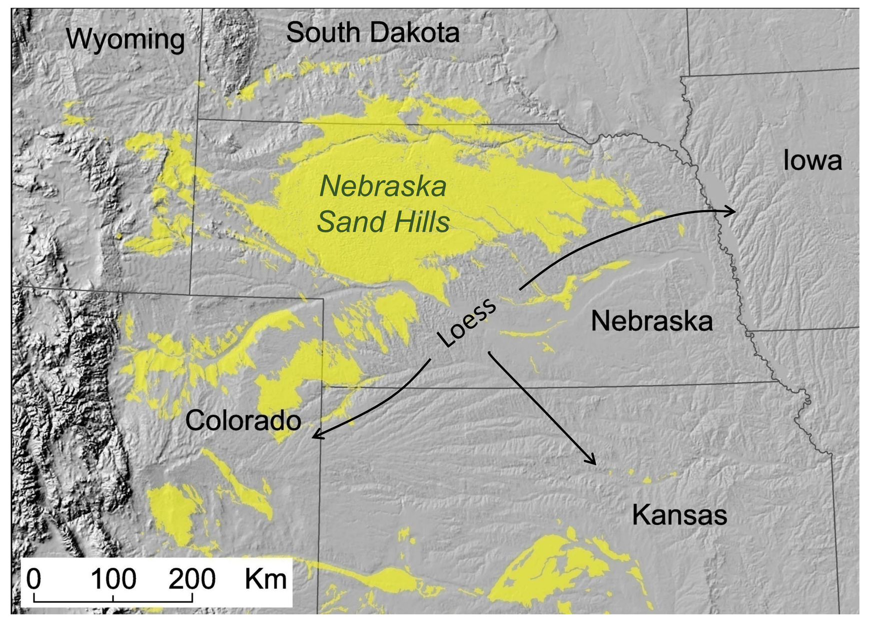
Loess Tableland Evolution in the Central Great Plains, USA, and implications for preservation potential of the loess record, stored sediment, and buried soil carbon

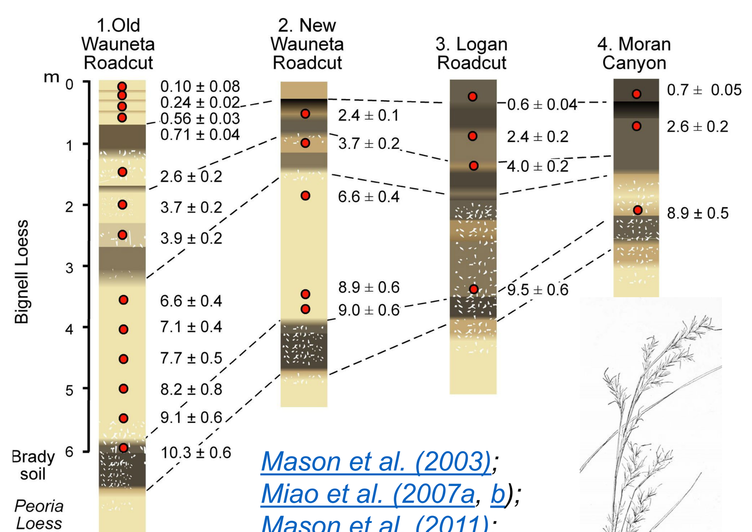
Joe Mason, Taylor McDowell, Tien Vo, Chase Kasmerchak, and Erika Marín-Spiotta
University of Wisconsin-Madison

Background

Study Area: Thick loess downwind of major dunefields, Central Great Plains
Funding: EAR-1920625 and earlier grants



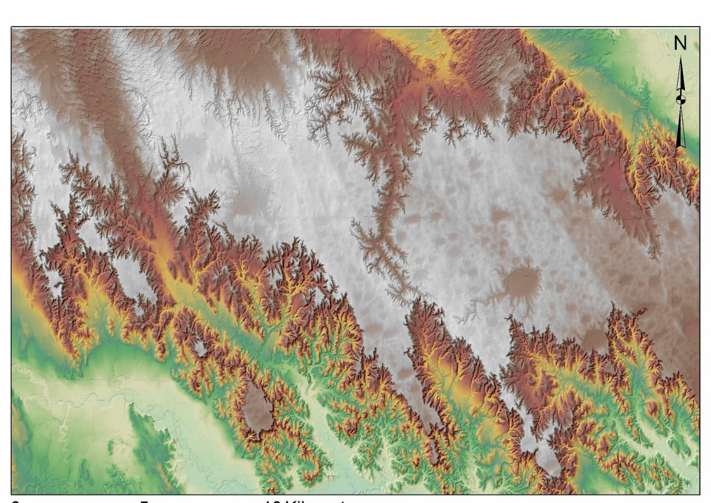
Central Great Plains Loess Record: High-resolution Holocene record of wet-dry climatic change, extremely thick Late Pleistocene loess, Middle Pleistocene loess and paleosols



