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Late Pleistocene and Holocene aeolian sedimentation in Gonghe Basin, northeastern Qinghai-Tibetan Plateau: Variability, processes, and climatic implications

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ABSTRACT

Although stratigraphic sequences of aeolian deposits in dryland areas have long been recognized as providing information about past environments, the exact nature of the environmental processes they reflect remains unclear. Here, we report the results of a detailed investigation of eight outcrop sections in the Gonghe Basin, northeastern Qinghai-Tibetan Plateau. Measurements of sediment grain-size and chemical composition indicate that the deposits are primarily of aeolian origin, consisting of interbedded, well-sorted sand, silty sand, loess and/or palaeosol; however, their occurrence varies from site to site. Fossil dune sands mainly occur in or close to the currently stabilized or semi-stabilized dune fields, whereas loess is distributed along the downwind marginal areas. This pattern of basin-scale differentiation was controlled mainly by spatial variability of sediment supply due to the antecedent sedimentary patterns within the basin. Together with previously-published optically stimulated luminescence (OSL) ages, 24 new OSL dates are used to elucidate the history of aeolian activity and its relationship to climatic changes. There is no apparent relationship between past dune activity and downwind loess deposits. Deposition of silty sand probably occurred during past phases of windy, dry and cold climate in the Late Pleistocene. However, climatic factors alone cannot explain the occurrence of silty sand deposition. This is because the deposition of silty sand was always preceded by episodes of fluvial deposition prior to river incision, thereby indicating the importance of an 'activated' sediment supply associated with fluvial processes. Deposition of well-sorted sand occurred episodically, not only during the Late Pleistocene, but also during the early- to mid-Holocene. Vegetation conditions, controlled either by the occurrence of intervals of moisture deficit during the Late Pleistocene or by changes in the balance between precipitation and evapotranspiration at a local scale, played an important role in sand mobility and deposition. The effect of vegetation on sand mobility is also suggested by independent evidence of aeolian activity from Genggahai Lake in the Gonghe Basin. Here, the deposition of aeolian sand in the basin during the early- to mid-Holocene indicates a low level of effective moisture caused by high evaporation induced by higher summer insolation, despite the coeval increased regional precipitation recorded by lacustrine sediments. In contrast, late Holocene palaeosols represent a high level of effective moisture, and their formation did not necessarily require increased regional precipitation. Overall, our results suggest that the relationship between aeolian activity and regional climate change is complex, and that sand accumulations do not represent the consistent action of surface processes that are related to climatic changes.

1. Introduction

As the major part of arid central Asia, the drylands of China consist of the arid basins in northwestern China and the semi-arid

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zones along the northwestern margin of the influence of the Asian summer monsoon (Zhu et al., 1980; Yang et al., 2011) (Fig. 1A). In these regions, arid and semi-arid climates are prevalent because of the long distance from the oceans and the blocking of moisture transport by high mountains (Yang X. et al., 2012). The climatic conditions not only result in the ecological systems in the drylands being very fragile, but they also make the drylands one of the major source areas for Asian dust in the Northern Hemisphere (e.g. Uno et al., 2009). Dust can be entrained through aeolian activity in the drylands, which is then dispersed across the Chinese Loess Plateau, East Asia, the Pacific Ocean, and even as far as the Greenland ice sheet (Liu, 1985; Rea, 1994; Biscaye et al., 1997). Thus, environmental changes in the drylands are extremely important for understanding their role in the changing global climatic system.

In general, there are few well-preserved, nearly continuous and sequential aeolian deposits in the arid basins of northwestern China; this is due to frequent, intense aeolian activity. However, along the semi-arid boundary between deserts and loess deposits, aeolian deposits always consist of interbedded aeolian sand, palaeosol and/or sandy loess (e.g. Lu et al., 2005). Since they are transitional from sandy deserts to major dust depositional areas such as the Chinese Loess Plateau (Qiang et al., 2010a), the aeolian deposits of the drylands provide key information on desert expansion or stabilization, and thus have been regarded as important for investigating environmental changes within these regions. Recently, many optically stimulated luminescence (OSL)

