Earth and Planetary Science Letters 496 (2018) 10–19

Contents lists available at ScienceDirect

Earth and Planetary Science Letters

www.elsevier.com/locate/epsl

Late Quaternary climate in southern China deduced from Sr–Nd isotopes of Huguangyan Maar sediments

Shikma Zaarur [a,*], Mordechai Stein [a,b], Ori Adam [a], Jens Mingram [e], Guoqiang Chu [c], Jiaqi Liu [c,d], Jing Wu [c], Yigal Erel [a]

[a] Institute of Earth Sciences, The Hebrew University of Jerusalem, Givat Ram, 91904, Israel
[b] Geological Survey of Israel, 30 Malkhe Israel St., Jerusalem, 95501, Israel
[c] Key Laboratory of Cenozoic Geology and Environment, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing, China
[d] College of Earth and Planetary Sciences, Chinese Academy of Sciences, Beijing, China
[e] GFZ German Research Centre for Geosciences, Potsdam, Germany

ARTICLE INFO

Article history:
Received 7 December 2017
Received in revised form 13 May 2018
Accepted 16 May 2018
Available online xxxx
Editor: D. Vance

Keywords:
paleo-climate
East Asian monsoon
Huguangyan Maar
Sr–Nd

ABSTRACT

The hydro-climatic conditions that prevailed during the last Glacial and early to mid-Holocene periods in South China are inferred from chemical compositions and Sr–Nd isotope ratios of sediments from lake Huguangyan Maar and its vicinity. The lake sediments are comprised of organic matter, volcanic materials and aeolian input from nearby granitoid-derived soils. Variations in $^{87}Sr/^{86}Sr$ ratios in the lake sediments indicate two modes of climate conditions: wet intervals during which the lake sediments are mainly derived from the volcanic-lake rim materials, expressed in low $^{87}Sr/^{86}Sr$ ratios, and dry intervals during which fine particles from the nearby granitic soils are windblown to the lake and supply local dust expressed in high $^{87}Sr/^{86}Sr$ ratios in the sediments. These wet and dry intervals generally correspond to regional climate records (e.g., speleothem $\delta^{18}O$ profiles in southeast China) and correlate with global climate events (e.g., Heinrich events). While $\delta^{18}O$ records of speleothems from southeast China caves are dominated by the precession signal, the Huguangyan Maar Sr record mainly correlates with obliquity. This most likely reflects masking of the precession signal due to regional climate variability, accentuating the obliquity signal. These local effects may also account for some of the differences that have been observed between the various East Asian monsoon records. More importantly, the masking of the precession signal reveals the direct influence of obliquity on the hydro-climate regime in South China.

1. Introduction

The East Asian monsoon is an important climate system, impacting the lives and livelihood of billions of people. Understanding the dynamics of the system and its sensitivity to climate forcings are instrumental in predicting its future response to global and regional climate changes. The history of the East Asian monsoon has been inferred from cave deposits (e.g., Cheng et al., 2016; Wang et al., 2001; Yuan et al., 2004), loess-based proxies (e.g., Li et al., 2017; Maher, 2016; Porter, 2001; Sun et al., 2006), lacustrine (An et al., 2011; Ao et al., 2012) and marine sediments (e.g., Ao et al., 2011), as well as numerical paleo-climate simulations (e.g., Mohtadi et al., 2016). Millennial-scale North Atlantic climate events have been shown to have dramatic effects on the climate in East Asia. For example, Heinrich Event 1 (H1) at ∼17.4–16 ka, is thought to have invoked a catastrophic drought (Zhou et al., 2016); similarly, the mid-Holocene north Atlantic cooling is associated with an intensification of the East Asian winter monsoon (Hao et al., 2017). Long-term variability in the various paleo-monsoon records is related to eccentricity (∼100 ka), obliquity (∼41 ka) and precession (∼23 ka) orbital cycles. Glacial–interglacial rhythms (obliquity and eccentricity) dominate aeolian deposits in the Chinese loess (Sun et al., 2006) and lacustrine deposits (An et al., 2011; Ao et al., 2012), while changes in the $\delta^{18}O$ cave deposits are dominated by precession (e.g., Cheng et al., 2016). These differences raise questions regarding the primary drivers and controls on monsoon variability over time and the role of local versus global climate variability and proxy sensitivity.