Mason et al. (2003); Miao et al. (2007a, b); Mason et al. (2011); Tecsa et al. (2020)

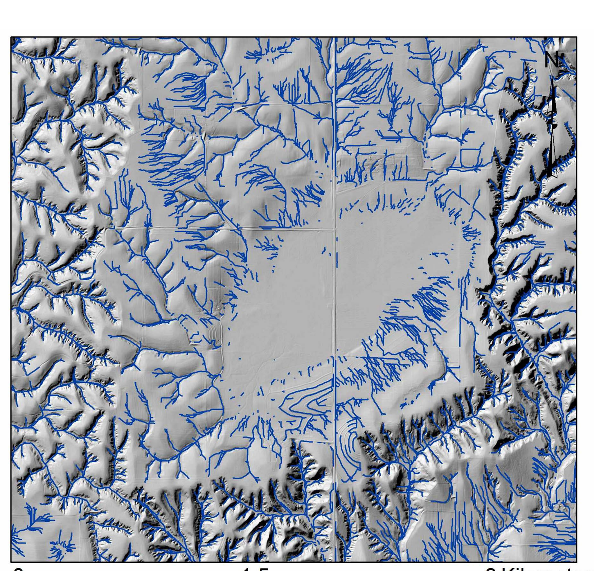
Loess Tablelands

- Have gently sloping summits, *often with closed depressions*, steep dissected margins
- Preserve most complete loess sequences, large volumes of sediment stored as loess, and C in buried soils
- *What controls formation and preservation of tablelands?*



Explaining effect of depressions: Surface runoff flowpaths

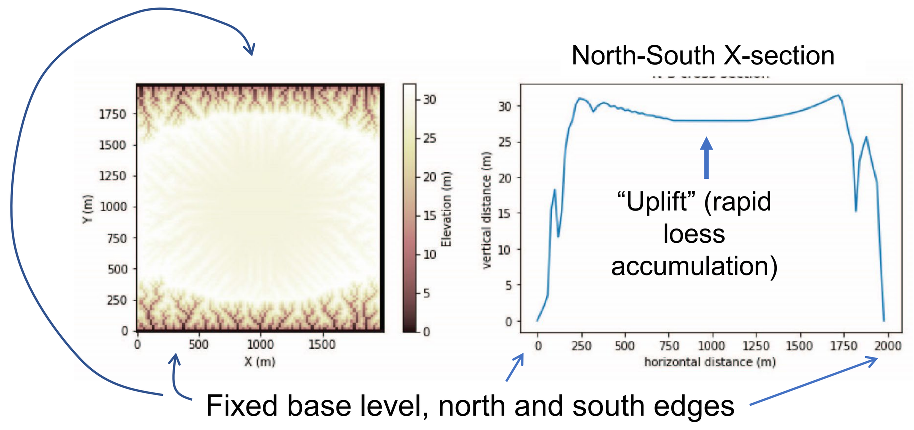
- Based on 1-m DEMs from airborne LiDAR, various alogorithms yield similar results (and artifacts)
- *Results support mainly internal drainage, from table edge into depressions* (now affected by road ditches, field terraces)

