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Glaciers in Kansas

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Introduction

With heightened debate regarding global climate change, much conversation includes evidence of melting glaciers in the earth's polar and alpine regions. To better understand these issues, it is helpful to consider past glaciation and climate-change examples. Glaciers seemingly couldn't be further removed from the hot summers and windswept plains of Kansas. However, in the not-so-distant geologic past, glaciers repeatedly advanced across the Midwest and at least two glacial advances reached northeast Kansas. As the ice progressed across the continent, the landscape, climate, plants, and animals all changed.

The purpose of this Public Information Circular is to show how Kansas was once literally on the forefront of climate change when a continental ice sheet extended into the northeast corner of the state some 700,000 years ago. The geologic sciences are uniquely capable of describing these events, in that geologists nearly always look backward in time to understand the earth from a present-day perspective.

This publication provides an unaccustomed view of the Midwest as it responded to repeated continent-sized glacial advances during the Pleistocene. It explains glaciation in Kansas and the ecological and climate response since the last ice sheet retreat. The Pleistocene provides an important analog or past example to better understand some of the concepts associated with climate change.

The Pleistocene

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The Pleistocene Epoch or "Ice Age" spans a period about 1.8 million years before present (yrs bp) to 10,000 yrs bp. It encompassed many different glacial events and warm and cool climates (fig. 1). It was also a period of volcanic activity in North America and along the North and South American Pacific (Levin, 1988). In Kansas, at least three large ash falls—collectively called the Pearlette ash—from volcanoes in California, New Mexico, or the Yellowstone National Park area, were deposited throughout the state.

Continent-sized ice sheets formed in different parts of the world: North America, Greenland, Eurasia, Tibet, the Himalayas, and Antarctica. Ice sheets in the polar regions and Greenland were fairly stable, but other areas, including North America, saw repeated expansion and contraction (Aber, 1988).

North American glaciation consisted of multiple "Ice Ages" which geologists recognize as the pre-Illinoian (1.8 million–302,000 yrs bp), Illinoian (302,000–132,000 yrs bp), Sangamonian (132,000–122,000 yrs bp) and Wisconsinan (122,000–10,000 yrs bp) (Richmond and Fullerton, 1986). During each "Ice Age" many smaller, regional lobes locally advanced and retreated (fig. 2). The Sangamonian was a warm interglacial period of ice retreat. The pre-Illinoian included many glacial and interglacial periods that were once subdivided into the Nebraskan, Aftonian, Kansan, and Yarmouthian Ages, but these terms are no longer recognized (Hallberg, 1986).

Figure 1. Extent of glaciation in North America (modified from Illinois State Geological Survey, 2008).

