Soil morphological characteristics of prairie mounds in the forested region of south-central United States

Brad Lee[A] and Brian Carter[B]

[A]Plant and Soil Sciences Department, University of Kentucky, Lexington, KY 40546, Email brad.lee@uky.edu
[B]Plant and Soil Sciences Department, Oklahoma State University, Stillwater, OK 74078, Email brian.j.carter@okstate.edu

Abstract
Prairie mounds are common in the prairie islands of the forested regions of the south-central United States, however their origin is not well understood. A topographic survey and pedon investigation of a mound and intermound area was conducted in a grassed field of prairie mounds 15 – 25 m in diameter and ~ 1 m. Both soils contain three parent materials: loess over an alluvial silty clay paleosol underlain by weathered shale. The mounded soil loess thickness is ~1.5 m while the loess in the intermound area is ~0.5 m thick. Fragic soil properties (dense, brittle, silt coats above dense horizon) are present in the loess immediately above the paleosol contact. Crayfish (*Cambarus spp.*) chimneys in the intermound and abundant gopher burrows (*Geomys spp.*) above the fragic horizon in the mound mound and loess of the intermound soil indicate the soils across the field are actively bioturbated. Depletions near the surface of the intermound soil indicate a seasonally high water table. Relict crayfish krotavinas in the paleosol under the mound and active crayfish burrows in intermound areas suggest the entire plain was previously bioturbated by crayfish. Bioturbation by gophers appears to be more recent and associated with the loess deposit.

Key Words
Prairie pimples, pimpled plains, mima mounds, Arkansas River valley.

Introduction
Numerous theories exist concerning the formation of small (approximately 10 – 30 m in diameter and 0.5 – 1.5 m high) hemispherical mounds that are found in many areas of central and western North America. The unique characteristics of these mounds include an overthickened A horizon relative to adjacent soils between mounds. These mounds have been referred to as "Mima mounds", "prairie pimples" and "pimple mounds" and the numerous theories of their genesis can be grouped into 5 categories: erosional, depositional, fossorial (burrowing animals), periglacial and seismic. It is likely that one process is hierarchically dominant in producing mounded tracts, but subordinate processes also play a role in soil development (Horwath and Johnson 2006). In the southern mid-continent Prairie mounds are common in the Arkansas River valley and the Ouachita mountains (Knechtel 1952, Seifert *et al.* 2009). The purpose of this study is to characterize soils below a mound and intermound area in the Arkansas River valley within the Ouachita physiographic province.

Methods
Environmental setting
The study site was located in 6 km east northeast of Poteau River that drains north into the Arkansas River valley. Elevation is approximately 140 m. The area has a mean annual precipitation of 1217 mm and a mean annual temperature of 16.3 C. The mound density in the field where the study site is located is approximately 9 mounds per hectare. The land use at the study site has been pasture for over 85 years.

Field
A topographic survey was conducted over a 60 x 60 m plot using a laser level to determine the determine shape and elevation of mounds relative to intermound areas. Adjacent to the plot, two pedons were described and sampled to a depth of bedrock at a mound summit and an intermound area according to standard United States Department of Agriculture – Natural Resources Conservation Service methods (Schoeneberger *et al.* 2002). Horizontal distance between the pedons is ~25 m.

Laboratory
Soil samples were dry sieved to separate coarse (20 – 75 mm), medium (5 – 20 mm) and fine (2 – 5 mm) rock fragments. Particle size distribution of the < 2 mm fraction was determined by wet sieving the sand fraction (50 µm to 2 mm) silt and clay (< 50 µm) by the pipet method (Gee and Bauder 1986). Bulk density was determined on saran-coated clods (Brasher *et al.* 1966).

Results and discussion

Topography

The mounds are circular footprint approximately 15 to 20 m in diameter (Figure 1). The intermound area has a small 0.2 % slope toward the southwest. Other researchers have observed mid-continent prairie mounds are on gently sloping to horizontal alluvial terraces of streams and rivers (Allgood and Gray 1974; Collins 1975).

