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Wind-Strength Variations Inferred from Quartz Grain-Size Trends in the Lower Cutler Beds Loessite (Pennsylvanian-Permian, Utah, U.S.A.)

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Introduction

The loess-paleosol sequences of the Chinese Loess Plateau record a high-resolution record of Plio-Pleistocene climate change. Of the several proxies used for paleoclimatic analysis in the Chinese Loess Plateau, magnetic susceptibility and grain size have been particularly key. Magnetic susceptibility increases reflect pedogenesis during interglacials, driven by increased precipitation and temperature (e.g. Maher and Thompson, 1992). In addition, grain-size analysis of the quartz fraction in particular (Porter et al., 1995; Xiao et al., 1995) has been used as a proxy for monsoonal wind strengths. To date, such analyses have been applied only to Plio-Pleistocene loess sucessions. Here, we attempt to extend these techniques to very ancient loess successions. Similar to the Quaternary, the Late Paleozoic is well known as a time of significant glaciation, marked at high (paleo)latitudes by widespread and unequivocal evidence for continental glaciers, and at low latitudes by pervasive and classic Pennsylvanian “cyclothems” typically consisting of intercalated marine and continental strata that record the repeated waxing and waning of the Gondwanan ice sheets (Crowell, 1978; Veevers and Powell, 1987). The glacial-interglacial fluctuations that drove glacioeustasy were also recorded in low latitudes of Pangea as fundamental climatic shifts, from relatively arid glacials to more humid interglacials (e.g., Soreghan, 1994, 1997), recorded within loessitic sections as alterations between loess and paleosol, respectively (G. Soreghan et al., 2002). Within the southeastern Paradox basin (southeast Utah), the lower Cutler beds consist of approximately 250 m of lithified loess (eolian silt) with interbedded paleosols, and accumulated in western equatorial Pangea during Late Pennsylvanian-Early Permian time (ca. 300 Ma). Pedologic, geochemical, and magnetic studies of this loess-paleosol sequence indicate that the system behaves much like that of the Chinese Loess Plateau, wherein magnetic susceptibility can be related to pedogenic alteration (cf. Maher and Thompson, 1992), and reflects probable glacial-interglacial fluctuations that operated in western equatorial Pangea (G. Soreghan et al., 1997, 2002). In addition to “icehouse” conditions, however, the paleogeography of late Paleozoic Pangea has led many to suggest extreme seasonality and mega-monsoonal circulation patterns (e.g. Parrish, 1993). M. Soreghan et al. (2002) employed provenance analysis of upper Paleozoic loessite deposits of the western U.S. to document apparent monsoonal circulation in western equatorial Pangea. Accordingly, loess systems of late Paleozoic western Pangea record the influence of both icehouse and monsoonal conditions, analogous to today. In this contribution, we present preliminary data on quartz grain-size trends through loessite-paleosol couplets of the lower Cutler beds, in order to assess their temporal variation, and possible relation to atmospheric circulation (wind strength and variation) in western equatorial Pangea during late Paleozoic time.

Methods

The lower Cutler beds loessite is well lithified, and not easily disaggregated to allow standard grain size analysis. Accordingly, we employed image analysis of backscattered electron (BSE) microprobe images to measure a proxy for grain size. For this study, we chose nine loessite-paleosol couplets, three each from the base, middle and top of the section, in order to examine both short- and long-term trends in relative grain size. We prepared polished microprobe rounds of 54 samples from the nine couplets and acquired several (8-12) BSE images of each sample (Fig. 1a). Each image was then digitally analyzed and filtered in Adobe Photoshop to highlight grain outlines of approximately 800 quartz grains per sample. We focused on quartz alone, owing to its usefulness as a wind strength proxy and its resistance to chemical weathering that may have occurred in both pedogenic and diagenetic environments (cf. Porter and An, 1995; Xiao et al., 1995). In BSE mode in the microprobe, quartz grains can be identified as uniformly gray grains with smooth surfaces and their grain boundaries are distinct. A series of filtering steps, including noise reduction, edge finding, and thresholding were employed to isolate and highlight the quartz grains (Fig. 1b). Although these image filtering and processing steps worked well in general, problems and ambiguities arose in samples containing, for example, minor authigenic silica. Accordingly, it was sometimes necessary to manually eliminate non-quartz grains, or segment grains.

Following image processing, we used the National Institute of Health‘s (NIH) freeware to measure the grain area, perimeter, and major and minor axes of the imaged quartz grains in order to determine the variation in apparent quartz grain sizes among the different samples in a single profile, and among different profiles.

