ARTICLE IN PRESS

Quaternary International xxx (2017) 1–8

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

Late Pleistocene and mid-Holocene climate change derived from a Florida speleothem

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ARTICLE INFO

Article history:
Received 8 January 2017
Received in revised form
17 April 2017
Accepted 8 May 2017
Available online xxx

Keywords:
Pleistocene
Holocene
Speleothem
Paleoclimate
Florida

ABSTRACT

A stalagmite collected from Brooksville Ridge Cave in west-central Florida was deposited from ~30 to 20 kyr BP, encompassing Heinrich event 2 (H2), and from ~5 to 4 kyr BP, the later part of the mid-Holocene. The H2 event in the speleothem occurs at ~24 kyr BP which is temporally similar to its timing in other paleoclimate reconstructions. However, the oxygen and carbon isotope values indicate the climate in Florida was relatively warm and wet for a glacial period rather than extremely cool and dry, as seen in other regions. The higher temperatures and increased precipitation, compared to the preceding climate state, produced a shift towards enhanced vegetation growth (dense forest) during this period. One possible cause is the faltering of the North Atlantic Thermohaline Circulation, due to increased glacial meltwater input, thereby preventing heat transfer via the Gulf Stream from the tropics to the northerly latitudes. This change in the circulation would lead to warmer Gulf of Mexico and subtropical Atlantic sea surface temperatures (SSTs). These higher SSTs would promote an increase in convective thunderstorm activity due to higher evaporation rates. However, to give this shift some paleoclimate perspective, the average mid-Holocene speleothem oxygen isotope values were more depleted by ~1‰ indicating even warmer temperatures and higher precipitation amounts compared to the glacial period. Additionally, the carbon isotopes show a ~3‰ shift towards more negative values, indicating a more heavily forested west-central Florida. The variability within both the mid-Holocene and Late-Pleistocene data support the possibility of atmospheric teleconnections between the tropics/subtropics and northerly latitudes contributing to shorter-term shifts in precipitation amount superimposed on the larger-scale glacial-interglacial isotopic composition of the speleothem.

1. Introduction

Few paleoclimate records in Florida extend into the last glacial period mostly due to the lack of preservation or availability of suitable, high-resolution climate proxies (Grimm et al., 1993, 2006; Huang et al., 2006). Even more rare in Florida are those proxies that provide a glimpse into both present interglacial and the last glacial climates. These two periods are characterized by abrupt climate events from changing teleconnections, ice sheet advance and retreat, varying ocean circulations, and major shifts in global temperature. The previous long-term paleoclimate work in Florida is mainly limited to lacustrine and marine studies. Willard et al. (2007) analyzed pollen and ostracods in a sediment core from Tampa Bay and found much cooler and drier conditions than modern times, with the Intertropical Convergence Zone (ITCZ) possibly influencing climate during the last deglaciation in Florida. Grimm et al. (1993) reconstructed climate over the last 50 kyr using pollen analysis from a Lake Tulane sediment core, first proposing cool, wet Heinrich events in Florida, then later revised their interpretation of these events to be warm and wet based on increases in *Pinus* species (Grimm et al., 2006). This revision concurs with the Watts and Hansen (1994) palynology study, also from Lake Tulane. The most recent Lake Tulane paleoclimate reconstruction spanning 62 kyr (Huang et al., 2006) also found increased *Pinus* during Heinrich events with an abundance of C_4 vegetation. They also found a warm/wet mid-Holocene paleoclimate. The objective of this study is to use speleothem $\delta^{18}O$ and $\delta^{13}C$ data from west-central Florida to further evaluate the climate conditions during

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http://dx.doi.org/10.1016/j.quaint.2017.05.008
1040-6182/© 2017 Published by Elsevier Ltd.

Please cite this article in press as: van Beynen, P., et al., Late Pleistocene and mid-Holocene climate change derived from a Florida speleothem, Quaternary International (2017), http://dx.doi.org/10.1016/j.quaint.2017.05.008

the Late Pleistocene in comparison to the mid-Holocene, but particularly the climatic response to Heinrich Event 2. Speleothems from cave environments offer a proxy that is protected from surface processes and able to record long-term changes in the environment (Gascoyne, 1992; Fairchild et al., 2006; Lachniet, 2009; Wong and Breecker, 2015). Presented here is a speleothem record of climate change from west-central Florida spanning the later parts of the mid-Holocene and last glacial intervals.

There is a myriad of research studies investigated climatic change during the last glacial period (Boulton and Clark, 1990; MacAyeal, 1993; Alley and MacAyeal, 1994; Licciardi et al., 1999; Balco and Rovey, 2010; Kleman et al., 2010; Schoof, 2010; Hughes et al., 2013; Zhang et al., 2014) with the CLIMAP research project being the most prominent of these (CLIMAP, 1984). Research mainly focused on Milankovitch-cycles and millennial-scale climate changes using numerous ice cores from Greenland and Antarctica, and marine sediment cores from the North Atlantic Ocean (Grootes et al., 1993; Masson et al., 2000; Bard et al., 2000; Alley et al., 2001; Rasmussen et al., 2008). More recent work includes lacustrine sediments and speleothem records which provide evidence of terrestrial responses to millennial-scale climate forcing and abrupt climatic events, including Dansgaard-Oeschger and Heinrich events (Dansgaard et al., 1985; Heinrich, 1988; Grimm et al., 1993, 2006; Frumkin et al., 1999; Holmgren et al., 2003; Genty et al., 2003; Huang et al., 2006).

