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Aeolian sorting processes in the Ejina desert basin (China) and their response to depositional environment

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ABSTRACT

Granulometric analysis of Aeolian and fluvial sediments in a middle-latitude desert basin (Ejina) was conducted. Sediments were collected from four main geomorphological units (Gobi/foredune, interdune, dune crest and riverbed) which represent the typical surficial conditions. Dunes studied are relatively coarser and lie towards the worse-sorted end of the range in comparison with other deserts. Both the M_z values of aeolian and fluvial sediments tend to decrease as the distance increase toward the Langxinshan but in different variational patterns for sorting parameters between them, indicating a regular change of grain size but different sorting processes in the regional scale between Aeolian and fluvial sediments. Dune sands become finer and better sorted and less positively skewed from dune crest to interdune and foredune. This sorting pattern in dune unit appears to follow those described from the Libya and Namib deserts. While, the Ejina dunefield is located close to its sand sources, which for the most part are believed in this study to be distal palaeo-alluvial fan deposits (Gobi sediments) rather than modern fluvial sediments. The Ejina dunes therefore contain significant amounts of coarse grains with weak sorting degree. This is unlike so-called "mature" sand seas (e.g., central Namib Sand Sea), which lie at some distance in time and space from the original sources of sediment, indicating that the availability of particle sizes in source area exerts a strong influence on the spatial patterns of particle size and sorting in the Ejina dunes.

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1. Introduction

Aeolian processes operate within geomorphic systems that form an interrelated set of processes and landforms in which sediment is transported from source areas to depositional sinks by wind. They are an important component of the environment in arid deserts (both hot and cold), because Aeolian processes are the result of interactions between the atmosphere and the land surface, and thus they are sensitive to changes in both atmospheric parameters and surface conditions that affect both sediment supply and mobility (Lancaster, 1997). Understanding how Aeolian sediment systems respond to internal and external forcing factors is important to evaluating their significance as an environmental proxy (Lancaster, 1997; Lancaster and McCarley-Holder, 2013).

Dunes are depositional landforms. As a result their sediments provide a record of dune accumulation and can therefore provide important information on the processes of dune formation and development (Lancaster, 1995). The importance of grain size sorting and other textural statistical parameters in characterizing dune sediments has been appreciated for some considerable time. Later studies have increased our knowledge of the mechanics and physics of sediment transport by Aeolian (e.g., Bagnold, 1941; Bagnold and Barndorff-Nielsen, 1980; Lancaster, 1995) and fluvial processes (e.g., Visher, 1969; Bagnold, 1977; Allen, 1985), but there remain many uncertainties when research involves the highly dust-dynamic desert environment with alluvial, fluvial and lacustrine processes (Lancaster, 1988, 1995; Lancaster et al., 2002; Dong et al., 2013). Because the size-range, mixing, and sorting of sediment populations vary systematically in relation to sedimentary processes, dynamics and provenance (Visher, 1969). So the study of the genetic identification of Aeolian sediment textures has been a long and difficult work. A major problem is that the same sedimentary processes may occur within a number of different environments and the consequent textural response is similar. In other words, the problem lays in the relation of sedimentary processes to textural responses. How to identify specific response of Aeolian sand to depositional environments thus need a textural study at a different (local and regional) scale to provide a separate line of evidence to aid in interpreting Aeolian deposits of unknown origin (Lancaster, 1988, 1995). Until now, little attempt has been made to relate these measures to the mode of deposition or to the environmental characteristics in the middle-latitude desert zones of central Asia, and even less studies of this nature focus on the desert basins of northern China.

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It is widely accepted that particular geological, geomorphological and climatic conditions in central and eastern Asia have led to substantial transportation and accumulation of Aeolian dust in northern China (Derbyshire et al., 1998). Aeolian sediments from the Gobi (stony desert) in southern Mongolia and from the adjoining Gobi and sand deserts in northern China, rather than those from the three inland desert basins (the Tarim, Jungar and Chadam), are argued to be the dominant source of Aeolian sediments in the Loess Plateau (Sun, 2002) and even occur in the East China Sea, Japan, and in the northern Pacific Ocean (Rea, 1994). Determining the sources and depositional environment of Aeolian sediment in these areas is crucial to develop a better understanding of past and present global climate systems (Yang et al., 2007, 2011). The Ejina desert basin in the Inner Monglia is one of the important duststorm source regions of northern China (Wang et al., 2008, 2013). Its specific information on the Aeolian units is sparse because little attention has been paid to the Ejina dunes. In this study the Ejina dune units and riverbed sediments were granulometrically studied to characterize Aeolian sorting processes and their response to depositional environment, which would contribute to our understanding on the formation of Aeolian landforms in the Ejina. Through the study we hope to improve our understanding on the dust-related Chinese deserts and the control of Aeolian sorting processes. It may serve as a basis for future studies in other desert areas.

