



Optical ages on loess derived from outwash surfaces constrain the advance of the Laurentide Ice Sheet out of the Lake Superior Basin, USA



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ARTICLE INFO

Article history:

Received 14 May 2013

Available online 15 January 2014

Keywords:

Wisconsin

Loess

Chippewa River

Outwash surfaces

MAR OSL

Luminescence dating

ABSTRACT

We present textural and thickness data on loess from 125 upland sites in west-central Wisconsin, which confirm that most of this loess was derived from the sandy outwash surfaces of the Chippewa River and its tributaries, which drained the Chippewa Lobe of the Laurentide front during the Wisconsin glaciation (MIS 2). On bedrock uplands southeast of the widest outwash surfaces in the Chippewa River valley, this loess attains thicknesses >5 m. OSL ages on this loess constrain the advance of the Laurentide ice from the Lake Superior basin and into west-central Wisconsin, at which time its meltwater started flowing down the Chippewa drainage. The oldest MAR OSL age, 23.8 ka, from basal loess on bedrock, agrees with the established, but otherwise weakly constrained, regional glacial chronology. Basal ages from four other sites range from 13.2 to 18.5 ka, pointing to the likelihood that these sites remained geomorphically unstable and did not accumulate loess until considerably later in the loess depositional interval. Other OSL ages from this loess, taken higher in the stratigraphic column but below the depth of pedoturbation, range to nearly 13 ka, suggesting that the Chippewa River valley may have remained a loess source for several millennia.

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Introduction

Loess deposits help constrain the timing of the geomorphic events that led to their formation (Roberts et al., 2003; Sweeney et al., 2007), particularly the paleoclimatic conditions that promoted their production (Muhs and Bettis, 2000; Muhs et al., 2008). Optical dating is now well established as viable means of establishing the age of loess deposits worldwide (Forman et al., 1992; Singhvi et al., 2001; Forman and Pierson, 2002; Bettis et al., 2003; Roberts et al., 2003; Timar-Gabor et al., 2011; Brown and Forman, 2012). A key advance that has recently emerged, however, is the ability to link loess deposits to small- and regional-scale glacial deposits and events, e.g., active outwash plains, thawing end moraines, or recently drained proglacial lakes (Schaetzl and Loope, 2008; Stanley and Schaetzl, 2011; Luehmann et al., 2013; Schaetzl and Attig, 2013).

In this context, successful dating of loess can help constrain the timing of the related glacial activity, and the goal of our study is to provide one of the first examples of just such an application: the timing of the advance of the Laurentide Ice Sheet in Wisconsin. Considerable debate exists as to the dynamics and synchronicity of the late Wisconsin (MIS 2) ice margin in the central United States (Attig et al., 1985;

Eschman and Mickelson, 1986; Carson et al., 2012; Kehew et al., 2012). For example, the Des Moines Lobe advanced several millennia later than many other Midwestern ice lobes (Patterson, 1997). This example stands in contrast with the Saginaw Lobe in Michigan, which stagnated early, allowing its ice and debris to be overridden by bounding lobes (Kehew et al., 2005, 2012). In Wisconsin, this debate is particularly difficult to resolve, because several major ice lobes flowed into the region, each with a unique history, bed topography and bed conditions. These circumstances dramatically affected flow rates and directions, as well as stagnation and possible streaming (Mickelson et al., 1983; Clayton et al., 1985; Attig et al., 1989; Clark, 1992; Lundqvist et al., 1993; Colgan and Mickelson, 1997; Patterson, 1998; Cutler et al., 2001; Bauder et al., 2005; Syverson and Colgan, 2011).

Unfortunately, because of widespread permafrost near the last glacial maximum (LGM) ice margin in Wisconsin, and consequently the lack of forests and buried wood, carbon-rich materials for ¹⁴C dating are difficult to obtain in the glacial deposits (Holmes and Syverson, 1997). Thus, ice margin dynamics and chronology within the upper Midwest USA are generally poorly constrained (Clayton et al., 2001), with a few exceptions, and these generally occur later in the deglacial sequence (Blewett et al., 1993; Kaiser, 1994; Larson et al., 1994). Fortunately, other geochronometric dating methods have the potential to constrain the timing of the ice advances in the Midwest (Colgan et al., 2002; Schaetzl and Forman, 2008; Attig et al., 2011b; Ullman et al.,

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2011; Carson et al., 2012). Many of these methods are now being applied to inform the debate on the apparent asynchronicity of some of the major Midwestern ice lobes.

Our research goal was to better constrain the timing of the advance of the Chippewa Lobe in west-central Wisconsin (Fig. 1), through luminescence dating of eolian deposits (loess) that were likely derived from its outwash. Meltwater from the Chippewa Lobe of the Laurentide Ice Sheet flowed through the study area, to the Mississippi River, beginning when the ice advanced into the Chippewa River basin and continuing until it had receded back into the Lake Superior basin. During this interval, including when the ice was at its maximum extent, we hypothesize that silt was being deflated from the broad, sandy, outwash deposits, i.e., valley train, of the Chippewa River and its tributaries. Preliminary fieldwork confirmed that thick loess occurs on most uplands near this meltwater system. We dated the basal loess from five such sites using luminescence techniques, with the goal of using these ages to constrain the advance of the ice, southward into the Chippewa drainage basin, and thus provide minimum-limiting ages for advance of the ice into the basin. Although absolute ages on this terminal moraine are emerging for sites in southern Wisconsin (Attig et al., 2011b; Ullman et al., 2011; Carson et al., 2012), our data provide the first age control for the ice in western and west-central Wisconsin, and for the Chippewa Lobe in particular.

