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Constraints from strontium and neodymium isotopic ratios and trace elements on the sources of the sediments in Lake Huguang Maar

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ABSTRACT

The sediments in Lake Huguang Maar in coastal South China were previously thought to originate mainly from wind-blown dust transported from North China, such that the lake sediments recorded the varying strength of the Asian winter monsoon. An alternative explanation was that the local pyroclastic rocks supplied the lake sediments, but the actual contributions from the different sources remained unclear. Geochemical analyses including $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ and trace elements support the local pyroclastic rock as the dominant source: <22% of the total Sr in the lake sediments and ~17% of the Nd arises from the distant source. Nb/Ta and Zr/Hf for the lake sediments are identical to those for the local rock but differ from the ratios for the wind-blown dust, and chondrite-normalized rare earth element patterns for the lake sediments are similar to those for the local rock and soil, but differ from those for the distant source. The sediments in Lake Huguang Maar are probably input into the lake through runoff and thus controlled by the hydrology of the lake. Wind-blown dust transported by the Asian winter monsoon from arid North China is only a minor contribution to the sediments.

Introduction

The Asian monsoon is an important component of the global climate system. Investigation of the Asian monsoon variation has long been one of the major goals for paleoclimatic studies, and reconstruction of the paleo-Asian monsoon based on the loess-paleosol series in the Loess Plateau in North China has been informative (Liu, 1985; Liu and Ding, 1998; An, 2000). Nevertheless, these investigations suffer from uncertainties in the dating and the low deposition rate of aeolian sediments. Thus the loess has only been useful for studying climatic and environmental changes on multi-centennial or longer time scales. However, increasing evidence indicates significant variations of the Asian monsoon system on shorter decadal to interannual time scales (Charles et al., 1997; Kumar et al., 1999). It is necessary to understand these variations and their controlling mechanisms.

Although speleothem stable oxygen isotope ($\delta^{18}O$) records from monsoonal China (Wang et al., 2001; Yuan et al., 2004; Dykoski et al., 2005; Hu et al., 2008; Zhou et al., 2008a) provide an opportunity to explore the Asian summer monsoon variation on short time scales, similar reconstruction of the winter monsoon has proven less satisfactory. Recently, however, Yancheva et al. (2007a) provided such a record for the last 16,000 yr based on the Ti content of the sediments in Lake Huguang Maar in coastal South China. They suggested that the lake "receives a minimal quantity of material by runoff" and "acts as a natural sediment trap for dust delivered to the site by the northerly winds of the winter monsoon," and thus the Ti content of the sediments in the lake should reflect the strength of the winter monsoon. This suggestion was disputed by Zhou et al. (2007), who suggested that a local source might contribute more sediment and Ti in Lake Huguang Maar than wind-blown dust from remote North China. They suggested that the variation of the Ti content of the sediments might be related to the paleohydrology of the lake. This alternative interpretation was based on the abundance of coarse grains in the lake sediments, and on sedimentological evidence of a high flux of lithogenic materials to the lake (Wang et al., 2000). Neither Yancheva et al. (2007a) nor Zhou et al. (2007) presented detailed geochemical evidence such as $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ ratios and rare earth element (REE) spectra, which are commonly used in sediment-source tracing (Cullers et al., 1988; Gallet et al., 1996; Jahn et al., 2001; Sun, 2005). Sr and Nd isotopic ratios and REE patterns of wind-blown dust and basaltic rock should contrast strongly, providing a useful test of the competing hypotheses (e.g., Dia et al., 2006; Kurtz et al., 2001). In addition, the sedimentological evidence

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Table 1
Grain size distribution (%) of the sediment samples collected from Lake Huguang Maar and comparison with typical wind-blown dusts from the Loess Plateau in North China.

Sample ID	Sand	Silt			Clay		Φ_{50} (μm)	M_z (μm)	Sediment type
	>63 μm	63–30 μm	30–16 μm	16–4 μm	4–2 μm	<2 μm			
HGY-4	15.51	19.13	25.04	25.25	6.52	8.55	19.6	18.6	Lake sediments
HGY-6	1.60	14.09	27.93	36.01	9.34	12.10	12.2	9.5	
HGY-7	7.61	21.18	26.73	28.35	6.87	9.27	15.2	13.7	
HGY-8	9.64	25.02	26.22	25.90	5.37	7.84	19.6	15.6	
HGY-9	53.65	12.05	14.83	12.71	2.66	4.08	136	100	
HGY-10	21.84	17.63	25.57	22.73	4.90	7.33	22.9	22.9	
L1-1	2.92	22.65	28.34	31.72	6.81	7.56	15.1	13.5	Aeolian sediments
L1-8	0.68	16.61	26.43	34.83	10.49	10.96	11.4	10.2	
L15-1	1.62	19.98	27.73	34.34	7.91	8.42	13.5	12.0	
L15-2	1.52	19.22	28.09	35.78	7.68	7.72	13.5	12.3	

Note. Φ_{50} is median grain size and M_z is mean grain size.

provided by Zhou et al. (2007) cannot determine whether wind-blown dust from North China has made a significant contribution to the sediments of Lake Huguang Maar, which may be resolved with some isotopic ratios such as $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ (Faure and Mensing, 2005). This is important not only for interpretation of the paleoclimatic and paleoenvironmental proxies archived in this lake, but also for modern economic and social development in coastal South China because a lithogenic flux to the lake as high as suggested by Yancheva et al. (2007a) is comparable with the modern mineral dust flux monitored on the Loess Plateau (Sun et al., 2003), and implies that coastal South China may be frequently affected by dust storm as was witnessed in North China in past decades (Chen et al., 2003).

