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Variation in grain size and morphology of an inland parabolic dune during the incipient phase of stabilization in the Hobq Desert, China

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A B S T R A C T

A significant increase in rainfall in the summer of 2012 on the southern fringe of the Hobq Desert, Inner Mongolia, resulted in the vegetation and thus stability of dunes in this area. Our research focuses on a typical parabolic dune, which was active in 2011 and became stabilized after vegetation colonization. Topographic surveys and surface sediment analysis of the morphology and surface sands of the parabolic dune indicate that decreasing mean grain size and sorting values (better sorting), slightly more positive skewness and increasing kurtosis occurred over the dune surface during the incipient phase of stabilization. There was a strong relationship between grain size sorting and dune mobility. Surface sand from the stabilized dune was generally finer and better sorted than at the same location when the dune was active. During 2011–2012 the dune head had moved eastwards (by approximately 2.3 m) while its two arms expanded outward (by approximately 3.2 m), the height of the dune decreased, and the dune became larger with a decreasing volume. Once anchored (2013–2014), the overall morphology, and the grain size and sorting characteristics of the dune became more constant and quite different than when the dune was active.

1. Introduction

Both the temporal and spatial variations in the grain size and sorting characteristics of the surface sands on dunes have been documented, but these studies have often been conducted on linear dunes (e.g., Folk, 1971; Lancaster, 1981, 1986; Livingstone, 1989; Roskin et al., 2011; Li et al., 2015), star dunes (Lancaster, 1989, 1995; Wang et al., 2003), reversing dunes (Lancaster et al., 2002), coastal dunes (Vincent, 1996; Saye and Pye, 2006; Navarro et al., 2015), transverse dunes (Lancaster, 1982; Hasi and Wang, 1996; Zhang and Dong, 2015), zibars (Lancaster, 1982; Wang et al., 2009; Qian et al., 2015) and crescentic dunes (Watson, 1986; Lancaster, 1995; Hasi and Wang, 2001), while they have rarely been undertaken for parabolic dunes (Ghrefat et al., 2007), especially inland parabolic dunes. Studies have shown that the grain size distribution plays an important role in the dynamic processes and morphology of dunes (Bagnold, 1941; Tsoar, 1986; Pye and Tsoar, 1990) and is highly dependent on wind conditions (Lancaster, 1985; Livingstone, 1989; Anderson and Walker, 2006), vegetation cover (Arens, 1996; Lancaster and Baas, 1998; Hesp, 2002) and sand supply (Hugenholtz et al., 2008, 2009). Direct field measurements indicate that the erosion and deposition of sediments on a dune are controlled by wind direction and velocity; for example, bi-directional wind regimes induce seasonal responses in the grain size characteristics on a linear dune in the Namib sand sea (Livingstone, 1989). Hasi et al. (2006) conducted a field study on a transverse dune on the south edge of Mu Us Sandy Land in northern China, and the results indicated that there were temporal changes and spatial patterns in the grain size that responded to different wind directions and magnitudes. Lancaster et al. (2002) also found that grain size and sorting of surface sands reflect changes in the competence of the wind on a small reversing dune on the Silver Peak dune field in west central Nevada. Furthermore, there were changes in sand transport on different dune forms that resulted from interactions between wind flow and dune morphology (Hasi et al., 2001).

Vegetation plays an important role in stabilizing dunes (Levin et al., 2008; Hugenholtz et al., 2010). It suppresses wind erosion on dunes by trapping particles (Fearnehough et al., 1998; Hansen et al., 2009), protecting the surface cover (Wolfe and Nickling, 1993), extracting momentum from the air flow (Brown, 1997), and changing airflow direction (Lancaster and Baas, 1998). The formation and evolution of parabolic dunes are strongly controlled by vegetation (Livingstone and Warren, 1996) and can be very sensitive to changes in environmental controls (Girardi and Davis, 2010; Yan and Baas, 2015); for instance, active barchans can transform into parabolic dunes when vegetation is established (Anthonsen et al., 1996; Tsoar and Blumberg, 2002; Wolfe and Hugenholtz, 2009). Conversely, when the vegetation cover decreases, parabolic dunes may change back to barchans and transverse dunes (Hack, 1941; Anton and Vincent, 1986). Many dune fields have undergone repeated transitions between mobility and stability due to climate change (Hugenholtz and Wolfe, 2005; Thomas and Wiggs,

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2008; Tsoar et al., 2009; Martinho et al., 2010; Navarro et al., 2011; May, 2013), in some dune fields, mobile and stabilized dunes can coexist (Yizhaq et al., 2007, 2009), and the grain size and sorting characteristics may change with dune mobility. Katra et al. (2009) found that in the northern Coachella Valley of southern California, fine-grained sand (<0.125 μm) was associated with inactive aeolian environments and coarse-grained sand (~280 μm) was linked with active aeolian environments.

In northern China, high precipitation with weak winds occurred in the summer of 2012, which significantly changed local surface vegetation cover, and as a consequence of vegetation colonization, parabolic dunes became stabilized. The aim of this paper is to determine the patterns of grain size and sorting characteristics of a parabolic dune throughout the active to inactive transformation period. We conducted repeated topographic surveys and surface sediments analysis from 2011 to 2014.