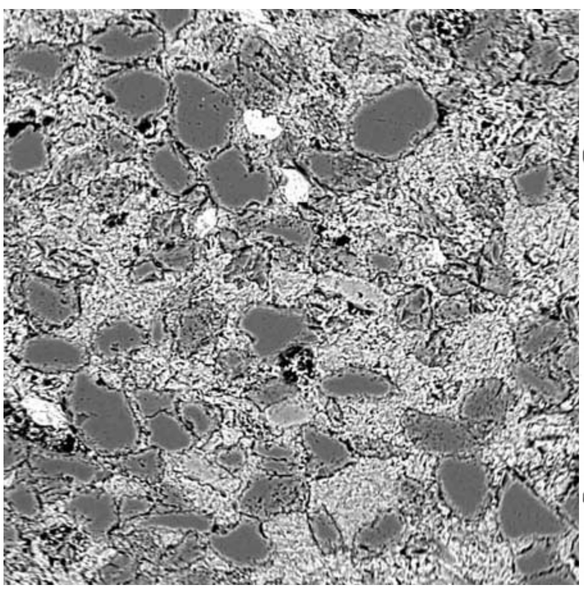

Figure 1a. M195p5 (BSE image) (527x527 μm)

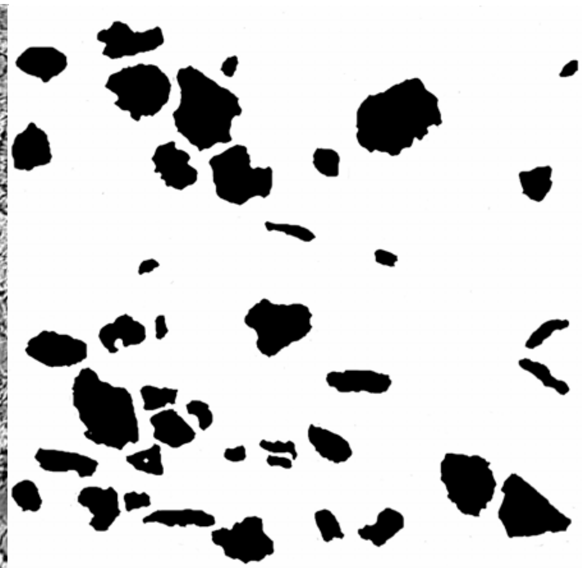

Figure 1b. M195p5 (filtered and cleaned) (527x527 μm)

Results and Discussion

In general, within loess-paleosol couplets, the median grain area of quartz commonly fines from the loess into the paleosol (Fig. 2). We follow Porter and An (1995) and Xiao et al. (1995) in using quartz as a good proxy for wind strength, and thus infer that the general fining-up trend reflects decreasing wind strengths from time of significant loess accumulation (glacials) to times of pedogenesis (interglacials). Further, integration of the apparent quartz grain size data with previously collected data on magnetic susceptibility through the section reveals a strong inverse correlation (r^2 =

0.7885) wherein smaller median grain area values correlate to higher magnetic susceptibility values, similar to results reported by Porter et al (2001) for the Chinese Loess Plateau. Because magnetic susceptibility appears to reflect a primary climate control in this system (G. Soreghan et al., 2002), we infer that this correlation supports our inference of using quartz grain size as a proxy for wind strength in this very ancient system.

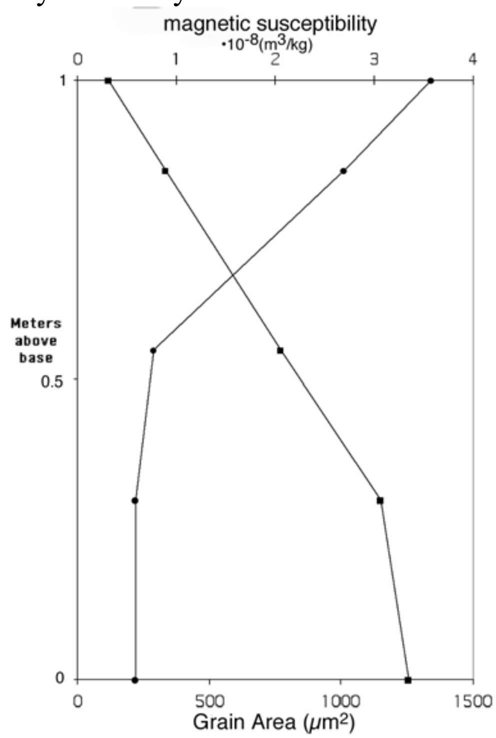

Figure 2 Quartz grain size (grain area = squares) and magnetic susceptibility (circles) versus stratigraphic position. Paleosol is at top of section.

Conclusions

(1) Grain-size analysis on lithified loessite is possible using digital image analysis.

(2) In the upper Paleozoic lower Cutler beds loessite, apparent quartz grain sizes generally decrease upward within a loess-paleosol couplet, which we infer to reflect decreasing wind strengths associated with the transition from glacial to interglacial conditions.

(3) Quartz grain size inversely correlates with magnetic susceptibility, which we infer to suggest a primary climatic control on both parameters.

(4) Our study suggests that techniques applied for paleoclimatic analyses in Plio-Pleistocene loessite may also be applicable to very ancient loess successions.

(5) Loess-Paleosol successions of the late Paleozoic preserve high-frequency climatic cyclicity related to glacial-interglacial fluctuations, analogous to Plio-Pleistocene successions.

Acknowledgments

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