AN ABSTRACT OF THE THESIS OF

Ibrahim Z. Abdelsaheb for the Master of Science Degree in Physical Science presented on April 18, 1988.

Title: TILL PALEOMAGNETISM IN NORTHEASTERN KANSAS

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Recent chronometric studies of Early Pleistocene deposits in the plains of central North America have resulted in considerable revision of the presently used terms for the North American Pleistocene stages. Modern investigations have suggested these terms need to be either redefined and given suitable stratotypes or abandoned.

Paleomagnetic studies have not previously been conducted on tills in northeastern Kansas to verify their age. During the fall of 1987, 51 samples of Lower Kansas Till were used for this study. Thirty-five samples were surface samples from the Kansas Drift stratotype in Atchison County; another 16 were subsurface samples from test-drilling sites in Nemaha County, Kansas.

The natural remnant magnetism for all samples was

measured on a "Molspin" spinner magnetometer. Samples were subjected to alternating field (a.f.) demagnetization at 15, 50, and 100 Oersteds. The data were analyzed using the microcomputer program PALMAG. The output included the declination and inclination before and after each a.f. demagnetization step, plus the intensity for each sample.

Paleomagnetic data show that the Lower Kansas Till has stable primary remnant magnetism with normal polarity, except where obvious structural deformation is present. The normal polarity of the Lower Kansas Till restricts its age to the Brunhes Epoch, which began about 700,000 years ago. Consequently, age of the Kansas Drift is between 600,000 and 700,000 years old. In addition, as the Lower Kansas Till shows a positive polarity, the Fremont Till at Cedar Bluffs, Nebraska, which also has a positive polarity, should be of Kansan age. The Nebraskan Till which has reversed polarity, is not present in northeastern Kansas.

TILL PALEOMAGNETISM IN NORTHEASTERN KANSAS

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By

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Chapter 1. INTRODUCTION

The Kansan glaciation is regarded as an important episode of Early Pleistocene continental glaciation. It was the most extensive ice coverage to ever take place on the plains of central North America (fig. 1).

A suitable stratotype for the Kansas Drift is a series of long-studied exposures found immediately west of the City of Atchison, Kansas (fig. 2), on the southern side of White Clay Creek in sections 2, 10, and 11, T6S, R20E (Aber 1985).

Schoewe (1938:227) was the first who described these exposures; he stated that:

> ... two distinct tills are present. The lower till is a typical unaltered or fresh, dark gray to blue, compact boulder clay, as much as 20 feet thick. Its upper surface is irregular. The upper till, from 10 to 15 feet thick, is separated from the lower one by 50 feet or more of stratified sand. This till, in contrast to the lower one, is brown in color, and is very stony ... Whether this first drift is to be correlated with the Nebraskan glacier, or whether it represents the first of two advances of the Kansan ice sheet, must remain unsettled until further studies are made.

Recent chronometric studies by Boellstorff (1978) of Early Pleistocene deposits in Nebraska, Iowa, South Dakota and Minnesota have resulted in considerable revision of the classical Nebraskan, Aftonian, and Kansan stratigraphic succession.

According to Boellstorff (1978) , the conceptual applications of terms to the North American Pleistocene stages by different geologists has resulted in most of the terms having overlapping time spans. In addition, the classic North American Pleistocene stages as defined in their type areas, represent less than the last half of Pleistocene

