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A LATE PLEISTOCENE CEILING COLLAPSE IN BOGUS CAVE, JONES COUNTY, IOWA: A POTENTIAL RELATIONSHIP TO COEVAL ACCELERATED MASS WASTING EVENTS ACROSS THE CENTRAL MIDWEST

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*A thick accumulation of boulder-size dolostone blocks, the result of one or more episodes of ceiling collapse, was encountered during geoarchaeological excavations in the front room of Bogus Cave, east-central Iowa. The rockfall layer was buried by a veneer of Holocene sediments that contained prehistoric artifacts dating to the Woodland Period (2500-1000 yr BP). An AMS ^{14}C age of 17,260 ±120 yr BP, obtained from a caribou (*Rangifer tarandus*) mandible found wedged among the boulders, dates the collapse near the close of the last glacial maximum, a time when the projected mean annual temperature for this area was at least 14°C lower than at present. Paleoenvironmental evidence based on ä^{13}C values from select vertebrate remains and their encompassing sediment, together with a uranium series age of 16,900 ± 4800 yr BP from a stalagmite formed atop one of the boulders, strongly support a late Wisconsinan age for the collapse. The episode (or episodes) of collapse appears to be the result of cryoclastic processes associated with late glacial conditions and the onset of accelerated mass wasting that has been previously documented across the central Midwest.*

The transition from late Pleistocene to Holocene time encompasses a period of major environmental change across the central Midcontinent (Van Zant 1979; Baker *et al*. 1986, 1992, 1996, 1998; King & Graham 1986). During the last glacial maximum (21,500-16,000 yr BP), the landscape immediately south of the glacial margin consisted of open tundra and parkland inhabited by arctic and subarctic flora and fauna (Baker *et al*. 1986; King & Graham 1986). Sediment features and soil patterns (e.g., ice-wedge casts and relict patterned ground) indicate that permafrost developed across this region and extended as far south as 38° 30'N latitude between 21,000 and 16,000 yr BP, the coldest interval of the late Wisconsin, when postulated mean annual air temperature was at least 14°C colder than at present (Johnson 1990; Walters 1994). At most localities, permafrost probably existed for <1000 years. Its development and subsequent degradation appear to be time-transgressive and closely related to ice margin proximity (Johnson 1990). Furthermore, evidence for accelerated mass wasting within this region has been dated to the late glacial period and suggests a causal link with the periglacial climate and the development of permafrost (Harris 1987; Mason 1995; Mason & Knox 1997).

As part of a geoarchaeological investigation conducted at Bogus Cave, Jones County, Iowa (Fig. 1), two test units were excavated in the front room of the cave, the principal site of human occupation. The excavations revealed a layer of boulder-size dolostone blocks buried beneath an organic-rich, sandy loam veneer (Josephs 2000). This accumulation represents at least one episode of ceiling collapse. Through a combination of sedimentologic, stratigraphic, micromorphologic, and isotopic geochemical and geochronologic techniques, this paper proposes a correlation between late glacial accelerated mass wasting, previously documented throughout the region, and the ceiling collapse recorded in the subsurface profile of the cave.

Figure 1. Site location plotted on physiographic map of Iowa (from Iowa Department of Natural Resources, Geological Survey Bureau).

SITE LOCATION AND SETTING

Bogus Cave is located ~6 km northwest of the town of Anamosa, Jones County, Iowa, at 42°08'47"N latitude, 91°20'33"W longitude. This section of Jones County lies within a heavily wooded, karstic region of the Southern Iowa Drift Plain along its interdigitated boundary with the Iowan Erosion

