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A new depositional model for sand-rich loess on the Buckley Flats outwash plain, northwestern Lower Michigan

Kelsey E. Nyland [a], Randall J. Schaetzl [a,*], Anthony Ignatov [a], Bradley A. Miller [b,c]

[a] Department of Geography, Environment, and Spatial Sciences, 673 Auditorium Rd., Michigan State University, East Lansing, MI 48824-1117, United States
[b] Department of Agronomy, Iowa State University, Ames, IA 50011, United States
[c] Leibniz-Centre for Agricultural Landscape Research (ZALF) e.V., Institute of Soil Landscape Research, 15374 Müncheberg, Germany

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ABSTRACT

Loess was first studied in Michigan on the Buckley Flats, where outwash, overlain by ≈70 cm of loamy sediment, was originally interpreted as loess mixed with underlying sands. This paper re-evaluates this landscape through a spatial analysis of data from auger samples and soil pits. To better estimate the loamy sediment's initial textures, we utilized "filtered" laser diffraction data, which remove much of the coarser sand data. Textures of filtered silt data for the loamy sediment are similar to loess. The siltiest soils are found in the low-relief, central part of the Flats. Spatial analyses revealed that many silt fractions are nearly uniformly distributed, suggesting that the loess was not derived from a single source. The previous depositional model for the loamy mantle relied on loessfall followed by pedoturbation, but does not explain (1) the variation in sand contents across the Flats, or (2) the abrupt contact below the loamy mantle. This contact suggests that the outwash was frozen when the sediments above were deposited. Deep gullies at the western margins of the Flats were likely cut as permafrost facilitated runoff. Our new model for the origin of the loamy mantle suggests that the sands on the uplands were generated from eroding gullies and saltated onto the uplands along with loess that fell more widely. Sands saltating to the west of the Flats may have entrained some silts, facilitating loessfall downwind. At most sites, the loamy mantle gets increasingly silty near the surface, suggesting that saltation ended before loess deposition.

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1. Introduction

Loess is a silt-dominated sediment, deposited by aeolian processes. In the humid, glaciated areas of North America and Europe, loess is often derived from proglacial outwash or valley-train deposits (Grimley, 2000; Frechen et al., 2003; Haase et al., 2007; Buggle et al., 2008; Muhs, 2013; Schaetzl et al., 2014). Some of the thickest and most extensive loess deposits in North America were derived from large outwash valleys that were active for long periods of time, e.g., the Mississippi, Missouri, Illinois and Wabash Rivers (Bettis et al., 2003). Such deposits have been highly useful for determining paleowind direction and strength. However, recent studies have documented and focused on smaller, thinner, and sometimes spatially discontinuous, loess deposits, which may provide important paleoenvironmental information for more localized areas (e.g. Schaetzl and Attig, 2013). Much of this loess may have been derived (at least in part) from smaller source areas that were potentially active for relatively short periods of time (Schaetzl and Hook, 2008; Schaetzl and Loope, 2008; Luehmann et al., 2013). Many of these thinner loess deposits however, are often partially mixed with the underlying sediment. If the underlying sediment is sandy, the resultant surficial sediment often has surface textures that classify as loamy, rather than silty (Schaetzl and Hook, 2008; Schaetzl and Luehmann, 2013; Luehmann et al., 2016). Historically, the loamy textures of these loess deposits have sometimes resulted in (1) incorrect geologic interpretations, in the literature and on soil and geologic maps, or (2) erroneous thickness estimates and textural characterizations.

The first study of loess in Michigan occurred on the Buckley Flats outwash plain, in the northwestern Lower Peninsula, named for the nearby village of Buckley (Fig. 1). The soils on the Flats are loamy in their upper profiles, and sandy to gravelly at depth (Weber et al., 1958; Buchanan, 1985). The Flats area supports a prosperous cash grain industry (Fig. 2A, B), in a region that otherwise is dominated by forests and swamps, on comparatively infertile, sandy soils. The presence of agriculture here is generally attributed to the extensive areas of low relief, on loamy soils. (Luehmann et al., 2016), soils at the Flats were not initially thought to be loess-derived.

* Corresponding author.
E-mail address: soils@msu.edu (R.J. Schaetzl).