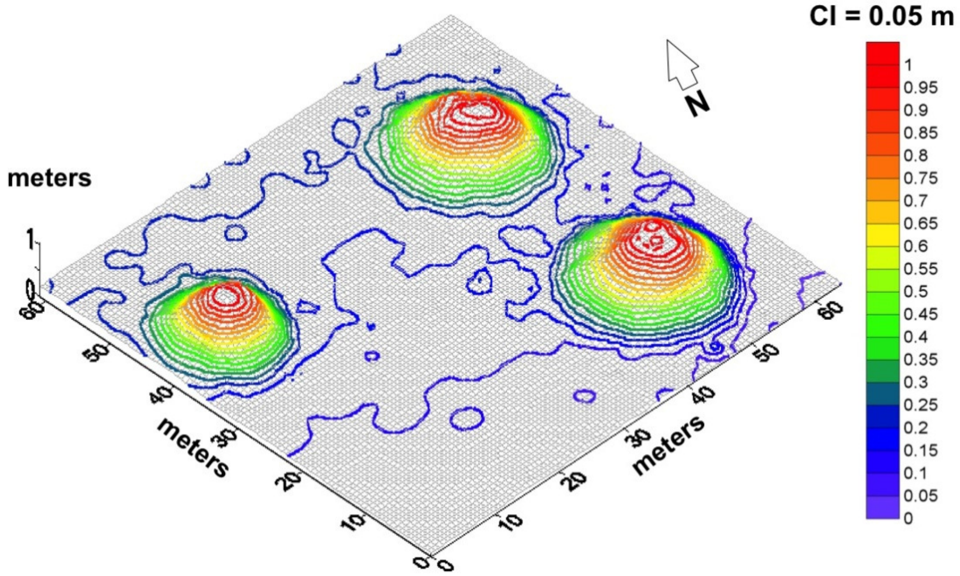

Figure 1. Topographic survey of 60 x 60 m study plot in prairie mound field.

Morphology and particle size distribution

The silt loam texture of the surface of both pedons (mound 0 – 146 cm and intermound 0 – 48 cm) suggests that the parent material of the surface is aeolian in origin (Table 1). With the exception of the brittle horizons and the dense silt loam in the mound soil (85 – 119 cm), the loess in both pedons is being actively bioturbated by gophers (*Geomys. spp.*). Between 85 – 119 cm (Bw4) of the mound soil there is a gravelly horizon (lowest D_b in subsoil = 1.22 g/cm^3 over a dense horizon (119 – 146 cm) with fragic characteristics

Table 1. Particle size distribution and texture of pedons.

Horizon	Depth cm	Rock fragments[A] 5–75 mm	Rock fragments[A] 2–5 mm	Sand 50–2000 mm	Coarse silt 20–50 µm	Medium silt 5– 20 µm	Fine silt 2–5 µm	Clay < 2 µm	Texture
						Mound			
A1	0-26	2	13	19	35	26	7	13	Silt loam
A2	26-50	2	11	18	35	26	7	14	Silt loam
Bw1	50-70	3	8	18	36	26	7	13	Silt loam
Bw2	70-85	4	9	18	36	29	7	10	Silt loam
Bw3	85-99	2	16	18	36	28	7	11	Silt loam
Bw4	99-119	6	30	16	34	28	7	15	Fine gravelly silt loam
Bx	119-146	3	15	15	31	25	7	22	Silt loam
2Bt1	146-174	2	11	9	20	22	7	42	Silty clay
2Bt2	174-202	3	15	10	16	20	7	47	Silty clay
3Bt	202-232	4	25	9	15	19	7	50	Fine channery silty clay
3Cr	232-272	66	20	11	8	23	13	45	Extremely channery silty clay
						Intermound			
A1	0-11	1	7	10	25	32	9	24	Silt loam
A2	11-35	2	13	12	25	30	10	23	Silt loam
Bg	35-48	5	15	12	21	28	10	29	Silty clay loam
2Bt1	48-64	0	14	3	8	14	4	71	Clay
2Bt2	64-97	0	12	8	21	16	7	48	Silty clay
2Btg	97-128	4	17	9	15	20	7	49	Silty clay
3Cr	128-157	63	18	12	8	29	19	32	Extremely channery silty clay loam

[A]Rock fragments determined on weight %.

(Bx) (D_b = 1.61 g/cm^3). It appears that the Bx horizon impedes vertical water movement resulting in the formation of skeletans in the Bw4 horizon. The abrupt textural change at 146 cm coupled with paleo crayfish Krotavinas below 146 cm to a depth of bedrock suggests a period of soil development before the aeolian addition. In nearly all mid-continent occurrences, fields of prairie mounds have been noted to overlie a dense subsoil pan (claypan, fragipan) or bedrock that limits rooting at shallow depths below the intermound elevation (Knetchel 1952; Melton 1954; Horwath and Johnson 2006).

In the intermound soil, redox concentrations at the soil surface coupled with a gleyed horizon immediately above the paleosol suggest that the upper pedon is seasonally saturated during wet periods. Below 48 cm of loess, active crayfish (*Cambarus spp.*) burrows are visible. Crayfish chimneys are present on the soil surface in the intermound areas during the wet spring months. However during the late summer when these soils were sampled, there is little evidence of crayfish burrows in the loess probably due to dry season activity of gophers destroying crayfish burrows.

Table 2. Selected soil morphologic properties and bulk density of sampled horizons.