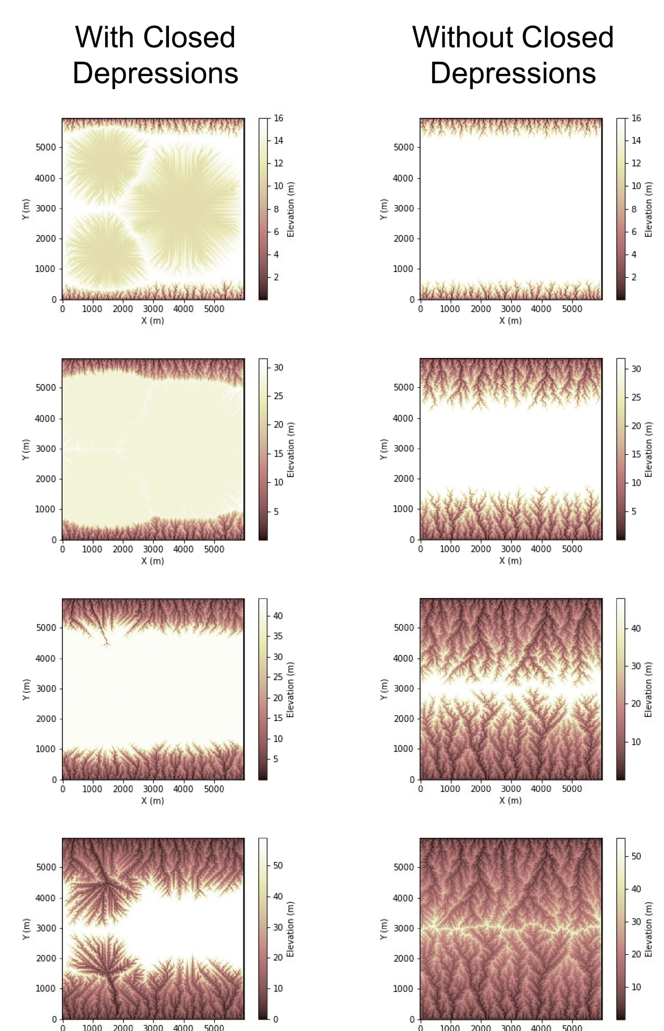


Role of Depressions

Hypothesis:
Tableland summits drain internally, *into closed depressions*, limiting erosion of steep tableland margins

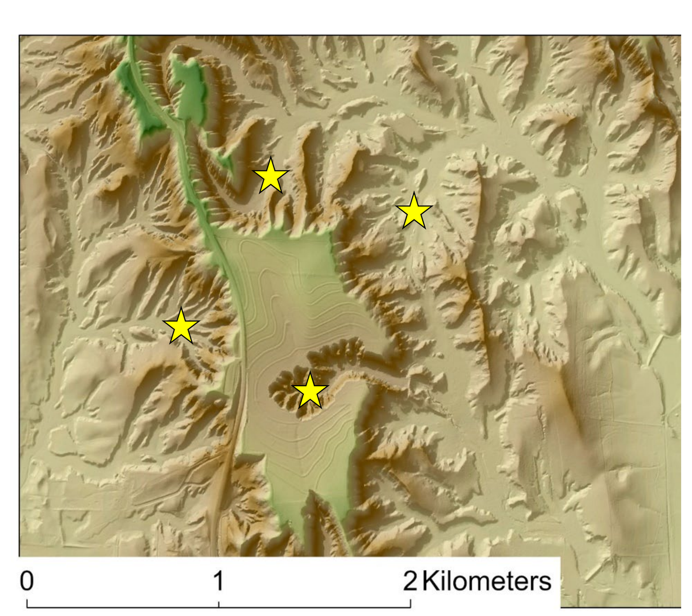
Landscape evolution modeling:
Used Landlab toolkit (Hobley et al., 2017; Barnhart et al., 2020) to simulate erosion of the tablelands during and after loess accumulation *with and without depressions* on the summit





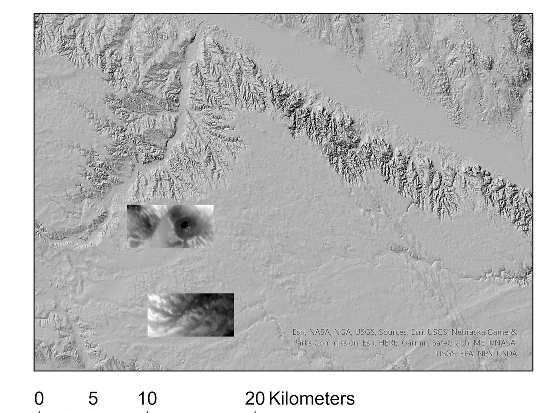
Simple example:

- Simultaneous *loess accumulation and erosion* (mostly fluvial, based on stream power), without and with closed depressions
- *Tablelands persist much longer with depressions*
- Depressions enhance tableland preservation, but eventually they are breached by gullies
- *Radial drainage patterns* are the signature of this sequence, in modeling and around real tablelands



