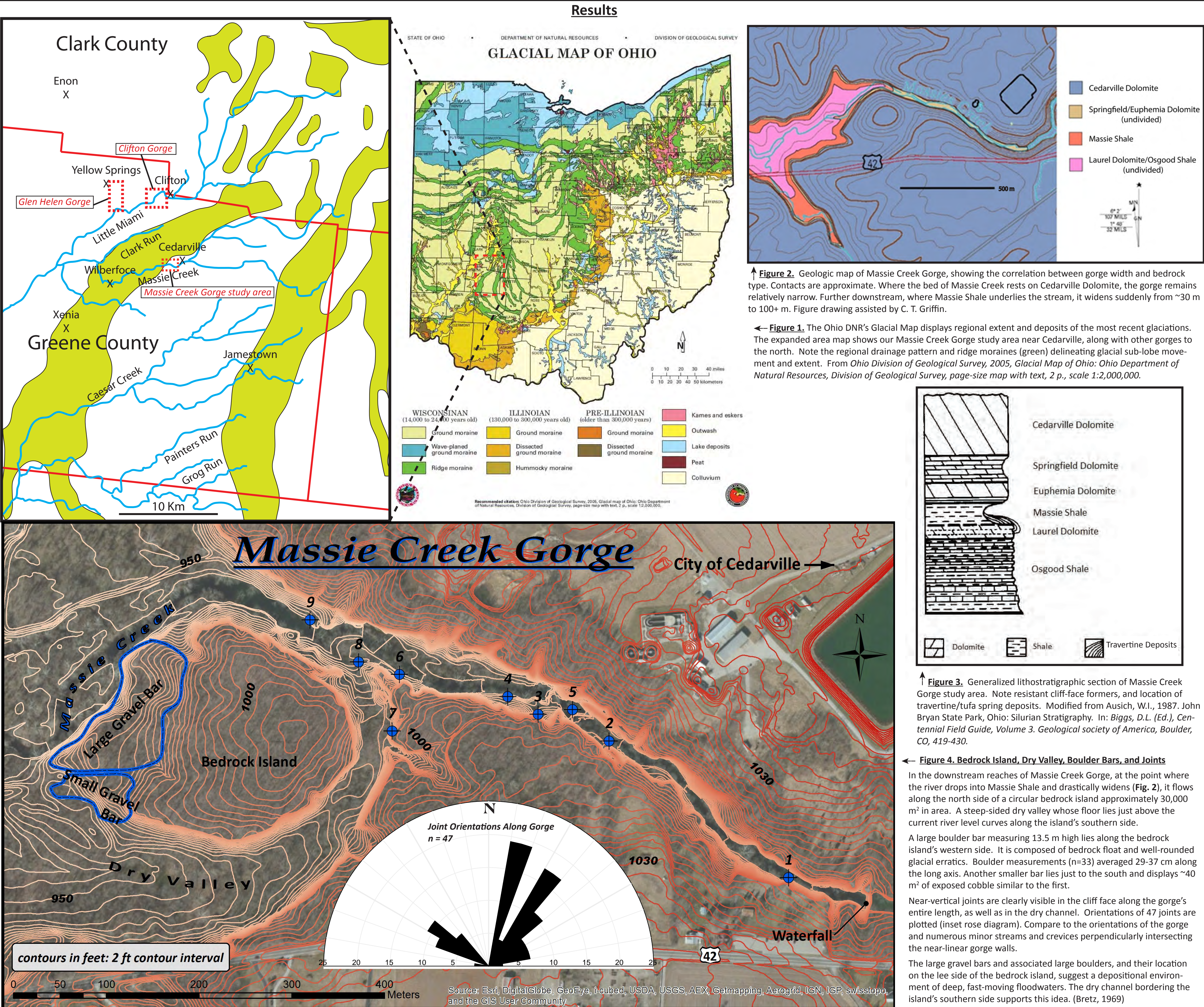
Advisor: Professor John H. Whitmore

Abstract:

Massie Creek Gorge is one of several small but impressive canyons in Greene County, Ohio that cut through a typically low-relief landscape. It displays spectacular dolomite cliffs (up to 20 m high), large rockfalls (up to 1800 m³), numerous large potholes (up to >5 m wide and >7 m high), a dry valley branching off the main channel with a resultant bedrock island (≈30,000 m² in area) and two boulder bars on its lee side (the largest ≈13.5 m thick). Short, dry side canyons are cut to the same depth as the main drainage and sometimes contain potholes on their walls. Massie Creek Gorge's geomor-phological features, its location in relation to end moraines from the last glaciation episode, and regional surficial deposits and stratigraphy indicate the terminus of the glacial ice was directly above the proximal end of Massie Creek Gorge. With the exception of some late-occurring rockfalls, sediment deposition, aggrading spring deposits, and the undersized river show Massie Creek Gorge is a relict landscape. Joint orientations correlate locally with gorge direction and perpendicular side-streams/crevices, and regionally with morphologically similar Clifton Gorge and Glen Helen Gorges. Previous studies concerning these two nearby gorges were analyzed, along with work describing glacial history, processes, and features in southwestern Ohio.

Studies dealing with pothole types and formation were reviewed and applied to Massie Creek Gorge. These along with the dry river channel, the bedrock island, boulder bars and short but deep side canyons testify to very significant past flow conditions. Evidence suggests the gorge was cut by high-volume, sediment-laden outwash from ice lying in close proximity to the gorge, probably during a glacial outburst flood or rapid glacial melting and retreat. This is consistent with the scale of potholes and boulder bars found within the canyon. The origin of this gorge may provide clues concerning the origin of other deep canyons located near significant end moraines.

Morphological features similar to those noted in this study are also seen on extraterrestrial landscapes, especially on Mars. Applying this proposed model for their origin may provide insight into past conditions and processes, and further this blooming field of extraterrestrial analysis.



Conclusions

Multiple mechanisms may have contributed to Massie Creek Gorge's formation. A jökulhlaup, or glacial outburst flood, occurs when a subglacial or proglacial lake catastrophically drains after the breaching of a dam consisting of glacial ice or a terminal moraine (Rushmer, 2006). These events can be episodic. Also, rapid melting and receding of the glacial lobe produced large volumes of meltwater, which may have been dammed by proglacial moraines, whose subsequent breach resulted in catastrophic outwash. Lastly, subglacial flow may have eroded into bedrock, similar to current formation of karst caves.

Due to the location of Massie Creek Gorge between two end moraines, our proposed hypothesis employs subglacial processes as the initial cause of canyon formation. A lack of significant glacial till between end moraines points to later rapid glacial retreat. First, subglacial bedrock erosion and episodic outwash from jökulhlaups resulted in significant flow following joint-controlled drainage, and massive pothole formation and rapid bedrock removal. Sediment-laden outflow following glacial retreat continued these processes, and explains the large bedrock island, abandoned channel, and boulder bars. Rockfalls formed and were left along canyon walls as flow subsided.

Evidence for both glaciation and catastrophic flooding on Mars has been abundantly noted in the literature and strongly supported by improving imaging technology. As resolution improves, if features similar to those observed in Massie Creek Gorge are discovered then a similar catastrophic, glacial-outwash process of formation may be inferred.

Status of Project

This study's objectives have been completed, although further work (such as calculating potential flow volumes and velocities and analyzing downstream deposits to see if they support the proposed processes) could significantly improve this study's conclusions.

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