Chemical Geology 268 (2009) 233–247

Contents lists available at ScienceDirect

Chemical Geology

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

Deglacial variations of Sr and $^{87}Sr/^{86}Sr$ ratio recorded by a stalagmite from Central China and their association with past climate and environment

Houyun Zhou [a,b,f,*], Yue-xing Feng [c], Jian-xin Zhao [c], Chuan-Chou Shen [d], Chen-Feng You [e], Yin Lin [d]

[a] School of Geography, South China Normal University, Guangzhou 510631, China
[b] State Key Laboratory of Loess and Quaternary Geology, Institute of Earth Environment, Chinese Academy of Sciences, Xi'an, 710075, China
[c] Radiogenic Isotope Laboratory, Centre for Microscopy and Microanalysis, the University of Queensland, Brisbane, Qld 4072, Australia
[d] Department of Geosciences, National Taiwan University, Taipei 106, Taiwan, ROC
[e] The Earth Dynamic System Research Center, National Cheng-Kung University, Tainan 701, Taiwan, ROC
[f] Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou 510640, China

ARTICLE INFO

Article history:
Received 24 November 2008
Received in revised form 1 September 2009
Accepted 4 September 2009

Editor: B. Bourdon

Keywords:
Speleothem
Strontium
Strontium isotope ratio
The last deglaciation
Wind-blown dust
Central China

ABSTRACT

A low-resolution strontium isotopic ratio ($^{87}Sr/^{86}Sr$) record coupled with a high-resolution Sr concentration profile covering the last deglacial period were obtained for a stalagmite, SJ3, collected from Songjia Cave, northeast Sichuan province, Central China. Both Sr and $^{87}Sr/^{86}Sr$ display significant variations during the period between 20 and 10 ka, which correlate well with oxygen isotope records from Greenland ice cores and speleothems in the East Asian summer monsoon regime, with higher Sr and more radiogenic $^{87}Sr/^{86}Sr$ values occurring during cold-dry climatic phases and vice versa. The Sr in SJ3 shows a negative linear relationship between $^{87}Sr/^{86}Sr$ and 1/Sr, suggesting the binary mixing of two end-members, the host rock of Late Permian limestone with a relatively lower $^{87}Sr/^{86}Sr$ ratio (~0.7071) and an exotic Sr source with a relatively radiogenic $^{87}Sr/^{86}Sr$ ratio (~0.7109 deduced from the $^{87}Sr/^{86}Sr$-1/Sr correlation). Atmospheric dust activity was suggested to be the most probable factor influencing the two indices. Because the carbonate fraction in wind-blown dust is enriched in Sr and has a more radiogenic $^{87}Sr/^{86}Sr$ ratio, enhanced atmospheric dust activity under stronger Asian winter monsoon which is associated with cold-dry climate would lead to higher Sr concentrations and more radiogenic $^{87}Sr/^{86}Sr$ ratios in SJ3 and vice versa. This interpretation is supported by the general parallelism of the two Sr indices to winter monsoon proxy from East Asia such as the dust flux and quartz median diameter in Luochuan loess profile during the same period. This study suggests that the speleothem $^{87}Sr/^{86}Sr$ ratio and Sr concentration, especially the former in northeastern Sichuan Province can be used to investigate the atmospheric dust activity and Asian winter monsoon.

