Genesis of upland soils in northeastern Kansas

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Summary

- Where landscapes are old, soils are complicated
- Parent materials are fun and interesting to figure out
Pre-Illinoian glacial till
>300,000 years
Geologic time scale, 650 million years ago to the present

- **Era**: Quaternary
  - **Event**: Evolution of humans

- **Era**: Cenozoic
  - **Period**: Tertiary
    - **Event**: Mammals diversify
  - **Period**: Cretaceous
    - **Event**: Extinction of dinosaurs, first primates, first flowering plants
  - **Period**: Jurassic
    - **Event**: First birds, dinosaurs diversify
  - **Period**: Triassic
    - **Event**: First mammals, first dinosaurs
  - **Period**: Permian
    - **Event**: Major extinctions, reptiles diversify

- **Era**: Paleozoic
  - **Period**: Carboniferous
    - **Event**: First reptiles, scale trees, seed ferns
  - **Period**: Mississippian
    - **Event**: First amphibians, jawed fishes diversify
  - **Period**: Devonian
    - **Event**: First vascular land plants
  - **Period**: Ordovician
    - **Event**: Sudden diversification of metazoan families
  - **Period**: Cambrian
    - **Event**: First fishes, first chordates

- **Era**: Proterozoic
  - **Period**: First skeletal elements, first soft-bodied metazoans, first animal traces
Flint Hills Bedrock

- **Permian Period** (which lasted from about 286 to 245 million years ago) shallow seas covered much of the state.
Chert = Flint

- Limestones in the Flint Hills contain numerous bands of chert, or flint
- Like quartz, but with cryptocrystalline structure
- Probably a chemical precipitation but could be biological
- Less soluble so when bedrock weathers, leaves behind cherty gravel. Benches and flat tops = lots of chert.
Loess 101:
Loess covers ≈ 2/3 of surface of KS (Welch and Hale, 1987)

Source: 1:500,000 Geologic Map of Kansas (1991)
<table>
<thead>
<tr>
<th>Stratigraphic name</th>
<th>Absolute age</th>
<th>Marine Isotope Stage</th>
<th>Glacial/Interglacial stage</th>
<th>Epoch</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bignell loess</td>
<td>9,000 to present ?</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brady soil</td>
<td>10,500 – 9,000</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peoria loess</td>
<td>25,000 – 11,000</td>
<td>2</td>
<td>Wisconsinan</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gilman Canyon Loess</td>
<td>40,000 – 22,000</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sangamon soil</td>
<td>125,000 – 55,000</td>
<td>5 to 3</td>
<td>Sangamon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loveland loess</td>
<td>160,000 – 127,000</td>
<td>6</td>
<td>Illinoian</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Not recognized east of 97°W**
- **Most common surficial loess in KS**
- **First recognized in SC NE in 1965, found in central and eastern KS**
- **Most widespread unit in midcontinent**
- **Continuous throughout KS**
Source of loess?

“The origin of massive silt deposits (loess) has been a subject of controversy for more than fifty years” (Swineford and Frye, 1951)

“The source of the loess in Kansas has been debated for the last fifty years” (Welch and Hale, 1987)

The source of Great Plains loess is probably nonglaciogenic (but glacially influenced) sediments eroded from nonglaciated landscapes to the west of Kansas, perhaps at a great distance (Aleinikoff et al., 1998; Mason, 2001; Mason and Jacobs (1998), Muhs et al., 1999; Reheis et al., 1995)

Hot topic for 116 years and going!
Pre-Wisconsin glaciation boundary in Kansas (200,000 + years ago)
Objectives

1. To describe the morphology and determine genesis
2. To examine relationships between soil properties and landscape positions
3. To evaluate how properties of soil series vary geographically
Part 1: Polygenetic soils of the Bluestem Hills, Kansas
Introduction

- Objective: To describe the morphology of the soils of interest and determine genesis
- Genesis: 5 soil forming factors
- Polygenesis: Multiple sets of factors
Introduction

- Polygenetic
  - Loess/colluvium/colluvium/residuum

- What Quaternary loess and paleosol stratigraphic units are present in the Flint Hills?

- How old are paleosols that clearly aren’t pure loess?
Methods

- Sampling
  - Profile descriptions
- Laboratory characterization
  - Standard characterization:
    - PSD, pH, C, CEC, BD
  - Silt and clay mineralogy
- Micromorphology
Bluestem Hills Major Land Resource Area (76)

19,400 km² (7,490 mi²)
60% rangeland
20% cropland
Tallgrass prairie
750 to 900 mm annual precipitation
1.8 meters to shale
Site 3

Silty, contains 1% rocks

Dark, red paleosol

Shale
Particle size distribution: Site 3

The A1 and A2 horizons: A different loess unit? Bi-modal particle size distribution indicative of aggregate transport (Mason et al., 2003)
Particle size distribution: Site 3

Red paleosol: More similar to loess, not residuum
Holocene loess?

