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Numeric control on the late-glacial chronology of the southern Laurentide Ice Sheet derived from ice-proximal lacustrine deposits

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ABSTRACT

We used a combination of radiocarbon and OSL dating in ice-proximal lacustrine silt and clay and outwash sand to estimate when ice of the Green Bay Lobe of the Laurentide Ice Sheet began retreating from its maximum position in south-central Wisconsin. The radiocarbon ages indicate that lakes had formed in the two tributary valleys by ~17.2 and 20.1 ka, respectively. The OSL ages indicate that the Green Bay Lobe was at its maximum position from about 26.4 ± 5.1 ka to 21.4 ± 3.3 ka. These data provide entirely new chronologic control on late Wisconsin (Marine Isotope Stage 2) glacial event in the upper Midwest, as well as the opportunity to directly compare radiocarbon and OSL ages in this setting.

Introduction

Establishing a detailed chronologic record of ice margin fluctuations for the southern margin of the Laurentide Ice Sheet has historically proven to be an elusive goal. Despite concentrated efforts over the past several decades, no well-constrained numerical chronology exists for fluctuations of lobes of the Laurentide Ice Sheet during the middle and late Wisconsin (see Mickelson et al., 1983; Attig et al., 1985). Much of our understanding of the Midwest glacial record rests on studies of key stratigraphic sections and sites (e.g., Maher, 1982; Leigh and Knox, 1994; Maher and Mickelson, 1996; Lowell et al., 1999). While understanding the stratigraphy, sedimentology, and chronology at a specific site is valuable, it fails to provide the broader insight provided by a regional perspective. The numerical data that form our regional understanding of the glacial chronology in the midcontinent relies primarily on a relatively small number of radiocarbon and, more recently, cosmogenic exposure dates (e.g., Colgan et al., 2002; Ullman et al., 2011).

The struggles to develop a radiocarbon-based chronology for the southern Laurentide Ice Sheet have been driven by several factors. Permafrost conditions existed in Wisconsin and elsewhere in the midcontinent during and following the late Wisconsin maximum based on the presence of ice-wedge casts, ice-wedge polygons, and other permafrost-related features that are preserved in sediments deposited during the late Wisconsin maximum (Clayton et al., 2001). The existence of permafrost likely plays a critical role in the absence of closely limiting radiocarbon ages in the midcontinent during the critical time period of 32 to 16 ka (Syverson and Colgan, 2011). The radiocarbon dates that do exist from glacial environments are often difficult to interpret and correlate with discrete events. Glacial sediments and landforms can be unstable for a significant time following deposition, directly limiting the ability to relate the age of organic growth relative to glacial events (e.g., Lowell, 1995; Grimm et al., 2009). For example, basal dates from kettles reflect the timing of stagnant blocks melting to form the kettles rather than retreat of the ice sheet; a lag of centuries to millennia can occur between the glacial retreat and kettle formation (Porter and Carson, 1971; Mickelson and Borns, 1972). Radiocarbon data can limit the timing of glacial advances and retreats but rarely constrain an ice margin in place and time. The Two Creeks forest bed in east-central Wisconsin is such an example (Broecker and Farrand, 1963; Hooyer, 2007). The numerous dates from this site document the timing of ice retreat that allowed the spruce forest to grow and the timing of ice advance that overran the forest, but the dates provide no insight into the ice margin position at the ends of the retreat and advance.

Due to the pervasive lack of easily interpretable organic material dating to the late Wisconsin maximum, alternative dating methods have been employed, including OSL dating. Over the past several decades, OSL dating has been successfully applied to a range of geomorphic settings (see Rittenour, 2008; Wintle, 2008). In recent years, OSL dating has been applied in a number of settings in the upper Midwest in an attempt to refine the chronology of late glacial events by directly dating sediment from ice-marginal lakes (e.g., Hooyer, 2007; Lepper et al., 2007; Fisher et al., 2008). However, these studies were conducted in large lakes with complex histories where lake levels may not be easily associated with moraine positions, and may have been hampered

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by problems with the use of OSL in lacustrine settings that include partial bleaching (Fuchs and Owen, 2008), low luminescence signals in quartz grains (Lukas et al., 2007), and uncertainties in estimating environmental dose-rate values.

Recently, Attig et al. (2011) applied OSL dating to lacustrine sediments deposited in small ice-dammed lakes high in the Baraboo Hills in south-central Wisconsin. The lakes' landscape positions clearly show that they drained as soon as ice began to retreat from its maximum position; OSL ages indicate that this occurred at ~18.5 ka. These promising results suggest that OSL can be applied to ice-proximal lacustrine sediments for constraining the local glacial history; however, the lakes from this study did not contain datable carbon and therefore the OSL age estimates are not supported by ages obtained using other dating methods.

In the Baraboo Hills and lower Wisconsin River valley, many small ice-proximal lakes existed. Regional geologic studies (Clayton and Attig, 1989, 1990, 1997) indicate that these lakes' histories can be confidently correlated to discrete events of the Green Bay Lobe. Initial coring at two sites, Marsh Valley and Swamplovers Valley (Fig. 1), has suggested a direct relationship between the lakes' histories and the Green Bay Lobe's late Wisconsin advance and retreat, and has also revealed a unexpected wealth of organic matter to provide radiocarbon control from the end of the late Wisconsin maximum (Carson et al., 2011). These data represent new numeric control on the onset of retreat from the late Wisconsin maximum. They also provide the opportunity to directly compare radiocarbon and OSL age estimates derived from ice-proximal lake sediments. In this paper, we describe the evolving methodology and application of OSL dating in ice-proximal lacustrine settings combined with radiocarbon control to both evaluate the utility of OSL dating in this environment and to provide new, precise numeric control on the timing of the late Wisconsin maximum for the Green Bay Lobe.