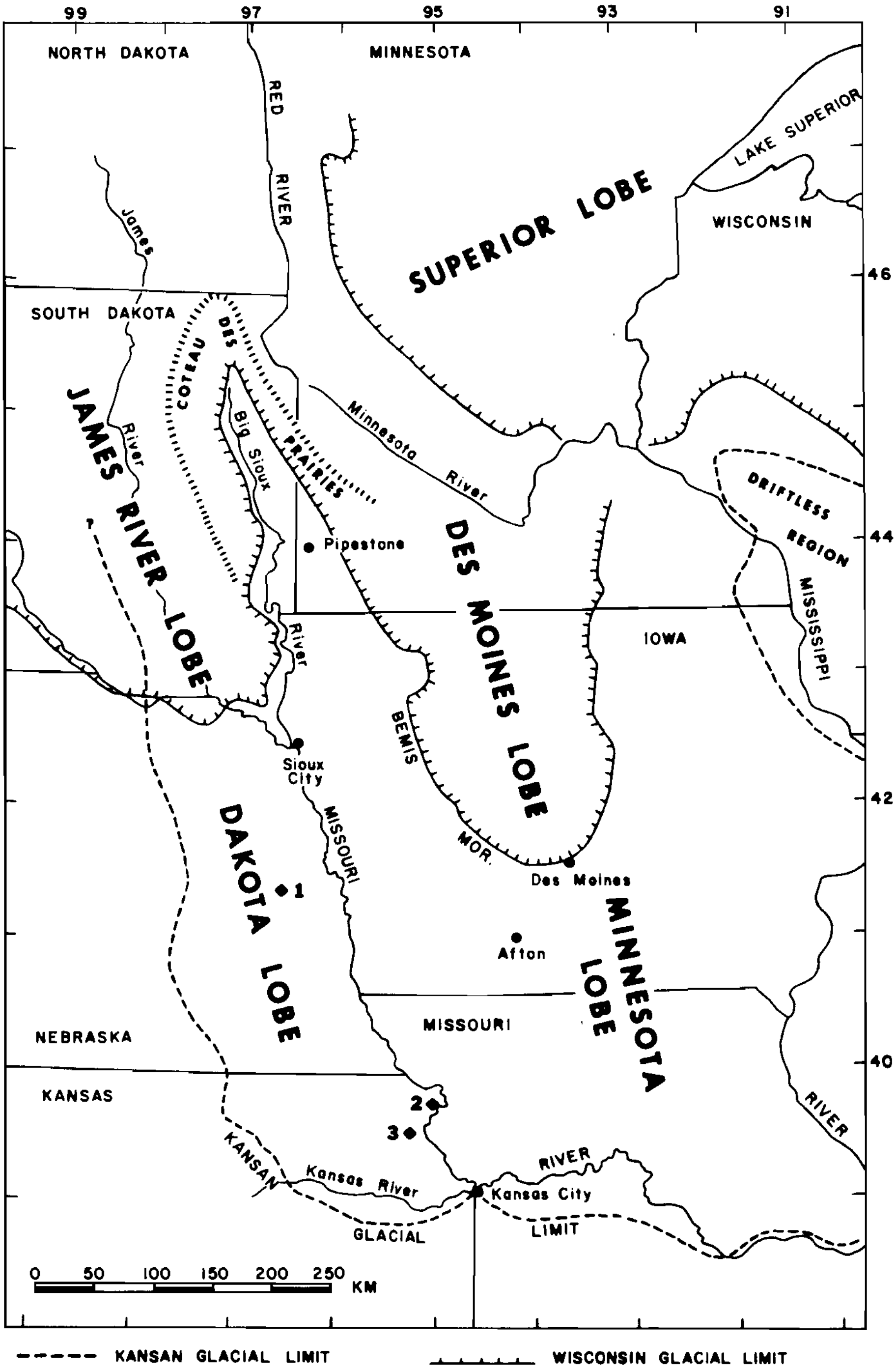


Figure 1. Map showing maximum extent of Wisconsin and Kansan glacial ice lobes. Numbered locations are: 1 = Cedar Bluffs site, 2 = Wathena site, 3 = Kansas Drift stratotype. Modified from Aber (1982, fig. 1).

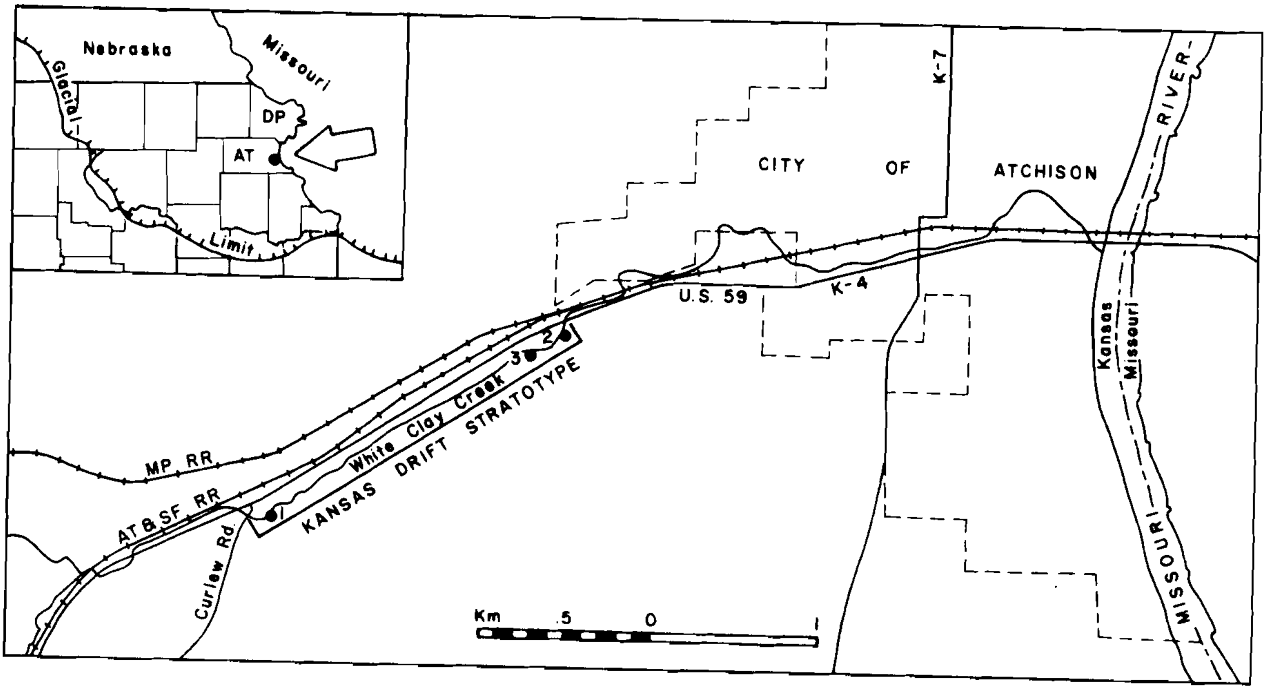


Figure 2. Map showing location of Kansas Drift Stratotype along White Clay Creek west of the City of Atchison, Kansas. Numbered locations are: 1 = Atchison No. 1, 2 = Atchison No. 2, 3 = type section of Atchison Formation. Inset map shows counties and glacial limit in northeastern Kansas; AT = Atchison County, DP = Doniphan County. Taken from Aber (1988, fig. 1).

time, which began about 2.5 million years ago. Consequently, terms that are presently used for North American Pleistocene stages need to be either redefined and given suitable stratotypes or abandoned (Easterbrook and Boellstorff 1981).

Chronometric studies of Easterbrook and Boellstorf (1981) and new field observations of Aber (1985) have shown that the regional stratigraphy for the Kansas Drift is complex. However, Paleomagnetic studies have not previously been conducted on tills in northeastern Kansas to verify their age and correlation with glacial deposits to the north. With this study of Kansas Drift paleomagnetism, a potential new source of information is demonstrated for the correlation of surface and subsurface glacial stratigraphy and verification of age. Overall our knowledge of glacial geology in northeastern Kansas should improve.

