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Paleomagnetism of Pre-Illinoian Till Near Kansas City, Kansas

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Four till exposures in the Kansas City area were sampled and analyzed for remanent magnetism. These analyses indicate that unoxidized and unleached till has normal polarity. The primary carrier of remanent magnetism is magnetite. Normal polarity probably is recorded by detrital remanent magnetism (DRM) or post-depositional remanent magnetism (pDRM). Some of the oxidized and leached samples show evidence of alteration of magnetite and the presence of mineral phases such as hematite, goethite, and maghemite. Normal polarity of till in the Kansas City area suggests that till was deposited within the last 780,000 years. Because glacial sediments are older than terrace deposits along the Kansas River containing the Lava Creek B ash (dated at 620,000 years old), glacial deposits probably are between 780,000 and 620,000 years old. Glacial sediments in the Kansas City area are time equivalent to the Independence Formation described in northeastern Kansas.

INTRODUCTION

The present stratigraphic framework for pre-Illinoian glacial deposits in the Central Plains is based on volcanic ash chronology and paleomagnetism (Boellstorff, 1973; Hallberg, 1986). Till stratigraphically below the Yellowstone source Lava Creek B ash (~620,000 BP, Sarna-Wojcicki and Davis, 1991) has both normal and reverse polarity (Boellstorff, 1973; Easterbrook, 1983). The last major reversal in Earth's magnetic field was approximately 730,000 to 780,000 years ago (Mankinen and Dalrymple 1979; Baski and others, 1992). The Brunhes-Matuyama reversal boundary is an excellent stratigraphic marker in assigning ages to pre-Illinoian glacial deposits in central North America (Richmond and Fullerton, 1986; Hallberg, 1986).

At least two glacial advances invaded northeastern Kansas and northwestern Missouri (Frye and Leonard, 1952). Aber (1991) suggests the first advance was from the northeast and reached a position about 50 km north of Kansas City (Fig. 1). A later advance from the northwest deposited sediments as far south as the Kansas River near Kansas City. Rovey and Kean (1996) identify five tills suggesting multiple glacial advances in north-central

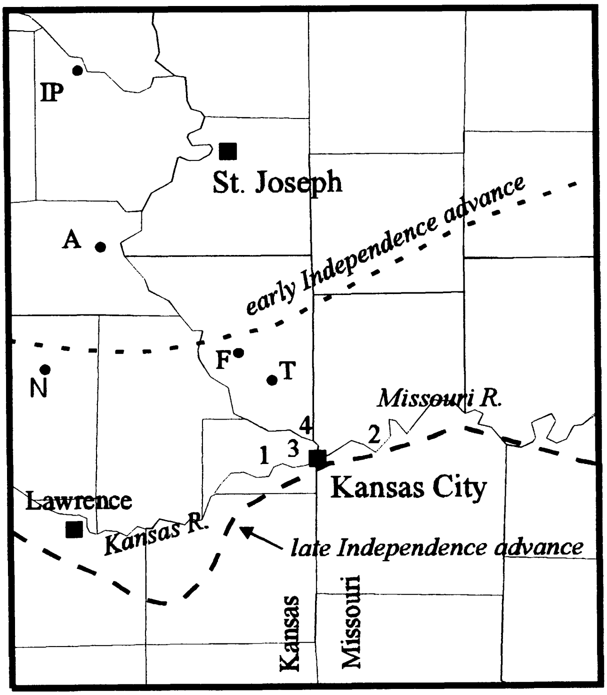

Figure 1. Location of sampling sites near Kansas City: 1. I-70 site (NW SE SW sec. 10, T11S, R24E, Shawnee, Kansas Quadrangle); 2. Nebo Hill site (NW SE sec. 23, T51N, R31E Missouri City, Missouri Quadrangle); 3. Parallel Avenue site (NE NE NE sec. 1, T11S, R24E, Parkville, Missouri Quadrangle); 4. Riverside site (NW NE SE sec. 5, T50N, R33W, Parkville, Missouri Quadrangle). Letters indicate location of important pre-Illinoian sections; IP—Iowa Point till site; A—type section of Independence Formation (Aber, 1991); N—type area for Nortonville Clay; F—type area for Ferrelview Formation; T—multiple till site near Tiffany Springs (Colgan, 1992).

