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Geochemical and isotopic characteristics of sediments for the Hulun Buir Sandy Land, northeast China: implication for weathering, recycling and dust provenance

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ABSTRACT

Fluvial, lacustrine and aeolian sediments in the Hulun Buir Sandy Land (HBSL), northeast China are investigated for the first time to be a key supplementation of the Asian aeolian dust system. Fine-grained components (< 10 μm, < 30 μm and < 63 μm) were separated for elemental and isotopic analyses. Major and trace elements, Rare Earth Elements (REE) and Sr-Nd isotopic compositions were employed to evaluate their source-area chemical weathering, sediment recycling and source-rock composition, and to infer their contribution to aeolian deposits to the proximal Northeast China Plain (NCP) and the distant regions such as the Japan Sea. Low chemical index of alteration (CIA) and high weathering index (WIP) indicate that the sediments in the HBSL were characterized by weak chemical weathering and moderate sedimentary recycling. Volcanic ash components were detected in these sediments, implying that the parent rocks are dominated by felsic with minor contribution of intermediate igneous rocks. These sediments were originated from the weathering-eroding products of the Great Xing'an Range terrane via fluvial process. Based on multiple tracers such as the ratio of immobile elements, REE and Sr-Nd isotopic compositions, and the vegetation, geomorphic and meteorological features, it is suggested that the sediments in the HBSL have limited contribution to the aeolian deposits in the eastern and central NCP, as well as further-away areas such as the Japan Sea.

1. Introduction

Clastic sediments have enormous potential to unravel past geological processes. Their geochemical characteristics provide valuable insights into source-area paleoweathering, source-rock composition, sorting and recycling processes, dust provenance and transportation (Bhatia, 1985; McLennan et al., 1993). Although sedimentary processes like weathering, erosion, transportation, sedimentation and diagenesis, are likely to, to a certain extent, modify the primary composition of sediments, it has been extensively accepted that the geochemical composition of sediments are still dominantly influenced by their source rocks (e.g., Ahmad et al., 2016). Accordingly, the geochemical composition of sediments has been extensively served for deciphering provenance (e.g., Wronkiewicz and Condie, 1987; Gu, 1994; Asiedu et al., 2000, 2004; Bauluz et al., 2000; Armstrong-Altrin et al., 2004, 2015; Chen et al., 2007; Hao et al., 2010; Li et al., 2009, 2011; Ferrat et al., 2011).

The Asian aeolian dust system comprises the surface materials from extensive desertification areas in northern and western China (e.g., Liu, 1985; Chen and Li, 2011). The investigation of sediments in the desert/sandy lands is of great importance to understanding the formation and evolution of these desert/sandy lands, and their links to paleoclimate change and regional-to-global dust cycling. Previous geochemical investigations were focused on the major Asian dust sources, including three interior basins in western China as well as the Gobi (stony desert) and deserts in western and northern China (e.g., Zhang et al., 1996; Hu and Yang, 2016). However, geochemical compositions of the surface sediments in the Northeast Sandy Lands, especially the Hulun Buir Sandy Land (HBSL), have never been investigated as a key supplementation of the Asian aeolian dust system.

The sandy lands of the western Northeast China Plain (NCP), including the Horqin Sandy Land, the Songnen Sandy Land and the HBSL, are located at the eastern edge of the mid-latitude giant desert/sand land in the Asian interior (Fig. 1). These sandy lands were often considered as minor sources of the Asian aeolian dust system, with very limited data available in the previous investigations (e.g., Chen et al.,

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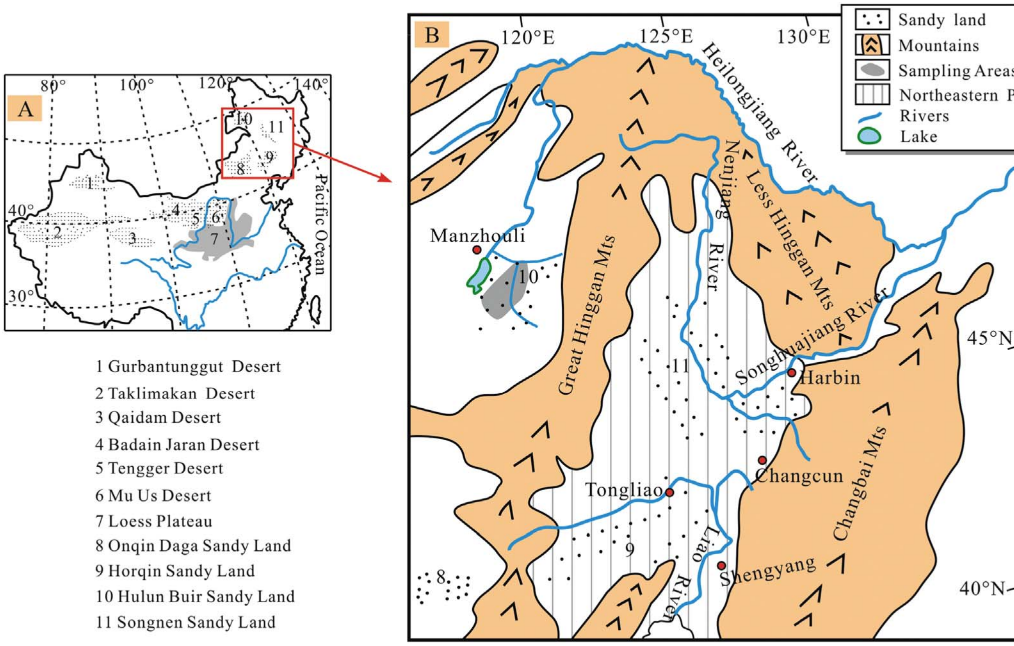

Fig. 1. (A) Sketch map of East Asia, showing the deserts and sandy land in northern China suggested to be main sources to Asian dust; (B) Sketch map of the Northeastern Plain in China (modified from Xie and Chi, 2016), showing location of the study area and sampling sites.