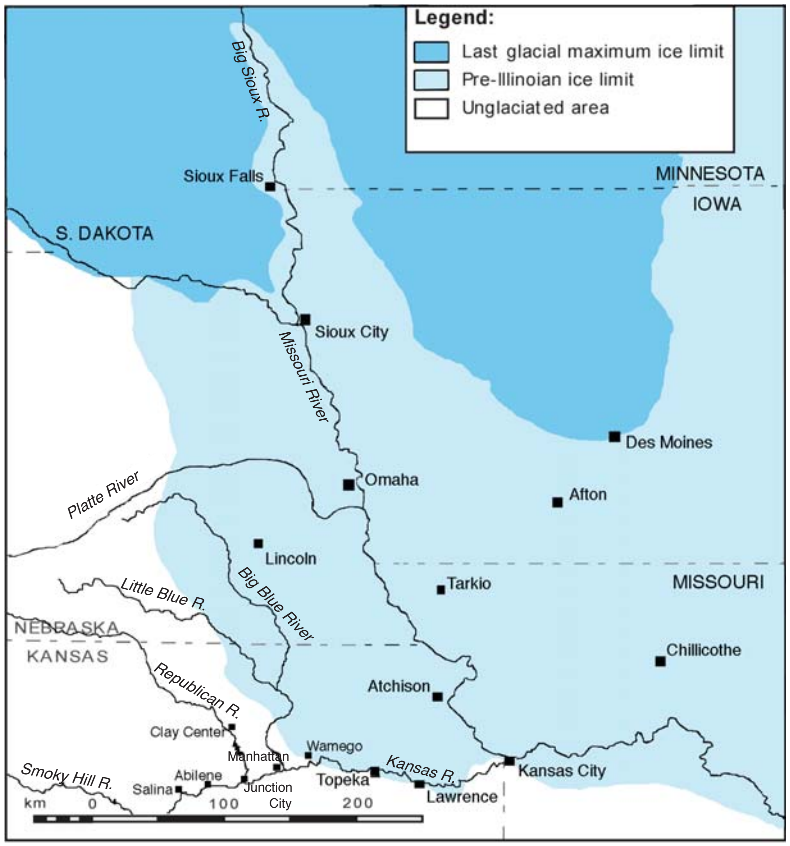

Figure 2. Maximum extent of pre-Illinoian and late Pleistocene ice sheets (after Roy et al., 2004).

At its height, pre-Illinoian ice covered over one-third of North America and extended into northeastern Kansas. In Kansas, at least two separate glacial advances took place, first from Minnesota and later from the Dakota regions (Aber, 1991). Ice lobes dammed the Ancestral Kansas River in several places and crept over the location of present-day Topeka, Lawrence, and downtown Kansas City (fig. 2).

At its maximum, Illinoian ice covered most of Illinois and did not enter Kansas. Wisconsinan ice reached as far south as Nebraska and Iowa, and glacial deposits from this period provide important clues to the Pleistocene ecology and climate.

The end of the Wisconsinan to present day is the Holocene Epoch (10,000 yrs bp to present). It has been a warm period without active glaciation. However, many geologists believe we haven't left the last "Ice Age" and simply consider the Holocene as just a short warm period before the next glacial onset.

What Caused the Glaciers?

In the last billion years, roughly three long glacial periods and the start of a fourth (our present age) have occurred. In general, the long periods last tens of millions of years and have shorter oscillating glacial and interglacial periods that last about 100,000 years (Pielou, 1991). Long glacial periods occur when continents drift toward the poles and block warm ocean currents from reaching the poles, causing a cooler average climate. Orbital variations associated with the tilt and wobble of the earth's revolution and its oval-shape path around the sun control the shorter glacial periods (Levin, 1988). This phenomenon is known as the Milankovitch effect. When orbital variances are aligned, the sun's solar radiation is concentrated in different parts of the globe. For example when most of the sun's heat reaches the northern latitudes, interglacial periods occur. This happened about 10,000 years ago and caused the North American ice sheets to melt (Pielou, 1991). Since then, the quantity of solar radiation reaching the northern latitudes has declined and the Milankovitch effect suggests that the earth is again trending towards its next glacial period, although when it will arrive is not precisely known (fig. 3).

With a glacial period approaching, it would seem that average temperatures should decrease, but this is not always the case (fig. 3). Many other factors complicate climate change, such as solar-energy fluctuation and reflection; sun spots; ocean salinity and currents; meteorological effects caused by wind patterns, cloud cover, volcanic ash and dust; and greenhouse-gas fluctuation, including carbon dioxide. All may aid or hinder the Milankovitch effect on a much smaller scale (1 to 1,000's of years). Recent ice-core research in Greenland provides insight on these varying factors. Ice cores contain air bubbles, dust, and impurities that represent atmospheric CO_2, temperature change, sea salt, and ice-accumulation rates. Research indicates that climate change can be abrupt due to either ocean (50–150 years) or atmospheric (1–3 years) circulation changes (Fluckiger, 2008).

Some scientists think abrupt climate change in the northern hemisphere starts in the tropic ocean or atmosphere, and ice-core research clearly indicates that increasing atmospheric CO_2 is a bellwether to these changes (Steffensen et al., 2008). Atmospheric CO_2 is important because it increases the greenhouse effect and because it may be linked to oceanic processes that cause climate change (Ahn and Brook, 2008). The addition of anthropogenic or human-generated greenhouse gases might unbalance what may be a relatively delicate global carbon cycle and increase the risk of abrupt climate change or exacerbate other climate effects such as sea-level rise.