- Dust additions to pedon could explain
  - Difference in particle size of A horizon
  - Thick mollic epipedons

- Aggradational pedogenesis: Deposition of loess on a microbially-active surface causing simultaneous A horizon burial and melanization (Jacobs & Mason, 2005).

- Bignell loess not reported east of 97°W (the west edge of the Flint Hills)
Left: 58-79 cm, only stress-related clay coatings, XP.

Center: 107-124 cm, contains lenticular gypsum and has illuvial clay coatings, XP.

Right: 155-175 cm, has thick, laminated clay coatings, PP.
# Revisions to horizonation

<table>
<thead>
<tr>
<th>Original</th>
<th>Particle Size</th>
<th>Thin section</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>A1</td>
<td>A1</td>
</tr>
<tr>
<td>A2</td>
<td>A2</td>
<td>A2</td>
</tr>
<tr>
<td>Bt1</td>
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<td>Btk1</td>
<td>Btk1</td>
<td>Btk</td>
</tr>
<tr>
<td>Btk2</td>
<td>Btk2</td>
<td>2Btky</td>
</tr>
<tr>
<td>2Bt3</td>
<td>2Bt3</td>
<td>3Bt3</td>
</tr>
<tr>
<td>2Bt4</td>
<td>2Bt4</td>
<td>3Bt4</td>
</tr>
<tr>
<td>3C</td>
<td>3C</td>
<td>4C</td>
</tr>
</tbody>
</table>

- Clay Films
- Gypsum
Stratigraphy: Hypothesis

4 units in these soils? There are 4 loess units correlated in KS…

- Bignell loess
- Peoria loess
- Gilman Canyon loess
- Loveland loess
- Permian shale
- A1
- A2
- Bt1
- Bt2
- Btk
- 2Btky
- 3Bt3
- 3Bt4
- 4C
- Clay Films
- Gypsum
Sodium and Gypsum
Dwight series

- Fine, smectitic, mesic Typic Natrustolls
- Natric: >15% Exchangeable sodium in argillic horizon
- Site 4: Morris County
Gypsum in thin section

107-124 cm, contains lenticular gypsum and has illuvial clay coatings, XP.
Upland Depression, a.k.a. buffalo wallow.

More correctly, a bison wallow that bison do not wallow in.

(Coppededge et al, 1999)
EM-38 and GPS

Wes Tuttle

07/27/2006
Site 4a: Mapped Dwight

Values typical for Irwin
Not natric
Site 4b: Mapped Irwin

Map by Wes Tuttle
Site 4b: Mapped Irwin

Values > 15% = natric = Dwight

Only one in whole study to meet criteria, other suspected areas of high sodium have been sampled
Conclusions: Part 1

- Within one soil profile, up to 4 units of parent materials
- Just how old are these soils/paleosols?
  - How do they fit into the Quaternary record?
Part 2: Gemorphology and Terrain Analysis
Methods

- Sampling
  - Profile descriptions

- Laboratory characterization
  - Standard characterization:
    - PSD, pH, C, CEC, BD
  - Silt and clay mineralogy

- Radiocarbon dating and stable carbon isotopes (Illinois Geological Survey)

- Terrain analysis in Geographic Information System (GIS)
Fly-through animation
## Absolute dating and isotopes

<table>
<thead>
<tr>
<th>Landscape Position</th>
<th>Paleosol Dated</th>
<th>Age (^{14}\text{C} \text{ yr BP})</th>
<th>Isotope (\delta^{13}\text{C} \text{ %o})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summit</td>
<td>Lower</td>
<td>22,490 ± 90</td>
<td>-16.8</td>
</tr>
<tr>
<td>East bench</td>
<td>Upper</td>
<td>20,140 ± 70</td>
<td>-17.5</td>
</tr>
<tr>
<td>West bench</td>
<td>Lower</td>
<td>24,490 ± 120</td>
<td>-16.9</td>
</tr>
<tr>
<td>Paleoterrace</td>
<td>Upper</td>
<td>19,030 ± 60</td>
<td>-19.2</td>
</tr>
</tbody>
</table>
Severance Formation (Mandel, KU)

- Valley paleosols:
- 14C ages and soil properties are typical of paleosols composing the pedocomplex of the Gilman Canyon Formation, a unit of late Wisconsinan loess on the adjacent uplands.
- Established a new lithostratigraphic unit, the Severance Formation, for the late Wisconsinan valley fill (alluvium and colluvium). Previously, these deposits were referred to as the valley facies of the Gilman Canyon Formation.
Conclusions—Part 2

- Lack of relationship between profile features and landscape position confirms the existing mapping
- Consistent loess (or colluviated loess) stratigraphy across landscape positions
  - Gilman Canyon loess/Severance formation (colluvium)
  - No Loveland loess
Overall conclusions

- Polygenetic soils are complicated
- $\text{Na}^+$ is pretty high, but rarely makes natric
- A contribution to Quaternary geology can be made in this region

Future work
- Lipid analysis of paleosols: Finer detail paleo-vegetation record