1. Introduction

In areas intensively influenced by the East Asian summer monsoon (EASM), speleothem-derived stable oxygen isotope ($\delta^{18}O$) records have been widely and successfully used to reconstruct summer monsoon intensity and amount of precipitation (Wang et al., 2001; Zhao et al., 2003; Yuan et al., 2004; Dykoski et al., 2005; Wang et al., 2008; Hu et al., 2008; Zhou et al., 2008a,b). Meanwhile, however, much less attention has been paid to other proxies such as annual layer thickness of stalagmite, trace elements and uranium and strontium isotopic compositions ($^{234}U/^{238}U$ and $^{87}Sr/^{86}Sr$) (e.g., Fairchild et al., 2006a). These proxies, especially trace elements such as magnesium (Mg), strontium (Sr) and barium (Ba) have been demonstrated to be appropriate and were often used for reconstruction of past climate and environment (Goede et al., 1998; Roberts et al., 1998, 1999; Fairchild et al., 2001; Huang et al., 2001; Baldini et al., 2002; Ma et al., 2003; Treble et al., 2003; Li et al., 2005a; Cruz et al., 2007). In the EASM regime, only a few attempts have been made to investigate past climate and environment using speleothem-derived trace element records (Ma et al., 2003; Hu et al., 2005; Li et al., 2005a; Johnson et al., 2006; Zhou et al., 2008c,d). For example, Li et al. (2005a) reported a long-term record of Sr/Ca ratio but with a relatively low resolution. The trace metal records reported by Johnson et al. (2006) had a high resolution but covered a very short period, less than 20 years, and thus cannot inform us how these trace metals behave during major climate shifts such as glacial–interglacial transition in the EASM regime.

In this paper, a high-resolution long-term Sr record is recovered from a stalagmite SJ3 collected from central China. This stalagmite was developed during the late Pleistocene from 38 to 10 ka and its stable isotopes ($\delta^{18}O$ and $\delta^{13}C$) and rare earth elements have been

* Corresponding author. Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, No. 511, Kehua Street, Wushan, Tianhe, Guangzhou 510640, PR China. Tel.: +86 20 85290296; fax: +86 20 85290130.
E-mail address: hyzhou@gig.ac.cn (H. Zhou).

0009-2541/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.chemgeo.2009.09.003

reported previously (Zhou et al., 2008a,c,d). For comparison, the Mg and Ba records for SJ3 are presented as well.

In addition to trace elements, $^{87}Sr/^{86}Sr$ data for SJ3 are also reported in this paper. Until now, only a few speleothem $^{87}Sr/^{86}Sr$ records have been reported (Banner et al., 1996; Goede et al., 1998; Ayalon et al., 1999; Bar-Matthews et al., 1999; Verheyden et al., 2000; Frumkin and Stein, 2004; Li et al., 2005a), which could be mainly due to the high cost for $^{87}Sr/^{86}Sr$ measurement. Speleothem $^{87}Sr/^{86}Sr$ ratio directly records the Sr isotopic composition of cave water and its variations reflect changes in relative contribution of various Sr sources that have different $^{87}Sr/^{86}Sr$ signatures (Faure and Mensing, 2005). One of the most important Sr sources for speleothem is the host rock (Banner et al., 1996; Goede et al., 1998; Ayalon et al., 1999; Bar-Matthews et al., 1999; Verheyden et al., 2000; Frumkin and Stein, 2004; Li et al., 2005a). Other significant sources include overlying soil layer, wind-blown dust and sea spray. In particular, previous studies suggested that speleothem $^{87}Sr/^{86}Sr$ variations might be related to atmospheric dust activity (Ayalon et al., 1999; Bar-Matthews et al.,

