

## Research Advances

## Tracing the Provenance of the Huguangyan Maar Lake Sediments in Coastal Regions of South China

SHENG Mei<sup>1</sup>, WANG Xisheng<sup>1,\*</sup>, CHU Guoqiang<sup>2</sup>, CHEN Yun<sup>1</sup> and TANG Ling<sup>1</sup>

<sup>1</sup> Institute of Geomechanics, Chinese Academy of Geological Sciences, Beijing 100081, China

<sup>2</sup> Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029, China

The Huguangyan Maar Lake (HML) (21°9'N, 110°17'E), situated on the Leizhou Peninsula in the southernmost of mainland China, is the deepest recent crater lake among the identified volcanic structures in the Leiqiong Volcanic Field. The bi-lobate lake, with a diameter of ~ 1.7 km and a depth of ~ 20 m, is surrounded by a high tephra wall and is underlain by a basalt sheet. K/Ar dating on basalts from the volcanoclastic breccia of the crater rim yielded an age of ca. 127 ka. Climatically, the HML lies in the transition zone between southern subtropical zone and tropical north, and is influenced by both the East Asian summer and winter monsoons. A recent study by Yancheva et al. (2007) has shown that the HML sediments record plentiful paleoclimatic and paleoenvironmental details since the Late Pleistocene. However, the sediment sources of HML have become a matter of intense debate since Yancheva et al. (2007) proposed that wind-blown material transported by the East Asian winter monsoon from arid North China is the main lithogenic sources to the HML sediments. In order to better understand the provenance of the HML sediments, which is a prerequisite for comprehensively assessing the reliability of various paleoclimatic and paleoenvironmental proxies, we carried out a combined rock magnetic and geochemical analyses of both the HML sediments and local pyroclastic rocks surrounding the lake.

Four parallel long cores (A, B, C, and D) were recovered from a water depth of 13.5 m during a drilling campaign in September 2011, among which cores B and C are used for this study, with the length of 9.6 m and 10.6 m, respectively. Ten sediment samples collected at 0.5–1 m intervals from the B/C composite section, which extends back to ca. 20 ka, and ten pyroclastic rock samples obtained from 8 localities surrounding the lake for the determination of magnetic susceptibility ( $\chi$ ) and rare earth element (REE) distribution patterns. Measurement of the  $\chi$  was performed with an AGICO KLY-4S Kappabridge. REE analyses were carried out with an ICP-MS (PE300D) in National Research Center for Geoanalysis.

The  $\chi$  values of sediment samples range from  $70.55 \times 10^{-8}$  to  $784.28 \times 10^{-8}$  m<sup>3</sup>/kg with an average value of  $402.58 \times 10^{-8}$  m<sup>3</sup>/kg. For the local volcanic breccia and tuffite, the  $\chi$  values range between  $140.53 \times 10^{-8}$  and  $1220.93 \times 10^{-8}$  m<sup>3</sup>/kg with an average value of  $407.2 \times 10^{-8}$  m<sup>3</sup>/kg. Since the  $\chi$  values of core sediments are significantly larger than that of typical loess samples from the Chinese Loess Plateau (CLP) and even obviously larger than that of the most pedogenized paleosol S5 with the most prominent  $\chi$  value of ca.  $300 \times 10^{-8}$  m<sup>3</sup>/kg across the CLP, it seems unrealistic that the much stronger magnetic signal at HML compared to the Chinese loess reflects predominant contributions from the remote arid Gobi and associated deserts of northwestern China, as proposed by Yancheva et al. (2007). Alternatively, the comparable  $\chi$  values between the core sediments and local volcanic rocks probably suggest that the lake may have received a significant amount of material from local rocks that are dominated by olivine tholeiites, with ferrimagnetic ilmenite and titanomagnetite as the main Fe-oxides.

The chondrite-normalized REE patterns for local pyroclastic rocks, HML sediments and Chinese loess are illustrated in Fig. 1. The results indicate that the REE distributions of all volcanic rocks and core sediments are remarkably similar to each other except for the distinctly positive Ce anomalies in lake sediments (Fig. 1a). Möller et al. (1993) have suggested that the REE patterns for alkaline, carbonate-rich, aerobic lake waters display positive Ce anomalies which result from the oxidation of trivalent Ce to tetravalent Ce by dissolved carbonate and stabilization of (penta)carbonato-Ce<sup>IV</sup>-complexes in solution. The lake water is weakly alkaline with a pH 7.6 and Ca<sup>2+</sup>, Mg<sup>2+</sup> and HCO<sub>3</sub><sup>-</sup> are the dominant cations and anions in lake water. The characteristics of HML water meet all conditions above for the development of a positive Ce anomaly, further strengthening the reliability of our data. In contrast, the REE distribution patterns for the Miocene loess samples from Qinan and the Plio–Pleistocene loess samples from Xifeng consistently exhibit negative Eu anomalies, with enriched light REEs and