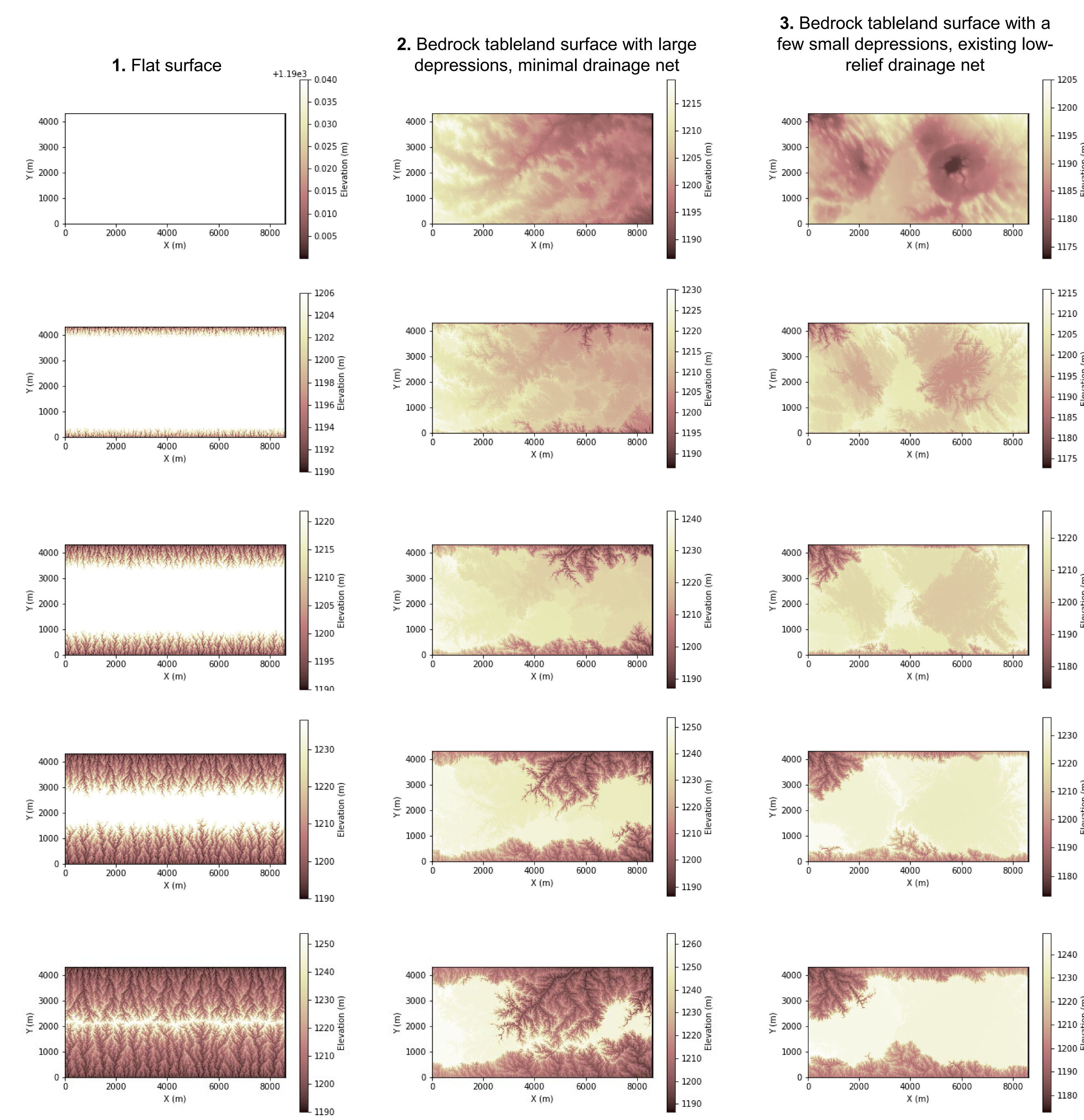
Role of Pre-Existing Bedrock Tablelands

Hypothesis:
Loess tablelands originated through Pleistocene loess accumulation on *pre-existing bedrock tablelands* of the High Plains, underlain by the Miocene Ogallala Group, locally overlain by Pliocene gravels



Bedrock tableland surface used as initial state in modeling

Landscape evolution as thick loess accumulates on:



Notes on Modeling Shown Here:

