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Millennial-scale erosion rates in three inland drainage basins and their controlling factors since the Last Deglaciation, arid China

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ABSTRACT

In the regions surrounding the Qinghai Tibet Plateau, changes in erosion rates have been linked to the tectonics, climate and topography over different time scales. To understand the mechanisms governing the changes of erosion rates, it is important to study erosion rates by different methods and for different time scales. In inland drainage basins, deposition rates of terminal lake sediments can indicate basin-wide erosion rates at the millennial-scale. This paper presents three lake records of the Last Deglaciation and Holocene (Huahai Lake, Zhuye Lake and Yanchi Lake) from the Hexi Corridor, north of the Qilian Mountains, in arid China. Organic matter, terrestrial pollen concentrates, seeds, grasses and plant debris are used for conventional and AMS ^{14}C dating. On the basis of 66 radiocarbon dates, lithology and grain-size, we infer relatively high basin-wide erosion rates during the Last Deglaciation and early Holocene in the three drainage basins, when the three lake sediments were seriously affected by reworking. The deposition rates were an order of magnitude or greater in these lakes during the Last Deglaciation and early Holocene than during the mid-to-late Holocene. During the transition period of the last glacial–interglacial cycle, significant climatic changes occurred in East and Central Asia, corresponding to the strengthening of the Asian summer monsoon and to increasing effective moisture in arid Central Asia, which can have strong impacts on basin-wide erosion rates north of the Qinghai Tibet Plateau. Moreover, melting glaciers in the Qilian Mountains probably also contributed to the high basin-wide erosion rates. At the same time, tectonic activity was not recognizable in the study area during that period. In the arid and semiarid regions surrounding the Qinghai Tibet Plateau, dramatic changes in erosion rates appear during the transition periods of the glacial–interglacial cycles, which illustrate the climatic controls on erosion rates at this time scale.

1. Introduction

Documenting erosion rates, patterns, and processes is essential for understanding how sediment loading affects stream ecosystems and for modeling landscape evolution (Molnar and England, 1990; Small and Anderson, 1995; Zhang et al., 2001). Strong feedbacks exist between erosion and climate, tectonics, topography, soil production and land use (Molnar and England, 1990; Brozovic et al., 1997; Beaumont et al., 2001; Molnar, 2003; Hodges et al., 2004). For long timescales, climate changes commonly occur at higher frequencies than sustained periods of tectonics; therefore, basin-wide erosion rates over short time intervals may significantly deviate from the rate of tectonics. For short timescales, several factors, e.g., base level, precipitation, discharge, river's sediment load, land use and cover, compete with each other for variable basin-wide erosion rates (Bull, 1990; Mol et al., 2000; Hetzel et al., 2006). At millennial time scales, erosion rates can be affected both by tectonics and climate changes, so it is a key time scale for investigating the relative effects of each.

The collision between India and Eurasia has caused widespread late Cenozoic deformation in East and Central Asia resulting in uplift of the Qinghai-Tibet Plateau, while the global late Cenozoic cooling and glacial–interglacial cycles have had significant impacts to climatic changes in the region; therefore, it is an ideal region to study climatic or tectonic controls on erosion rates for different time scales (Fig. 1A, B and C) (Meyer et al., 1998; Tapponnier et al., 2001; Zhang et al., 2001). In the surrounding regions of the Qinghai-Tibet Plateau, erosion rates have been widely reported by different methods (e.g., at the timescale of $>10^5$ yr: Zhang et al., 2001; Charreau et al., 2009; at the timescale of 10^2–10^5 yr: Burbank et al., 2003; Pan et al., 2003; Hetzel et al., 2006; at the timescale of $<10^2$: Gabet et al., 2008; Pan et al., 2010); however, millennial-scale erosion rates are rarely studied because of the lack of study methods. Conventional techniques used to assess