2. Setting

The Ejina desert basin (1.146×10^5 km^2) is located at the western margins of the Badanjilin Desert and is the western part of the Alashan Plateau, NW China, between 40–43°N and 99–102°E in the middle-latitude zone of Central Asia (Fig. 1a). Due to its location in the inland of the Asian continent and adjacent to the Mongolia high-pressure center, the Ejina Basin is one of the driest areas of the world. The mean annual temperature was 8.8 °C at Ejina over the last five decades, with a maximum daily temperature of 41 °C (July) and a minimum of −36.4 °C (January). The rainfall regime is continental and the average annual precipitation in the last five decades recorded at the weather stations of Ejina is 35.6 mm. Prevailing winds come from the west and the northwest (Fig. 1a). The Ejina River is the unique river system in the Ejina Basin and drains meltwater from the Qilian Mountains (Fig. 1b). The river flows in a southwesterly direction across an area from Langxinshan into the northern end of Juyan Lake, where a relatively large ancient delta and alluvial fan had formed (Fig. 1). Aeolian dune fields are dominated at the central area of the Ejina and is often crossed by Ejina river channels that occasionally carry short-lived, ephemeral flows. Most sand dunes in these areas are of simple linear or barchan forms, nebkhas and sand sheets, with a spacing of 5–500 m and NW–SE or NNW–SSE alignments. The dunes are generally between 1.5 and 15 m high and have gentle slopes on their southeast (mean angle 4–15°) compared to their northwest flanks (mean angle 3–12°). Most dune crests have no vegetation cover and are active, exposing the sand surface to Aeolian transport.

3. Materials and methods

The various types of land surface sediments including dune and Gobi sediments were investigated and sampled in this study. Dune fields and nearby Gobi areas were sampled at eighteen sites throughout the study area. At each site, transects were surveyed across adjacent barchan/linear dunes or sand sheets and surface

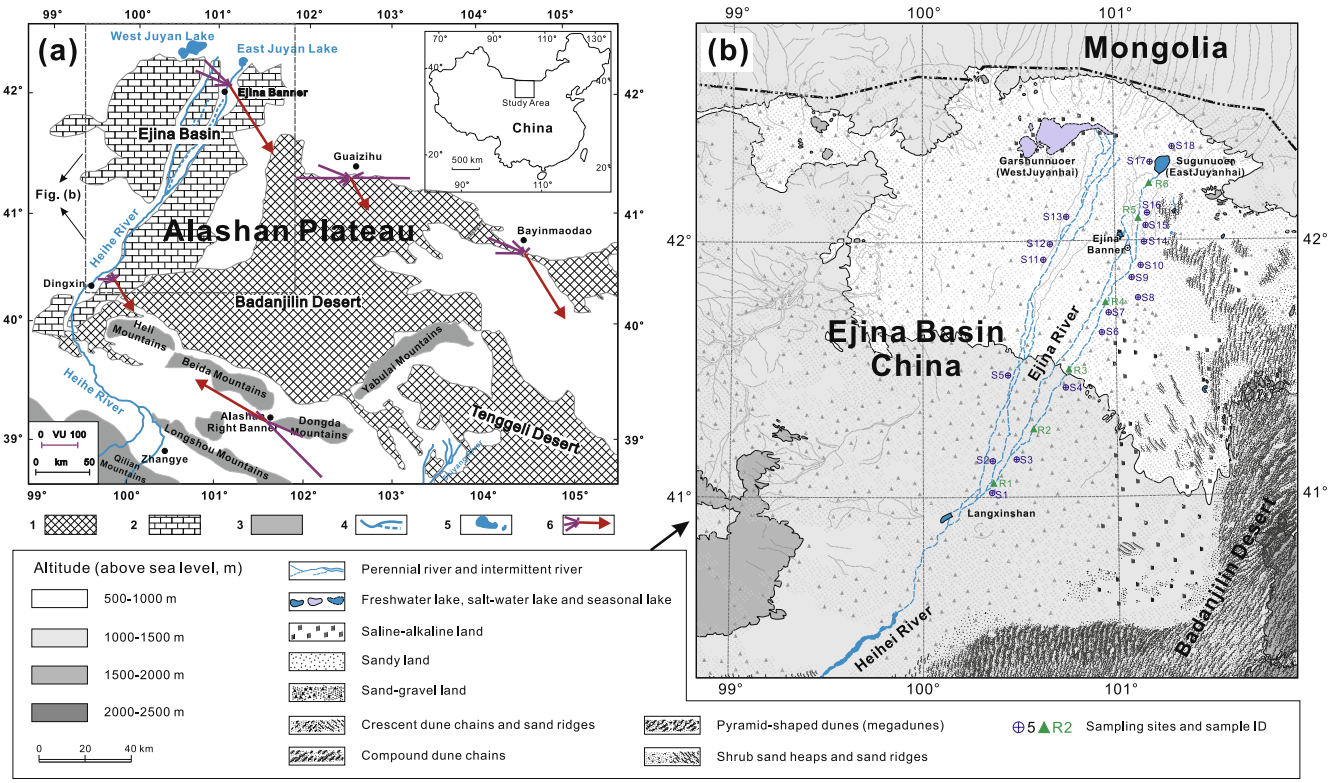

Fig. 1. (a) Overview of the landscape of the Alashan Plateau in northwestern China (modified from Yang et al., 2011) and (b) the topographic and geomorphologic map of the Ejina Basin showing sampling sites. The compound directions of wind systems in different areas in the Alashan Plateau are also shown in Fig. 1a. Legend: 1: sand dunes, 2: fluvial/alluvial sediments associated with the Heihe River, 3: adjacent mountain ranges, 4: rivers, 5: lakes, and 6: sand roses (Fryberger and Dean, 1979) for each of the five surrounding weathering stations, with brown lines showing winds capable of transporting sand from various directions and red arrows indicating the resultant sand transport trend. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

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