Kansas Glacial Features

The initial Kansas ice front was probably only tens of feet thick and slid irregularly forward under pressure from thicker ice to the north (Dort, 2006; fig. 4). Buried wood in Atchison and Doniphan counties indicates that it likely overrode a spruce forest that grew in Kansas at the time (Aber, 1991). If a time-lapse pic-

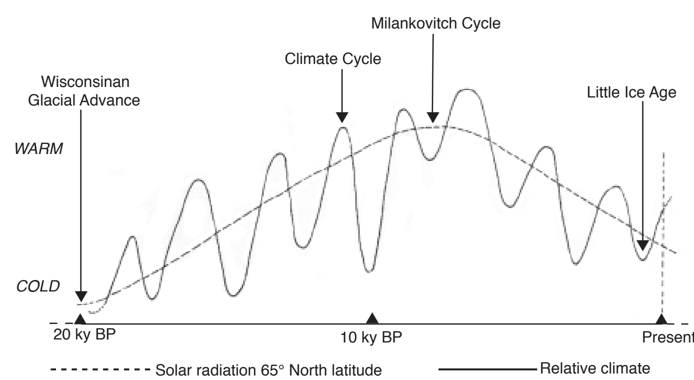

Figure 3. The graph shows a climate estimate relative to the Milankovitch cycle. One extended cold climate from 1350 to 1870 AD, called the Little Ice Age, contributed to widespread social unrest. In France, crop failure and the 1789 bread riots in part sparked the French Revolution and Marie Antoinette's beheading (modified from Pielou, 1991).

ture could record the Pleistocene Epoch some 1.8 million to 10,000 yrs bp, it would show a lurching, amoeba-like ice movement along with ecological waves of tundra, forests, and grasslands flowing across the Great Plains before the advance and retreat of the glaciers.

Advancing ice reshaped the land, forcing new stream channels and burying others. Before glaciation, the ancestral Missouri River was a lesser tributary to a larger ancestral Kansas River (Bayne et al., 1971). But advancing ice pushed the drainage from a now-buried river valley that flowed past Tarkio and Chillicothe, Missouri, into the present-day Missouri River (fig. 2). The Big and Little Blue rivers in Marshall and Pottawatomie counties probably developed as ice-margin streams or spillways to a proglacial lake near Atchison (Aber, 1991). Advancing ice also buried ancestral rivers that once flowed east through Marshall, Nemaha, Jackson, Brown, Atchison, and Doniphan counties in northeastern Kansas. Some of these valleys were more than 3 miles wide, 400 feet deep, and 75 miles long. These buried valleys are now important water sources in an area that does not have much ground water. Thus, knowing glacial history is important economically (Denne et al., 1998).

When the ice flow reached a depression such as the Kansas River, it "spilled" over the side, slowly filling the valley until it flowed over the opposite side (Dort, 2007). The ice was perhaps 300 feet (91 m) thick north of the river near Wamego and 500 feet (153 m) thick over the Kansas River valley (Dort, 2006). An ice lobe over downtown Kansas City was probably hundreds of feet thick (Gentile, 1998; fig 2).

According to Dort (2007), ice damming the Kansas River east of Wamego formed the ancestral Kaw Lake that extended at least 70 miles (112 km) west, likely reaching Salina (fig. 5). The open water dwarfed the combined size of Tuttle Creek and Milford reservoirs. What are now Manhattan, Junction City, Abilene, and Clay Center were either lakeside or inundated by Kaw Lake.

Glacial ice transports all sizes of sediment and rocks, often for hundreds of miles (fig. 4). Glacier deposits are collectively called **drift**, a European term originally used to describe deposits thought to be caused by the biblical flood (Bloom, 1991). Most glacial landforms, such as **moraines**, are largely absent in Kansas due to long periods of erosion since pre-Illinoian time.

