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Orbital scale lake evolution in the Ejina Basin, central Gobi Desert, China revealed by K-feldspar luminescence dating of paleolake shoreline features

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ABSTRACT

The Ejina Basin in the central Gobi Desert contains the terminal lakes of the Heihe River. Paleoenvironmental changes in the basin are important since its deposits are a significant source of Northern Hemisphere dust. In this study we employed a K-feldspar pIRIR dating technique to date shoreline features ≥940 m at multiple locations in the Ejina Basin ~45–50 m above the modern basin floor. Internal checks of luminescence characteristics were employed to test the reliability of the pIRIR dating. In combination with our previously reported stratigraphy and chronology of shorelines at ≤927 m in the Ejina Basin, these results imply that a paleolake was present in the basin prior to ~350 ka. Other high stands in the basin occurred at ~320-310 ka, 240-180 ka, 120-80 ka, and ~5 ka, corresponding to MIS 9, MIS 7, MIS 5 and the mid Holocene (MIS 1), respectively, indicating a strong link with glacial-interglacial cycles. Extensions of the East Asian Summer Monsoon (EASM) during interglacial periods, possibly interacting with the Westerlies, apparently caused higher precipitation and lake formation. The impact of orbital eccentricity on the EASM/Westerlies appears to be responsible for the formation of major lake/desert cycles on the northeastern margin of the Tibetan Plateau.

1. Introduction

The Gobi Desert in arid central Asia covers more than 1,300,000 km^2, and accounts for a large portion of the arid lands in the middle latitudes of the Northern Hemisphere (Fig. 1). The Gobi Desert and its cover of Quaternary eolian, fluvial and lacustrine deposits is an atmospheric dust source influencing global atmosphere circulation and climate change (Biscaye et al., 1997; Uno et al., 2009). Quaternary palaeoenvironmental changes in the fluvial-terminal lake systems of the arid Gobi Desert are therefore important in understanding palaeoclimatic dust emissions controls in the region (Wang et al., 2012).

The Ejina Basin, in the central Gobi Desert, is composed of three major sub-basins: Gaxun Nur, Sogo Nur and Juyanze (from west to east). Together these constitute the terminal lake basin of the Heihe River (Fig. 1). The Heihe River is the second largest inland river of China and originates in the Qilian Mountains before flowing 800 km north to the Ejina Basin. During low lake periods, as at present, the river alternatively feeds the three sub-basins as it shifts back and forth across its delta. During such low water intervals lake evolution in the sub-basins of Ejina Basin is a complex response to a combination of geomorphological shifts and climate change (Jin et al., 2015). During higher lake periods, when a contiguous lake is formed, lake fluctuations more directly respond to climatic changes (Li et al., 2015b). Lake fluctuations in the Ejina Basin during the late Quaternary have been increasingly explored in recent decades. A series of stratigraphic sections and drill cores in the Ejina Basin have been studied for paleolake evolution and paleoenvironment reconstruction (Wünnemann and Hartmann, 2002; Wang et al., 2004; Chi et al., 2006; Zhang et al., 2006; Wünnemann et al., 2007; Hartmann et al., 2009). Together these drill core and sedimentary records suggest the presence of lakes in the Ejina Basin dating to at least MIS 5 and probably earlier, but the discontinuous nature of the core sequences and the problematic chronologies for the lacustrine deposits currently prevent a clear understanding of when these lake intervals occurred. On the other hand, well-preserved paleolake shorelines in the Ejina Basin can be readily seen in remotely sensing images (Jin et al., 2015; Li et al., 2015b) (Fig. 2) and provide evidence for lake evolution histories in this region. Wünnemann et al. (1998) investigated shorelines in the Ejina Basin (the western Juyanze and Gaxun Nur basins), and provide a chronology for these shoreline features by relying primarily on ^{14}C dating of freshwater

