Prolonged wet period in the southwestern United States through the Younger Dryas

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ABSTRACT

The Younger Dryas was one of the more dramatic climatic transitions ever recorded. How these types of climatic shifts are expressed in continental interiors is of primary scientific interest and of vital societal concern. Here we present a speleothem-based absolutely dated record (using uranium-series data) of climate change for the southwestern United States from growth chronology of multiple speleothems. The stalagmite growth represents the onset of wetter climate (12,500 yr B.P.) soon after the start of the Younger Dryas; the wetter climate persisted a millennium beyond the termination of the Younger Dryas. This wet cycle is likely related to a more southern positioning of the polar jet stream in response to cooler Northern Hemisphere climate. The end of the wet period coincides with the peak of the Holocene summer insolation maximum ca. 10,500 yr B.P. The Allerød (prior to the Younger Dryas), which corresponds to Clovis occupation in the southwestern United States, was drier in comparison and seems in line with a climatic contribution to megaflora extinction.

Keywords: Carlsbad Caverns, stalagmite, paleoclimate, U-series, Younger Dryas.

INTRODUCTION

The Younger Dryas climatic event represents the last episode in which North Atlantic climate returned to near-glacial conditions. This event occurred between 13,000 and 11,200 yr B.P. (Bennett et al., 2000); ice cores have more distinctly defined the Younger Dryas to have occurred from 12,940 to 11,640 yr B.P., with return to normal conditions with unprecedented rapidity in less than a decade (Alley et al., 1993). Understanding climate conditions in continents around the Younger Dryas chronosome is important because it provides insight into the response of continental interiors to such dramatic climate change. How rapidly climate deteriorates and recovers is of vital societal importance. Current understanding of climate change in continental interiors during the time of the Younger Dryas is unclear, in part because of the lack of well-dated proxies. Here we present a well-dated speleothem climate proxy from around the time of the Younger Dryas.

In arid regions such as the southwestern United States, speleothem growth is moisture limited (Polyak and Asmerom, 2001). Thus, in decorated but inactive cave interiors, the dry speleothems usually represent past periods of wetter-than-present conditions. High-precision uranium-series (U-series) dating of six small stalagmites from three caves in the Guadalupe Mountains, southeastern New Mexico (Fig. 1), shows a record of stalagmite growth from ca. 30,000 to 10,500 yr B.P. Most of the ages are robust (low error) determinations. Some ages have large errors due primarily to samples with low U and high 232 Th (detrital); such samples require significant initial 230 Th/232 Th ratio corrections based on 230 Th/232 Th versus 234 Th/232 U isochrons. The U-series dates are cited as calendar years before present (yr B.P.; present is A.D. 2002). Images of samples and tabulated U-series data are available.1

METHODS

Numerous U-series dates were acquired, and we found that construction of (230 Th/232 Th) versus (234 Th/232 U) (activity ratios) three-point isochrons was necessary to determine the initial 230 Th/232 Th ratio because of intermittently higher initial 230 Th/232 Th ratios or excess detrital Th combined with low U concentrations in some subsamples. Significant amounts of detrital 230 Th in the calcite result in anomalously older U-series ages. A correction is needed in young (<20 ka), low-uranium samples. The U-series dates constrain the period of stalagmite growth around the Younger Dryas and encompass the Pleistocene-Holocene transition in calendar years before A.D. 2002. Reversed (uncorrected) ages in the lower section of stalagmite BC2 were found to be due to higher initial 230 Th/232 Th ratios. A 230 Th/232 Th versus 234 Th/232 Th three-point isochron indicated an average initial 230 Th/232 Th = 6 × 10⁻⁵ = 60 ppm, significantly greater than bulk silicate

1GSA Data Repository item 2004001, tabulated U-series data and photographs of samples, is available online at www.geosociety.org/pubs/ft2004.htm, or on request from editing@geosociety.org or Documents Secretary, GSA, PO. Box 9140, Boulder, CO 80301-9140, USA.
The wet episode (Fig. 2). This wet period (of C10-3 at 12,500 yr B.P. marks the onset of after the start of the Younger Dryas. The base stalagmite growth), wetter conditions were es-
hanced initial ratios of $^{230}\text{Th}/^{232}\text{Th}$. The BC2 hi-
series dates that are robust even with sizably Holocene calcite below the hiatus yields U-
to late Pleistocene stalagmite growth. The ear-
Polyak et al., 2001) from the early Holocene 
Pleistocene paleoclimates, and increased moisture in much of the Great 
Basin, indicated by the prevalence of black 
mats (Quade et al., 1998). Globally, climate 
proxies with high-resolution chronologies 
from the Atlantic margin settings, both in 
coastal regions (e.g., Cariaco Basin; Hughen 
et al., 2000) and continental interiors (e.g., 
Great Lakes area; Yu and Eicher, 1998), show 
strong synchronicity with the Young Dryas 