Study area

Quaternary history

In Wisconsin, the Chippewa River and its tributaries (Figs. 1, 2) were one of the major meltwater systems draining the southern margin of the Laurentide Ice Sheet. This system began functioning as meltwater

drainageways when the southern margin of the ice sheet crossed the drainage divide marking the southern margin of the Superior basin, and flowed into the northern part of the Chippewa River drainage. The Chippewa River system carried meltwater throughout the advance of the Chippewa Lobe to its maximum extent, ceasing only when the Chippewa Valley Lobe again receded north of the divide. Although the glacial geomorphology of this landscape is reasonably well understood (Syverson, 2007; Syverson and Colgan, 2011), the local glacial chronology is poorly constrained (Clayton and Moran, 1982; Mickelson et al., 1983; Attig et al., 1985, 2011a) because of the lack of closely controlling radiocarbon dates. Regional correlations indicate that the southern margin of the Laurentide Ice Sheet probably advanced southward out of the Superior basin by about 30,000 years ago, reached its maximum extent in the Chippewa River lowland prior to about 22,000 years ago, and that its margin had receded back into the Lake Superior basin by about 17,000 years ago. Dates that could substantiate or refine this general chronology are lacking.

Loess deposits are widespread, although not continuous, throughout Wisconsin (Scully and Schaetzl, 2011). Loess on the uplands near the Mississippi River valley is thick and was likely derived from the valley, while it functioned as a major meltwater drainageway (Leigh and Knox, 1993; Bettis et al., 2003). Loess deposits far from this valley are thinner and spatially disjunct (Scully and Schaetzl, 2011), suggesting that they were derived not from the Mississippi River valley proper, but from other, often more localized, source areas. For example, Stanley and Schaetzl (2011) concluded that the late Wisconsin moraine in central Wisconsin, with its abundant ice-walled lake plains, was a major loess source for the thin loess deposits to its immediate south. Schaetzl and Attig (2013) were able to link the loess deposits covering the drumlins of northeastern Wisconsin to outwash plains on either side of the drumlin field. Luehmann et al. (2013) took this type of

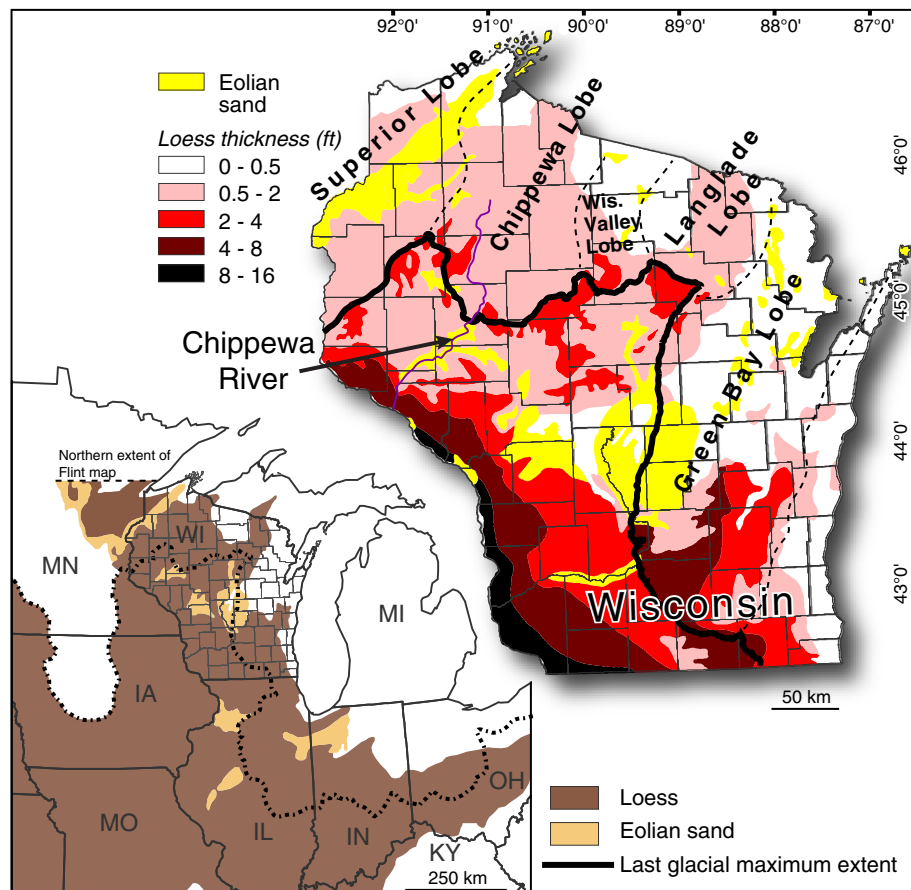


Figure 1. Distribution of loess in the Midwest and in Wisconsin, based on Hole (1950) and Flint (1971), both of which were from a small-scale map by Thorp and Smith (1952).

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