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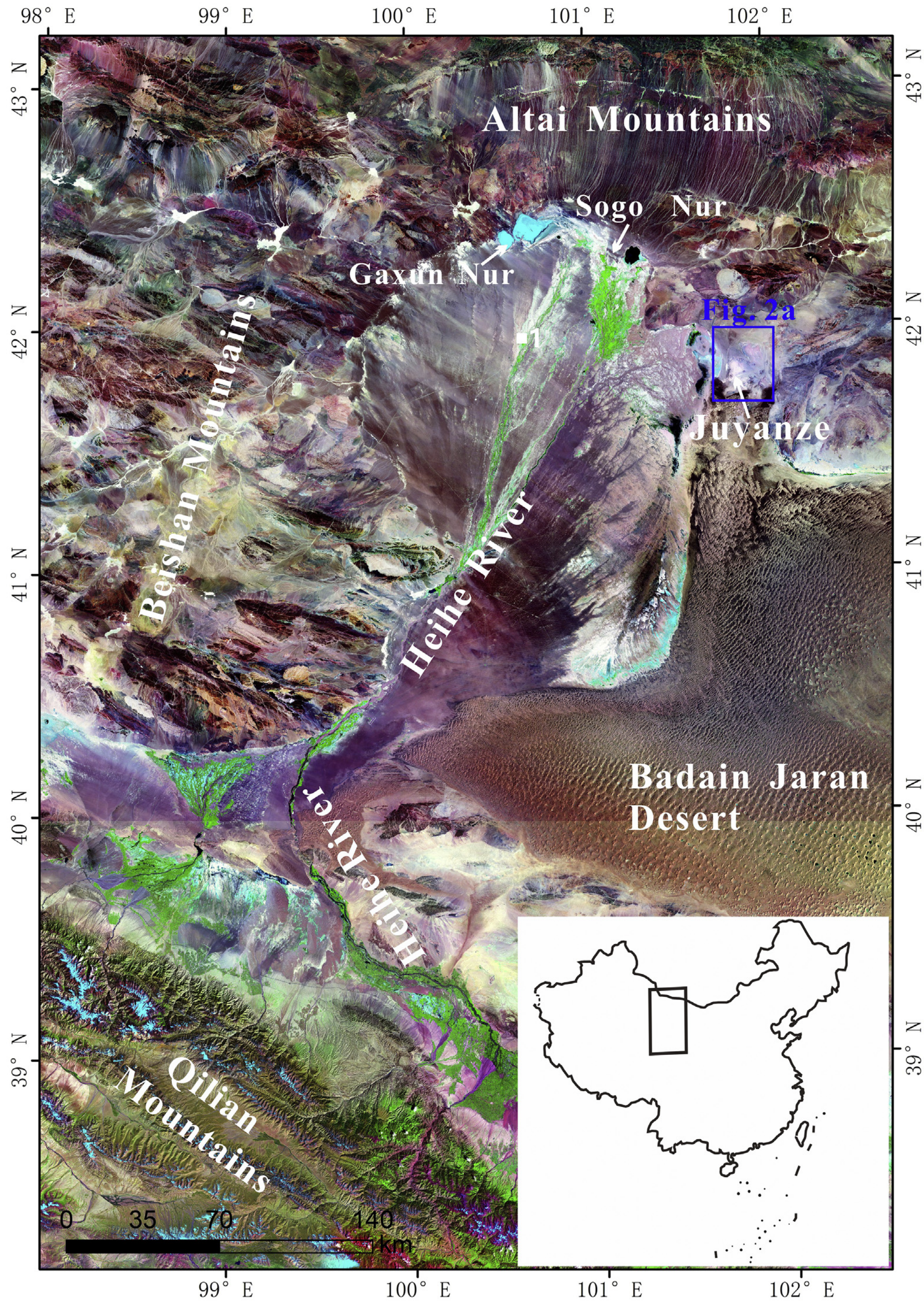

Fig. 1. The remote sensing image of the Heihe River system and its surroundings (modified from Li et al., 2016).

clam shells (*Corbicula fluminea*) and carbonates. Radiocarbon dates on carbonates, organic material, and shells from sediment stacks in the Sogo Nur and Juyanze basins suggest a relatively high MIS 3-age lake in the Ejina Basin reached at least ~935 m (Wünnemann et al., 1998; Hartmann et al., 2009). ^{14}C ages on mollusk shells from 913 m to 917 m shorelines in the Juyanze sub-basin are ~5.3 and ~2.8 cal ka, respectively (Wünnemann and Hartmann, 2002). While these mid-to-late Holocene ages are likely reliable, those that fall in MIS 3 may be problematic as ^{14}C age estimates from many Chinese lakes of > 30 ka appear to be contaminated by younger carbon (e.g., Lai et al., 2014; Long et al., 2015a; b; Mischke et al., 2015). As a result, paleolake evolution in the Ejina Basin, especially for periods prior to the Holocene, remains unclear primarily because of the erosional unconformities and a lack of robust age controls in core data and because investigation of paleoshoreline features has been limited and there are few reliable ages for the higher shorelines (Wünnemann et al., 2007).

Optically stimulated luminescence (OSL) dating can be used to date paleolake shoreline features by directly measuring the time elapsed since the features were last exposed to sunlight (Aitken, 1985). Traditional quartz OSL dating methods have been widely applied to late