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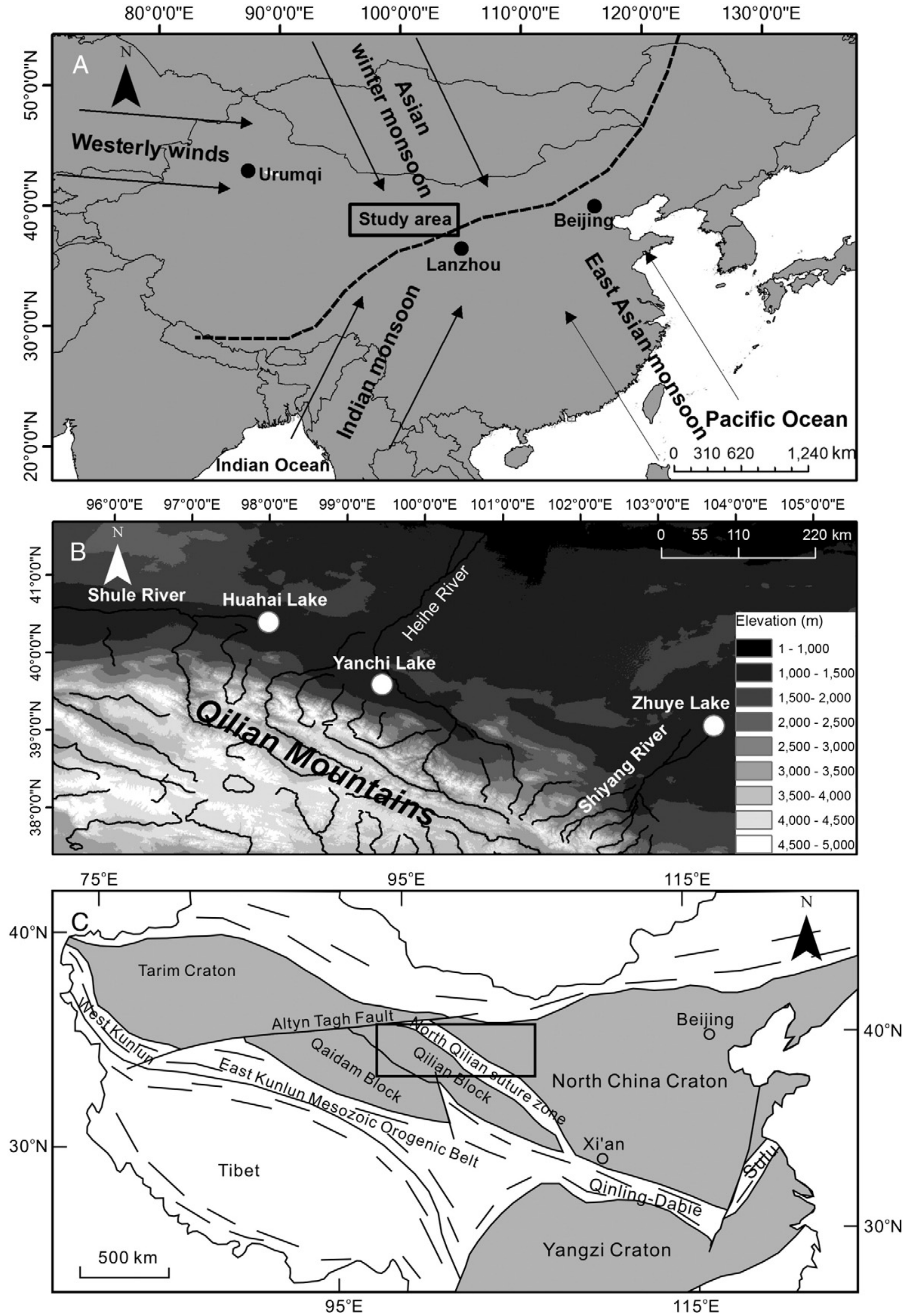

Fig. 1. (A) Map showing the modern climate systems of the study area and China. The dashed line indicates the modern Asian summer monsoon limit. (B) Map showing the topography of the study area. Zhuye Lake, Yanchi Lake and Huahai Lake are three terminal lakes of inland drainage basins, located in the Hexi Corridor, north of the Qilian Mountains, in arid China. (C) Schematic map showing major tectonic units of central China. The study area was shown by a rectangle in the northern Qinghai-Tibet Plateau.