Still, many glacial features and deposits remain in Kansas. Directional grooves carved into limestone bedrock have been mapped in Nemaha, Brown, Doniphan, Atchison, Jefferson, Leavenworth, Wyandotte, Johnson, and Shawnee counties (Aber, 1991). A thick blanket of mixed soil and rocks, which geologists call **diamicton** or **till**, covers large portions of northeastern Kansas. "Till" is Scottish for a drift deposit formed underneath glacial ice without reworking by meltwater. Drift deposits close to old ice margins, called **ice-contact stratified drift**, were carried by rushing torrents of meltwater and are composed of chaotic, wide-size-ranging sediments. Further from the ice margin are **outwash** deposits that are more evenly sorted. **Lacustrine** deposits represent old proglacial lakes that now are mostly covered by younger sediments that have since filled the valleys. Drift deposits are found in Washington, Marshall, Nemaha, Brown, Doniphan, Riley, Pottawatomie, Jackson, Atchison, Jefferson, Leavenworth, Wyandotte, Johnson, Douglas, Shawnee, and Wabaunsee counties.

Sometimes glaciers carried and dropped previously weathered rocks from different parts of the continent into Kansas. Collectively called **erratics**, the most common of these is Sioux Quartzite, a pink metamorphosed sandstone more than a billion years old. Sioux Quartzite found in Kansas came from southern Minnesota, South Dakota, and northwestern Iowa. Sometimes these rocks occur in such density that geologists describe the feature as a **felsenmeer**, German for "sea of rocks" (fig. 6).

Other more exotic erratics such as granitic rocks, Lake Superior agate, Duluth-area iron ore, Keweenawan volcanics, and native copper are occasionally found in Kansas. Isolated occurrences of **catlinite,** which sometimes occurs with Sioux Quartzite, are present in the Tower Hill area north of MacFarland. Called **pipestone** because early Native Americans valued it for carving artifacts, catlinite is a purplish-red color, ultra fine grained, and soft. Erratic assemblages help geologists better understand origin and direction of glacial movement (fig. 7). In particular, catlinite is found in a small area at Pipestone National Monument in southern Minnesota, which means ice carrying these rocks traveled almost 345 miles (552 km) straight south before settling in Kansas (Dort, 2007).

Glacial retreat exposed lake beds, and meltwater left river valleys covered with silt-sized sediments. Climate change also left large tracts of land susceptible to wind erosion (Mason et al., 2006). Strong prevailing winds off the ice sheets picked up sediments and carried them across the Great Plains. Modern winds on Greenland and Antarctica have been clocked at 97 mph (Pielou, 1991). Similar fierce winds whipped up immense sand and sediment storms that far exceeded the storms of the Dust Bowl era and blanketed the Midwest with **eolian** sand dunes and thick, fine-grained **loess**. Loess is a yellowish silt composed of tiny angular