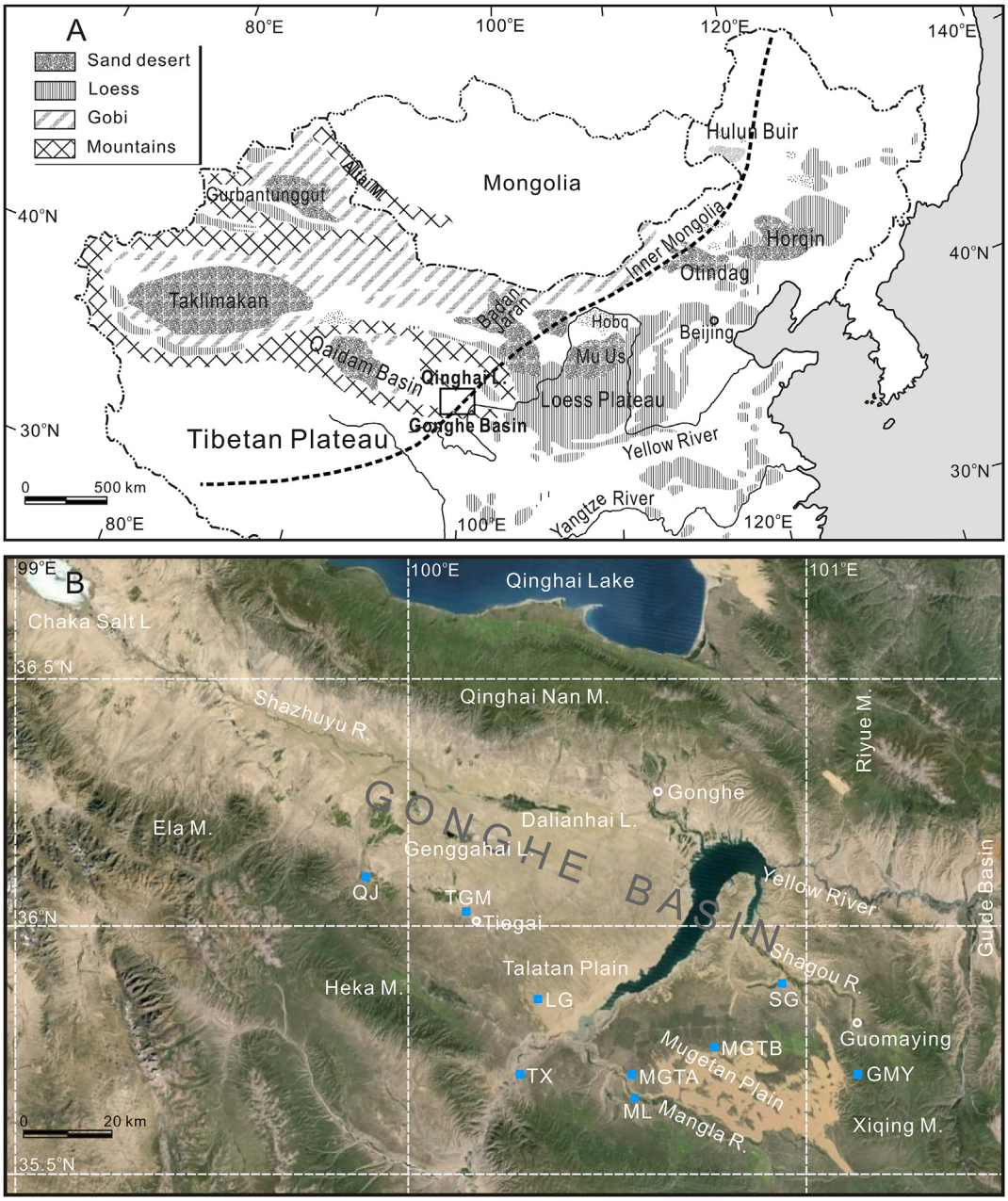

Fig. 1. Location of study area. (A) Overview of the drylands in north China. The Gonghe Basin is located in the marginal zone influenced by the Asian summer monsoon. The modern Asian summer monsoon limit is indicated by a dark dashed line redrawn from Gao et al. (1962). (B) The Gonghe Basin (Google Earth™), with locations of the studied aeolian sections and the Lagan (LG) section (Liu et al., 2013) indicated by solid blue squares. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)