Geomorphology 248 (2015) 363–381

Contents lists available at ScienceDirect

Geomorphology

journal homepage: www.elsevier.com/locate/geomorph

Invited Review

Up in the refrigerator: Geomorphic response to periglacial environments in the Upper Mississippi River Basin, USA

Joseph A. Mason

Department of Geography, University of Wisconsin, Madison, WI 53706, USA

ARTICLE INFO

Article history:
Received 28 March 2015
Received in revised form 4 August 2015
Accepted 5 August 2015
Available online 9 August 2015

Keywords:
Periglacial
Landscape evolution
Loess
Eolian processes
Driftless Area
Upper Mississippi River basin
James C. Knox
Robert V. Ruhe

ABSTRACT

James C. Knox was best-known for his work on Holocene and historical changes in fluvial systems, but he also had a long-standing interest in the effects of late Pleistocene periglacial environments on landscape evolution in parts of the Upper Mississippi River basin that were just outside the Laurentide Ice Sheet margin, or as Knox put it, 'up in the refrigerator.' Knox and others in the Quaternary community of the Midwestern U.S. often suggested that hillslope erosion was accelerated under periglacial conditions, so that glacial periods have had a dominant effect on the landscape we see today. This paper reviews the evidence and reasoning supporting that view in a study area of the Upper Mississippi basin bordered on three sides by ice margins of the last glaciation, including the Wisconsin Driftless Area and adjacent landscapes. Sparse but compelling paleoecological data and relict ice- or sand-wedge polygons provide clear evidence for a cold climate and widespread permafrost around the peak of the last glaciation. In highly dissected, relatively high-relief parts of the study area, the loess and soil stratigraphy on ridgetops and the colluvial mantles on steeper slopes are best explained by highly effective hillslope erosion, including solifluction, during and just after the Last Glacial Maximum. Knox used the post-depositional truncation of a loess unit to quantify contrasting late Pleistocene and Holocene sediment yields from a small Driftless Area watershed. While the late Pleistocene yield indicates accelerated erosion, it is still lower than modern sediment yields in many tectonically active or semiarid landscapes, and it may reflect deposition of highly erodible loess as well as effects of periglacial conditions.

The views of Knox and other Midwestern geomorphologists on landscape evolution through glacial–interglacial cycles were highly influenced by the work of Robert V. Ruhe. Ruhe proposed that an episode of widespread erosion during and just after the Last Glacial Maximum can explain enigmatic aspects of Quaternary stratigraphy and the soil landscape on the Iowan Erosion Surface, a very low relief landscape of the study area. Ruhe's key evidence is still valid, though it needs to be separated from an implausible model of landscape evolution. Interpretation of the Iowan Erosion Surface and other low-relief landscapes just outside the ice margin also requires recognition of the profound effect of eolian processes on those landscapes under periglacial conditions. Many new insights on landscape evolution in the study area could result from wider application of cosmogenic nuclide-based methods to assess glacial–interglacial changes in basinwide rates of erosion and residence time of soils. Just as important, a need exists for much more field-based characterization of hillslope, fluvial, and eolian sediments for comparison with those of modern permafrost regions and past periglacial environments in Europe.

Contents

E-mail address: mason@geography.wisc.edu.

http://dx.doi.org/10.1016/j.geomorph.2015.08.004
0169-555X/

1. Introduction

Throughout his long career as a geomorphologist, James C. Knox (1941–2012) worked in the tectonically stable, low- to moderate-relief landscapes of the North American midcontinent, especially in the Driftless Area of southwestern Wisconsin, USA (Fig. 1). While the relative contribution of such landscapes to global sediment flux is debated (Willenbring et al., 2013; Larsen et al., 2014b), they clearly represent an opportunity to study the effects of climate change on sediment yield, especially where they have not recently been affected by glaciation or reorganization of the drainage network (Hidy et al., 2014). Knox is best known for his work on the response of fluvial systems to Holocene climate change and human impacts, but he had a long-standing interest in effects of glacial–interglacial climatic change on rates of erosion, sediment yield, and overall patterns of landscape evolution. On field trips through the Driftless Area (Fig. 2), Knox would almost always reserve time to talk about the hillslopes of that region, and their response to periglacial conditions when the region was 'up in the refrigerator' during the last glaciation. He interpreted hillslope deposits in the Driftless Area as evidence of accelerated hillslope erosion in the late Pleistocene when the region was just outside the margin of the Laurentide Ice Sheet (Knox and Maher, 1974; Knox, 1983, 1989; Leigh and Knox, 1994; Mason and Knox, 1997). Whereas Knox was not the first to argue for a strong influence of past periglacial environments on the Driftless Area (Smith, 1949, is an early example of interest in the topic), his prominence in the Midwestern Quaternary community made him an especially important advocate of that view, shared by many of his colleagues in the region.