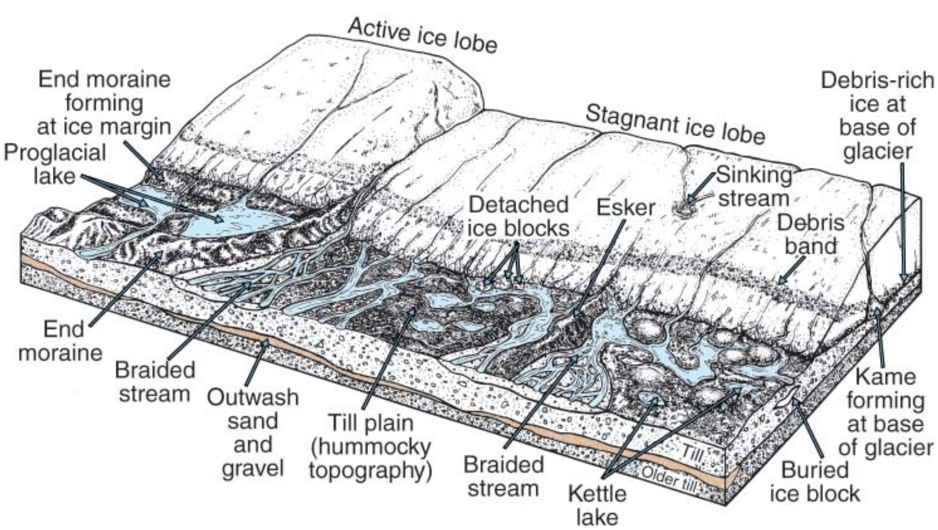

Figure 4. Continental glacier (modified from Illinois State Geological Survey, 2008).

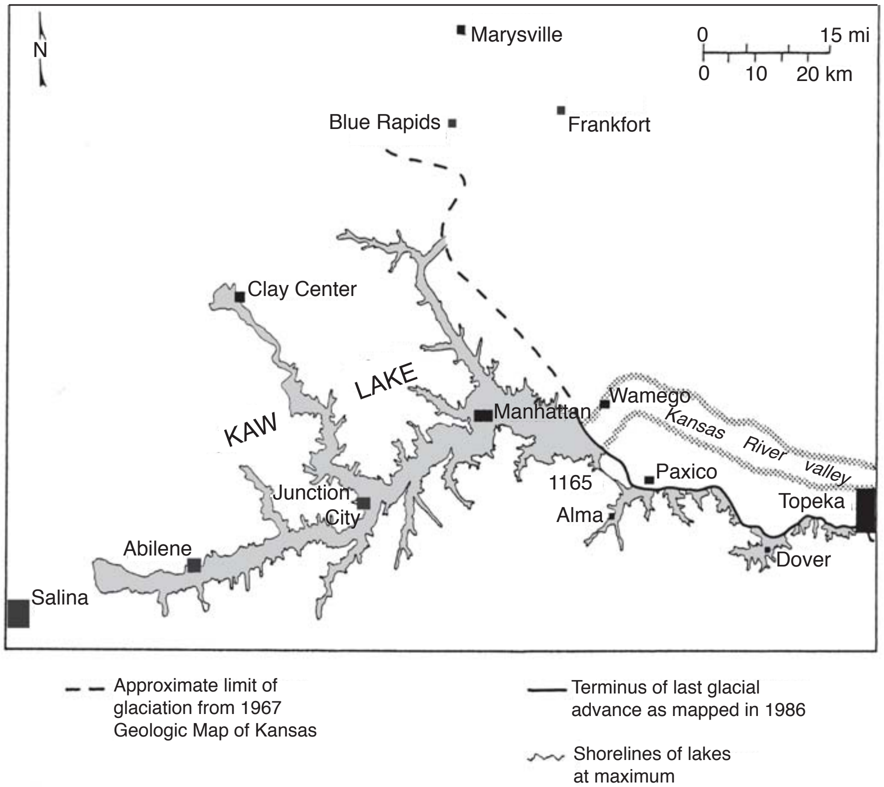

Figure 5. Proglacial lakes west of Topeka and Kaw Lake at the time of maximum ice advance. Location of Kaw Lake spillway, elevation 1,165 feet (355 m), is depicted on the figure north of Alma (Dort, 2006).

pieces of mostly quartz that are partly cemented with calcium carbonate. Due to its grain angularity and cementation, loess remains standing vertically for years in excavations and roadcuts; several examples can be seen around northeastern Kansas and the Kansas City area. Four Midwest loess units are generally recognized and one unit, the Peoria, is one of the most extensive loess deposits in the world (Mandel and Bettis, 2000; Mason et al., 2006; fig. 8). Sand dunes, likely originating from the ancestral Kaw Lake bed, are evident by the hummocky terrain on either side of I–70 west of Abilene (Dort, 2007). Stabilized dune sands also cover vast land tracts along the Arkansas and Cimarron rivers, as well as most of the land inside the “Great Bend” of the Arkansas River.