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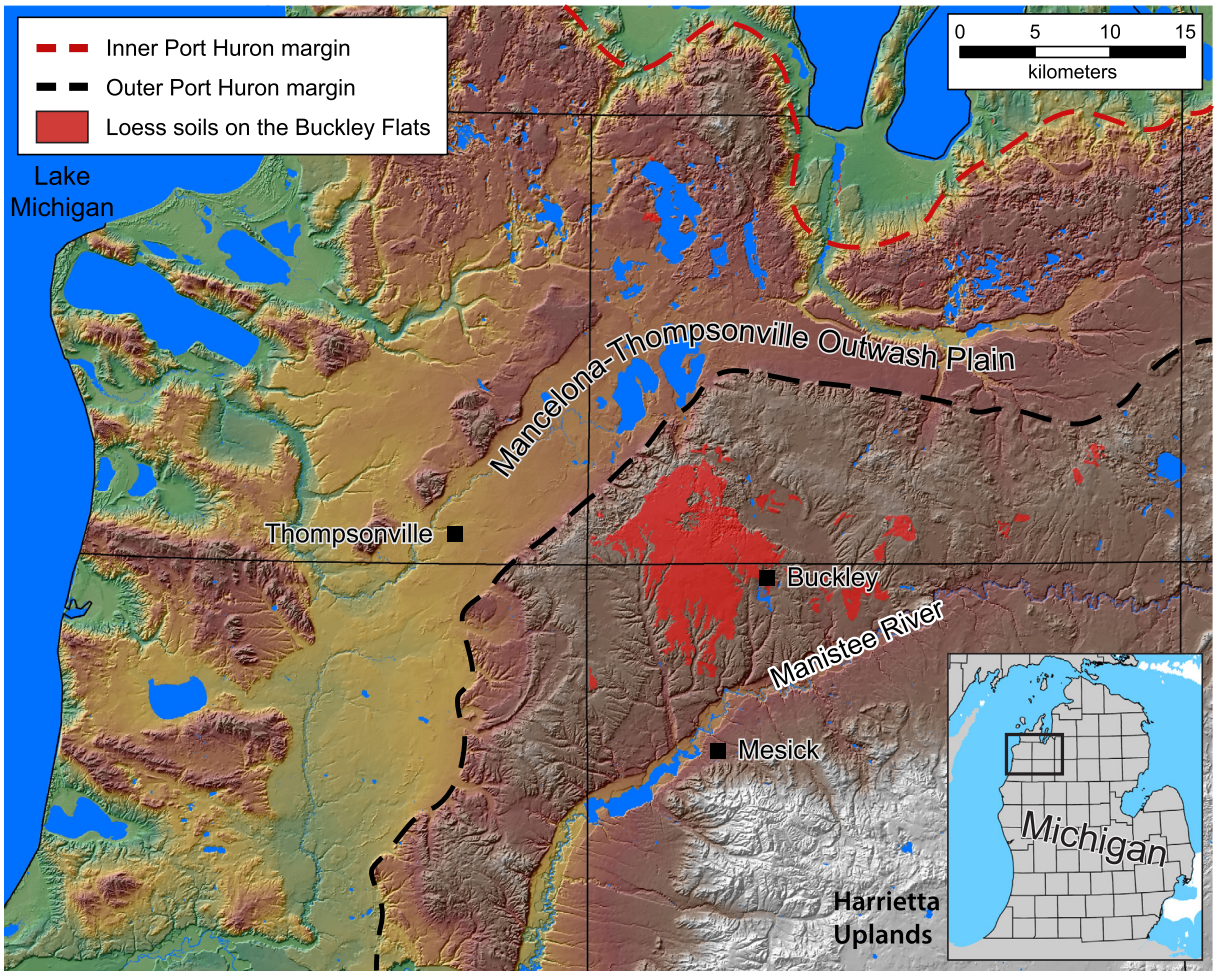

Fig. 1. Regional elevation map of the Buckley Flats in Michigan's northwestern Lower Peninsula. Soils interpreted as formed in loess over outwash (Coventry, Hodenpyl and Karlin series) are shown in red. County boundaries are shown as black lines.

Schaetzl and Hook's (2008) initial work on the soils of the Buckley Flats concluded that the loamy, upper part of the profile is loess, mainly derived from the Manistee River valley and floodplain to the southeast. They concluded that, the Flats provided a generally dry, stable and potentially vegetated upland capable of retaining any aeolian silt blow in from nearby sources. Aeolian silt retention occurred while the ice margin was in contact with the outwash surface, and later as the glacier retreated northward. They suggested that the loamy character of the mantle was due to pedoturbation of sands from below. As the first study of loess in Michigan, documenting the presence of loess on the Flats was, in and of itself, notable.

We use the generic term "loamy mantle" for the sediment that comprises the upper profile of these soils, i.e., above the contact with the outwash below. Schaetzl and Hook (2008) concluded that the loamy mantle formed as a result of pedoturbation of the thin loess with the sandy outwash below. Subsequent work has shown that many other thin loess deposits are often sandier than is typical for loess, displaying a bimodal particle size distribution (Schaetzl and Luehmann, 2013; Luehmann et al., 2016). Because of the frequent occurrence of such sediments, Luehmann et al. (2013) developed a "textural filtering" method, which they used to determine the textural characteristics of the original loess, before it had been mixed with sandy, underlying sediment (Schaetzl and Attig, 2013). The method determines the textural characteristics of the original loess by mathematically removing the data for the coarser, usually sand-sized, sediment, modeling the distribution for the removed portion of the textural curve, and recalculating the proportions of the resulting data to sum to unity. This filtering technique has been applied to data from other thin and texturally modified loess deposits, which facilitated their successful textural analysis and mapping (Schaetzl and Attig, 2013; Schaetzl et al., 2014; Luehmann et al., 2016). Schaetzl and Hook (2008) based many of their conclusions on raw, non-filtered, textural data. In this study, we applied the filtering method, when necessary, to better characterize the textural character of the loamy mantle on the Flats. In addition to applying the textural filtering technique, the present study expands upon the initial work of Schaetzl and Hook (2008) by sampling across a larger area, including areas not technically on the Flats, and on flat uplands nearby that were not mapped as loamy soils but which could have nonetheless retained some loess.

A. Typical scene in the northern part of the Flats where the topography is slightly rolling. Here, some woodlots still exist. B. Typical scene of the center of the Flats, where the landscape has less relief, soils are siltier, and intensive agriculture, with irrigation, is more common. C. A view looking south, off the southern margin of the Flats, looking across the Manistee River valley. In the background is the large, forested, Harrietta Upland, dominated by sandy soils.

Through a more thorough mapping effort, and filtering the textural data as needed, our work re-mapped the extent, thickness, and original textural properties of the loamy sediment on the

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