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Geochemical evidence for seasonal controls on the transportation of Holocene loess, Matanuska Valley, southern Alaska, USA

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ABSTRACT

Loess is a widespread Quaternary deposit in Alaska and loess accretion occurs today in some regions, such as the Matanuska Valley. The source of loess in the Matanuska Valley has been debated for more than seven decades, with the Knik River and the Matanuska River, both to the east, being the leading candidates and the Susitna River, to the west, as a less favorable source. We report here new stratigraphic, mineralogic, and geochemical data that test the competing hypotheses of these river sources. Loess thickness data are consistent with previous studies that show that a source or sources lay to the east, which rules out the Susitna River as a source. Knik and Matanuska River silts can be distinguished using Sc–Th–La, La_N/Yb_N vs. Eu/Eu*, Cr/Sc, and As/Sb. Matanuska Valley loess falls clearly within the range of values for these ratios found in Matanuska River silt. Dust storms from the Matanuska River are most common in autumn, when river discharge is at a minimum and silt-rich point bars are exposed, wind speed from the north is beginning to increase after a low-velocity period in summer, snow depth is still minimal, and soil temperatures are still above freezing. Thus, seasonal changes in climate and hydrology emerge as critical factors in the timing of aeolian silt transport in southern Alaska. These findings could be applicable to understanding seasonal controls on Pleistocene loess accretion in Europe, New Zealand, South America, and elsewhere in North America.

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1. Introduction

Loess is extensive over Asia, New Zealand, Europe, South America, North America, and over smaller areas of the Middle East and Africa (see maps in Muhs, 2013a,b). Loess can be one of the most reliable means by which to reconstruct past atmospheric circulation patterns, because the sediment is entrained and transported directly by the wind. Transport paths of aeolian silt, and therefore past wind directions, can be inferred when the source sediments are already known (a rare occurrence) or estimated indirectly when distance-decay functions (downwind trends in loess properties) point to a particular source (see examples in Muhs, 2013a,b). In the midcontinent of North America (Fig. 1a), loess is extensive and glaciogenic sources of loess have long been identified as the major outwash-bearing rivers issuing from Pleistocene ice sheets that once covered the region. Diminishing loess thickness, particle size, and carbonate content can identify sources of loess, as these trends are observed in a downwind direction (Smith, 1942; Ruhe, 1983; Muhs and Bettis, 2000). In Asia, similar trends are recognized on the Loess Plateau of China and document arid regions to the north or northwest as loess sources (Porter et al., 2001; Ding et al., 2005).

Problems can arise with distance-decay functions, however, when multiple candidate sediment sources lie upwind of a loess body. In such situations, use of mineralogical, isotopic, or geochemical signatures can be utilized to distinguish between competing loess and dust sources. For example, Chiapello et al. (1997) differentiated Sahel dust and Saharan dust in Africa on the basis of major element chemistry and clay mineralogy. Chen et al. (2007) used Sr and Nd isotopes to identify the most likely arid basins that are sources of loess in China. Aleinikoff et al. (2008) used Pb isotopes in K-feldspars and U-Pb ages of detrital zircons to distinguish loess sources in the Great Plains region of North America. Muhs and Budahn (2006) distinguished different fluvial sources of loess for central Alaska using a suite of relatively immobile trace elements, including the rare earth elements.

Study of modern or recent glaciogenic dust and loess deposits is important because such sediments are the closest analogs for many of the glaciogenic Pleistocene loess bodies around the world (Arnalds, 2010; Bullard, 2012; Prospero et al., 2012). Loess is extensive over much of Alaska (Fig. 1b) and much of it

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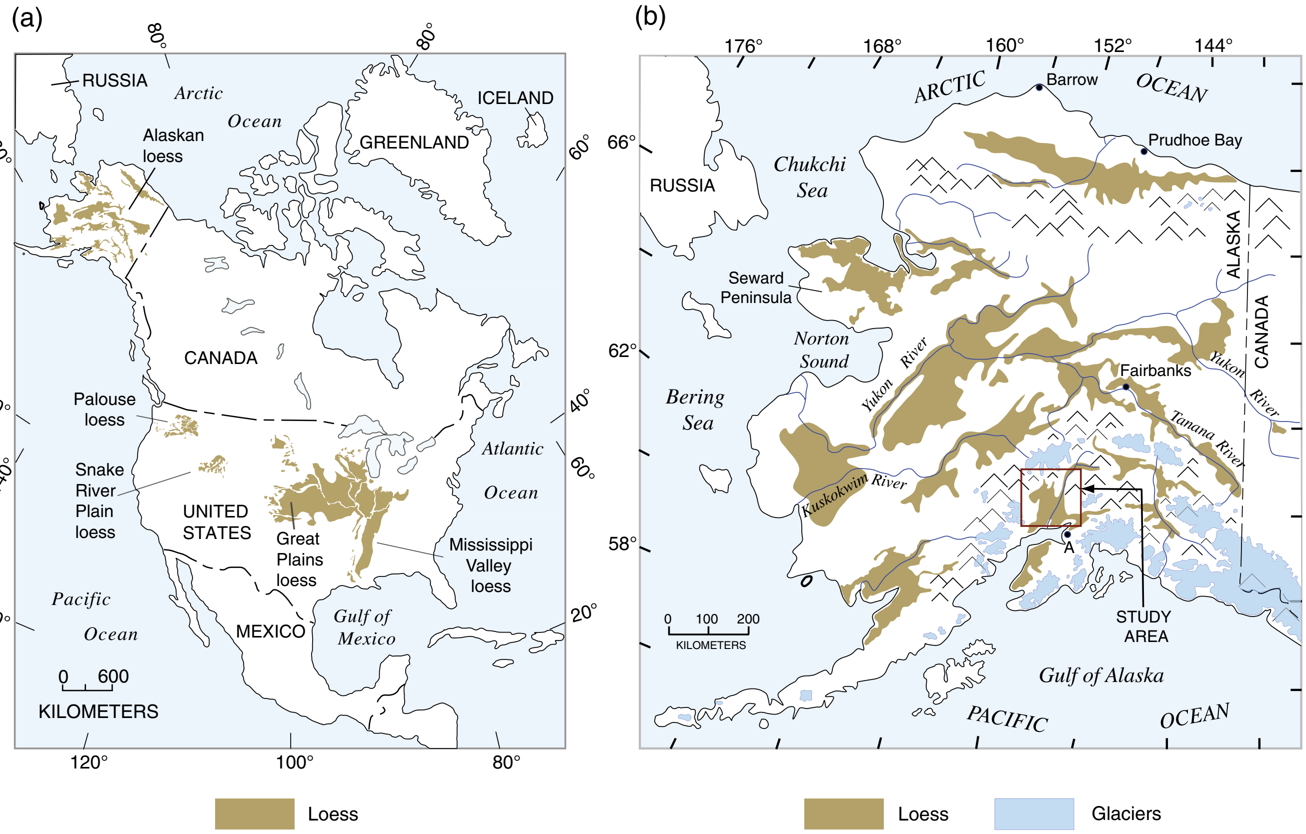