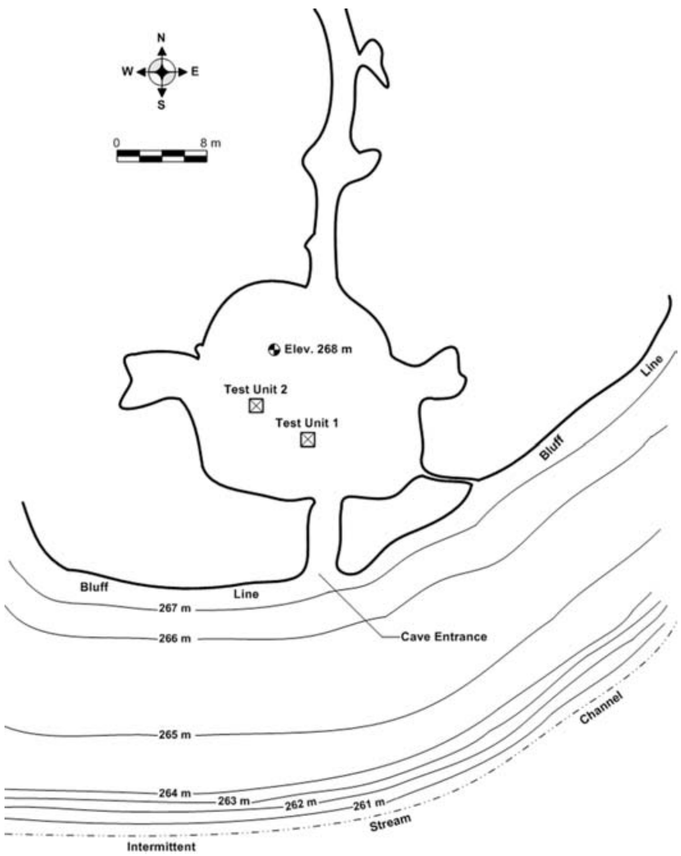

Figure 2. Map of Bogus Cave showing the location of the test units.

Surface (Prior 1991; Fig. 1). This irregular boundary closely approximates the Grassland-Deciduous Forest Contact as defined by Shelford (1963). The main entrance to the cave opens toward the south along a bluff line about 7 m above the channel of an unnamed, ephemeral first-order stream (Fig. 2). Present access into the cave is through a tunnel-like passageway that leads into a dome-shaped front room that is ~3 m high near its center and averages roughly 20 m in diameter. Passages of various size and shape radiate from this central area.

Bogus Cave has formed in the Anamosa Member of the Upper Silurian Gower Formation (Witzke *et al*. 1998). The Anamosa member is a non-fossiliferous, flat-lying, laminated dolostone (Witzke 1992). The age of Bogus Cave has yet to be determined. Hedges & Darland (1963) suggested that the cave "probably" formed during pre-Illinoian time. The development of karst in this area is controlled by the bedrock's "pre-karst" porosity (bedding-plane partings and joints), hydraulic conductivity, and clay content. Passage morphology in many of the shallow, phreatic caves formed in Silurian strata is controlled by the interrelationships among joints and the preferred direction of groundwater flow (Bounk 1983).

RESULTS

While excavating two test units, each roughly 1 m², in the front room of Bogus Cave, a buried, clast-supported accumulation of angular to subangular, boulder-size dolostone was contacted 35-55 cm below the existing cave floor (Fig. 3). A brown (10YR 4/3) silt loam fills the interstices. Micromorphological examination of the silt loam revealed a well-sorted, exogenous sediment, most likely deposited by infiltrating water. The majority of the mineral grains are silt-size quartz and feldspar. This stratum (Stratum II) is overlain by a veneer of dark olive brown (2.5Y 3/3) sandy loam (Stratum I) that contains a mixed assemblage of historic and prehistoric artifacts. The earliest prehistoric artifacts date to the Woodland Period (2500-1000 yr BP), a time when cave and rockshelter sites in this area were most intensively exploited (Alex 1968; Jaenig 1975; Logan 1976; Benn 1980; Marcucci & Withrow 1996; Josephs 2000). The collapse layer rests on a densely packed stratum (Stratum III) of cobble- and gravel-size, subangular to rounded, dolostone clasts in a culturally sterile, brownish-yellow (10YR 6/8) clay loam matrix. Thin sections of the clay loam matrix revealed an endogenous sediment formed largely by *in situ* chemical weathering.

