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Radiocarbon dating loess deposits in the Mississippi Valley using terrestrial gastropod shells (Polygyridae, Helicinidae, and Discidae)

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ABSTRACT

Small terrestrial gastropod shells (mainly Succineidae) have been used successfully to date late Quaternary loess deposits in Alaska and the Great Plains. However, Succineidae shells are less common in loess deposits in the Mississippi Valley compared to those of the Polygyridae, Helicinidae, and Discidae families. In this study, we conducted several tests to determine whether shells of these gastropods could provide reliable ages for loess deposits in the Mississippi Valley. Our results show that most of the taxa that we investigated incorporate small amounts (1–5%) of old carbon from limestone in their shells, meaning that they should yield ages that are accurate to within a few hundred years. In contrast, shells of the genus *Mesodon* (*Mesodon elevatus* and *Mesodon zaletus*) contain significant and variable amounts of old carbon, yielding ages that are up to a couple thousand ^{14}C years too old. Although terrestrial gastropod shells have tremendous potential for ^{14}C dating loess deposits throughout North America, we acknowledge that accuracy to within a few hundred years may not be sufficient for those interested in developing high-resolution loess chronologies. Even with this limitation, however, ^{14}C dating of terrestrial gastropod shells present in Mississippi Valley loess deposits may prove useful for researchers interested in processes that took place over multi-millennial timescales or in differentiating stratigraphic units that have significantly different ages but similar physical and geochemical properties. The results presented here may also be useful to researchers studying loess deposits outside North America that contain similar gastropod taxa.

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1. Introduction

Late Quaternary loess deposits blanket much of the upland areas immediately adjacent to the Mississippi Valley in Wisconsin, Iowa, Illinois, Missouri, Kentucky, Tennessee, Arkansas, Mississippi, and Louisiana (Fig. 1). The stratigraphy, age, and origin of these deposits have been the focus of studies for more than a century (Hilgard, 1879; Call, 1891; Mabry, 1898). One of the more challenging aspects of studying loess in the region has been to establish robust chronologies for the deposits. Charcoal and plant macrofossils are ideal for radiocarbon (^{14}C) dating, but are found in loess only occasionally, and rarely at multiple stratigraphic levels at a given site. Thus, researchers often must turn to less desirable materials for dating. Humic acids in soils developed in loess have been dated by ^{14}C at many localities in North America (e.g., Berg et al., 1985; Muhs et al., 1999; Mandel and Bettis, 2001; Muhs and Zárate, 2001; Bettis et al., 2003), but are limited to organic-rich strata and date the buildup of organic matter over time, rather than the act of loess deposition itself. Moreover, ^{14}C dates on bulk organic matter in loess represent some (unknown) duration of time that elapsed between loess deposition and when the organic material became concentrated enough to be targeted for dating. In most cases, the exact geochemical nature and origin of the carbon dated in bulk sediment samples are unknown, which further clouds interpretation of the resulting ages. Other chronometric techniques, including luminescence and amino-acid racemization (AAR), have been used previously to date loess deposits in the Mississippi Valley (Pye and Johnson, 1988; Clark et al., 1989; Forman et al., 1992; Rodbell et al., 1997; Markewich et al., 1998; Forman and Pierson, 2002). However, these techniques yield ages that are not as precise as ^{14}C ages, are relatively expensive and time consuming, and require assumptions regarding physical conditions (moisture content for luminescence) or climate parameters (variability in past temperatures for AAR) that cannot be known *a priori*.

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Radiocarbon dating of terrestrial gastropod shells may provide a viable alternative to these techniques for researchers interested in constraining the age and mass accumulation rates of loess deposits in the Mississippi Valley. Recent work has shown that the shells of some gastropod families yield reliable ^{14}C ages for the late Pleistocene, regardless of the depositional context, local lithology, or climatic regime (Pigati et al., 2010). Many of the taxa that have been evaluated thus far are annuals or live only a few years, spending most of their time scavenging for food at or near the ground surface (Barker, 2001). The stratigraphic position of gastropod shells, therefore, should be temporally equivalent to the sediment deposited when the gastropods were alive, provided they did not burrow deeply below ground and die. Thus, if the shells yield reliable ^{14}C ages and assuming they are not reworked, they can be used to determine the timing of loess deposition fairly accurately.

Members of the Succineidae family (genera: *Catinella*, *Oxyloma*, and *Succinea*) have proven especially reliable for ^{14}C dating, yielding ages that are identical to wood, plant macrofossil, and luminescence ages in Holocene and late Pleistocene loess, wetland, and glacial deposits throughout North America (Pigati et al., 2010, 2013). However, although Succineidae shells are common in the Quaternary loess deposits of Alaska and the Great Plains, they are not as prevalent in loess that is proximal to the lower Mississippi Valley. In this area, terrestrial gastropods within the Polygyridae, Helicinidae, and Discidae families are fairly common in loess deposits and potentially could be targeted for dating purposes. It is likely that these taxa have been dated previously at loess sites in the Mississippi Valley (e.g., Snowden and Priddy, 1968; Pye and Johnson, 1988; McCraw and Autin, 1989; Markewich, 1993; Oches et al., 1996; Grimley et al., 1998), but most of these studies do not include specific taxonomic information and potential errors associated with the "limestone problem" are usually ignored.