Setting

The juxtaposition of the well-integrated drainage system of in the Driftless Area of southwestern Wisconsin, the resistant quartzite uplands of the Baraboo Hills, and the late Wisconsin ice margin create a setting where many ice-proximal lakes formed in a variety of distinct geomorphic settings at different times relative to glacial advances and retreats (Fig. 1). Several moraines are found in close proximity to the Wisconsin ice margin: the Johnstown moraine (late Wisconsin maximum) and the Elderon and Milton moraines (recessional moraines post-dating the Johnstown moraine). Previous 1:100,000-scale geomorphic mapping and other research (see Clayton and Attig, 1989, 1990, 1997) has identified former ice- and outwash-dammed lakes that existed at various times and can be correlated to the different ice margin positions.

Two tributary valleys, Marsh Valley and an unnamed tributary informally referred to here as Swamplovers Valley, are located in a precise landscape position such that Johnstown-age ice advanced only roughly 2 to 3 km into their headwaters at the time of maximum ice extent. Outwash prograded down these valleys only when ice was at its maximum position; prior to and following the late Wisconsin maximum, lakes existed in these tributaries (Fig. 2). Radiocarbon and OSL dates from near the base and top of the outwash in the tributary valleys can therefore be interpreted to reflect the timing of advance to, and retreat from, the Johnstown position.

Methods

Field

Coring at Marsh Valley and Swamplovers Valley was conducted with Geoprobe direct-push coring which collected 5-cm diameter cores. At both sites, Geoprobe cores retrieved samples entirely through the

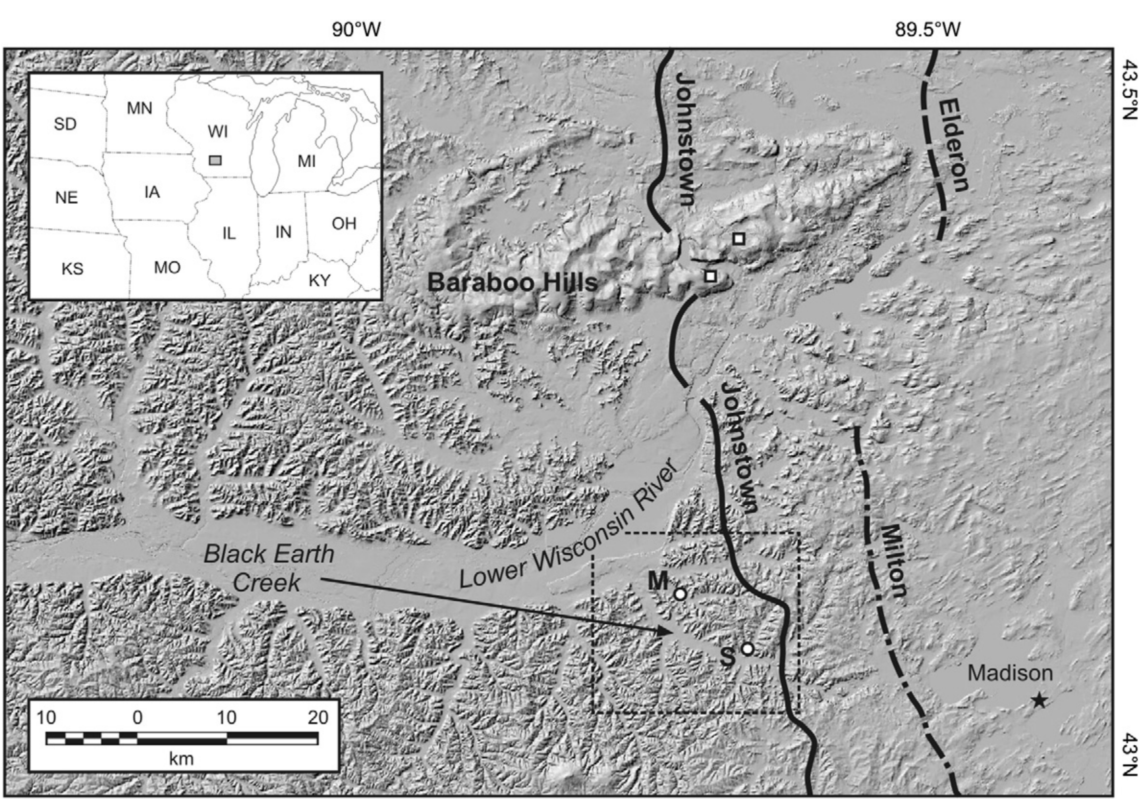

Figure 1. Topography of south-central Wisconsin showing Baraboo Hills and lower Wisconsin River valley in relation to Johnstown, Milton, and Elderon moraines. White circles identify locations of Swamplovers Valley ('S') and Marsh Valley ('M') coring sites; white squares identify study sites of Attig et al. (2011). Inset map shows location of study area as gray box. Area of Fig. 2 identified by dashed box.