Missouri. Field investigations near Kansas City provide information about the sediments in northwestern Missouri and indicate that there were at least two phases (advances) during deposition of the glacial sequence near Kansas City.

Abdelsaheb (1988) measured normal polarity in lower "Kansan" till in northeastern Kansas near Atchison and suggested that glacial sediments in northeastern Kansas were younger than the Brunhes-Matuyama reversal boundary. Till exposed in the Kansas City area is thought to be correlative or slightly younger than that in northeastern Kansas (Aber, 1991; Colgan, 1992). In order to test this correlation and determine the age of till in the Kansas City area, the paleomagnetism of till samples was analyzed to determine remanent magnetism.

Methods

Samples were taken from four sections near Kansas City (Fig. 1). Between 3 and 12 oriented samples were taken at each exposure. Seventeen samples were analyzed in total. Closely spaced samples were taken in sets of three (within 15 cm) to check for variability among samples. At each section a fresh vertical exposure was cleaned in matrix-rich till, which appeared to be undeformed and undisturbed. Most of the samples were taken from unoxidized and unleached till (40% sand, 43% silt, 17% clay, average of 12 samples) which generally occurs more than 10 m below the present land surface. Five samples were from oxidized and leached till (34% sand, 40% silt, 26% clay, average of 16 samples). These samples were taken in order to compare them to those from the unweathered till.

Samples were taken by pushing or gently tapping a polystyrene sample box (2.5 cm × 2.5 cm × 1.9 cm) into a fresh vertical face. In most instances it was possible to push the boxes into the sediment by hand, but in a few situations boxes were gently tapped in with a hammer. Easterbrook (1983) reports that shock remagnetism has not occurred in any of 300 samples he has driven with a hammer. Sediment distortion is possible, but the clear plastic holders enable identification of distorted samples that then can be discarded. After the sample holders were pushed in, their orientation was measured to the nearest 5 degrees. Vertical orientation was approximated by placing the boxes in a vertical position. Samples were then dug out, trimmed, and sealed. Some samples partially dried out prior to measurement, but shrinkage was minimal because of the low moisture content of the till.

Samples were measured at the University of Minnesota, Institute of Rock Magnetism with a three-axis ScT cryogenic magnetometer. The samples were demagnetized using a Schonstedt ASD-1 single axis alternating field demagnetizer, in steps of 2.5, 5, 7.5, 10, 15, 20, 30, 40, 60, 80, and 100 mT. The resulting remanent magnetism was remeasured after each demagnetization step.

Using standard vector equations (Butler, 1992), declination, inclination, and intensity were calculated from raw data. Best fit vectors and maximum angular deviation (MAD) values of selected components were calculated using a computer program provided by M.R. Farr of the University of Kansas. MAD values calculated with this program employ a free-line fit method in which the origin is not included in the best fit line. Best-fit vectors for a set of samples were plotted on equal area stereonets using Stereonet 4.1. Statistical analysis used Fisher distribution statistics to calculate 95% confidence cone (alpha 95), and a dispersion parameter (k).

To aid in determining magnetic mineralogy, samples were subjected to step remagnetization using an electromagnet (built at the University of Kansas) imparting an isothermal remanent magnetism (IRM). Steps for remagnetization were 10, 20, 30, 50, 100, 150, 200, 300, 500, and 820 mT. Between each remagnetization step the imparted magnetism (IRM) was measured on a Molspin Minispin spinner magnetometer at the University of Kansas. Induced magnetizations were calculated and IRM acquisition curves plotted for each sample.