Chapter 2. PREVIOUS WORK

Based on comparison of volcanic ash chronology, physical stratigraphy, and composition of glacial tills in Nebraska, Iowa, South Dakota and Minnesota, Boellstorff (1978) concluded that the classical Nebraskan-Aftonian-Kansasn sequence could be grouped into three sets of tills. They are labeled "type A, B and C" (fig.3). He recognized four "type A" tills, a "type B" till, and two "type C" tills, many of which are interbedded with volcanic ash suitable for fission track dating.

These early Pleistocene tills retain stable remnant magnetism which provides a previously unused basis for direct correlation of glacial deposits (Easterbrook and Boellstorff 1981). More than 500 samples were subjected to alternating field demagnetization at 50, 100, 150, 200, 300, 400, and 600 Oersteds. Remnant magnetism of these 500 samples of tills, silt and clay was measured. Twenty-three locations in Nebraska, Iowa and South Dakota were used as sits for core drilling samples. Among the samples analyzed were: the type locality of the Nebraskan Till at Hummel Park, Nebraska; the "Kansan-Aftonian-Nebraskan" stratigraphic sections near Afton, Iowa; and the type localities of the Elk Creek, Nickerson, Cedar Bluffs, Clarkson, Santee and Hartington Tills in eastern Nebraska.

According to Easterbrook and Boellstorff (1981), the Nebraskan Till is between 0.7 and 1.2 million years old and is reversely magnetized (fig. 4), which places it within the

	Till A1	"Kansan Till"
600,000 yrs		Pearlette Ash /restricted/
700,000 yrs		Hartford Ash
	Till A2	Cedar Bluffs Till
	Till A3	Nickerson, Santee, Hartington
	Till A4	Type Nebraskan Till
	Till B	Unnamed till
1.2 m.y.		Coleridge Ash
2.2 m.y.		Ash
	Till C1	Elk Creek Till /upper/
	Till C2	Elk Creek Till /lower/

Figure 3. Stratigraphy and age of Early Pleistocene glacial deposits in Nebraska, Iowa, and South Dakota. Taken from Easterbrook and Boellstorff (1981, fig. 1).

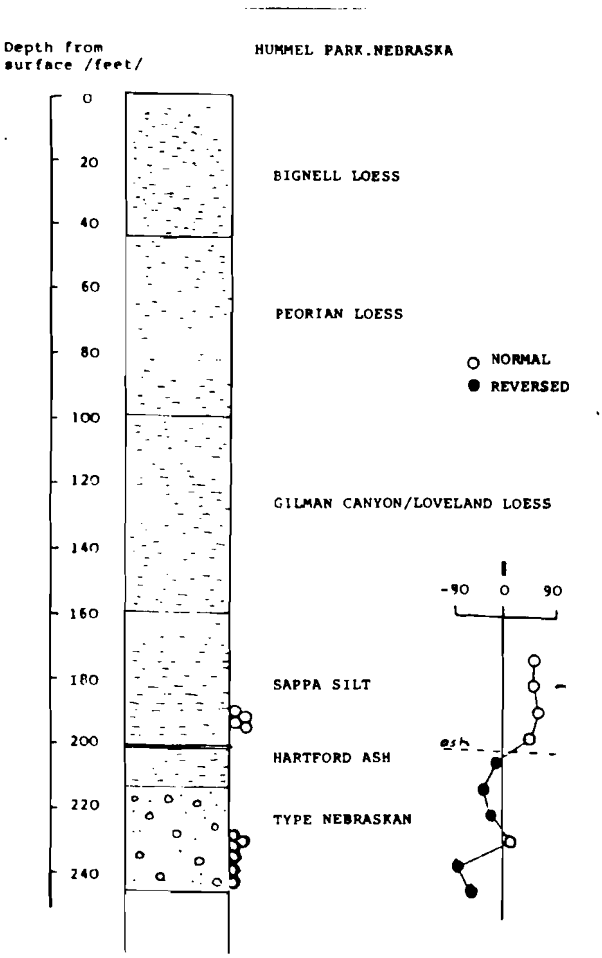


Figure 4. Paleomagnetism of Nebraskan Till type section in Hummel Park, Nebraska. Taken from Easterbrook and Boellstorff (1981, fig. 2).

Matuyama Reversed Epoch. All tills overlying the Nebraskan Till are younger and have normal polarity.

The Nickerson Till at Cedar Bluffs, Nebraska (fig. 5), was considered by Easterbrook and Boellstroff (1981) as a single till unit with normal polarity, placing it in the Brunhes Normal Epoch less than 700,000 years old. Close study of the Nickerson Till at Cedar Bluffs, shows that it is actually composed of two till units, different in color and lithology. These tills are the Nickerson Till and the Fremont Till (fig. 6).

The Fremont Till has been correlated with the Lower Kansas Till at Atchison and Wathena, Kansas (Aber and Wayne 1986). These two tills seem to have the same color, lithology, and wood inclusions. The Fremont Till has also been correlated with the type Nebraskan Till (Wayne 1987). Aber and Wayne (1986) proposed that all these tills and related drift be classified in a long, complex Kansan Stage of 0.6 to 1.0 million years age and corresponding to oxygen-isotope stages 16-22. They demoted the Nebraskan to become first substage of the Kansan.

Magnetic susceptibility of tills has been investigated in several other places, for example the tills of southern Ontario, Canada (Gravenor and Stupavsky 1974). The results indicated that the remnant magnetism of tills provides a rapid and accurate technique for the identification of the source area of tills and for the verification of their age.