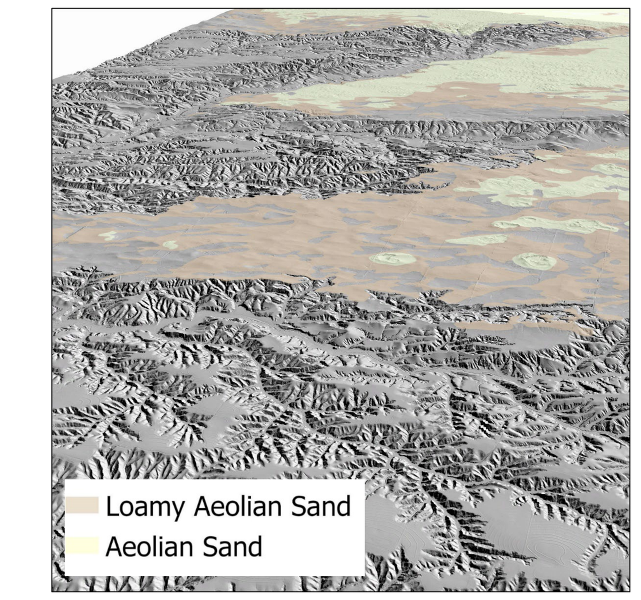
All results shown on this poster are from model using FastscapeEroder component of Landlab, a simple and efficient streampower-based model of fluvial erosion, combined with diffusive hillslope transport (which has a minor effect). FastscapeEroder does not include transport and deposition of eroded material. Simulations were also run with the ErosionDeposition component, which explicitly models transport and deposition and maintains sediment mass balance. Results are very similar except that there is some realistic filling of depressions with ErosionDeposition and some unrealistic net removal of sediment from depressions with FastscapeEroder (neither visible at the scale of the results shown here). Therefore, ErosionDeposition would be preferred, but it becomes unstable at later stages of these model experiments and accumulates highly unrealistic volumes of sediment at a few points in the tableland-margin drainage network. So, a work in progress….

Role of Aeolian Sand

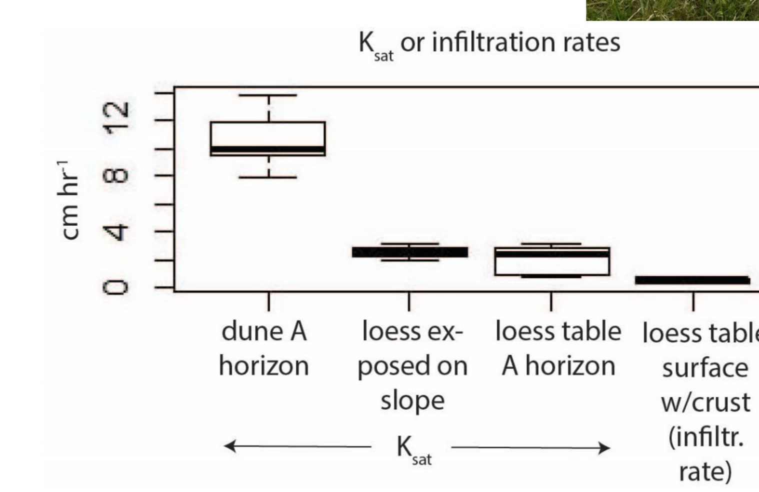
Sand-mantled tablelands:

- In southwestern Nebraska large tablelands extend far into the loess region, surfaces mantled by aeolian sand that migrated over thick loess in the latest Pleistocene to Holocene
- Hypothesis: The sand mantle reduces surface runoff, helping to preserve these tables from erosion

(looking WSW, VE = 2)



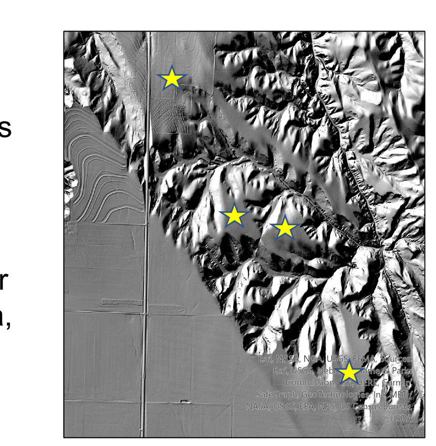
Hydraulic conductivity/infiltration rate measurements on surface soils in loess and aeolian sands. (initial results):



These initial results are consistent with the hypothesis. Hydraulic conductivity/infiltration rate measurements on **dune sands** suggest little or no runoff even during most intense summer storms, although we do not know enough about short-term extremes of rainfall rates and water-repellency of dune sand A horizons. Infiltration rates on **loess tableland surfaces** with crusts (common even in native grassland) suggest frequent runoff.

Holocene Climate Change and Hillslope Evolution

- Holocene alternation between wetter and drier climatic conditions is clearly recorded by loess-paleosol sequences and changes in dune activity
- We speculate that smoother, less-dissected, and more convex portions of hillslopes may be relicts from wetter periods, either ca. 6-4 ka or ca. 2-1 ka, when denser vegetation limited fluvial erosion and diffusive processes were more important
- Changes in rainfall frequency/magnitude relationships could also affect hillslope processes.
- Modeling can address these possibilities.



Thanks

We thank Emily Diaz Vallejo for help with field work, landowners for allowing access to our study sites, and the National Science Foundation for funding this project through EAR-1920625 and earlier grants that supporting our long-term research program in this area. Opinions, findings, conclusions or recommendations presented here do not necessarily reflect the views of the National Science Foundation.