Glacial Retreat

Before leaving Kansas, pre-Illinoian ice thinned, leaving hilltops exposed like islands in a sea of ice. Ice in valleys became stagnant and isolated and persisted for centuries before finally melting away (Dort, 2007). Ice sheets returned north of Kansas during the Illinoian and Wisconsinan. Under a warming climate, the Wisconsinan ice began its terminal retreat around 20,000 yrs bp. Because ice melt lags far behind initial climate change, the ice probably did not completely melt until 6,500 yrs bp (Pielou, 1991).

Wisconsinan ice locked up much of the world’s freshwater and lowered the sea level approximately 280 to 425 feet (85–130 m). This exposed many of the submerged continental shelves for use as dryland migration routes for plants, animals, and humans into North America (Pielou, 1991; fig 1). Glacial melt returned a vast amount of freshwater to the oceans, creating a rising sea level that continues today. It is important to note that sea level does not respond solely to changes in ocean volume (**eustasy**). Local elevation changes (**isostasy**) also have an effect as continents sink or float with the addition or subtraction of overlying ice weight (Bloom, 1991). Today, some of the most rapid uplift in the world occurs in the Hudson Bay region as it continues to rebound from the last ice melt. The bay will eventually drain unless weight from new ice reverses the process (Pielou, 1991).

Pleistocene Environments

Associated with the Pleistocene glacial cycles are climate changes that altered the Great Plains landscape. As the climate shifted and ice advanced, Kansas’ **biomes**, or plant and animal communities, moved along with the glacial front. Northern plants adapted and migrated south, covering Kansas with conifer forests typically found hundreds of miles to the north. Similarly, animal species not adapted to the cold, such as armadillos, sloths, and giant tortoises, migrated north during glacial retreat (Bennett, 1983).

Ecological succession in Kansas included tundra (e.g., permafrost found in alpine and arctic areas), taiga (e.g., spruce, fir, and pine found in Canadian areas), temperate deciduous forest (e.g., four-seasonal-change hardwoods found in eastern Kansas), and grasslands (e.g., temperate and semi-arid to arid climate found in central and western Kansas).

At the onset of the Pleistocene, Kansas was much like it is today, consisting of open prairies and rippling grass (Bennett, 1983). By the height of the last glaciation, spruce, balsam poplar, and aspen trees had returned to the Midwest. Animal populations were more diverse than their living relatives today, more similar to the wide diversity of the African Serengeti. In different parts of the world, some of these animals grew to exceptional sizes. Now extinct, a Pleistocene beaver species grew to the size of a modern grizzly bear (Levin, 1988).

Archeological evidence collected from seven mammoth sites at Lovewell Reservoir in Jewell County give a glimpse of life in Kansas near the Wisconsinan glacial maximum, approximately 18,000 to

Figure 6. Sea of Sioux Quartzite erratics on ridge crest 5 miles (8 km) south of Wamego (Dort, 2006).