Horizon	Depth cm	Matrix color	Depletions[A]	Bulk density g/cm^3	Structure[B]	Consis-tence	Krotavinas
				Mound			
A1	0-26	10YR4/3		1.04	2 m gr	friable	20% active *Geomys*
A2	26-50	10YR4/3		1.40	2 m sbk	friable	20% active *Geomys*
Bw1	50-70	10YR5/4		1.55	1 m sbk	friable	20% active *Geomys*
Bw2	70-85	10YR5/4		1.49	1 m sbk	friable	20% active *Geomys*
Bw3	85-99	2.5Y 6/4	f,2-3,d 10YR 4/4	1.47	1 m sbk	firm, slightly brittle	10% filled *Geomys*
Bw4	99-119	10YR 5/4	m,2-3,d 10YR 8/2 skeletans	1.22	2 f sbk	very firm, brittle	
Bx	119-146	2.5Y 5/4	c,1,d, 10YR 5/6	1.61	1 f sbk	very firm	
2Bt1	146-174	10YR 4/4	c,1,p 5YR5/6	1.65	1 m sbk	very firm	10% paleo *Cambarus*
2Bt2	174-202	10YR 6/4	c,1,d 5YR 4/6 c,1,p, 2.5N	1.50	1 m sbk	very firm	10% paleo *Cambarus*
3Bt	202-232	10YR 6/4	c,1,p 7.5YR 5/8 C,1,p 2.5N	1.36	1 m sbk	very firm	10% paleo *Cambarus*
3Cr	232-272	10YR 4/3	Thin, horizontally bedded weathered shale				
				Intermound			
A1	0-11	10YR 7/3	c,1,p 10YR 5/8	1.42	2 f, m gr	friable	
A2	11-35	10YR 6/3	c,1,p 10YR 5/8	1.42	2 f sbk	friable	
Bg	35-48	10YR 7/2	c,1,p 5YR 4/4	1.38	2 f sbk	friable	20% active, filled *Geomys, Cambarus*
2Bt1	48-64	10YR 4/4	c,2,p 2.5YR 4/8	1.50	2 m sbk	firm	10% active, filled *Cambarus*
2Bt2	64-97	2.5YR 4/8	m,2,p, 10YR 6/1	1.58	2 m sbk	firm	10% active, filled *Cambarus*
2Btg	97-128	7.5YR 6/1	m,2,p 10YR 4/8	1.50	2 m sbk	firm	10% active, filled *Cambarus*
3Cr	128-157	2.5Y 4/1	Thin, horizontally bedded weathered shale				

[A]f = few, c = common, m = many, 1 = fine, 2 = medium, d = diffuse, p = prominent
[B]1 = weak, 2 = moderate, f = fine, m = medium, gr = granular, sbk = subangular blocky

Conclusions

At this study site in the southern Arkansas River valley near the Ouachita Mountains the soils formed from a loess deposit over a silty-clay paleosol formed from alluvium over shale bedrock. About 0.5 m of loess is deposited in the intermound while 1.5 m of loess in the mounds. The mound contains a fragic horizon above the paleosol restricting water movement. Active bioturbation from gophers is prevalent in the loess above restrictive layers. Active crayfish burrowing is present in the intermound areas. The paleosol below the mound contains relict crayfish burrows suggesting that bioturbation by crayfish was a prominent soil process across this landscape in the past but is presently restricted to the intermound areas.

References

Allgood FP, Gray F (1974) An ecological interpretation of the small mounds in landscapes of eastern Oklahoma. *Journal of Environmental Quality* **3,** 37-41.

Brasher BR, Franzmeier DP, Valassis VT, Davidson SE (1966) Use of Saran resin to coat natural soil clods for bulk density and water-retention measurements. Soil Science **101**, 108.

Collins B (1975) Range vegetation and Mima mounds in north Texas. *Journal of Range Management* **28**, 209-211.

Gee GW, Bauder JW (1986) Particle-size analysis. In 'Methods of soil analysis, Part 1: Physical and mineralogical methods'. (Ed A Klute) pp. 11-34. (American Society of Agronomy: Madison WI).

Horwath JL, Johnson DL (2006) Mima-type mounds in southwest Missouri: Expressions of point-centered and locally thickened biomantles. *Geomorphology* **77**, 308-319.

Knechtel MM (1952) Pimpled plains of eastern Oklahoma. *Geological Society of America Bulletin* **63**, 689-700.

Melton FA (1954) "Natural mounds" of northeastern Texas, southern Arkansas, and northern Louisiana. *Oklahoma Geological Survey - The Hopper* **14**, 88-121.

Schoeneberger PJ, Wysocki DA, Benham EC, Broderson WD (2002) 'Field book for describing and sampling soils, Version 2.0.' (Natural Resources Conservation Service, National Soil Survey Center: Lincoln NE)

Seifert CL, Cox RT, Forman SL, Foti TL, Wasklewicz TA, McColgan AT (2009) Relict nebkhas (pimple mounds) record prolonged late Holocine drought in the forested region of south-central United States. *Quaternary Research* **71**, 329-339.

© 2010 19th World Congress of Soil Science, Soil Solutions for a Changing World

1 – 6 August 2010, Brisbane, Australia. Published on DVD.