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Interpretations and common challenges of aeolian records from North American dune fields

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ABSTRACT

Geomorphic and chronologic data for dune fields are evaluated for three contrasting areas of North America: 1) the Prairie, Parkland and Boreal ecozones of the northern Great Plains in Canada; 2) the Central Great Plains of the USA; and 3) the deserts of southwestern USA and northern Mexico. Luminescence and radiocarbon ages for periods of dune accumulation and stability are compared with palaeoenvironment proxies to provide an assessment of the boundary conditions of dune system response to changes in sediment supply, availability, and mobility.

Dune fields in the northern Great Plains were formed from sediment originating from glaciofluvial or glaciolacustrine sediments deposited during deglaciation 16–11 ka. Subsequent aeolian deposition occurred in Parkland and Prairie dune fields as a result of mid-Holocene (8–5 ka) and late-Holocene (<3.5 ka) activity related to drought conditions that reworked pre-existing aeolian sands. In the Central Great Plains, many dune fields are closely linked to fluvial sediment sources. Sediment supply was high during deglaciation of the Rocky Mountains and resulted in widespread dune construction 16–10 ka. Multiple periods of Holocene reactivation are recorded and reflect increased sediment availability during drought episodes. Dune fields in the southwestern deserts experienced periods of construction as a result of enhanced supply of sediment from fluvial and lacustrine sources during the period 11.8–8 ka and at intervals during the late Holocene centered on 1.5, 0.7, 0.4, 0.3, and 0.2 ka.

Despite spatial and temporal gaps in chronometric data as a result of sampling biases, the record from North American dune fields indicates the strong influence of sediment supply on dune construction, with changes in sediment availability as a result of drought episodes resulting in dune field reactivation and reworking of pre-existing sediment.

1. Introduction

Active and vegetation-stabilized aeolian dune fields are prominent features in many arid and semi-arid regions. Many of these landscapes stem from late Quaternary environmental conditions, and are important indicators of climatic and environmental changes including wind regimes and atmospheric moisture conditions. Dune fields occur throughout North America, from the Atlantic to the Pacific and the Arctic coastal plains to the deserts of Mexico, but are particularly prominent in the Great Plains and southwestern deserts (Muhs and Wolfe, 1999; Busacca et al., 2003) (Fig. 1). Many of these dune fields have been investigated with periods of aeolian activity and stability dated by luminescence and radiocarbon (^{14}C) methods.

Whereas earlier compilations of available datasets have been regional in scope (e.g. Halfen and Johnson, 2013), the advent of the International Union for Quaternary Science Global Digital Database and Atlas of Quaternary Dune Fields and Sand Seas (herein referred to as the INQUA Dune Atlas) chronologic database (http://inquadunesatlas.dri.edu/) provides an opportunity for a continent-wide synthesis of aeolian activity. Given the wealth of data available for most of North America, the timing of dune deposition may be compared, following the concepts of aeolian

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Fig. 1. Aeolian deposits of the Glaciated Plains, Central and Southern Great Plains, and Western Mountains and Southwestern Deserts. Individual dune fields in each region are identified on Figs. 2–4 (inset maps). Aridity Index background from Zomer et al. (2007, 2008).

system sediment state as per Kocurek and Lancaster (1999), to various palaeoclimate proxies to elucidate conditions of sediment supply, availability, and transport capacity in which dune fields formed. This may, in turn, provide an assessment of the boundary conditions for periods of dune accumulation, reworking, and stability during the late Pleistocene and Holocene.

In this paper, we demonstrate the applicability of the INQUA Dune Atlas by evaluating geomorphic and chronological data for dune fields in three contrasting areas: 1) the Prairie, Parkland and Boreal ecozones of the northern Great Plains in Canada; 2) the Central Great Plains of the USA; and 3) the deserts of southwestern USA and northern Mexico. Collectively, these areas contain the majority of continental dune fields in North America and have received much research attention, thus resulting in abundant data for analysis. They also provide examples of contrasting climatic and environmental conditions as reflected by spatially and temporally varying sediment supply, sediment availability and transport capacity.

The paper is organized regionally, so that pertinent issues with available data can be discussed in context. The latter part of this paper provides a synthesis of dune field responses to climate change, as modulated by aeolian system sediment states, and provides an assessment of knowledge gaps and future research needs.

2. The database

The INQUA Dune Atlas is a multi-year, multi-nation project aimed at developing a global digital database of chronologic information for periods of inland sand dune accumulation and stabilization, together with pertinent stratigraphic and geomorphic information. Researchers can use this database to: 1) document the history of aeolian processes for dune systems in low and mid

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