Owing to the size and composition of the clasts and the location and extent of the accumulation, the only plausible explanation for its emplacement is having fallen directly from the ceiling in one or more catastrophic collapse events, the most likely culprit being cryoclastism. Attempts to use attributes related to clast morphology to identify specific processes responsible for cave-ceiling collapse have proven largely unsuccessful. Freeze-thaw, heating and cooling, and hydration spalling, all possible agents for ceiling collapse, produce indistinguishable debris accumulations (Farrand 1985).

Caves typically acquire an air temperature that approximates the mean annual temperature of the area in which they are located. The current mean annual temperature for Jones County, Iowa, is 8.6°C (Minger 1991). The mean annual temperature for this area between 21,000 and 16,500 yr BP, the coldest part of late Wisconsin time, is projected to have been -6°C (Johnson 1990; Walters 1994). This supports freeze/thaw as the likely agent for initiating the collapse.

During the excavation of the rock fall unit (Stratum II) in test unit 1, the left half of a caribou mandible (*Rangifer tarandus*) was recovered from the south profile, 93 cm below the cave floor (Fig. 4). Despite having been wedged tightly among the boulders, it was in remarkably good condition. Its age at time of death is estimated to have been between 6 and 9 years old (Arthur E. Spiess, pers. comm., 2000). Its presence in the cave is a matter of speculation; however, carnivore predation is a likely explanation. Following laboratory examination, the roots of the third molar (M_3) were separated from the tooth crown and submitted to the Rafter Radiocarbon Laboratory, Lower Hutt, New Zealand, for accelerator mass spectrometry (AMS) ^{14}C dating and analysis of $\delta^{13}C$ content. The $\delta^{13}C$ value reflects the relative proportion of C_3 (cool, moist climate) ver-