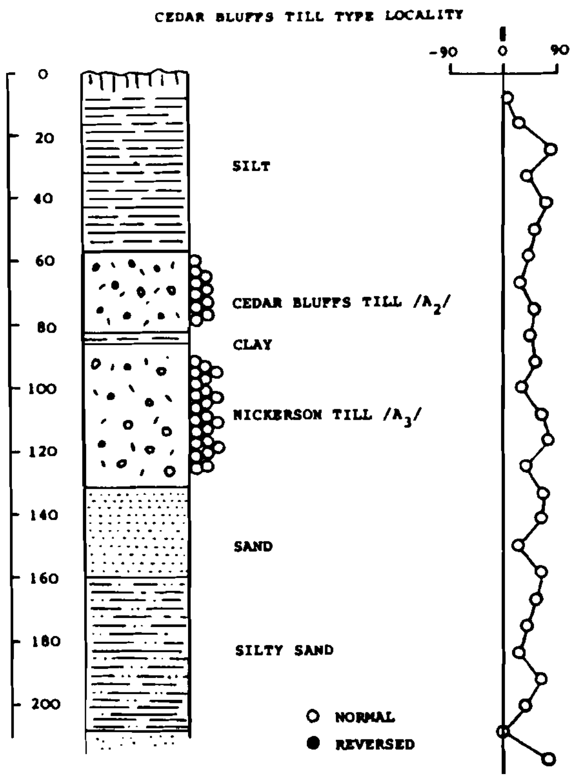


Figure 5. Paleomagnetism of Cedar Bluffs Till type section, including Nickerson Till, at Cedar Bluffs, Nebraska. Taken from Easterbrook and Boellstorff (1981, fig. 7).

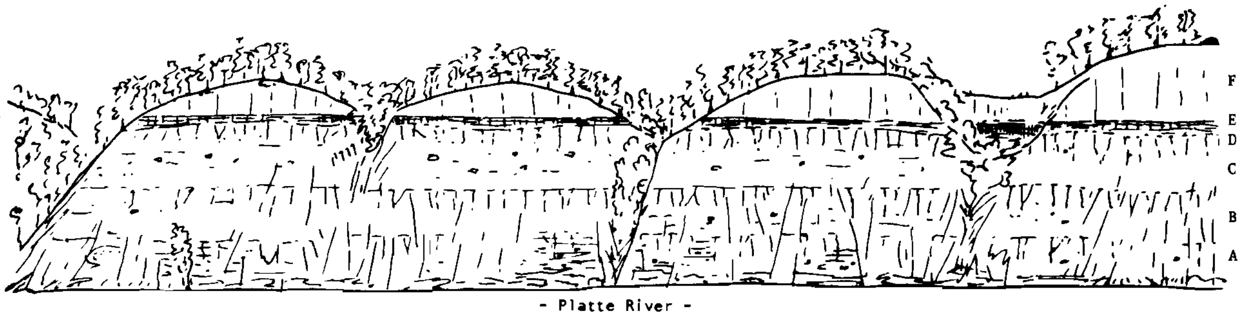


Figure 6. Sketch of Cedar Bluffs section near Fremont, as seen from northern side of Platte River in Hormel Park, Nebraska. Bluff is approximately 40 m high: A = Fremont Till (Nebraskan), B = Nickerson Till, C = Cedar Bluffs Till, D = Yarmouth/Sangamon Soil, E = Gilman Canyon Loess Bed, F = Peoria Loess. Taken from Wayne (1987, fig. 4); see Fig. 1 for location.

Chapter 3. METHODS

Field Work:

Two pebbly-clay tills separated by sand and displaying several kinds of ice-pushed structures are exposed in the stratotype section (fig. 7). The upper till is moderate to dark yellowish brown, and the lower is medium dark gray. The intervening Atchison Formation is a fine rippled sand containing scattered lenses of pebbly coarse sand.

The Atchison Formation is intruded by large diapirs of the lower gray till. The main diapir is a wedge-shaped body trending NW-SE, pushed from the northeast. A second smaller, but similar diapir is present to the southwest. The right side of the main diapir branches upward into an irregular till dike . Several minor folds or low-angle faults are displayed in the heads of the two diapirs.

The surface samples were collected in the fall of 1987 from seven locations along this section (A-G, fig. 7). A total of 35 oriented samples of Lower Kansas Till, five samples per location, were collected. Sites A and B are about 15 m northeast of the area where till starts showing signs of deformation. Sites C and D show signs of deformation within the lower part of the main diapir. Sites E and F are located in the area between the main and smaller diapirs. This part of the section has been affected slightly by deformation. Site G is at the head of the main diapir, where strong till disturbance is obvious.