RESULTS

A complete set of Zijderveld diagrams, equal area stereonets of remanence vectors, difference vectors, and intensity versus demagnetization plots for each sample is given in Colgan (1992). Figure 2 shows equal area stereonets for all samples. Figure 3 shows the IRM acquisition curves.

Samples 2910 and 2913 are from a light reddish brown, oxidized, silty sand approximately 5 meters below the surface. Both samples show two components of remanence (Fig. 2). One component is east declination and positive (north) inclination, and another is north declination and positive (north) inclination. The low-coercivity east component probably is a viscous remanent magnetism (VRM) acquired during sample storage. The high coercivity component probably is stable detrital remanent magnetism (DRM), postdepositional remanent magnetism (pDRM), or chemical remanent magnetism (CRM). The stable component for sample 2910 has a best-fit vector of positive (north) inclination of 51° and declination of 5° after demagnetization to 40 mT (Fig. 2). MAD values for this component is 6.5° [values below 10 are considered good (Butler, 1992)]. Sample 2913 shows a similar component with best-fit vector inclination of 71° and declination of 15°. MAD values for this component is 7.2°. In both samples half of the original intensity (J/J0 = 0.50) is lost near the 20 mT step (17 mT and 20 mT respectively) and the IRM plots show saturation between 100 and 200 mT (Fig. 3A). This indicates that magnetite is the primary carrier of remanence probably as high-coercivity, single-domain grains. Magnetite is abundant in tills including those with a distant provenance from Precambrian shield rocks in Minnesota and Canada (Boellstorff, 1973; Easterbrook and Boellstorff, 1984; Colgan, 1992). The normal remanent magnetism (NRM) probably is primary DRM or pDRM, although diagenic magnetite or other mineral phases contributing a secondary CRM cannot be entirely ruled out.

Samples 2917, 2921, 2922 are from a dark gray, unoxidized till at the same exposure where samples 2910 and 2913 were taken (see Fig. 1 for location). Sample 2917 was taken in till 10 meters below the surface and samples 2921 and 2922 were taken at the base of the exposure 12 meters below the surface. A single low-coercivity component is present in these samples. Best-fit vectors for this component have a generally northwest to west declination and positive (north) inclination (Fig. 2). All samples lost more than half of their original intensity (J/J0 = 0.50) by the 10 mT step (3.2 mT, 6.3 mT, and 2.6 mT respectively). This indicates that magnetite is

