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Palaeogeography, Palaeoclimatology, Palaeoecology 236 (2006) 20–38
PALAEO
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High resolution characterization of the Asian Monsoon between 146,000 and 99,000 years B.P. from Dongge Cave, China and global correlation of events surrounding Termination II

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Received 30 September 2004; accepted 11 November 2005

Abstract

Speleothem samples from Hulu (eastern China, 32°30′N, 119°10′E) and Dongge (southern China, 25°17′N, 108°5′E) Caves provide a nearly continuous record of the Asian monsoon over the last 160 ka [Wang, Y.J., Cheng, H., Edwards, R.L., An, Z.S., Wu, J.Y., Shen, C.-C., Dorale, J.A., 2001. A high-resolution absolute-dated Late Pleistocene monsoon record from Hulu Cave, China. Science 294, 2345–2348; Yuan, D., Cheng, H., Edwards, R.L., Dykoski, C.A., Kelly, M.J., Zhang, M., Qing, J., Lin, Y., Wang, Y., Wu, J., Dorale, J.A., An, Z., Cai, Y., 2004. Timing, duration, and transitions of the last interglacial Asian Monsoon. Science 304, 575–578]. We have obtained higher resolution data in the interval between ~99 and 146 ka B.P., providing a detailed account of $\delta^{18}O$ variations over most of MIS 5 and the latter portion of MIS 6. Precise ^{230}Th dating has replicated the chronology of the samples within error. The higher resolution data set confirms the timing of Asian Monsoon Termination II (the midpoint of the negative shift in $\delta^{18}O$ marking the onset of the Last Interglacial Asian Monsoon), placing it at 129.0±0.9 ka B.P. The bulk of this transition (~1.7‰) took place within approximately 70 years, with the total range of the transition being ~3‰. The most abrupt portion of the shift in $\delta^{18}O$ values (~1.1‰) marking the end of the Last Interglacial Asian Monsoon occurred in ~120 years, the midpoint of which is 120.7±1.0 ka B.P. The Dongge Cave monsoon $\delta^{18}O$ record over late MIS 6 exhibits a series of sub-orbital millennial-scale climate shifts that average 1.3‰ in magnitude and occur on average every 1.8 ky. Abrupt shifts in $\delta^{18}O$ of up to 1‰ also occurred throughout the Last Interglacial Asian Monsoon, with periods at multi-decadal to centennial timescales. Similar to the amplitude and periodicities of events found by Dykoski et al. [Dykoski, C.A., Edwards, R.L., Cheng, H., Yuan, D., Cai, Y., Zhang, M., Lin, Y., An, Z., Revenaugh, J., 2005. A high resolution, absolute-dated Holocene and deglacial Asian monsoon record from Dongge Cave, China. Earth and Planetary Science Letters 233, 71–86.] during the Holocene in the Dongge record, these shifts cover more than 1/2 of the amplitude of millennial-scale and multi-centennial-scale interstadial events during the Last Glacial Period [Wang, Y.J., Cheng, H., Edwards, R.L., An, Z.S., Wu, J.Y., Shen, C.-C., Dorale, J.A., 2001. A high-resolution absolute-dated Late Pleistocene monsoon record from Hulu Cave, China. Science 294, 2345–2348], and millennial-scale and multi-centennial-scale interstadial events during the Penultimate Glacial Period in China (this study). Abrupt decadal to millennial-scale climate events therefore appear to be a general feature of both glacial and interglacial climate. We demonstrate that monsoon intensity correlates well with atmospheric CH_4 concentrations over the transition into the Bølling-Allerød, the Bølling-Allerød, and the Younger Dryas. In addition, we correlate an abrupt jump in CH_4 concentration with Asian Monsoon Termination

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0031-0182/$ - see front matter
doi:10.1016/j.palaeo.2005.11.042

II. On the basis of this correlation, we conclude that the rise in atmospheric CO_2, Antarctic warming, and the gradual portion of the rise in CH_4 around Termination II occur within our "Weak Monsoon Interval" (WMI), an extended interval of heavy $\delta^{18}O$ between 135.5±1.0 and 129.0±1.0 ka B.P., prior to Asian Monsoon Termination II and Northern Hemisphere warming. Antarctic warming over the millennia immediately preceding abrupt northern warming may result from the "bipolar seesaw" mechanism. As such warming (albeit to a smaller extent) also preceded Asian Monsoon Termination I, the "bipolar seesaw" mechanism may play a critical role in glacial terminations.