Fig. 1. (a) Map showing the distribution of loess (brown) in North America, from Bettis et al. (2003) and sources therein; (b) Map showing the distribution of loess deposits (brown) in Alaska, compiled from Hopkins (1963) and Sainsbury (1972) for the Seward Peninsula and Péwé (1975) for all other parts of the region. Most mapping from these sources has been field checked by the authors. Also shown is the present extent of glaciers (blue) in the region, taken from Péwé (1975) and Brown et al. (1997). Red box in (b) outlines Matanuska Valley study area; A, Anchorage. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

accumulated during the Pleistocene (see reviews in Péwé, 1975; Muhs et al., 2003). Nevertheless, aeolian silt entrainment, transportation and deposition continue today because of extant glaciers (Fig. 1b) and abundant production of glaciogenic silt. Holocene loess accumulation has been observed at numerous locations within central and southern Alaska (Péwé, 1975; Muhs et al., 2003, 2004, 2013; Crusius et al., 2011).

The Matanuska Valley of southern Alaska is a good example of an area where there is documentation of historical and Holocene glaciogenic loess (Figs. 1b, 2, and 3). Radiocarbon ages reported by Muhs et al. (2004) indicate that deposition has been ongoing for the past ~7500 cal yr BP (calibrated years before present) and continues to the present day. Nevertheless, identification of the dominant source of loess in the Matanuska Valley has been controversial for more than half a century. Tuck (1938) thought that the loess in this area was derived primarily from the Knik River, whereas Black (1951) considered that various rivers in the area were likely sources. Stump et al. (1956) noted the physical similarities of silts in the Matanuska Valley to those of loess in Iowa, but did not specifically identify the Matanuska Valley silts as loess. Indeed, later Stump et al. (1959) questioned the aeolian origin of the silts in the Matanuska Valley. These investigators acknowledged the observations of modern dust storms from both the Matanuska and Knik Rivers and considered that an aeolian origin was possible, but left open the possibility that silts in the Matanuska Valley could be lacustrine. Rieger and Juve (1961), studying soils in the region, accepted Tuck's (1938) proposition that the Matanuska Valley silts are loess. These workers thought that the Knik River was the most important source at present, but offered the proposition that the Matanuska River was a more important source in the past. Trainer (1961) also considered that the silts of the region were indeed loess deposits and felt that both the Knik and Matanuska Rivers were sources. Schoephorster (1968) noted that both the Matanuska and Knik Rivers generate large dust storms at present (see his Fig. 2) and implied that these were both sources, but also pointed out that in the western part of the region, the Susitna River and its tributaries could be loess sources. Reger and Updike (1983) and Clark and Kautz (1998) also proposed that both the Knik and Matanuska Rivers were loess sources and noted that modern dust storms can be seen on the floodplains of both rivers (see Fig. 120 of Reger and Updike (1983) and Plate 1 of Clark and Kautz (1998)). Reger and Updike (1983), however, inferred from the loess thickness trends (Fig. 3) that the Matanuska River was the main source of loess immediately west of that river.

In this study, we report new stratigraphic, mineralogical, and geochemical data that provide a test of the various hypotheses that have been proposed about which river sources are the most important for the origin of Matanuska Valley loess. Our approach is similar to that used in determining the origin of Holocene loess in southeastern Alaska (Muhs et al., 2013) and Pleistocene loess of central Alaska (Muhs and Budahn, 2006). Understanding which river system provides the bulk of the loess to the Matanuska Valley is critical not only for determination of past wind direction but also for identifying the seasonality of aeolian silt transport. If loess in the region is derived from the Matanuska River, northern or northeastern winds are required. For the Knik River as a source of loess, southeast winds are required. Winds from both these directions occur in the region at the present, but at different times of the year. The Susitna River valley lies wholly to the west of the Matanuska Valley region (Fig. 2). Westerly winds are uncommon in this area