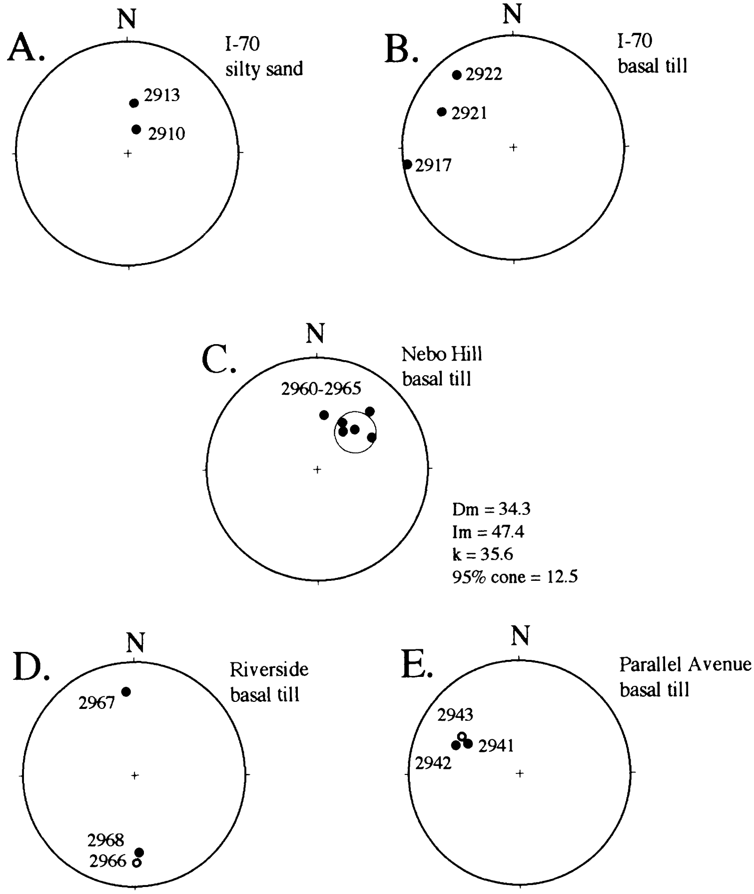

Figure 2. Equal area stereonets of best-fit vectors for samples from four sites. Dark circles indicate normal polarity and open circles reversed polarity. Most samples have stable remanence components that are north and normal. A–B. I-70 site (Fig. 1, #1); C. Nebo Hill site (Fig. 1, #2); D. Riverside site (Fig. 1, #4); E. Parallel Avenue site (Fig. 1, #3).

the primary carrier of remanence. IRM curves show saturation magnetization by the 200 mT step (Fig. 3). The slower approach to saturation by samples 2921 and 2922 may indicate that minor amounts of hematite are present (Thompson and Oldfield, 1986). Low-coercivity indicates that large, single-domain grains of magnetite are the primary carriers of remanence, perhaps as DRM or pDRM (Butler, 1992).

Samples 2960 to 2965 are from the Nebo Hill exposure, approximately 13 meters below the surface (Fig. 1). The till is dark gray (Munsell N4), unoxidized and unleached. All of these samples show a single component of remanent magnetism. Best-fit vectors show positive (north) inclinations