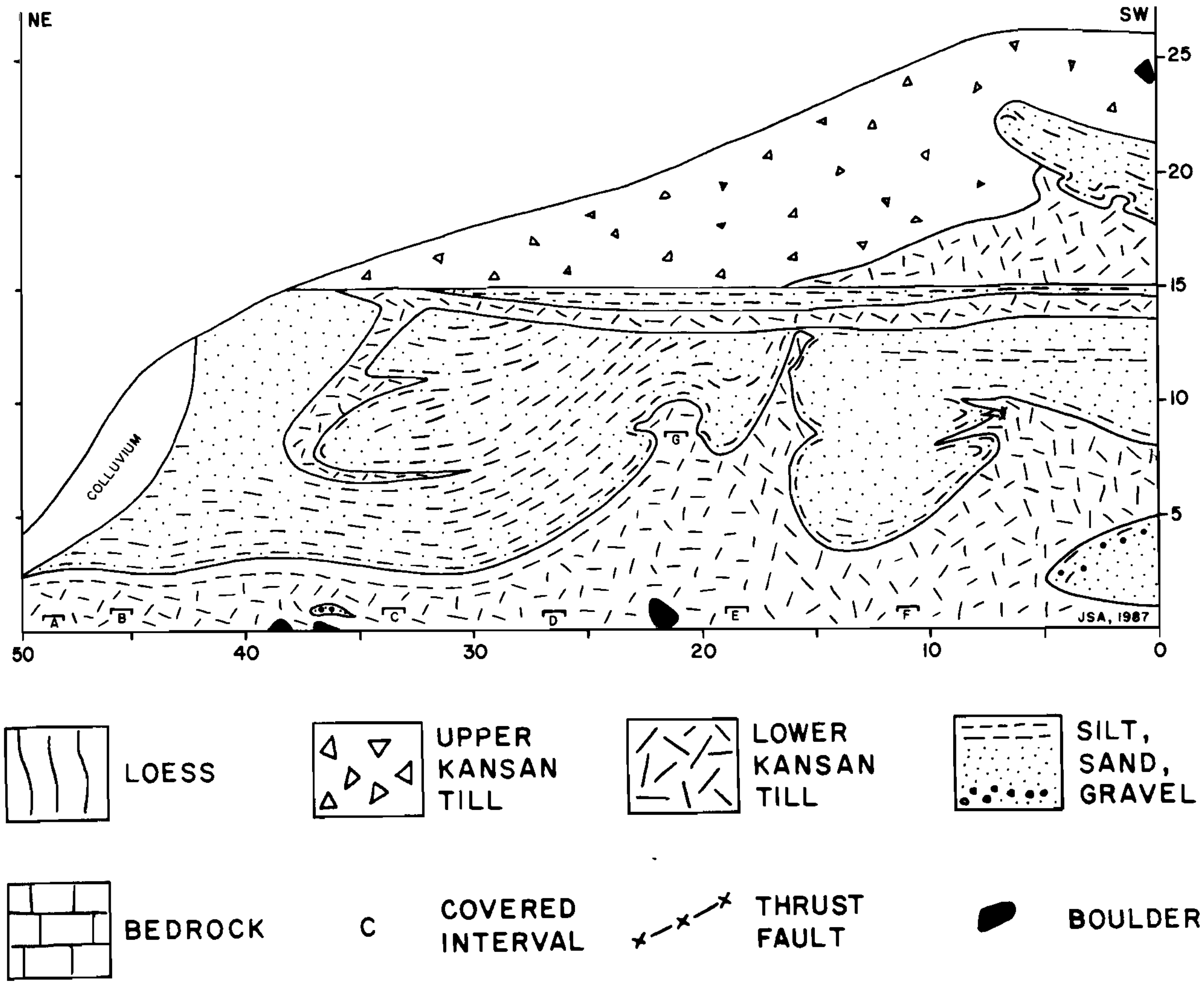


Figure 7. Measured section of Kansas Drift in Sec. 10, T6S, R20E as it appeared in fall, 1987. Lower Kansas Till (bottom) is separated from Upper Kansas Till (top) by Atchison Formation sand (middle). 35 samples were collected, five each from sites A, B, C, D, E, F, and G. Section measured in m; for location see site 1 (fig. 2).

Horizontal flat surfaces were made within the bluff to cut out oriented samples. Samples were collected using clear plastic tubes (fig. 8). A line was drawn on each tube to show compass orientation. Each tube was labelled and coated inside with petroleum jelly to faciliate an easy penetration. To avoid any disturbance of the till's magnetic fabric, tubes were pushed in a vertical position slowly into the till using a wooden plate.

Subsurface samples were provided by the Kansas Geological Survey. These samples were from test-drilling sites within a large buried valley in Nemaha County, Kansas (fig. 9). Samples 36, 38, 39, 40, 42, 43, 44, 50, 51, and 52 are from NM10 (4S-12e-34 BCD; Corning). Samples 45, 46, 47, 48, 53, and 54 are from NM9 (4S-12E-21 AAB; Corning).

Samples 39, 40, 42, 43, and 44 were collected at a depth between 16.5-16.7 m. Samples 53 and 54 were collected from a depth between 22-22.4 m. Samples 45, 46, 47, and 48 were from a depth between 40.2-40.5 m. Samples 50, 51, and 52 were from a depth between 50.7-51 m. And samples 36 and 38 were collected at a depth between 71.3-71.6 m.

Subsurface samples were collected from vertical drill cores by using plastic tubes in a manner similar to obtaining the surface samples. Tubes were labelled and coated the same way as for surface samples. However, the compass orientation of samples was unknown, as the cores had undoubtedly rotated during test drilling.

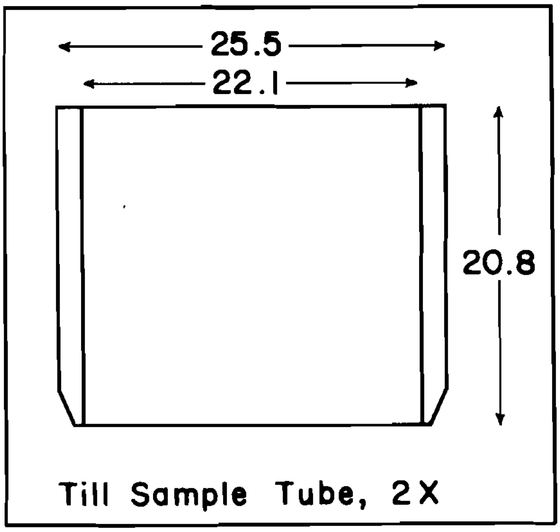


Figure 8. Longitudinal-section diagram of plastic sample tube showing internal and external dimensions in mm. Size of tube was designed to be compatible with laboratory equipment.

