ELSEVIER

Journal of Arid Environments 61 (2005) 357–375

Journal of Arid Environments

www.elsevier.com/locate/jnlabr/yjare

Phytoliths as paleoenvironmental indicators in a dune field on the northern Great Plains

M. Boyd*

Department of Anthropology, Lakehead University, 955 Oliver Rd., Thunder Bay, Ont., Canada, P7B 5E1

Received 6 October 2003; received in revised form 30 August 2004; accepted 14 September 2004
Available online 8 December 2004

Abstract

Recent applications of grass phytolith analysis on the northern Great Plains emphasize the use of this proxy as an indicator of regional paleoenvironmental change. In contrast, opal phytolith assemblages from a late Holocene (<4100 ^{14}C yrs BP) parabolic dune correlate more strongly with localized changes in topography and moisture during episodes of soil formation. This is because soils on eolian landforms are often short-lived, produce low phytolith inheritance, and are less likely to form and preserve during less humid intervals. Phytolith assemblages preserved in these contexts therefore lack the temporal and spatial integration necessary to be clear indicators of regional vegetative succession and climate change.

Keywords: Phytoliths; Northern Great Plains; Vegetation history; Buried soils; Climate change; Eolian landforms

1. Introduction

Dune fields are a common physiographic feature of the northern Great Plains (NGP). Parabolic dunes in these settings are typically geomorphic palimpsests, recording superimposed cycles of stability and deposition/erosion (David, 1998,

*Tel.: +1 807 343 8279.
E-mail address: matthew.boyd@lakeheadu.ca (M. Boyd).

0140-1963/$ - see front matter
doi:10.1016/j.jaridenv.2004.09.015

pp. 25–39). These cycles have been successfully used to reconstruct the complex responses of eolian landforms to Holocene climate change (David, 1971, pp. 293–299; Gaylord, 1990; Vance and Wolfe, 1996, pp. 251–263; Muhs et al., 1997; Wolfe et al., 2000). The sequences of buried soils that are sometimes preserved in parabolic dunes are also a potential source of information on past vegetation composition and paleoecological processes. However, these analyses have rarely been performed because pollen and plant macrofossils do not preserve well in these settings (Havinga, 1967, 1984; Birks, 1973; Warner, 1990, pp. 53–63). Consequently, most paleoecological studies in the vicinity of dune fields have been performed on sediment deposited in lake basins, where greater possibility of organic preservation exists (e.g., Bradbury, 1980, pp. 29–36; Vance, 1997; Shang and Last, 1999, pp. 95–110). Unlike lake basins, which typically integrate regional plant microfossil assemblages, however, buried soil sequences preserved in dunes permit reconstruction of vegetation growing directly in contact with the dune surface. This, in turn, may allow direct analysis of the relationship between landform evolution, climate change, and changes in the composition of stabilizing vegetation through time.

Although pollen and plant macrofossils do not typically preserve in (“dry”) terrestrial soils, phytoliths do. Silicophytoliths (opal phytoliths) are mostly composed of hydrated silicon dioxide ($SiO_2 \cdot nH_2O$). Production occurs through the uptake of monosilicic acid from soil water and the subsequent precipitation (by evaporation and metabolism) of silica in the cell lumen and around the cell walls of the plant. Because the silica is deposited within the cellular matrix, it often assumes the size, shape, and configuration of the cell in which it forms (Geis, 1973, p. 113). Morphological variation in phytoliths may therefore be used as a means of associating particular forms with the plant taxa that produced them. Although phytoliths are also composed of calcium oxalate (see Jones and Bryant, 1992 for the *Opuntia* genus), siliceous forms are abundant in grasses.

Phytoliths hold enormous promise for the paleoecology of grasslands because this proxy provides information that is not available through conventional pollen analysis. For example, unlike grass pollen which is only identifiable to the family level (Poaceae/Gramineae), grass phytoliths are diagnostic to the subfamily (Twiss et al., 1969; Twiss, 1992, pp. 113–128). This is crucial, because different grass subfamilies have different preferences with regard to temperature and precipitation (e.g., Hartley and Slater, 1960; Hartley, 1973; Tieszen et al., 1979; Gould and Shaw, 1983; Twiss, 1992). Consequently, changes in phytolith assemblages may potentially be used to reconstruct macroclimatic trends in grasslands (e.g., Diester-Haass et al., 1973; Mulholland, 1989; Cummings, 1996; Fredlund and Tieszen, 1994, 1997; Fredlund et al., 1998; Kelly et al., 1998). Secondly, although the pollen of many taxa are transported far from the source plant, phytoliths in soil are assumed by many to enter soil through in situ decay mechanisms (Dimbleby, 1978, p. 129; Piperno, 1988; Mulholland, 1989). Phytolith assemblages may therefore be used to reconstruct local (rather than regional) vegetation composition, adding high spatial precision and “realism” to paleoecological models built using other proxies. Furthermore, as recent studies have shown, phytoliths may even be used to reconstruct long-term grassland fire histories, based on the inclusion of particulate carbon (Boyd, 2002), or