Keywords: Speleothems; Monsoon; U–Th dating; Oxygen isotopes; Termination II

1. Introduction

The Asian Monsoon is an important component of the global climate system, for it has been linked to climate in the high northern latitudes, the equatorial ocean, and the southern hemisphere. For the last 2.5 Ma, global climate has been dominated by glacial–interglacial cycles. Continental responses to these cycles, including the monsoon, are important to the study of global circulation patterns and climate linkages. Speleothem calcite is one of the few terrestrial climate proxies with potential for continuous deposition over long periods of time, providing a detailed record of oxygen isotopic signatures for the duration of speleothem growth. If the calcite is formed under equilibrium conditions, oxygen isotope ratios recorded in speleothems from China may be considered a proxy for the $\delta^{18}O$ of monsoon precipitation. Oxygen isotopic data from speleothems combined with absolute ages determined by ^{230}Th dating has the potential to provide a high-resolution record of monsoon variability on both orbital and sub-orbital timescales.

Climate during the most recent glacial cycle has been extensively studied, but many questions remain regarding the Last Interglacial and the Penultimate Glacial periods. The Last Interglacial (MIS 5e) climate is particularly important because it may be considered an analog to the present warm period. The sequence of events surrounding glacial terminations is a key issue in understanding the connections between different areas of the globe. In addition, more precise studies of the Penultimate Glacial (MIS 6) as it compares to the well documented record of the Last Glacial Period will provide further insight on the present theory on glacial climate.

Previous work has demonstrated a strong correlation between the oxygen isotope record of speleothems from Hulu Cave, China, and the GISP2 $\delta^{18}O$ record between 11 and 75 ka B.P. (Wang et al., 2001). This includes the Younger Dryas event and Bølling-Allerød (B/A) transition, as well as millennial-scale climatic variations. Greenland Interstadial (GIS) events during the Last Glacial Period correspond to episodes of more negative monsoon $\delta^{18}O$ values at Hulu Cave. In addition, heavy excursions in the Hulu $\delta^{18}O$ record have been linked to Heinrich events 1–6 during the Last Glacial Period.

Yuan et al. (2004) presented the first stable isotope work on speleothems from Dongge Cave, China. They demonstrated a similar connection to high northern latitude climate as well as Northern Hemisphere insolation. To further our understanding of sub-orbital climate events we have increased the resolution of a portion of this record from 146 to 99 ka B.P. A higher resolution Asian Monsoon record over this time period has enabled more accurate correlations between global and regional climate records, and facilitates the understanding of forcing mechanisms and lead/lag relationships associated with insolation changes, ice volume, sea level, and terrestrial responses to these changes.

2. Site description

Dongge Cave is located in the Guizhou Province of southern China (25°17′N, 108°5′E), 680 m above sea level (Fig. 1). Our study focuses on stalagmites D3 and D4, which were located 100 m below the surface, and 300 and 500 m from the cave entrance, respectively. Modern climatic information from this area has previously been reported by Yuan et al. (2004). The mean annual temperature within the cave is 15.6 °C. Average annual rainfall is 1753 mm, 80% of which falls during the summer monsoon (May–October). Oxygen isotopic data of meteoric precipitation from nearby Guiyang, China (26.35°N/106.43°E) exhibits a seasonal pattern characteristic of a monsoon climate (IAEA/WMO, 2001). Despite generally higher temperatures during the summer months, weighted monthly $\delta^{18}O$