2. Study site

The study site is located on the southern fringe of the Hobq Desert on the northern Ordos Plateau, China (Fig. 1). The Hobq Desert is bounded by the Yellow River to the east, north, and west. The study area is at an elevation of 1230 m in an arid to semi-arid climate with cold, windy winters and warm, stormy summers. The mean annual precipitation varies from 299.0 to 403.1 mm, the average annual temperature is 7.4 °C, and the prevailing wind direction is WNW, with an average annual speed of 2.7 m s^{-1}, based on meteorological data from two of the nearest meteorological stations (Hangjin Banner and Dongsheng) from 2007 to 2014. The desert contains three geomorphic parts: the Yellow River floodplain in the north, Yellow River terraces in the middle, and the tectonic platform in the south. This study was conducted on a parabolic dune from the tectonic platform of the desert, which is

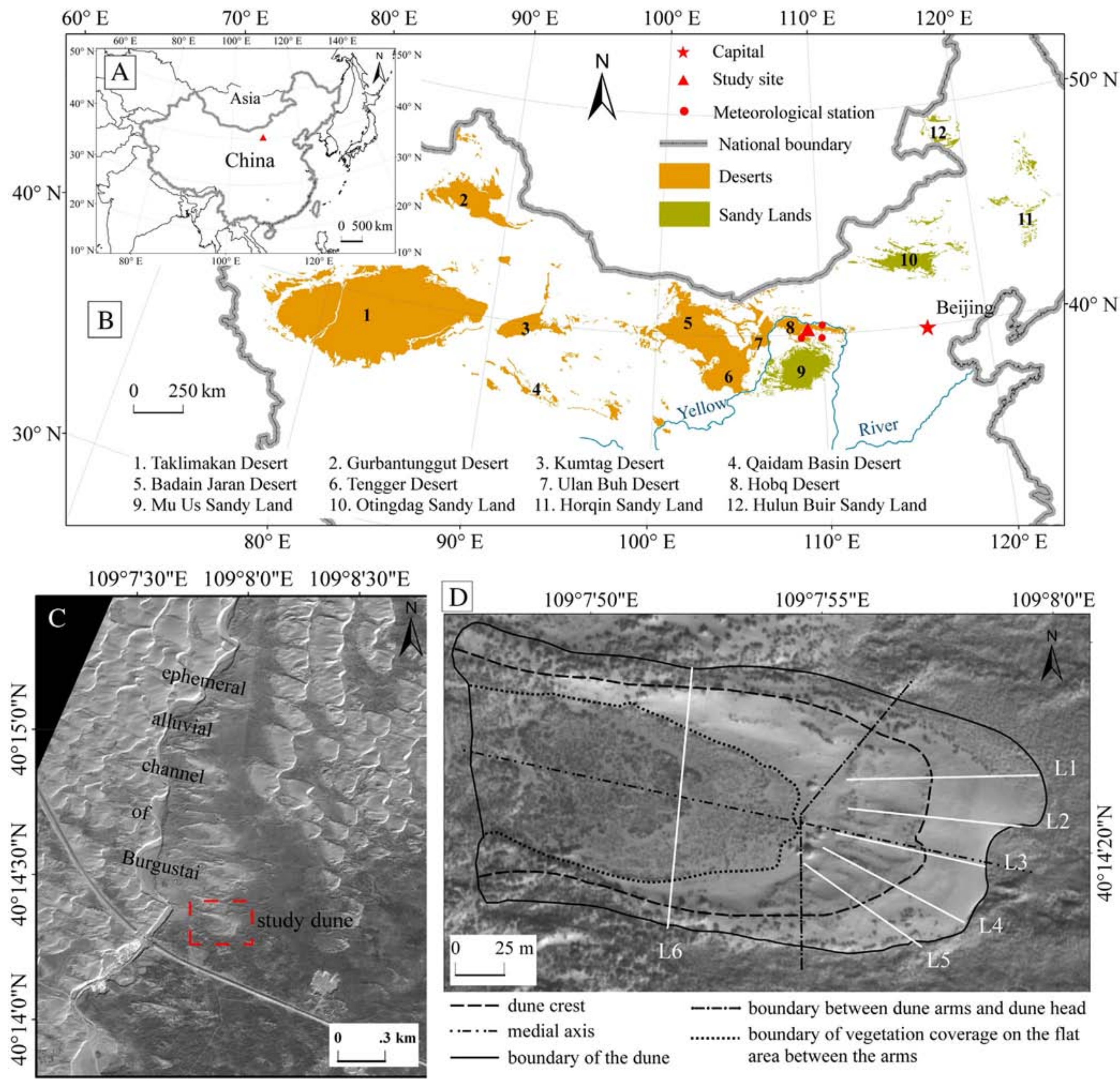

Fig. 1. Location map and satellite image of the study site. (A) Map showing the location of the China in Asia. (B) Map showing the location of the study site in the Hobq Desert in the context of other deserts and sandy lands in China. (C) GeoEye-1 satellite image showing the location of the study dune next to the ephemeral alluvial channel of Burgustai (the study dune is denoted by a red dashed line). (D) GeoEye-1 satellite image of the study dune in January 2012 (the sampled transects are denoted by white lines).