**CHRONOLOGY AND STALAGMITE GROWTH**

Our speleothem data show that, after an overall dry episode that started at the Bolling-
Allerød transition (ca. 14,000 yr B.P., lack of stalagmite growth), wetter conditions were esti-
blished by ca. 12,500 yr B.P. (Fig. 2), soon after the start of the Younger Dryas. The base of C10-3 at 12,500 yr B.P. marks the onset of the wet episode (Fig. 2). This wet period (= stalagmite growth) lasted for ~2000 yr. The termination of this wet period is best defined near the base of stalagmite BC2 (Carlsbad Caverns) by an 8000 yr growth hiatus that separates late Holocene stalagmite growth (= wet period, Polyak and Asmerom, 2001; 
Polyak et al., 2001) from the early Holocene to late Pleistocene stalagmite growth. The ear-
ly Holocene calcite below the hiatus yields U-
series dates that are robust even with sizably high initial ratios of $^{230}\text{Th}/^{232}\text{Th}$. The BC2 hi-
atus (distinct black layer possibly formed by thousands of years of organic debris settling onto the stalagmites from bat flights), estab-
blished by U-series dates and annual bands, oc-
curred at 10,900 yr B.P. , 300 yr (determined from annual bands) after an isochron-
determined date of 11,200 ± 140 yr B.P. Ter-
mination of early Holocene stalagmite growth is also well defined by the top of stalagmite 89038a (Hidden Cave), where aragonite layers become more abundant. This hiatus is at 10,500 yr B.P., ~130 yr following a date of 10,630 ± 190 yr B.P. (determined from band-thickness growth rate). The other four stalag-
mites all have tops with ages near 11,000 yr B.P. The period of Younger Dryas to early Ho-
locene growth is defined by the cave number 10 (C10) stalagmites (Fig. 2). Stalagmite 
C10-1 is probably most typical of the growth period, because it exhibits important hiatuses 
between 30 and 11 ka. Growth of this stalag-
mitate terminated near 20 ka; then minor growth occurred at 14 ka, and a final episode of 
growth occurred from 12 to 11 ka, possibly 
indicating the timing of the core of the Younger 
Dryas to early Holocene growth period. The C10-3 stalagmite grew from ca. 12.5 to 
ca. 10.6 ka. Overall, the timing of Younger Dryas–early Holocene growth appears to have 
been from ca. 12.5 to ca. 10.5 ka; most growth occurred between 12 and 11 ka (Fig. 2).

The C10 stalagmites show hiatuses or slowing of growth during the Allerød and early Younger Dryas chronozones and reestablish-
ment of growth by the early to middle Younger Dryas. These stalagmites do not exhibit growth after 10,500 yr B.P., suggesting that the conditions controlling growth of these sta-
lagmites were more pronounced prior to that time than during the entire Holocene. Stalag-
mites 89038 and 89038a also do not exhibit continued middle or late Holocene growth, al-
though late Holocene stalagmites from this same cave and Carlsbad Caverns have been 
reported (Polyak and Asmerom, 2001). Ter-
mination of growth of all six stalagmites by 10,500 yr B.P. equates to the onset of distinct-
ly drier conditions.

**DISCUSSION AND CONCLUSIONS**

Cessation of growth of these stalagmites by ca. 11,000 and no later than 10,500 yr B.P. was coeval with the termination of the last highstand of regional lakes, such as Lake Lu-
cero (Longford, 2003; <100 km north of our study area) and Lake Estancia (Anderson et al., 2002; <300 km north of the Guadalupe Mountains). It also coincides with a change from cooler wetter to warmer drier climate, 
evidenced in lake sediments in central and northern Arizona (Weng and Jackson, 1999) 
and increased moisture in much of the Great 
Basin, indicated by the prevalence of black 
mats (Quade et al., 1998). Globally, climate 
proxies with high-resolution chronologies 
from the Atlantic margin settings, both in 
coastal regions (e.g., Cariaco Basin; Hughen 
et al., 2000) and continental interiors (e.g., 
Great Lakes area; Yu and Eicher, 1998), show 
strong synchronicity with the Young Dryas
wet period occurred near the peak of the Ho-
ual, lasting well into the Holocene, ca. 10 ka
last glacial maxima and its recovery was grad-
California Current had collapsed prior to the
Periods in
this state, which the California Current is disrupted,
including the California Current, also in¯uence
the near-surface ocean along the Califor-
Prest, 1987). Atmospheric conditions that con-
ent in northwestern North America (Dyke and
Cordilleran-Laurentide ice sheet was still pres-
was expansion of Laurentide ice sheets during
the Last Glacial Maximum (Kutzbach and
Southward shift of the split jet stream during
at the start of the Younger Dryas likely re¯ects
interpretation (relative to 20 ka, 14 ka, and
climate also compliments an explanation that
climate change played a role in the extinction
of some megafauna, such as the mammoth, in
in the study area resulted in important faunal and
Harris, 1997) prior to hu-
man colonization. These changes likely
stressed the Pleistocene megafaunal popula-
An overkill explanation for megafaunal
mass extinction is more realistic during an
arid interval. The beginning of the Folsom
culture coincides with drier conditions by our
interpretation (relative to 20 ka, 14 ka, and
12.5–10.5 ka), which may explain evidence for
the Folsom drought (Holliday, 2000), but
we interpret an increasingly wetter Folsom
time from beginning to end for the south-
western United States.

ACKNOWLEDGMENTS

We thank D. Pate, S. Allison, and P Burger with
Carlsbad Caverns National Park and R. Turner with
the Lincoln National Forest for permission to collect
samples as well as assistance in the field. We are
grateful to P. Provenzo for assistance in the field.
We thank R.Y. Anderson for a constructive review of
an earlier version of the manuscript. W.S. Broecker and
an anonymous reviewer provided helpful comments and suggestions. This work was
supported by National Science Foundation grant
ATM-0117374.

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Manuscript received 18 June 2003
Revised manuscript received 5 September 2003
Manuscript accepted 8 September 2003
Printed in USA