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Geochemical and magnetic characteristics of aeolian transported materials under different near-surface wind fields: An experimental study

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ABSTRACT

By combining field investigations, field sampling, wind-tunnel experiments, and laboratory measurements, the relationships between near-surface winds and the geochemical and magnetic characteristics of wind-transported materials were statistically analyzed. Our study was conducted using bulk surface samples from a major potential dust source area in Central Asia (the Ala Shan Plateau). Under near-surface wind velocities ranging from 8 to 22 m/s, the coefficients of variation ranged between 1.6% and 14.9% for χ_{lf}, 1.4% and 11.0% for χ_{ARM}, and 0.7% and 12.3% for SIRM of the transported materials. For the 26 elements and oxides investigated, the coefficients of variation of Ti, Cr, As, Zr, Ce, Pb, and Cu in the samples were greater than 10%. No consistent patterns were found between magnetic characteristics and elemental and iron oxide concentrations as a function of variations in near-surface wind velocities. In potential dust source areas under near-surface wind velocities, there are variations in the relationships between magnetic and geochemical characteristics in the fine fractions of transported materials with different particle sizes. Given the wide variation in magnetic and geochemical characteristics of aeolian-transported materials under different near-surface winds, their use as proxies for past climate reconstruction must be carefully appraised.

1. Introduction

Ancient aeolian deposits derived from the transportation and deposition of atmospheric mineral dust can record the mechanisms and rates of emission from source areas and potential transport routes, as well as the effects of post-depositional weathering, pedogenesis and other processes strongly linked with regional environmental change (Kukla et al., 1988; Harrison et al., 2001; Larrasoaña et al., 2003; Maher, 2011). Analysis of data from the Moderate Resolution Imaging Spectroradiometer (MODIS) and the Total Ozone Mapping Spectrometer (TOMS), as well as of dust storm frequency over the past half-century at a global scale, suggests that the Gobi and other sandy deserts of Central Asia (Prospero et al., 2002), particularly those in arid western China and southern Mongolia (Natsagdorj et al., 2003; Wang et al., 2006, 2008), are major potential sources of modern aeolian dust.

Throughout the Quaternary, dust emissions from these regions, which include the Tarim Basin, the northeastern Qinghai–Tibetan Plateau (Honda et al., 2004; Stevens et al., 2010; Pullen et al., 2011), the Ala Shan Plateau, and the Southern Gobi Desert of Mongolia (Sun et al., 2000, 2002a, b), have been the source of the material transported to form vast accumulations of dust such as those on the Chinese Loess Plateau (Liu, 1985). Transported materials provide evidence concerning atmospheric circulation patterns as well as dust traces in ice cores in Arctic regions (Bory et al., 2002, 2003),and have been used as proxies for past climate changes (Hao and Guo, 2005; Bloemendal et al., 2008; Sun et al., 2008, 2010) in depositional areas. In East Asia, the effects of post-depositional weathering and other processes on the particle size, geochemistry, and magnetic properties of aeolian deposits have been used as proxies for variations in the intensity of the Asian monsoons (Chen et al., 2007; Chavagnac et al., 2008; Rao et al., 2009), regional precipitation (Maher and Thompson, 1991; Balsam et al., 2011), pressure gradients and resultant wind velocities (Yancheva et al., 2007; Sugden et al., 2009), and aeolian processes and chemical weathering (Jeong et al., 2011).

Transportation of materials by aeolian processes is a prerequisite for the emission, transportation, and deposition of fine particles such as dust aerosols far from the source regions. Because of the significance of this dust for regional climate and environmental change, post-depositional processes affecting their geochemical and magnetic characteristics have been discussed in detail. For example, Oldfield et al. (2009) suggested that, in a wide range of depositional environments, there is a strong link between particle size classes and magnetic properties. In addition, long-distance transportation and variations in transportation paths may change the magnetic characteristics of aeolian dust (Baker and Croot, 2010). Furthermore, over timescales of a few

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Fig. 1. (A) Aeolian geomorphology of Central Asia and (B) location of sampling sites.

hundred years (typical durations for soil formation), regional temperature and rainfall variations (Maher, 1998; Maher et al., 2003) and changes in the contributions of magnetotactic bacteria (e.g., Bloemendal et al., 1988) and cosmogenic and volcanic spherules (Maher, 2011) have led to significant variations in pedogenic magnetic susceptibility (Maher and Thompson, 1992; Liu et al., 2012), even though their major ingredients

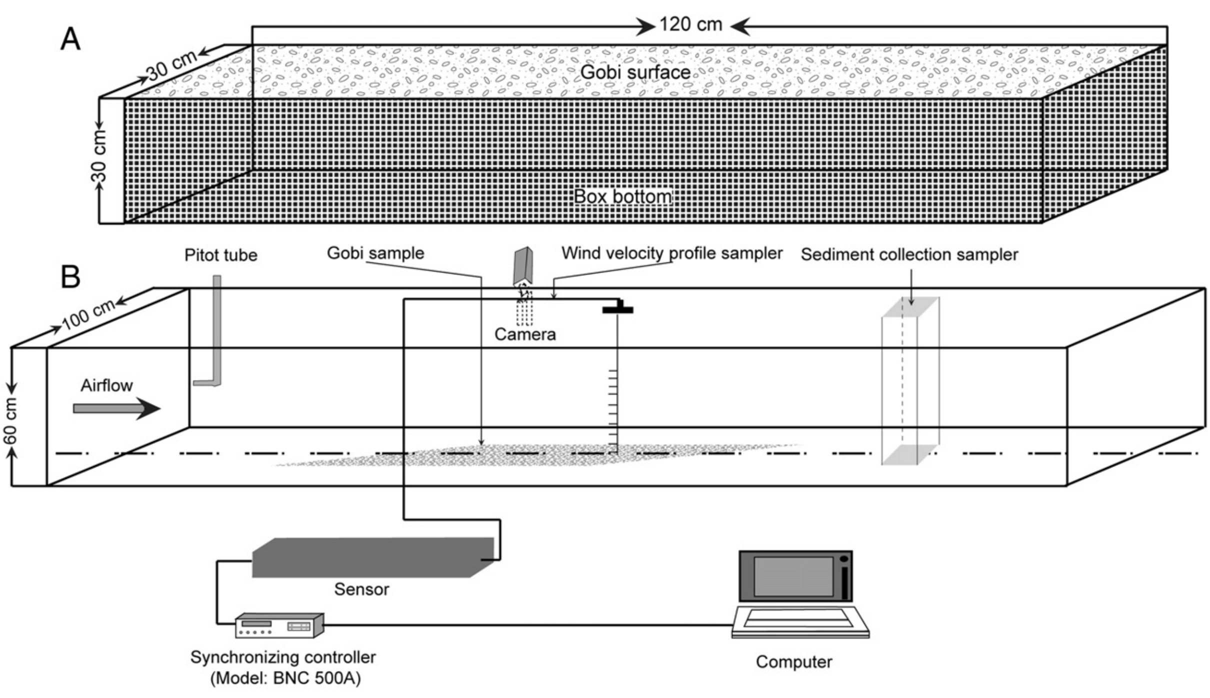

Fig. 2. Schematic diagram of (A) surface samples and (B) the wind tunnel and sample arrangement during the wind-tunnel experiments.