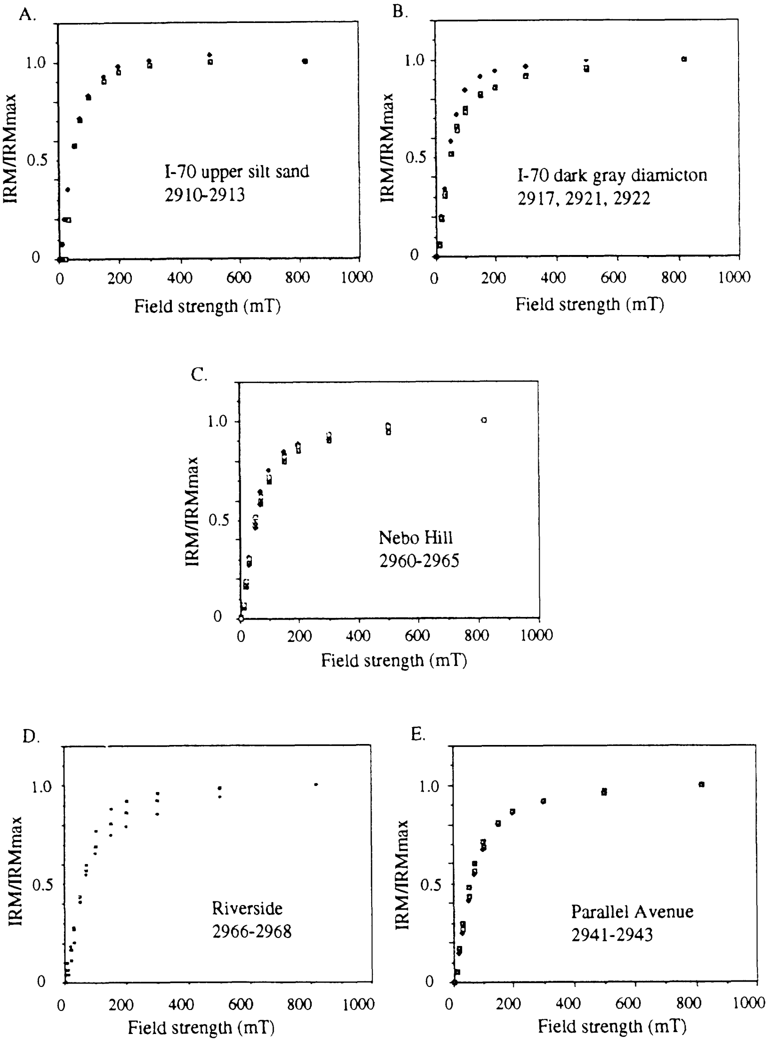

Figure 3. IRM plots for all samples. Maximum field strength was 820 mT. Samples show that most IRM is acquired by 200 mT step. This indicates that predominant magnetic mineral is magnetite. Samples that show slower approach to saturation probably include minor amounts of hematite, goethite, or maghemite.

and north to northeast declinations (Fig. 2). Sample 2960 has a high original intensity and coercivity. This sample retained 71% of its original intensity after the 100 mT step. IRM curves show a slow approach to saturation magnetization indicating that minor hematite or maghemite is present (Fig. 3). The cluster of best-fit vectors for this set of samples is reasonably good with a 95% cone of 12.5 degrees and a k value of 35.6. Low alpha 95 values and k-values above 25 are considered good (Butler, 1992). These samples are unweathered so the NRM is probably primary DRM or pDRM.

Samples 2966, 2967, and 2968 were taken from an exposure near Riverside, Missouri (Fig. 1). The till is dark gray (Munsell N4), unoxidized, and partially leached approximately 3 meters above striations (trending 150° to 155° azimuth) on bedrock and 2 meters below the surface. Samples 2967 and 2968 both have very high original intensities and show no decrease in intensity in stepwise alternating field demagnetization. Sample 2966 actually increases in intensity during demagnetization to 10 mT. IRM curves for 2966 and 2968 show saturation magnetization at 100–200 mT, whereas sample 2967 shows a slower approach to saturation. This suggests that they contain another mineral phase, such as hematite that contributes to the remanent magnetism, perhaps as CRM. Sample 2966 shows a south inclination and negative (south) declination, yet sample 2968 has a south declination and a positive (north) inclination. Sample 2967 has north declination and positive (north) inclination (Fig. 2).

Samples 2941, 2942, and 2943 are from oxidized and leached till (Fig. 1). All samples display a single component of remanent magnetism. Sample 2943 has inclination of negative (south) 40° and declination of 294° after the 10 mT step. Samples 2941 and 2943 have positive (north) inclinations of 64° and 37° respectively (Fig. 2). Declinations are to the west and northwest. These samples showed higher coercivity, losing half their original intensity between the 10 mT and 40 mT steps (13 mT, 16 mT, and 35 mT steps, respectively). IRM curves show that there is a more gradual approach towards saturation magnetization (Fig. 3). This suggests that another magnetic mineral phase besides magnetite is present. Because these samples are oxidized and leached this is to be expected. Perhaps hematite, maghemite, or geothite produced by the alteration of magnetite is present giving the samples a strong CRM component.

Discussion

The magnetic characteristics of the samples are fairly complex, indicating that the magnetic mineralogy consists of other magnetic minerals besides magnetite in at least the weathered samples. Considering the pre-Illinoian age of the samples and the degree of weathering of glacial sediments in the area this is not surprising. Demagnetization behavior and IRM analyses indicate that for the unweathered samples the primary carrier of remanence is probably magnetite. In most samples a small amount of high-coercivity mineral phase also is present. Magnetite is dominant in oxidized and leached samples, but its origin and weathering state are less certain than in unoxidized samples. Susceptibility analysis (Colgan, 1992) indicates that two different size populations of magnetite are present in the oxidized and unoxidized tills. This factor together with the presence of other magnetic minerals such as hematite, goethite, and maghemite, complicates the interpretation of the paleomagnetic results and suggest that only unoxidized and unleached tills are suited for analysis.