Here, using chemical compositions and Sr–Nd isotope ratios in sediments from Huguangyan Maar lake (Fig. 1), we examine the prevailing hydro-climatic conditions related to the East Asia monsoon systems in southern China, during the past ∼70 ka. The

---

[*] Corresponding author.
E-mail address: shikma.zaarur@mail.huji.ac.il (S. Zaarur).

https://doi.org/10.1016/j.epsl.2018.05.025

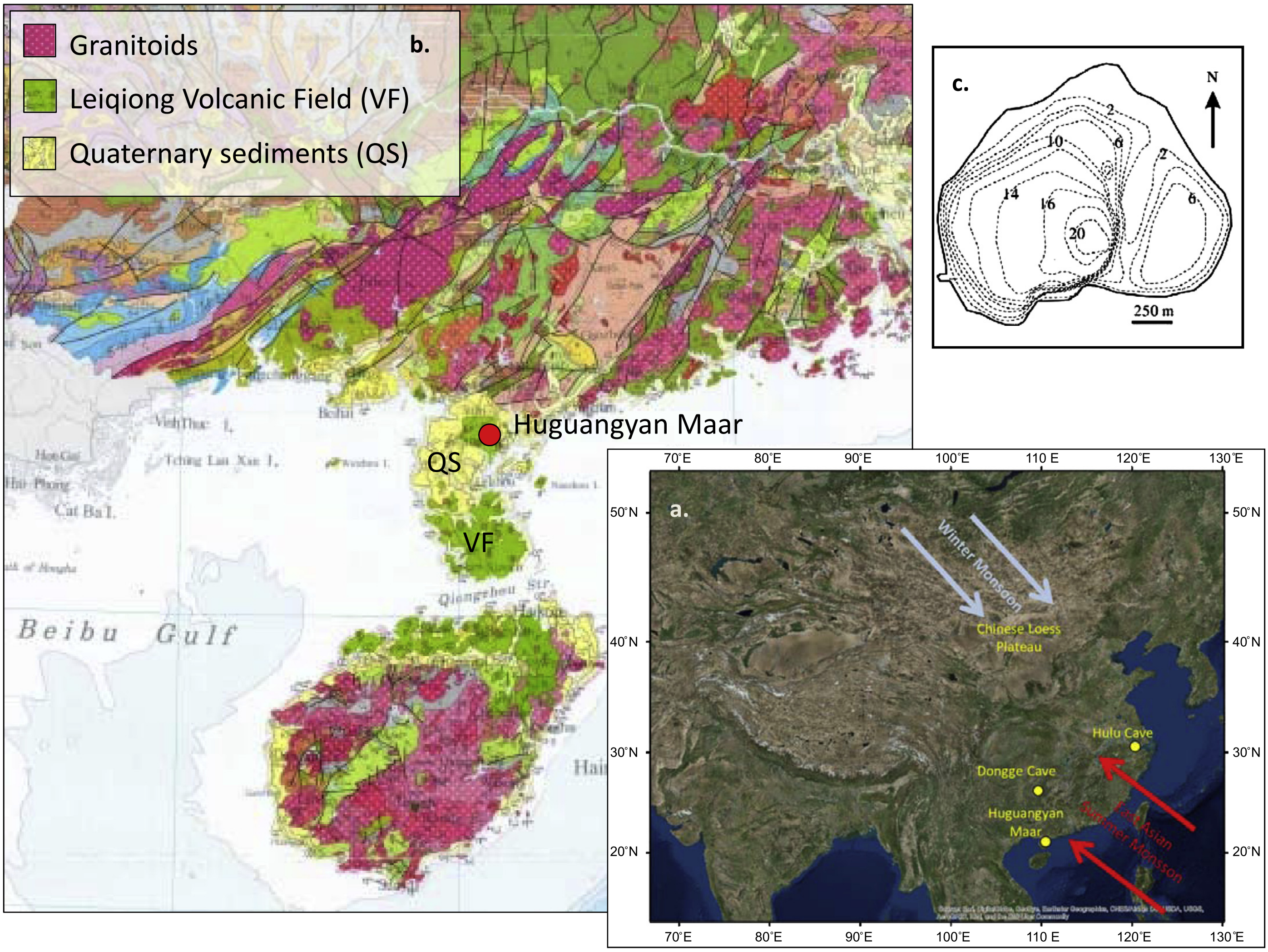

Fig. 1. Study area. (a) Map of East Asia depicting the location of Lake Huguangyan Maar. Red and blue arrows point to the general directions of the summer and winter monsoon systems, respectively. (b) Geological map (Lifang et al., 2004) of Lake Huguangyan Maar (red circle) basalt in volcanic field (bright green), surrounding Quaternary fluvial and alluvial sediments (light yellow), and granitic units (pink). (c) Huguangyan Maar lake after Mingram et al. (2004). (For interpretation of the colors in the figure(s), the reader is referred to the web version of this article.)

occurrence and sources of aeolian input to Huguangyan Maar sediment are at the core of a scientific debate, with far reaching consequences regarding our understanding of the East Asian monsoon system. Yancheva et al. (2007) assumed that relative changes in Ti concentrations in Huguangyan Maar sediments over the past 16 ka reflect variations in dust influx to the lake from remote or local sources in response to changes in the intertropical convergence zone (ITCZ) and strengthening of the winter monsoon winds. This argument was later challenged by the inconsistencies between the chemical and isotopic compositions of the lake sediments and the Chinese loess deposits (Wang et al., 2016; Zhou et al., 2009). We re-examine this question by expanding the information on the chemical and Sr–Nd isotopes of the lake sediments and nearby deposits, and extend the study to the last glacial cycle. Our analyses and results point to the importance of regional climate variability in interpreting the monsoon climate records.