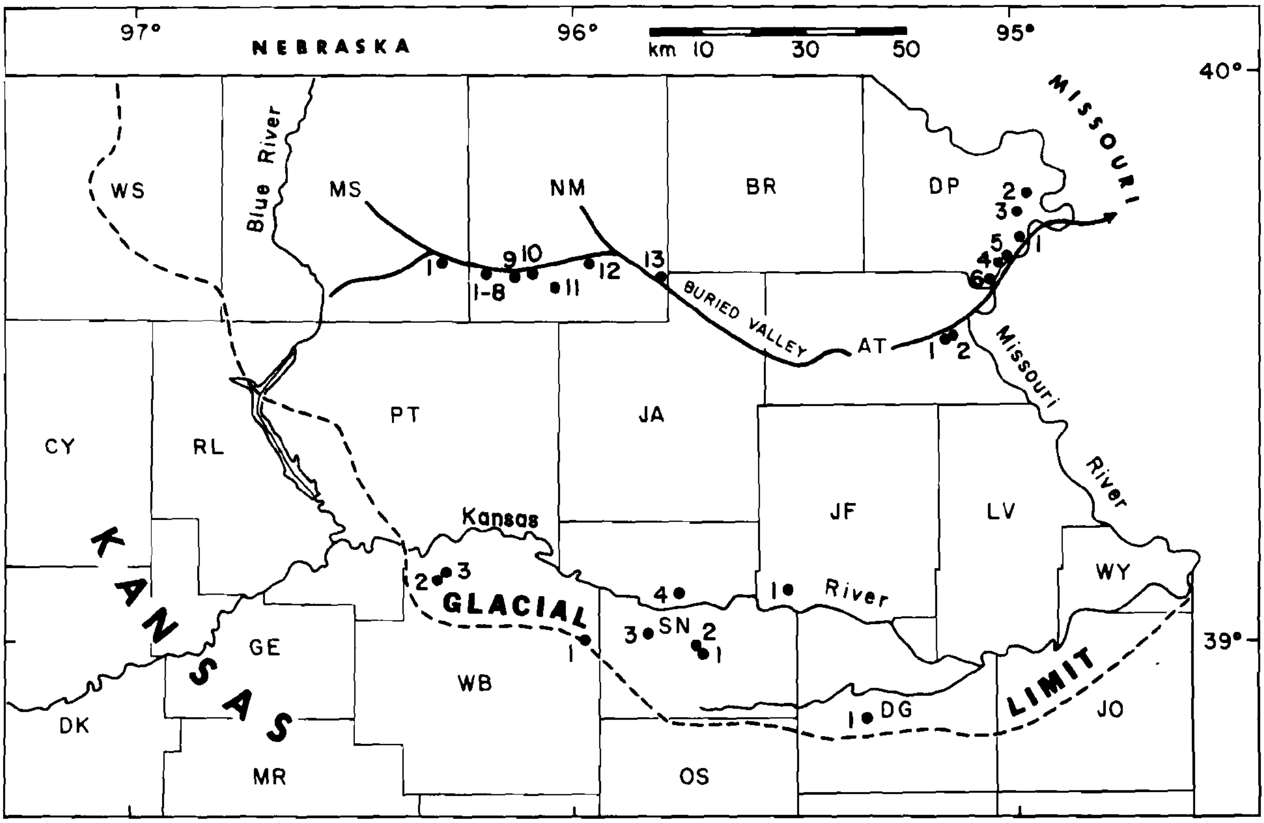


Figure 9. Map showing sites where surface and subsurface samples were collected. Surface sample site: AT1 = Atchison site. Subsurface sample locations are: NM9 and NM10 in Nemaha County, Kansas.

Lab Work:

A total of 51 oriented samples were taken to the Paleomagnetic Laboratory, Department of Geological Sciences, State University of New York at Binghamton to measure their natural remnant magnetism (NRM).

The NRM of each sample was measured on a "Molspin" spinner magnetometer. The usual procedure for NRM measurements is to spin each sample in six mutually orthogonal orientations (fig. 10). Each sample went through an alternating field (a.f.) demagnetization with step increments of 15, 50, and 100 Oersteds, and sample remnant magnetism was measured after each demagnetization step.

Data were input into a microcomputer program (PALMAG). The output included the declination and inclination before and after each a.f. demagnetization step plus intensity for each sample (Table 1).

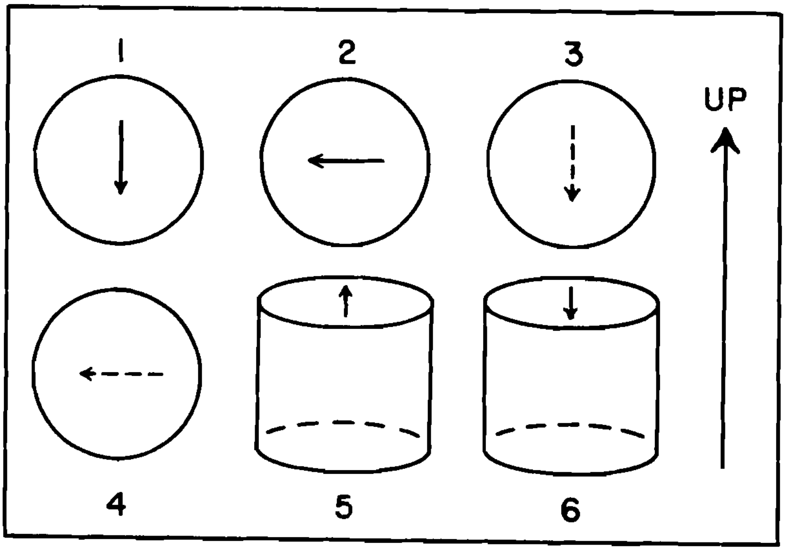


Figure 10. Examples of six-spin sample orientations for spinner magnetometer measurements. A side view of samples as they spin about a vertical axis (up arrow). The small arrow represents the compass orientation on sample top. Based on Collinson (1983, fig. 9.22).

Table 1. Summary of remnant magnetism data. D = declination in compass degrees; I = inclination in degrees; Intens. = intensity in millitesla. Demagnetization in Oersteds.