The limestone problem (or limestone effect) refers to the fact that terrestrial gastropods often consume limestone or other carbonate rocks and incorporate the old (^{14}C-dead) carbon when building their shells (Goodfriend and Stipp, 1983). The amount of dead carbon in a particular shell can be highly variable, ranging from negligible to ~30% of the total, which would cause the ages to be up to ~3000 ^{14}C years too old (Goodfriend and Stipp, 1983; Pigati et al., 2004, 2010; Rakovan et al., 2010). Thus, ^{14}C ages derived from unidentified or mixed assemblages of gastropod shells, as has been the case in most Mississippi Valley loess studies, should be viewed with caution because of potential contamination issues stemming from the presence of carbonate sediments in the

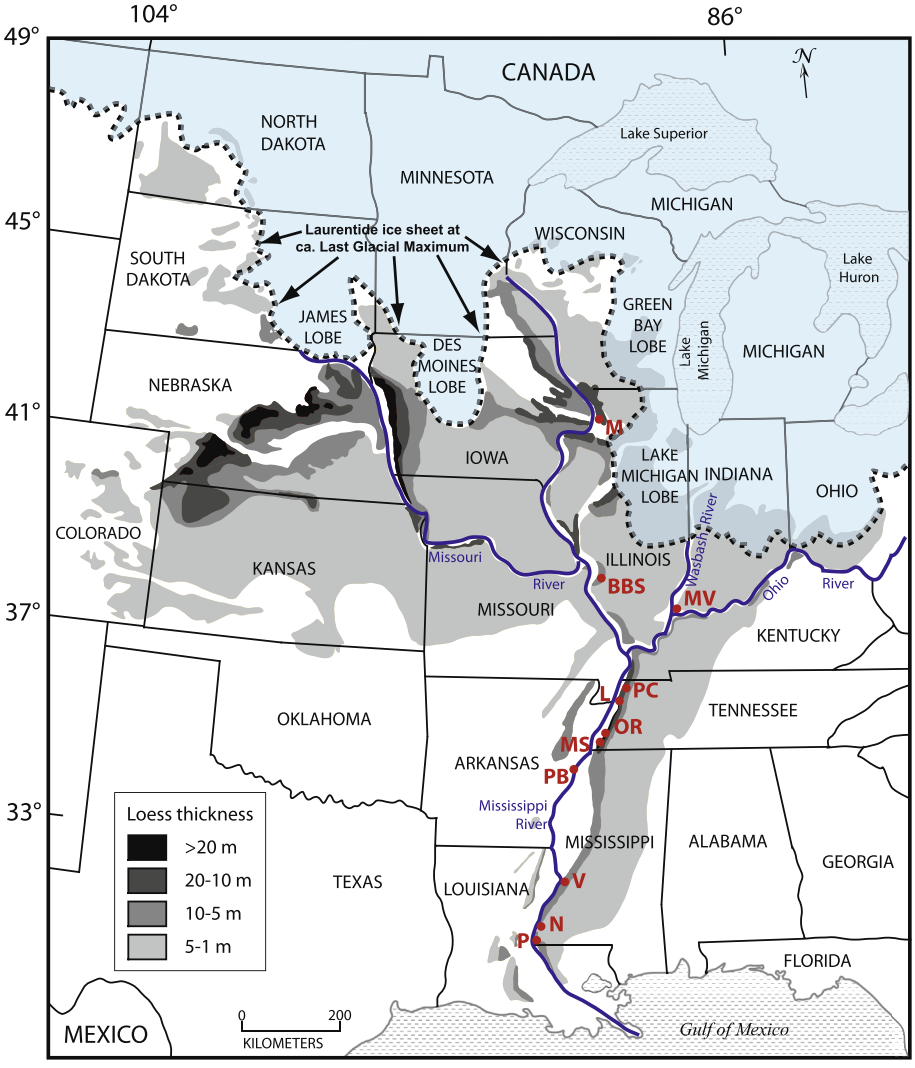

Fig. 1. Distribution and thickness of loess in the midcontinent of North America showing the maximum extent of the Laurentide ice sheet during the Last Glacial Maximum and our study sites in the Mississippi Valley (after Bettis et al., 2003, and references therein). Site abbreviations: M = Morrison, IL; BBS = Burdick Branch Section, IL; MV = Mount Vernon, IN; PC = Paw Paw Creek, TN; L = Lenox, TN; OR = Old River Section, TN; MS = Meeman-Shelby Forest State Park, TN; PB = Phillips Bayou, AR; V = Vicksburg, MS; N = Natchez, MS; and P = Pond, MS.