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 14C 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 δ13C 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.
A LATE PLEISTOCENE CEILING COLLAPSE IN BOGUS CAVE, JONES COUNTY, IOWA

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 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 (M3) were separated from the tooth crown and submitted to the Rafter Radiocarbon Laboratory, Lower Hutt, New Zealand, for accelerator mass spectrometry (AMS) 14C dating and analysis of δ13C content. The δ13C value reflects the relative proportion of C3 (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 C₄ (warm season grasses and herbs) plants in the environment at a given time (Herz 1990). The δ¹³C values range between -35 and -20‰ for C₃ plants and -16 and -9‰ for C₄ plants (van der Merwe 1982). The relative proportion of C₃ and C₄ plants is correlated with mean annual temperature and mean annual precipitation; therefore, the δ¹³C value serves as a valuable proxy for paleovegetation and paleoclimate (Herz 1990; Boutton 1996). It is also the most popular isotopic technique for studying paleoecot in both human and non-human mammals (Reitz & Wing 1999).

An age of 17,260 ±120 ¹⁴C yr BP together with a δ¹³C value of -18.4‰ were obtained for this sample (NZA 10448). The -18.4‰ δ¹³C value falls well within the range for a terrestrial herbivore feeding on C₃ (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 ²³⁰Th analysis of its organic carbon content. The value obtained was -24.1‰ (CR-101624), which further supports the evidence for paleovegetation dominated by C₃ 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 (²³⁸U-²³⁴U-²³⁰U) 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 (northeastern) portion of Bogus Cave, a section not suitable for human habitation (Slaughter 2001). The results of AMS ¹⁴C dating and ³³⁷Cs 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 ¹⁴C and U-series) date the collapse near the close of full-glacial conditions, circa 17,000 years before present.
4. Stable carbon isotope analyses (δ¹³C 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 cryoelastic processes associated with transitional, glacial-to-interglacial, conditions that initiated a period of accelerated mass wasting across the central Midwest.

ACKNOWLEDGMENTS

The author wishes to thank the following individuals for their indispensable assistance at Bogus Cave: E. Arthur Bettis III, Michael Cooper, Rhawn F. Denniston, and Richard W. Slaughter.

REFERENCES

Josephs, R.L., 2000, Sedimentology and speleothrography of Bogus Cave, Jones County, Iowa [PhD thesis]: Iowa City, University of Iowa, 153 p.
King, J.E., & Graham, R.W., 1986, Vertebrates and vegetation along the southern margin of the Laurentide Ice Sheet: Programs and abstracts 9th Biennial Meeting, American Quaternary Association, University of Illinois, Urbana-Champaign, p. 43-45.


Slaughter, R.W., 2001, Terminal Pleistocene and Holocene mammal remains from Bogus Cave, Jones County, Iowa [Ph.D. thesis]: Iowa City, University of Iowa, 83 p.


Witzke, B.J., 1992, Silurian stratigraphy and carbonate mound facies of eastern Iowa, field trip guidebook to Silurian exposures in Jones and Linn counties: Iowa Department of Natural Resources, Geological Survey Bureau, Guidebook Series No. 11, 73 p.