	Demagnetization			
	0	15	50	100
Sample #	D/I Intens.	D/I Intens.	D/I Intens.	D/I Intens.
1	224/22.4 0.001	225/26.2 0.700	221/27.5 0.950	182/.17 1.020
2	223/24.5 0.001	212/67.8 0.000	239/76.6 0.001	216/73.1 0.950
3	96/-26 0.350	*138/26 0.140	122/50 0.500	148/8 0.500
4	249/41 0.400	276/83 0.000	219/70 1.160	203/65 1.100
5	219/20 0.001	*210/23 0.001	207/28 0.001	197/28 0.001
6	323/60 0.400	8/77 0.300	26/63 0.500	25/80 0.400
7	41/11 0.500	49/33 0.200	55/63 0.200	56/30 0.300
8	296/58 0.600	48/77 0.000	45/79 1.500	27/38 0.870
9	335/1.1 0.500	345/1.6 0.100	8/15 0.500	15/31 0.500
10	240/18 0.200	235/45 0.100	238/47 0.100	168/31 0.100
11	358/40 0.620	12/48 0.400	336/82 0.400	256/15 0.200
12	128/-9 0.130	135/5 0.700	152/-3 0.800	77/-13 0.750

* a.f. demagnetization of 35 Oersteds.

Table 1. (cont.)

13	138/-22 0.880	134/15 0.400	124/3 0.900	126/-5 0.950
14	163/-35 1.100	184/-2 0.900	181/-9 0.140	176/-10 0.200
15	342/68 0.250	12/70 0.200	225/80 0.220	5/78 0.900
16	218/-50 0.900	216/-3 0.400	192/-40 0.250	194/-54 0.900
17	138/-.4 0.003	132/16 0.002	120/-12 0.003	103/18 0.003
18	93/53 0.130	174/83 0.130	152/50 0.002	89/-10 0.140
19	221/43 0.500	280/50 1.100	94/73 1.100	359/52 1.100
20	95/-3 0.002	89/24 0.002	102/.3 0.002	103/.7 0.002
21	342/-40 0.002	256/6.2 0.008	248/-11 0.012	238/-21 0.002
22	195/-25 0.002	192/14 0.600	123/-7 1.100	192/-8 1.100
23	104/48 0.400	108/40 1.200	136/30 0.750	142/20 0.750
24	82/33 1.000	160/23 0.000	166/20 1.060	172/3 1.100
25	40/61 0.800	60/64 0.400	26/72 1.200	28/72 1.070
26	138/76 0.000	134/81 0.000	80/85 1.100	331/71 0.700
27	312/61 0.400	321/61 0.300	313/56 0.003	311/75 0.005
28	159/20 0.900	159/6 0.001	167/8 0.005	298/-11 0.004
29	37/39 0.001	25/30 0.800	14/40 0.600	357/52 0.500

Table 1. (cont.)

30	345/60 1.030	336/61 0.001	340/51 0.001	324/33 0.600
31	101/52 0.800	120/-34 0.005	107/.7 0.003	104/17 0.002
32	104/-31 0.002	72/-15 0.002	93/-32 0.006	84/-33 0.006
33	108/-15 0.001	112/3.4 0.003	111/6 0.003	113/5 0.002
34	55/77 0.001	45/73 0.002	22/73 0.002	19/70 0.002
35	96/11 1.100	314/-1 0.006	190/-16 0.006	87/71 0.006
36	*/75 0.300	*/62 0.002	*/65 0.002	*/58 0.001
38	*/69 0.000	*/38 0.800	*/55 0.500	*/31 0.700
39	*/22 0.003	*/34 0.300	*/34 0.700	*/14 0.620
40	*/80 0.003	*/-86 0.500	*/43 1.000	*/78 0.600
42	*/-30 0.500	*/70 0.200	*/70 0.900	*/56 0.400
43	*/52 1.100	*/30 0.200	*/50 1.200	*/-34 0.800
44	*/79 0.000	*/70 0.200	*/71 0.350	*/70 0.300
45	*/67 0.900	*/51 1.000	*/56 0.003	*/55 0.001
46	*/84 0.400	*/69 0.001	*/76 0.002	*/78 0.001
47	*/67 0.440	*/70 0.003	*/61 0.002	*/61 0.002

Table 1. (cont.)

48	*/73 0.001	*/66 0.001	*/51 0.002	*/60 1.200
50	*/63 0.003	*/47 0.003	*/22 0.006	*/37 0.003
51	*/66 0.003	*/68 0.003	*/58 0.004	*/56 0.003
52	*/76 0.003	*/74 0.003	*/64 0.000	*/-75 0.005
53	*/84 0.600	*/85 1.000	*/72 0.920	*/69 0.700
54	*/88 0.200	*/75 0.300	*/85 0.300	*/79 0.200

* no declination is reported for core-drilling samples: 34-54.

Chapter 4. RESULTS

Surface Samples:

Computed values for declinations and inclinations for the surface samples are presented in Table 1. Stereographic projections of declination and inclination for each sample before demagnetization and after 100 Oersteds demagnetization were plotted (fig. 11).

The variation in inclinations for samples at site A (fig. 11A) exhibits a consistent pattern. All of the samples have a normal polarity after demagnetization, most with southwestern declination. Sample 3 shows a reversed polarity before demagnetization, but a normal southeastern polarity after demagnetization. This is due to a secondary magnetism. The consistency of sample remnant magnetism at site A is related to the slight amount of deformation visible in this part of the section.

Variations in remnant magnetism for samples at site B are shown in Figure 11B. All samples have a normal polarity before and after demagnetization, even though the samples show some scatter in orientation. Most declinations are in the northeast quadrant and most inclinations are at intermediate angles. This corresponds roughly to the modern magnetic field in northeastern Kansas, where declination is approximately 07 degrees and inclination is about +60 degrees. This site might be considered as having minimum deformation.

