

## Supplemental Material

### **1. Pre-processing of bulk samples and grain size analysis of samples from the Yaodian section (Tianshui Basin)**

Prior to grain size analysis, sediment samples (0.3–0.4 g) were washed with 10 ml of 10% H<sub>2</sub>O<sub>2</sub> in a beaker. After heating for two hours at 70 °C until no bubbles were present anymore in the beaker, 10 ml of 10% HCl was added and the sample heated again at 70 °C until any reaction ceased completely. The 10% HCl solution was washed out and samples were then stood in deionized water in the beaker for at least 8 h. After aspirating the supernatant using a syringe, 10 ml of (NaPO<sub>3</sub>)<sub>6</sub> (~30 g/L) was added with a concentration of 0.05 mol/L and samples were then placed in an ultrasonic bath for vibration and dispersion in batches for 5 min each. Samples were then ready for analysis.

### **2. Sources of data used in this study**

In this study, we used magnetic susceptibility (MS), Mn/Fe and grain size. The MS data in the Yaodian section and the spectral analysis results of these data are derived from Wang et al. (2019). These data have a sampling resolution of ~5 cm. The grain size in the Yaodian section is from this study, and has a resolution of ~20 cm. Rb/Sr data shown in Figure 2 are from Wang et al. (2019). The Mn/Fe ratios in the Yaodian section are also from this study, and have a resolution of ~5 cm. Mn/Fe was measured by handheld XRF, i.e., the same method used to measure Rb/Sr ratios in Wang et al. (2019).

The original MS data from the Jiarang section in the Jiazha Basin are derived from Fu et al. (2018), but the spectral analysis results presented in our study are our own.

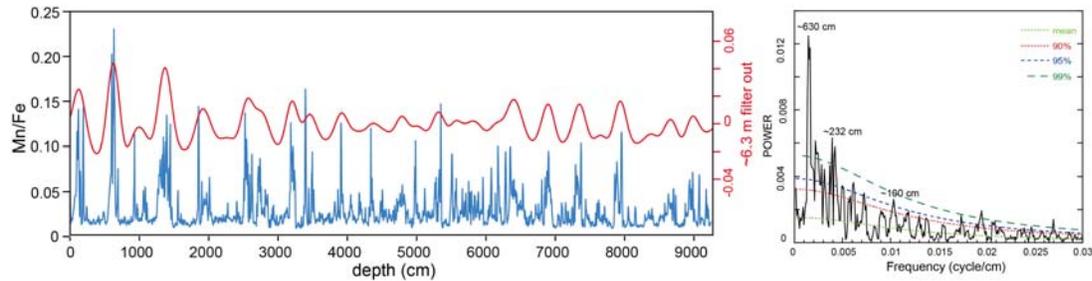


Figure S1. The Mn/Fe ratios in the depth domain from the Yaodian section with its  $\sim 6.3$  m filter (red curve,  $0.0015 \pm 0.002$  cycles/cm), and  $2\pi$  MultiTaper Method power spectrum in the depth domain. Significance of spectral peaks was measured using robust red noise modeling (Mann and Lees, 1996).

## REFERENCES CITED

Fu, C., Qiang, X., Xu, X., Xi, J., Zuo, J., An, Z., and Li, S., 2018, Late Miocene magnetostratigraphy of Jianzha Basin in the northeastern margin of the Tibetan Plateau and changes in the East Asian summer monsoon: *Geological Journal*, v. 53, p. 282-292.

[[Added from main text.]]Mann, M.E., and Lees, J.M., 1996, Robust estimation of background noise and signal detection in climatic time series: *Climatic Change*, v. 33, no. 3, p. 409–445, <https://doi.org/10.1007/BF00142586>.

Wang, Z., Huang, C., Licht, A., Zhang, R., and Kemp, D.B., 2019, Middle to late Miocene eccentricity forcing on lake expansion in NE Tibet: *Geophysical Research Letters*, v. 46, no. 12, p. 6926–6935, <https://doi.org/10.1029/2019GL082283>.