\* Corresponding author. E-mail: xishengwang@yahoo.com

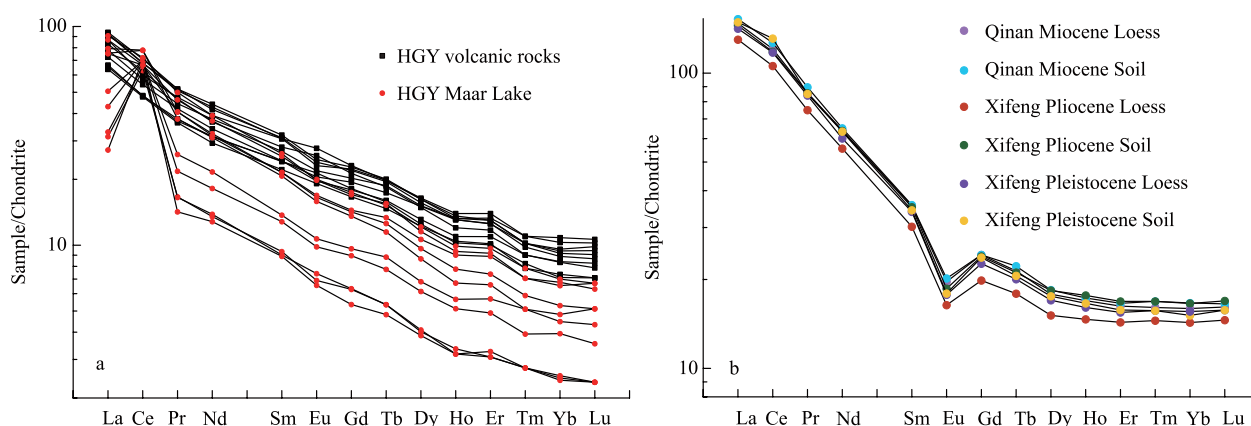


Fig. 1. The chondrite-normalized REE patterns for (a) Huguangyan volcanic rocks and sediments, and (b) the Miocene loess samples from Qinan and the Plio-Pleistocene loess samples from Xifeng (Liang et al., 2009).

relatively flat heavy REEs profiles (Liang et al., 2009), which are substantially different from those for the HML sediments (Fig. 1b).

In summary, this comparison of both  $\chi$  and REE distribution patterns for representative samples from different depths of HML sediments, surrounding volcanic rocks, and typical loess-paleosol samples from the CLP unambiguously confirms that the HML sediments are more closely related to local pyroclastic rocks than wind-blown material from arid North China. Correspondently, the viewpoint that high-resolution records of the magnetic properties and the titanium (Ti) content of the HGY sediments may be used as proxies for the strength of the East Asian winter monsoon, as proposed by Yancheva et al. (2007) seems to be untenable since eolian flux input into the lake transported by the East Asian winter monsoon from North China is likely to make only a minor contribution to the HML sedimentation. Alternatively, we propose that the variations in both Ti and magnetic signals may originate dominantly from titano-magnetite from local rock erosion

probably associated with the hydrology of the lake.

## Acknowledgments

This study was financially supported by the China Geological Survey (grant no. 1212011120045) and the NSFC (grant no. 41274074).

## References

- Liang, M.Y., Guo, Z.T., Kahmann, A.J., and Oldfield, F., 2009. Geochemical characteristics of the Miocene eolian deposits in China: their provenance and climate implications. *Geochemistry, Geophysics, Geosystems*, 10, doi:10.1029/2008GC002331.
- Möller, P., and Bau, M., 1993. Rare-earth patterns with positive cerium anomaly in alkaline waters from Lake Van, Turkey. *Earth and Planetary Science Letters*, 117(3): 671–676.
- Yancheva, G., Nowaczyk, N.R., Mingram, J., Dulski, P., Schettler, G., Negendank, J. F., Liu, J.Q., Sigman, D.M., Peterson, L.C., and Haug, G.H., 2007. Influence of the intertropical convergence zone on the East Asian monsoon. *Nature*, 445: 74–77.