The evidence of the millennial-scale events over the last ~100,000 ka is well documented in the Northern Hemisphere (Arz et al., 1998; Clark et al., 2001; Peck et al., 2007). Heinrich events, which were first discovered in North Atlantic marine sediments (Heinrich, 1988), are some of the most pronounced events have also been recorded in many other paleoclimate records from the North Atlantic spanning the Pleistocene's last glacial period (Leuschner and Sirocko, 2000; Scourse et al., 2000; Wang et al., 2001; Lewis et al., 2010; Marcott et al., 2011; Deplazes et al., 2014; Lynch-Stieglitz et al., 2014). Heinrich events, numbering H1-H6, occur approximately every 7 kyr–10 kyr, and last on average ~750 years, although some discrepancies exist regarding the length of each event based on the various proxy records analyzed since their initial discovery (Hemming, 2004). Paleoclimate proxies that contain these events show that not all regions exhibit the same changes in climate as seen in the Greenland ice cores and North Atlantic marine sediment records (Stoner et al., 2000; Grimm et al., 2006; Ellwood and Gose, 2006). The other significant glacial millennial-scale events recorded in proxy records are Dansgaard-Oeschger (D-O) events which are characterized by large-scale, abrupt warming episodes followed by a series of alternating gradual cooling and warming periods occurring approximately every 1500 years (Bond and Lotti, 1995; Bond et al., 1999). These cyclic, millennial-scale events occurred approximately 24 times during the last glacial period and are terminated by Heinrich events in couplings known as Bond cycles (Bond et al., 1999; Grimm et al., 2006).

2. Regional setting

The speleothem was collected from Brooksville Ridge Cave (BRC), in Hernando County, Florida (Fig. 1). This cave is situated in the Brooksville Ridge section of the Ocala Arch (Reeder and Brinkmann, 1998; Florea et al., 2007). BRC has only one entrance opened by quarrying around 50 years ago and is the longest air-filled cave in Hernando County with over one km of surveyed passage. The cave contains a series of chambers connected by low, tight crawls with several highly decorated rooms containing hundreds of active formations (Fig. 2). Relative humidity levels >98% and a constant temperature near 22 °C were measured at the point of sample collection approximately 100 m from the cave entrance.

The bedrock is primarily Eocene-aged Ocala and Suwannee Limestones, which are unconformably overlain by the Hawthorn Group, carbonates interspersed with siliclastics and phosphorite redeposition (Scott, 1997). In some places, the bedrock is topped with several meters of Pleistocene-aged quartz sands, but the majority of the study area consists of exposed limestone outcrops and little soil cover. Several infiltration points in the form of sinkholes and sinking streams are present in the landscape, but very little standing water occurs due to rapid drainage to the subsurface.

The climate above BRC has a mean annual temperature of 21.3 °C and mean annual precipitation of ~1350 mm. Mean maximum monthly temperatures occur in August (27.6 °C) and the minimum in January (13.6 °C). August also possesses the monthly maximum precipitation with 219 mm and October the least with 48.8 mm (SE Regional Climate Center). The area is upland hammock, with thin soil cover and significant exposures of bedrock. Vegetation mainly consists of flatwood and mixed hardwood forests (Watts and Collins, 2008). This type of environment includes longleaf pine (*Pinus palustris*), slash pine (*Pinus elliottii*), turkey oak (*Quercus laevis*), live oak (*Quercus virginiana*), saw palmetto (*Serenoa repens*), wire grass (*Aristida* sp.), ericads, species of Holly (*Ilex*), forbs, and various scrub vegetation. Soil cover mainly includes the Candler fine sand series (Watts and Collins, 2008).

3. Materials and methods

The BRC03-03 sample (Fig. 3) was cut in half down its central growth axis using an MK Diamond 10″ wet saw with a diamond-tipped blade, then polished to show the location of the laminae. The calcite in the top 8 cm was transparent and layers were hard to discern. Calcite samples (~200–300 mg) were taken from one half of the speleothem along visible growth layers and hiatuses using an automated CNC milling machine fitted with a fine dental bit for Uranium-series dating. Samples were dated at the University of New Mexico's Radiogenic Isotope Lab. Stable isotope samples were taken from the opposing half using a handheld dremel device with a 0.24 mm dental bit to collect ~80 μg of sample and processed at the University of South Florida's College of Marine Science Paleoclimatology, Paleoceanography and Biogeochemistry Laboratory in St. Petersburg, Florida.

3.1. ^{234}U-^{230}Th chronology

Adhering to methods described by Polyak and Asmerom (2001), uranium-series (^{234}U-^{230}Th) isotope measurements were performed at the Radiogenic Isotope Laboratory, University of New Mexico in 2005. 50–200 mg of clean carbonate powders for 12 dates were dissolved in nitric acid and spiked with a mixed ^{229}Th-^{233}U-^{236}U spike to eliminate propagation error. U and Th were co-precipitated using $FeOH_3$ and separated using conventional anion exchange chromatography. The U and Th isotopic measurements were performed on a Micromass Sector 54 multi-collector thermal ionization mass spectrometer (TIMS). The TIMS analyses utilized a single ion-counting Daly multiplier in peak jumping mode. Both U and Th isotopes are measured on the ion-counting Daly multiplier with abundance sensitivity in the range of 20 ppb at one mass distance in the mass range of U and Th, requiring very little background correction, even for samples with large ^{232}Th content. Multiplier dark noise is approximately 0.12 counts per second. ^{233}U/^{236}U ratio (1.0046) was used for fractionation correction for U analyses. Th fractionation in TIMS is negligible.

A CRM145 U isotope standard was measured with every batch obtaining the conventionally accepted δ^{234}U value of −37.09 ±