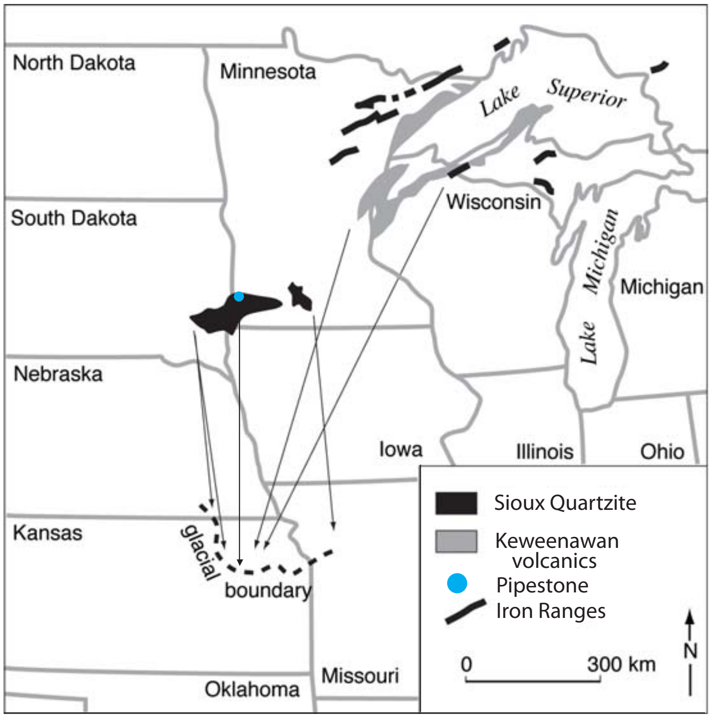

Figure 7. Sources of identifiable glacial erratics found in northeastern Kansas. Fragments of Sioux Quartzite are common throughout the terminal zone, and eastward into Missouri. Specimens of ore from the Iron Ranges are scarce. Distribution of Lake Superior agates from the Keweenawan volcanics is highly localized, seemingly restricted to an area in and near Topeka (Dort, 2006).

21,000 **radiocarbon** yrs bp. The river here probably supported lush vegetation during a relatively dry period and attracted a diversity of animals and humans. Archeological research documents mammoths, bison, camel, dire wolf, horse, llama, and sloth, as well as many smaller mammals, reptiles, and birds species still found in Kansas. Spiral-fracture patterns and "stacked" mammoth bones suggest that some of these mammoths were either killed or scavenged by humans around 20,000 radiocarbon yrs bp (Holen, 2007).

Other Kansas Pleistocene mammals, now extinct, include a giant beaver, the stag-moose, fronted musk-ox, peccaries, rhinos, and saber-toothed and dirk-toothed cats. In addition to mammoths, mastodons lived in Pleistocene forests of Kansas, eating leaves and bark in spruce swamps or pine parks. Mammoths, in contrast, were larger and specialized in eating grass and preferred comparatively open ground, especially tundra (Bennett, 1983; Pielou, 1991).

Conclusions

Imperceptively, Kansas is still in the crossroads of climate change. Glacial cycles continue and hints of the glacial past and future are still found in certain plant and animal adaptations. The honey locust tree, much like the African acacia tree which evolved thorns in defense to grazing elephants, may have developed thorns in defense of grazing mastodons and has yet to realize their absence (Barlow and Martin, 2002). Mosaic patchwork forests in eastern Kansas retain older prairie hilltops that have yet to completely transition to younger deciduous forests. And like a weather forecast, warm-climate "invasive" species have begun to migrate and take root in Kansas again. Road runners and armadillos are examples of species expanding their range north in response to the climate.

Kansas will remain on the forefront of climate debate as new studies continue to document evidence of and attempt to forecast the economic impact of climate change. Much of this debate concerns the rate at which human or anthropogenic activities, such as carbon emission or accumulation of greenhouse gases, cause climate change to accelerate. When the next ice age will arrive is not known, but attendant climate change could arrive much sooner rather than later, and human activity may affect when it does.

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Glossary

Biome—Climatically determined plant and animal community, typically characterized by a particular vegetation type that spans a large geographic region.

Catlinite—Brownish-red to black, metamorphosed mudstone that typically occurs with Sioux Quartzite. Catlinite was used by Dakota Native Americans for making tobacco pipes. Named after George Catlin, American painter of Indians.

Diamicton—Nonsorted, nonstratified glacial drift, deposited directly from ice without reworking by meltwater, sometimes called till.

Eolian—Pertaining to wind, said of such deposits as loess and dune sand.

Erratic—Rock fragment carried by glacial ice, or floating ice, deposited at some distance from the outcrop from which it was derived. Size ranges from pebble- to house-sized block.

Eustasy—Worldwide sea-level change that affects all oceans, such as the addition or removal of water from continental ice caps.

Felsenmeer—German for "sea of rocks." A block field, or masses of rock rubble on summits.

Glacial drift—Sediment and rocks transported by glaciers and deposited directly on the land or indirectly in streams, lakes, and oceans. It consists of a heterogeneous mixture of clay, silt, sand, gravel, and boulders ranging in size and shape.