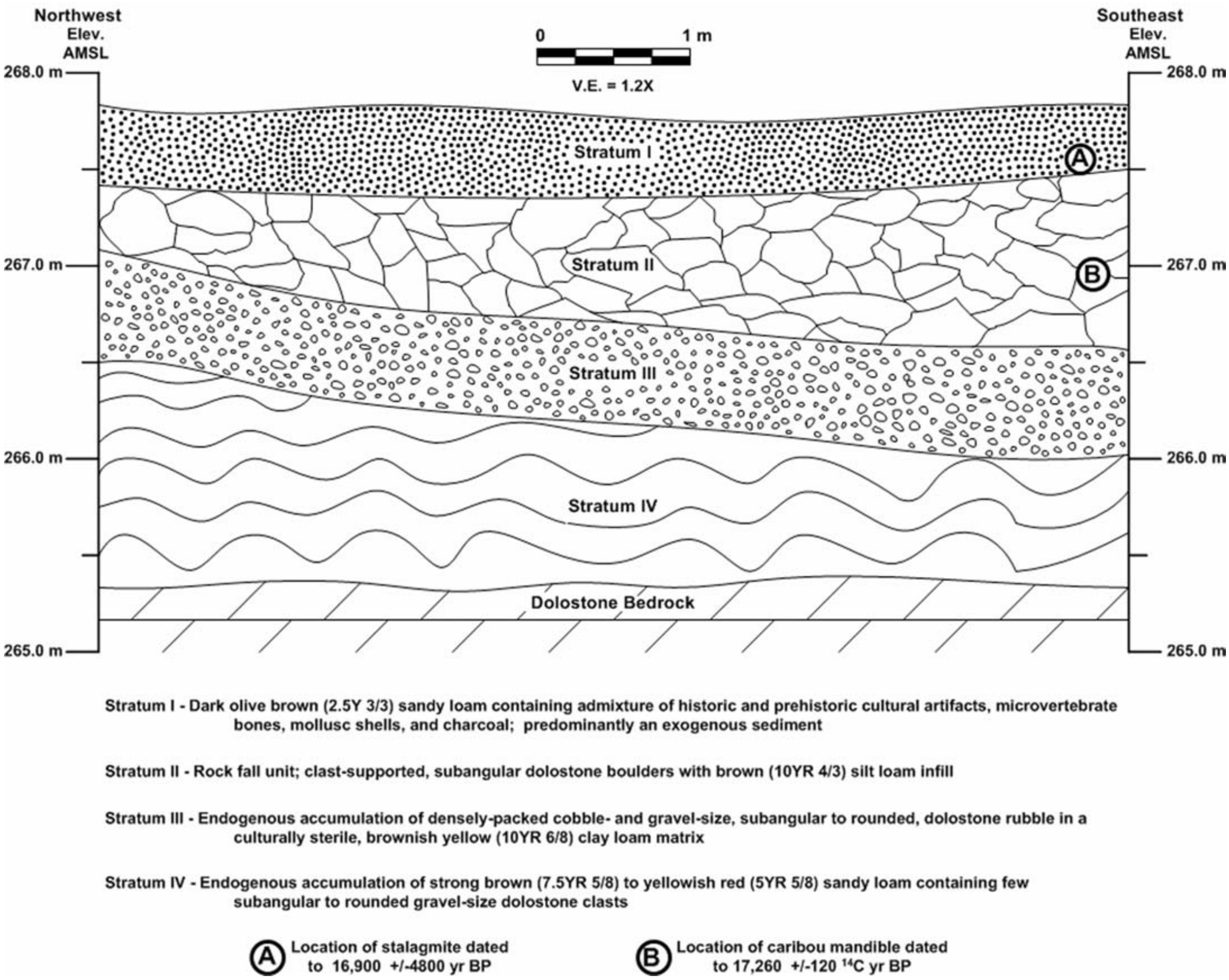

Figure 3. Northwest – southeast profile of Bogus Cave stratigraphy.

