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Phytoliths in plants and soils of the interior Pacific Northwest, USA

Mikhail S. Blinnikov*

Department of Geography, St. Cloud State University, St. Cloud, MN 56301-4498, USA

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Abstract

Phytoliths are a useful paleoproxy in the arid environments. This modern analog study assessed variability of silica phytoliths in 38 species of plants and 58 modern soil samples from 24 locations in the interior Pacific Northwest. Phytoliths were grouped into 20 broadly defined morphotypes based on their 3D shapes under light microscope and presumed anatomical origin within the plant. Grasses (all C_3) have most diverse forms. Most examined conifers, sedges and some shrubs produce identifiable phytoliths as well. Eight different community types can be distinguished based on their modern phytolith record in soils, including shrublands, four regional grassland types, and three forest types. Low percentages of grass phytoliths and high incidence of non-grass forms correspond to forest vegetation in the region today, while certain grass phytoliths allow further differentiation among different grasslands. Phytolith assemblages were further compared to 5 environmental variables, including elevation, mean annual temperature, mean annual precipitation, a moisture index and a growing-degree days index. Some morphotypes tend to occur within relatively narrow environmental windows, which could enable direct paleoenvironmental inferences from phytoliths in geological sediments from the region.

Keywords: climate; modern analogs; Oregon state; plant opal; vegetation; Washington state

1. Introduction

Phytolith analysis is a powerful, yet relatively underutilized, method of paleoenvironmental reconstruction that can be used to supplement pollen and macrofossil analyses (Piperno, 1988; Pearsall, 2000). In North America, both archaeologists (Rovner, 1971; Mulholland, 1993) and paleoecologists (Kurman, 1985; Fredlund and Tieszen, 1997a,b; Kearns, 2001; Blinnikov et al., 2002) used phytoliths to infer a range of paleoenvironmental conditions. Despite some early applications of phytoliths in paleoenvironmental and paleopedological work (Smithson, 1958; Witty and Knox, 1964; Twiss et al., 1969; Rovner, 1971; Norgren, 1973), the use of phytoliths in paleoecology remains uncommon (Piperno and Persall, 1993). Recent studies suggest that any paleoenvironmental reconstructions using phytoliths must begin with analyzing modern phytoliths distribution in plants and soils in the given region (Bowdery, 1998; Carnelli et al., 2001; Lu and Liu, 2003).

* Tel.: +1 320 308 2263; fax: +1 320 308 1660.
E-mail address: mblinnikov@stcloudstate.edu.

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In this paper I present results of a modern analog study of phytoliths in plants and soils of the US interior Pacific Northwest defined as states of Washington and Oregon east of the Cascade Range. This study provides a modern analog dataset required for any paleoenvironmental reconstruction of the late Pleistocene and Holocene vegetation of the region, including the previously published work (Blinnikov et al., 2001, 2002). In fact, only two other studies of phytoliths in plants and modern soils are available from the Pacific Northwest (Witty and Knox, 1964; Norgren, 1973). The former mostly focused on phytoliths in soils at a forest-grassland ecotone in central Oregon, while the latter focused on Douglas-fir forests of the western Cascade Range and grasslands of north-central Oregon. Together they provide data on phytoliths from ca. 15 species in the region, mostly conifers and grasses. Neither study provided an adequate sampling design to compare phytolith distributions among different vegetation types.

In temperate North America, phytoliths have been mostly studied in grasses (Twiss et al., 1969), sedges (Walter, 1975; Ollendorf, 1992), conifers (Klein and Geis, 1978), deciduous trees (Geis, 1973), and some dicotyledonous shrubs and herbs (Bozarth, 1992). Their distribution in grasses has been studied most extensively within Alberta (Blackman, 1971), North Dakota (Mulholland, 1989), central Great Plains (Twiss et al., 1969; Fredlund and Tieszen, 1994), northern Great Plains (Brown, 1984), southeastern states (Lanning and Eleuterius, 1987; Lu and Liu, 2003), and northern Arizona (Kearns, 2001).

The number of modern soil studies on phytoliths on the continent is even smaller. Two important examples include reports of Bozarth (1993) from Alberta and Fredlund and Tieszen (1994) from the northern Great Plains. Earlier soil studies included work of Beavers and Stephen (1958) in Illinois, Verma and Rust (1969) in Minnesota, and Kurman (1985) in Kansas, but none of these provide sufficient data for interregional comparisons.

The following questions are addressed in this paper:

1. What is the overall diversity of phytoliths in the main phytolith-producing plants in the interior Pacific Northwest? Which taxa can be identified on the basis of their phytoliths and at what level (e.g., species, genus, family)?
2. What is the pattern of modern phytolith distribution in soils under present-day vegetation? Can different vegetation types be distinguished on the basis of their phytolith record in modern soils?
3. What is the relationship between modern phytolith assemblages in soils and climate?

2. Area description

Franklin and Dyrness (1988) describe 15 physiographic provinces in Oregon and Washington within the study area (Fig. 1), of which two are most important. The Columbia Basin Province is flat and low (300–600 m elevation) and is covered with extensive basalt flows of 7–15 Ma (million years BP) in age (Baker et al., 1991). The Blue Mountains Province includes the Ochoco, Blue, and Wallowa mountains and has a more variable relief, ranging from 750 m elevation to 3000 m in the Wallowas. The Pacific Northwest lies in the path of westerly storm tracks coming from the Pacific Ocean (Bryson and Hare, 1974). The position of these storm tracks shifts seasonally from 60° N in summer to about 35° N latitude in winter as a result of shifts in the position and strength of the polar jet stream. Westerly winds during fall, winter, and spring bring most of the precipitation. The summers are sunny and dry. The study area, located on the leeward side of the Cascade Range, sits in a pronounced rain shadow with distinctly more continental climate than west of the range. In my study, the mean annual temperature (MAT) ranged from 0 °C at subalpine sites in the Wallowas, OR (WA on Fig. 1) to +12 °C at the Boardman Range, OR (BR on Fig. 1). The mean annual precipitation (MAP) ranged from semi-desert (172 mm) at the Boardman Range to 1492 mm at subalpine sites in the Wallowas. The climate data for the research sites were interpolated using an appropriate topographic adjustment from datasets in Thompson et al. (2000).

In the dry interior of the Pacific Northwest, vegetation zones are often discontinuous, with distribution determined by available moisture (Franklin and Dyrness, 1988). The driest sites are located at low elevations in the western Columbia Basin near the Cascade Range. The wettest sites are located at high