2. Geological and climatic background

Huguangyan Maar lake (21°9′N, 110°17′E) is located in a volcanic crater in the Leiqiong Volcanic Field, on the Leizhou Peninsula (Fig. 1). The lake is 23 m above sea level, and is surrounded by a tephra rim, reaching 88 m above sea level with a steep inner slope. The lake is ∼1.7 km in diameter, 20 m deep and has a surface area of 2.25 km^2. The catchment area comprises only the inner slopes of the crater rim, with no surface in- or out-flows (Mingram et al., 2004). The hydrochemistry of the lake is influenced by surface flow in the catchment area, regional groundwater flow, aeolian deposits, sea-spray, and authigenic precipitation–dissolution processes (Mingram et al., 2004; Yancheva et al., 2007).

The Leiqiong Volcanic Field is located in an extensional basin at the granitic-passive continental margins of South China (Fig. 1; Ma and Wu, 1987). Volcanic activity began in the Oligocene and lasted through the Holocene. Early volcanism was dominated by quartz tholeiites and olivine tholeiites, and late volcanism was dominated by alkali olivine basalts and basanites (Huang et al., 2007); ilmenite and titanomagnetite are the main Fe-oxides (Ho et al., 2000). The basalts intruded the South China Precambrian Basement (e.g., the Neoproterozoic Cathaysia Granitoids, Chen and Jahn, 1998; Jahn et al., 1976, 1990) whose granitoid terrains are exposed about 50 km north of the maar (Fig. 1). The volcanic field is overlain by Quaternary fluvial and alluvial deposits (Lifang et al., 2004), likely derived from the exposed granitoid terrains.

The mean annual temperature and precipitation in the area are 23.1 °C and 1440 mm/yr, respectively (Mingram et al., 2004). The region is strongly affected the East Asian summer monsoon and to a lesser degree by the Indian monsoon, and northern cold fronts