This paper first reviews the evidence and reasoning that underlie this view of landscape response to late Pleistocene periglacial conditions in the Driftless Area and surrounding regions. I use the term periglacial to encompass cold-climate environments in which ground freezing and thawing strongly affect geomorphic processes. As noted by French (2007, p. 5), 'permafrost is a central, but not defining, element' of periglacial geomorphology; and deep seasonal frost can potentially explain some, though not all, of the landforms and sediments that have been attributed to past periglacial environments. Therefore I begin by reviewing paleoecological and geomorphic evidence on the specific nature of the periglacial environment in the region of interest, including clear evidence for widespread permafrost. This is followed by a review of hillslope and fluvial stratigraphy in the Driftless Area and similar landscapes, interpreted by Knox as the result of accelerated erosion under periglacial conditions. I then turn to the work of Robert V. Ruhe (1918–1993), focusing on his study of a distinctive low-relief landscape outside the late Pleistocene glacial limits in Iowa that was also of great interest to James Knox. Though rarely cited in contemporary geomorphological literature, Ruhe was highly influential from the 1960s through the 1980s among Midwestern Quaternary geologists and pedologists. Knox worked with him in the field while in graduate school and continued to cite Ruhe's ideas throughout his career (e.g., Knox,

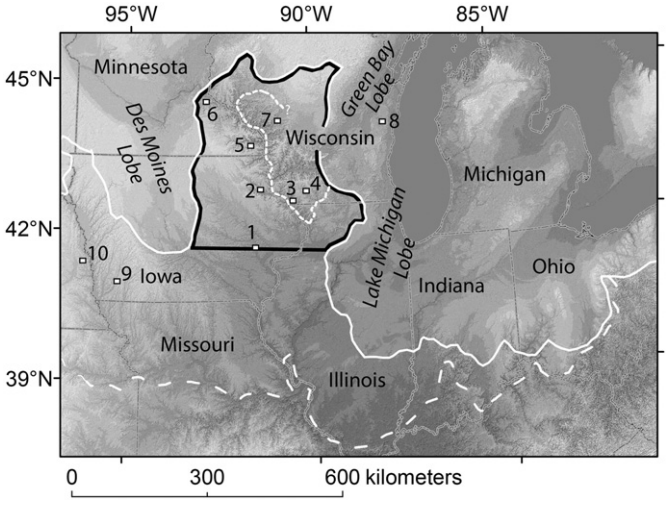

Fig. 1. Location of the study area (solid black line) of this paper in the central U.S., relative to the outermost ice margins of the last glaciation (solid white line) and of earlier late Cenozoic glaciations (long-dashed white line). Wisconsin Driftless Area, within the larger study area, outlined by short-dashed white line. Background gray shades represent elevation. Three ice-sheet lobes mentioned in text are labeled. Sites mentioned in text or shown in figures are marked by numbers: 1. Conklin Quarry, 2. Elkader site, 3. Kieler site, 4. Moscow Fissure, 5. Houston County area, Minnesota (Jore site, Lehman site, Caledonia roadcut, BE Site), 6. Hampton Town Hall site, 7. Sparta ice-wedge cast site, 8. Valders Quarry, 9. Study area of Ruhe et al. (1967) in southwestern Iowa, 10. Study area of Mason et al. (2007) in eastern Nebraska. The Wolf Creek paleoecological site (Birks, 1976) is just off north edge of map.

Fig. 2. James C. Knox (second from right) at an exposure of Holocene alluvium, on a field trip to the Driftless Area in 2011.