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Geochemistry and mineralogy of late Quaternary loess in the upper Mississippi River valley, USA: Provenance and correlation with Laurentide Ice Sheet history

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ABSTRACT

The midcontinent of North America contains some of the thickest and most extensive last-glacial loess deposits in the world, known as Peoria Loess. Peoria Loess of the upper Mississippi River valley region is thought to have had temporally varying glaciogenic sources resulting from inputs of sediment to the Mississippi River from different lobes of the Laurentide Ice Sheet. Here, we explore a new method of determining loess provenance using K/Rb and K/Ba values (in K-feldspars and micas) in loess from a number of different regions in North America. Results indicate that K/Rb and K/Ba values can distinguish loess originating from diverse geologic terrains in North America. Further, different loess bodies that are known to have had the same source sediments (using other criteria) have similar K/Rb and K/Ba values. We also studied three thick loess sections in the upper Mississippi River valley region. At each site, the primary composition of the loess changed over the course of the last glacial period, and K/Rb and K/Ba values parallel changes in carbonate mineral content and clay mineralogy. We thus confirm conclusions of earlier investigators that loess composition changed as a result of the shifting dominance of different lobes of the Laurentide Ice Sheet and the changing course of the Mississippi River. We conclude that K/Rb and K/Ba values are effective, robust, and rapid indicators of loess provenance that can be applied to many regions of the world.

1. Introduction

Similar to the famous loess deposits of China (Liu, 1988; Liu and Ding, 1998; Sun, 2002), some of the most extensive deposits of last-glacial-age loess on the planet are found in the mid-continental region of North America (Fig. 1). This loess is typically referred to as “Peoria Loess” or “Peoria Silt,” based on the thick deposits found near Peoria, Illinois (Smith, 1942; Willman and Frye, 1970; Hansel and Johnson, 1996). Peoria Loess deposits in mid-continental North America are derived from a wide variety of sources. In the Great Plains region west of the Missouri River (Fig. 2), loess is derived from both glacial and non-glacial sources (Aleinikoff et al., 1999, 2008; Muhs et al., 1999, 2008a; Yang et al., 2017). Farther east, however, near the southern terminus of the Laurentide Ice Sheet in the greater Mississippi River drainage basin (Fig. 2), a classical glacial model for the origin of loess has been established for more than a century (Chamberlin, 1897). This model proposes that loess accumulated as a result of the eolian transport of silt from valley-train outwash that, in turn, was derived from the till of the Laurentide Ice Sheet. Outwash from this ice sheet filled the valleys of the Mississippi River and its tributaries, the Missouri River, Illinois River, Wabash River, and Ohio River, during the most recent glacial periods. The model of glacial outwash as the major supplier of loess in the greater Mississippi River drainage basin withstood the test of time for many decades (see reviews in Ruhe [1983]; Bettis et al., [2003]; and Muhs [2013]), although non-glacial sources may have been a secondary sediment contributor (Frye et al., 1962; Ruhe and Olson, 1980; Grimley, 2000).

Since Chamberlin's time, however, a number of studies have demonstrated that Peoria Loess has a compositional variability in sections thick enough to record the entire last glacial period in detail. Thick Peoria Loess in Illinois (Figs. 2 and 3) has a number of compositional zones that can be differentiated on the basis of clay mineralogy (Frye et al., 1968), carbonate mineral content (McKay,

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Fig. 1. Map of North America and adjacent islands showing the distribution of loess and the extent of ice sheets during the last glacial period. Loess distribution in Alaska is from Péwé (1975); loess adjacent to the Snake River Plain is from Lewis and Fosberg (1982); Palouse loess distribution is from Busacca and McDonald (1994). Loess in other regions is from sources given in Fig. 2; ice sheet extent is from Dyke et al. (2002). Note also that loess is found in some areas northward of the maximum southern extent of the Laurentide Ice Sheet and appear as dark brown delineations. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

1977, 1979a; 1979b), magnetic mineral content (Grimley et al., 1998), and silicate mineral content (Grimley, 2000). These differing compositions have been interpreted as the result of delivery of temporally varying proportions of glaciogenic silt ultimately derived from different lobes of the Laurentide Ice Sheet. Different ice lobes traversed terrains with distinct bedrock compositions. Adding to this complex picture, it is necessary to consider the changes in the drainage systems that were affected by movements of the Laurentide Ice Sheet. Perhaps the most dramatic example of this was the diversion of the Mississippi River at ~24.4 ka (in calibrated years; note that all radiocarbon ages throughout the text are in calibrated years unless otherwise noted) that resulted from the advance of the Lake Michigan Lobe (Figs. 2 and 3) of this ice sheet (Shaffer, 1954; Frye et al., 1962, 1968; Glass et al.,