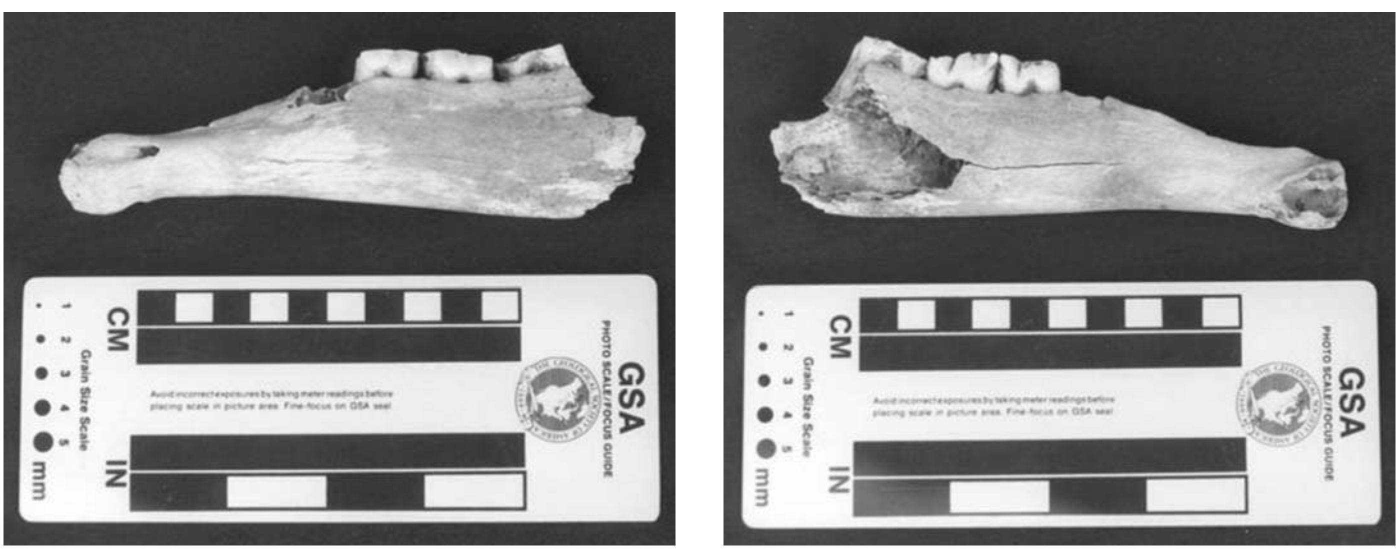

Figure 4. Left half of *Rangifer tarandus* mandible: left photo buccal view, right photo lingual view

sus C_4 (warm season grasses and herbs) plants in the environment at a given time (Herz 1990). The $\delta^{13}C$ values range between -35 and -20‰ for C_3 plants and -16 and -9‰ for C_4 plants (van der Merwe 1982). The relative proportion of C_3 and C_4 plants is correlated with mean annual temperature and mean annual precipitation; therefore, the $\delta^{13}C$ value serves as a valuable proxy for paleovegetation and paleoclimate (Herz 1990; Boutton 1996). It is also the most popular isotopic technique for studying paleodiet in both human and non-human mammals (Reitz & Wing 1999).

An age of 17,260 ±120 ^{14}C yr BP together with a $\delta^{13}C$ value of -18.4‰ were obtained for this sample (NZA 10448). The -18.4‰ $\delta^{13}C$ value falls well within the range for a terrestrial herbivore feeding on C_3 (cool, moist climate) vegetation (Herz 1990; Reitz & Wing 1999) and agrees well with the paleoenvironmental scenario for this region during the full glacial (Baker *et al*. 1986). A sample of the silt loam fill was submitted to Geochron Laboratories, Cambridge, Massachusetts, for ä^{13}C analysis of its organic carbon content. The value obtained was -24.1‰ (CR-101624), which further supports the evidence for paleovegetation dominated by C_3 flora. A post-collapse stalagmite that had formed atop one of the boulders in the northeast corner of test unit I, just beneath the Stratum I sediments, was removed and submitted to the Paul H. Nelson Stable Isotope Laboratory, Department of Geoscience, University of Iowa, for uranium series (^{238}U-^{234}U-^{230}U) disequilibrium dating (Faure 1986; Reagan *et al*. 1994). It produced a U-series age of 16,900 ±4800 calendar years before present (Rhawn F. Denniston, pers. comm., 1999).

As part of a separate investigation, micromammalian remains were collected from buried contexts in the rear (northern) portion of Bogus Cave, a section not suitable for human habitation (Slaughter 2001). The results of AMS ^{14}C dating and ä^{13}C analyses performed on select tooth and jaw samples, together with their biostratigraphic relationships, support the geochronologic and paleoclimatic scenario evinced in the front room of the cave (Josephs 2000; Slaughter 2001).

CONCLUSIONS

Geologic and paleoenvironmental evidence from Bogus Cave, Jones County, Iowa, supports the following conclusions:

1. The buried accumulation of dolostone boulders found within Bogus Cave is the result of one or more episodes of ceiling collapse.
2. Mean annual temperatures below 0°C support freeze/thaw as the most likely initiating agent for the collapse.
3. Radiometric methods (AMS ^{14}C and U-series) date the collapse near the close of full-glacial conditions, *circa* 17,000 years before present.
4. Stable carbon isotope analyses ($\delta^{13}C$ values) of vertebrate remains and their encompassing sediment corroborate previous paleoenvironmental reconstructions for this area, at this time.
5. The date of the collapse and associated climatic conditions coincide with other mass wasting events documented from this area at this time.

It is, therefore, presumed that the Bogus Cave ceiling collapse was the result of cryoclastic processes associated with transitional, glacial-to-interglacial, conditions that initiated a period of accelerated mass wasting across the central Midwest.

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