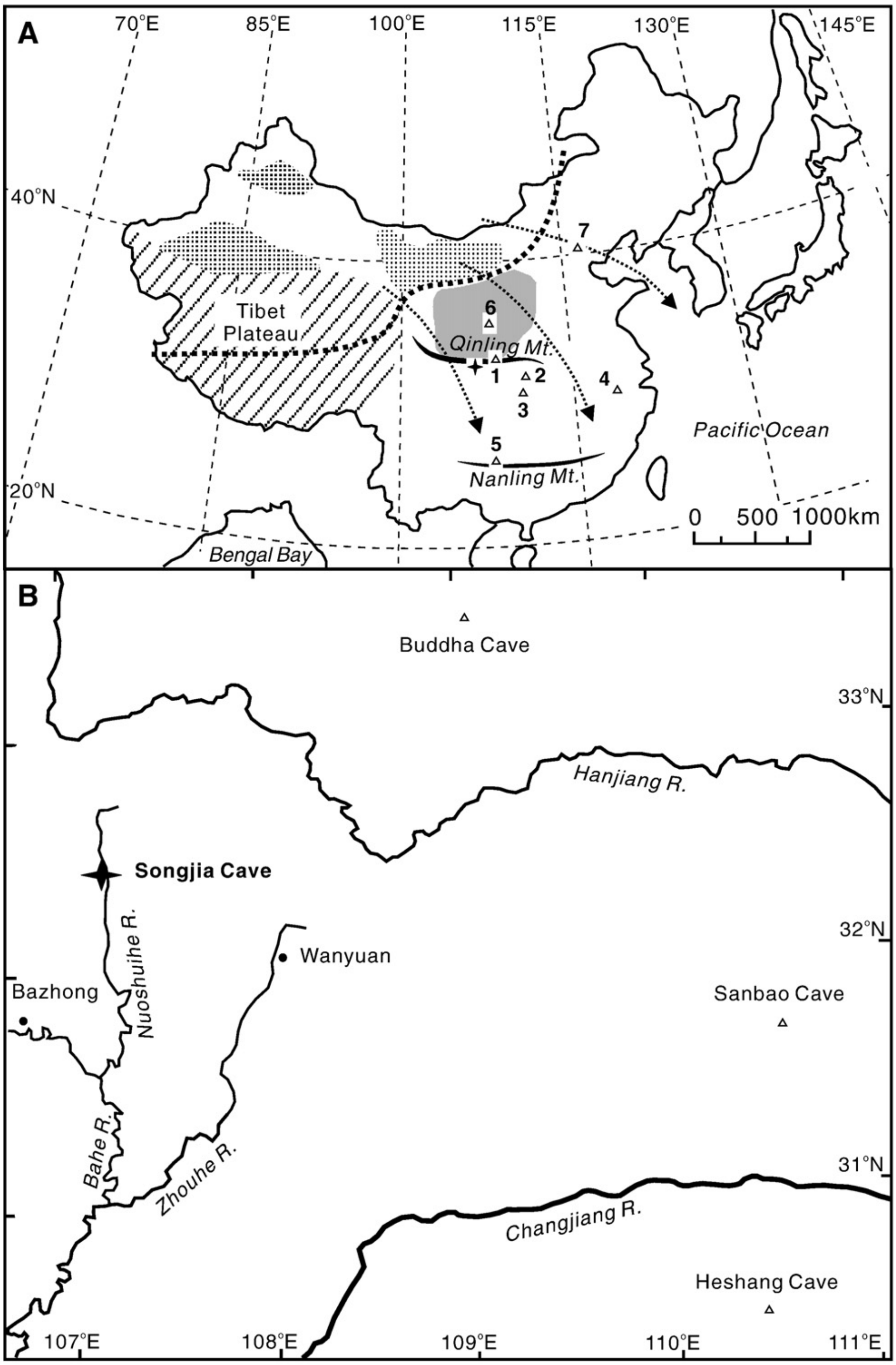

Fig. 1. Location of Songjia Cave [the star in (A)]. The cave is on the south flank of Qinling Mountain Ranges. In (A), the shaded area is the Loess Plateau; the dotted areas are deserts in northwest China; the hatched area is the Tibet Plateau; the thick dashed line indicates the northwestern limit of the East Asian summer monsoon; the dashed arrows indicate routes of winter monsoon and dust transportation. 1-Buddha Cave (Li et al., 2005a). 2-Sanbao Cave (Wang et al., 2008). 3-Heshang cave (Hu et al., 2005). 4-Hulu cave (Wang et al., 2001). 5-Dongge Cave (Yuan et al., 2004). 6-the Luochuan loess profile (Xiao et al., 1995). 7. Jingdong Cave in North China (Ma et al., 2003).