The unweathered samples exhibit a remanent magnetization of normal polarity (positive and north inclination) that is stable during alternating field demagnetization. Two samples (2966 and 2943) possess a reverse (negative and south inclination) remanent magnetization before and after alternating field demagnetization. One of the reversed samples (2943) is from leached and oxidized till and the other sample (2966) has magnetic characteristics suggesting hematite is present. Unoxidized and unleached samples display a stable positive (north normal) polarity that is most likely DRM or pDRM. Partially oxidized samples also display normal polarity, but this could be DRM or CRM acquired some time after deposition.

A normal remanent magnetism acquired as DRM or pDRM suggests that deposition of till occurred during a time when Earth's magnetic field was normal. The last major reversal occurred sometime between 730,000 (Mankinen and Dalrymple, 1979) and 780,000 years ago (Baski and others, 1992). Paleomagnetism alone cannot provide a date for sediments because any number of reverse or normal polarity epochs exist. The results of this study suggest that till in the Kansas City area was deposited during the Brunhes normal polarity epoch because tills in northeastern Kansas are thought to be younger than 1.0 million years because they overlie the Wathena fauna of about that age (Aber, 1991). However, the possibility also exists that till was deposited during an earlier normal polarity event between 2.1 and 0.9 million years ago.

The lower limit on the age of glacial deposits in the Kansas City area is provided by the stratigraphy of a regionally extensive bed of volcanic ash that originated in the Yellowstone area about 620,000 years ago (Sarna-Wojcicki and Davis, 1991). Glacial deposits in the Kansas City area seem to be older than alluvial terrace deposits containing the Lava Creek B ash (Dort, 1987a, 1987b; Geil, 1987). Volcanic ash exposed in an abandoned loess pit was described by Colgan (1992) near Muncie Creek just west of Kansas City (NE NW NW sec. 14, T11S, R24E, Shawnee Kansas Quadrangle). Volcanic ash is present in several other locations between Kansas City and Lawrence along the Kansas River (Geil, 1987). The ash is included in alluvial deposits that are interpreted to be post-glacial in age and stratigraphically younger than glacial sediment (Table 1). This, together with the paleomagnetic evidence, suggests that the till in the Kansas City area is between 620,000 and 780,000 years old.

Conclusions

Pre-Illinoian till samples from exposures near Kansas City exhibit remanent magnetism of normal polarity and were most likely deposited during the Brunhes epoch. Magnetite is the primary carrier of remanent magnetism

Table 1. Stratigraphy of unconsolidated deposits in northeastern Kansas and in Missouri.

Lithostratigraphy Kansas	Missouri	Chronology	Age
unnamed	unnamed	Holocene	< 10 ka
Bignell Loess	Bignell Loess	late Wisconsin	12–10 ka
Peoria Loess	Peoria Loess	late Wisconsin	25–12 ka
Gilman Canyon Loess	Roxana Silt	Wisconsin	?
Sangamon Geosol	Sangamon Geosol	last interglacial	?
Loveland Loess	Loveland Loess	Illinoian	?
paleosol	paleosol	pre-Illinoian	?
Lava Creek B ash	Lava Creek B ash	pre-Illinoian	620 ka
Nortonville Clay[1]	Ferrelview Fm.[2]	pre-Illinoian	780–620 ka
Independence Till[3]	McCredie Fm.[4]	pre-Illinoian	780–620 ka
Geary School Till?	Moberly Fm.[5]	pre-Illinoian	> 780,000 ka
	Atlanta Fm.[6]		

[1] Frye and Leonard (1952)
[2] Howe and Heim (1968)
[3] includes all pre-Illinoian in northeastern Kansas including Iowa Point Till (Aber, 1991)
[4] Guccione (1983)
[5] Rovey and Kean (1996)

probably as DRM or pDRM. Because till is older than alluvial terrace deposits that contain the Lava Creek B ash, it is probably between 620,000 and 780,000 years old.

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