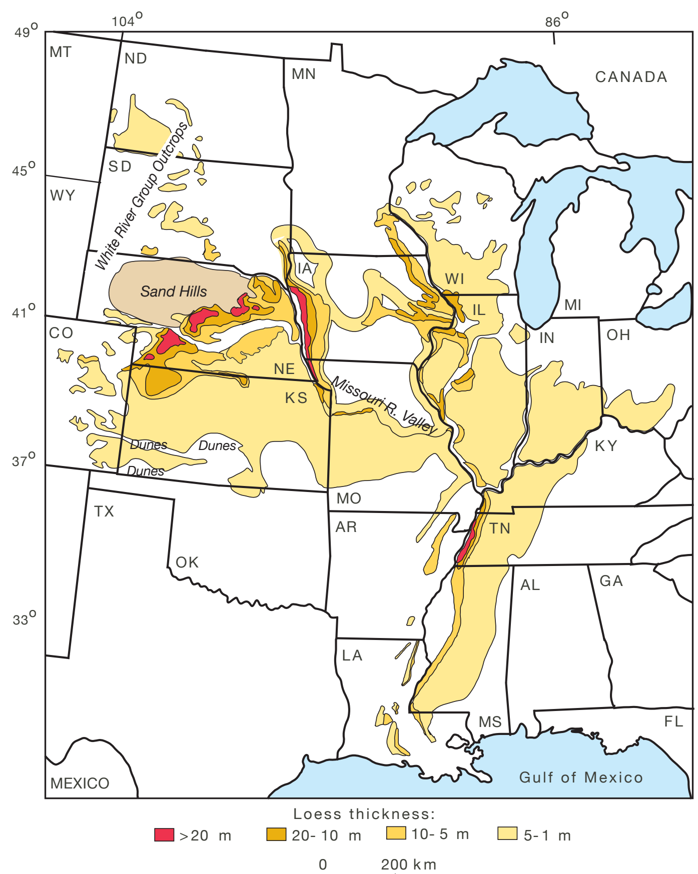

Figure 8. Map showing thickness of Peoria Loess (modified from Mason et al., 2006).

Ice-contact stratified drift—Drift modified by meltwater during or after deposition in close contact with, or close proximity to, melting ice.

Isostasy—Condition of equilibrium, or the floating balance of the earth's solid crust and upper mantle over the soft asthenosphere. Added or removed water, soil, or ice can cause an area to sink downward or float upward.

Lacustrine—Pertaining to or formed in a lake.

Loess—Windblown dust carried from deserts, outwash plains, or glaciofluvial deposits without stabilizing vegetation. Loess deposits consist of mostly fresh, angular, silica grains and may be traversed by networks of vertical tubes left from generations of grass roots. Angular grains and calcareous cement allow loess to stand in steep or nearly vertical faces.

Moraine—Mound, ridge, or landform of drift, mainly till, deposited by direct action of glacier ice.

Outwash—Alluvium deposited by meltwater not in close proximity to melting ice.

Pipestone—*See* catlinite.

Proglacial lake—Lake formed just beyond the frontal margin of an advancing or retreating glacier, generally in direct contact with the ice.

Radiocarbon years—Carbon-14 dating. Method of determining age in years by measuring the concentration of carbon-14 remaining in organic material, mostly in formerly living matter. The method assumes assimilation of radioactive carbon-14 stops upon death while decay continues, reducing the amount of carbon-14 over time. Most ages are calculated using a half-life of 5,730 yrs (+/- 40 yrs).

Till—*See* diamicton.

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The mission of the Kansas Geological Survey, operated by the University of Kansas in connection with its research and service program, is to conduct geological studies and research and to collect, correlate, preserve, and disseminate information leading to a better understanding of the geology of Kansas, with special emphasis on natural resources of economic value, water quality and quantity, and geologic hazards.

The Geology Extension program furthers the mission of the KGS by developing materials, projects, and services that communicate information about the geology of Kansas, the state's earth resources, and the products of the Kansas Geological Survey to the people of the state.

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