2007; Li et al., 2009). However, a few investigations using a regional climate model indicated that the Northeastern Sandy Lands (e.g., Horqin and Onqin Daga Sandy Lands) played a part role in regional aeolian dust emission and transportation (e.g., Shi and Liu, 2011). Until now, the HBSL has not yet been investigated and thus little is known about the origin and impacts of dust emissions from the HBSL source. In this study, the sediments in the HBSL are investigated from the perspective of an Asian aeolian dust system. The geochemical data of the HBSL sediments, including major and trace elements, rare earth elements (REE), and Sr-Nd isotopic ratios were employed to assess weathering, sedimentary recycling in the source areas, to distinguish the potential host rocks of the sediments, and to evaluate whether the HBSL contributes to dust cycling over near-surface and far-away ranges.

2. Materials and methods

2.1. Setting and sampling

The HBSL with an area of 7435.2 km^2 is one of the highest latitude sandy lands in China and the smallest of the NE Sandy Lands, and located at the southwestern Hulun Buir city, Inner Mongolia, China (Fig. 1). The HBSL is developed from an alluvial-lacustrine plain and bound by the Yimin River and the Great Xing'an Range to the east, by Hulun Lake to the west (Qiu, 2008b). The aeolian dunes are scattered sparsely in the sandy land with a height of ca. 5 to 15 m and are comprised of small-sized fixed to semi-fixed shrub or tussock dunes. The prevailing wind direction is northwesterly as detected from the array and shape of the aeolian dunes. Thirteen representative surface sediment samples (marked from HL1 to HL13) were collected from the HBSL (Fig. 1). Among them, samples HL1, HL3, HL4, and HL6 are fluvial sands; HL2 is a paleosol sample; HL5 is a lacustrine muddy silt, and the remaining (HL7-13) are aeolian sands. All the samples were separated into < 63 μm fraction by dry sieving. Additionally, samples HL1, HL3, HL4, HL5, and HL6 were further separated into < 30 μm and < 10 μm fractions by dry sieving, respectively. All the subsamples obtained above by dry sieving were analyzed for major, trace, and rare earth elements (REE) as well as Sr and Nd isotopic compositions.

In order to identify whether the sediments in the HBSL supply a certain amount of dust to the downwind eastern and central NCP or not, thirteen dust storm samples and seven loess samples from the Harbin were selected for geochemical analyses after being separated into two size fractions (< 63 μm and < 10 μm) (For detailed descriptions of these samples, see Xie et al., 2014 and Xie and Chi, 2016). Grain-size compositions of several subsamples with different grain-size fractions obtained by sieving were measured at least three times using a Malvern Mastersizer 2000 particle analyzer. The grain-size distributions are consistent with dry-sieved results, indicating high efficiency of grain size separation by dry sieving method.

2.2. Analytical methods

Major elements were analyzed by a standard X-ray fluorescence (XRF) spectrometer (AL104, PW2404) on fused glass beads at the Analytical Laboratory of Beijing Research Institute of Uranium Geology. The detection limit is ~0.01 wt% and analytical precision (relative standard deviation) is $< 1\%$ for major elements. Trace elements and REE were determined using an inductively coupled plasma mass spectrometer (ICP-MS, Finnigan MAT, ElementI), also at the Analytical Laboratory of Beijing Research Institute of Uranium Geology. The sample preparation procedure was performed following the methods proposed by Yang et al. (2007). Four Standard Reference Materials (GSS, Geochemical Standard Reference Sample Soils, Ministry of Land and Resources of the People's Republic of China) for rock were used for external calibration. Analytical uncertainties (relative standard deviation) were $< 2\%$, suggesting a high degree of reliability of the measurements.

The Sr-Nd isotopic ratios of acid-insoluble residues of the samples were determined by thermal ionization mass spectrometry (TIMS) following the method of Chen et al. (2007) at the Analytical Laboratory of Beijing Research Institute of Uranium Geology. Sr and Nd isotope ratios were normalized to $^{86}Sr/^{88}Sr = 0.1194$ and $^{146}Nd/^{144}Nd = 0.7219$, respectively. The analytical blanks are insignificant: < 1 ng for Sr and < 50 pg for Nd, respectively. Reproducibility and accuracy were checked by running the Sr standard NBS987 and Nd standard JMC, with a mean $^{87}Sr/^{86}Sr$ value of 0.710250 ± 7 (2σ) and a mean $^{143}Nd/^{144}Nd$ value of 0.512109 ± 3 (2σ), respectively.