Therefore, more geochemical investigation is needed to determine whether wind-blown dust from arid North China is an important source for the sediments deposited in Lake Huguang Maar. This is the main purpose of the present study. We focus on the $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ isotopic ratios and trace elements of the sediments of Lake Huguang Maar, which give a strong support to the argument that the sediments in Lake Huguang Maar were provided mainly by local pyroclastic rock (Zhou et al., 2007) rather than by wind-blown dust transported by the Asian winter monsoon from remote arid North China (Yancheva et al., 2007a,b).

Geological setting

Yancheva et al. (2007a) provided a detailed description of the geological setting, which is summarized here. Lake Huguang Maar was formed in a volcanic crater situated in the north part of the Leizhou

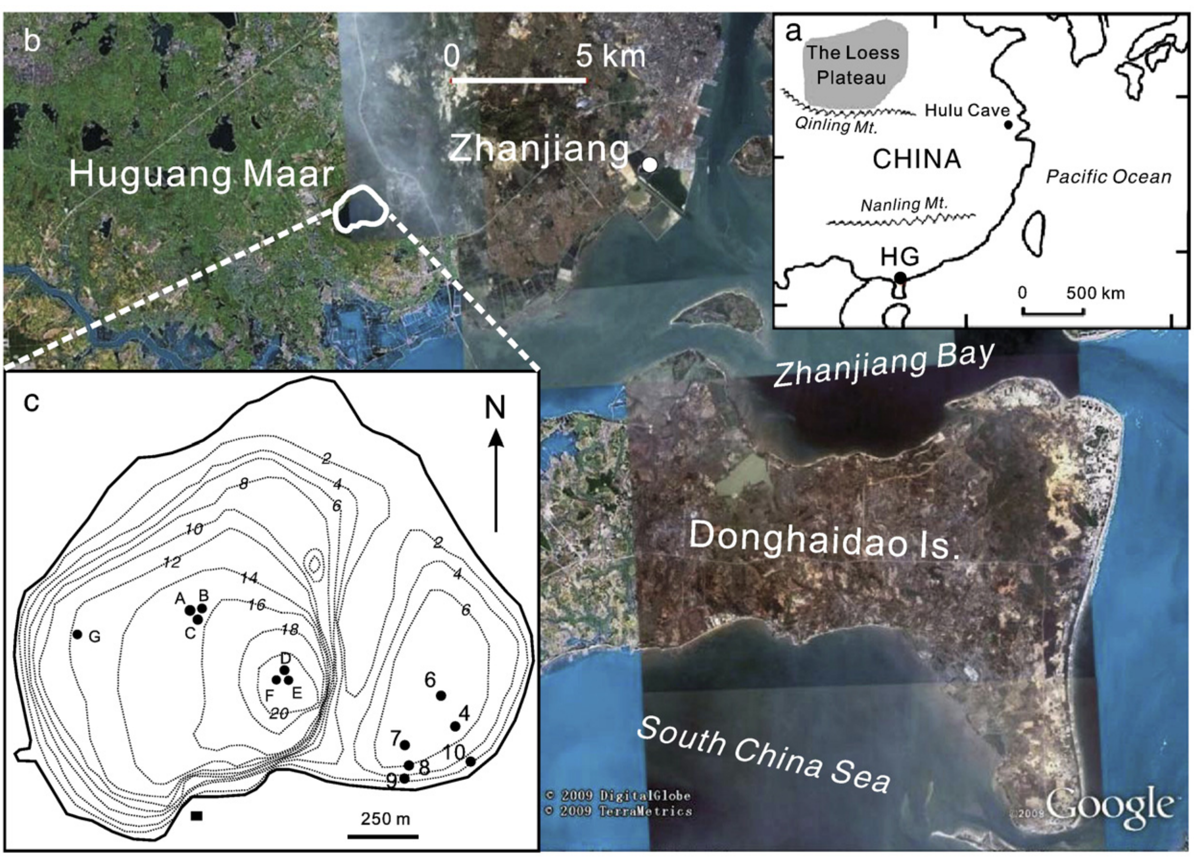

Figure 1. (a) Locations of Lake Huguang Maar (HG), Hulu Cave and the Loess Plateau in China. (b) A snapshot from Google Earth showing a part of coastal South China in which Lake Huguang Maar is located. (c) An enlargement of Lake Huguang Maar with isobath. A to G in the west part of the lake indicate the seven cores studied by Yancheva et al. (2007a). In the east part of the lake, the numbers 4, 6–10 near black solid circles indicate the sediment samples HGY-4, HGY-6 to 10, respectively. The black square indicates the naturally exposed profile of pyroclastic rock along the southwest margin of the lake. Three pyroclastic rock samples, SSB, SSM and SST were collected from this profile and the soil sample HGY-11 was collected in the woodland near this profile.