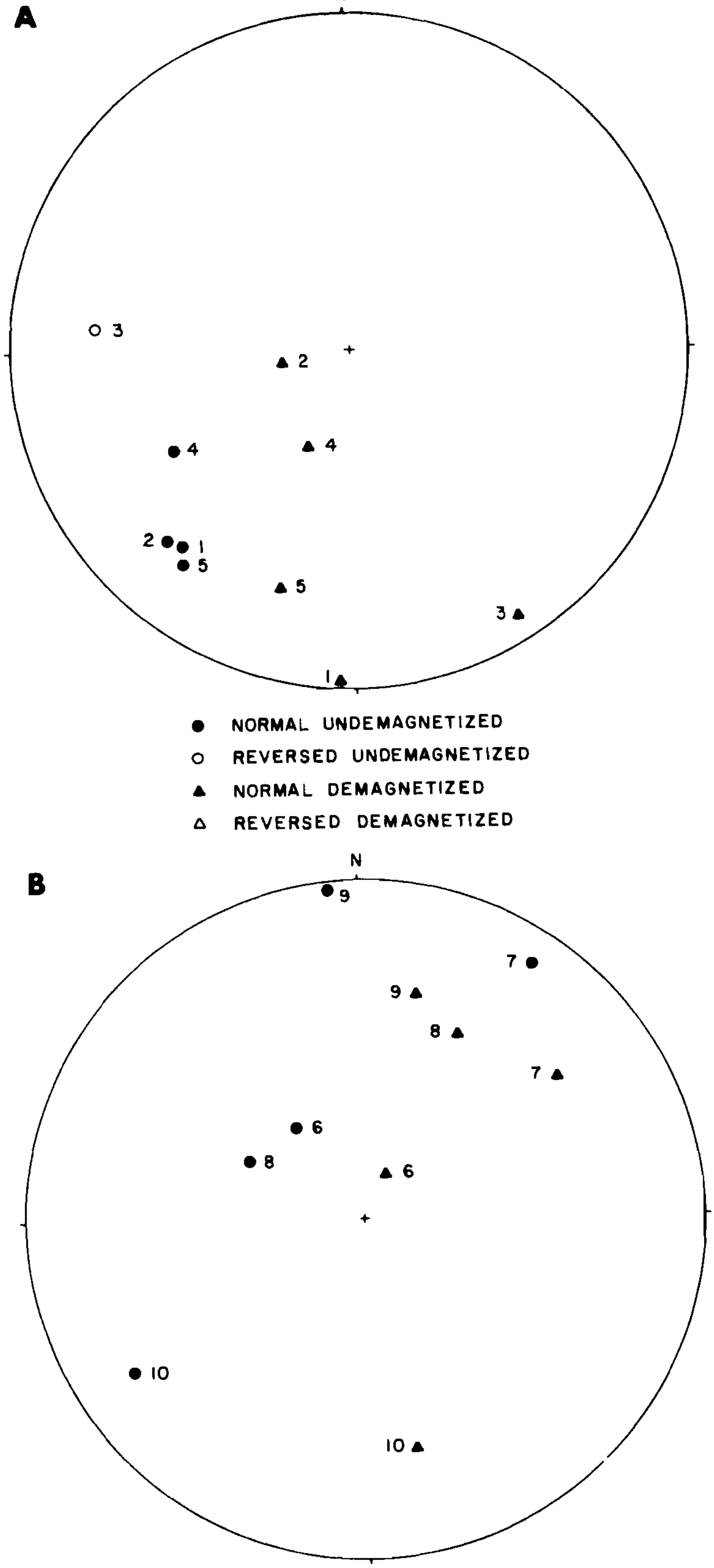
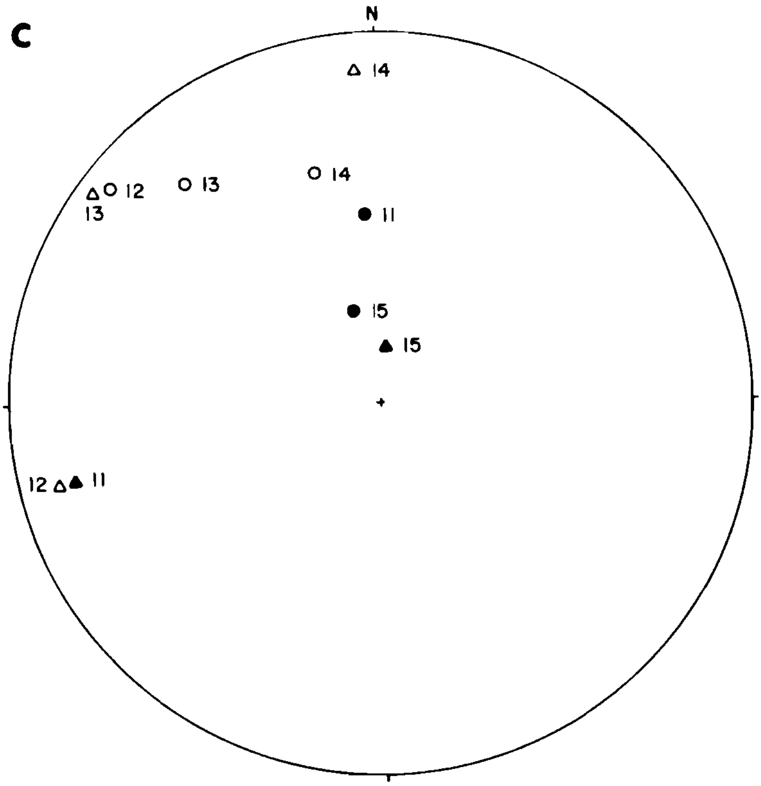


Figure 11. Stereographic projections of remnant magnetism directions of surface samples from sites A, B, C, D, E and F of Kansas Drift stratotype section.



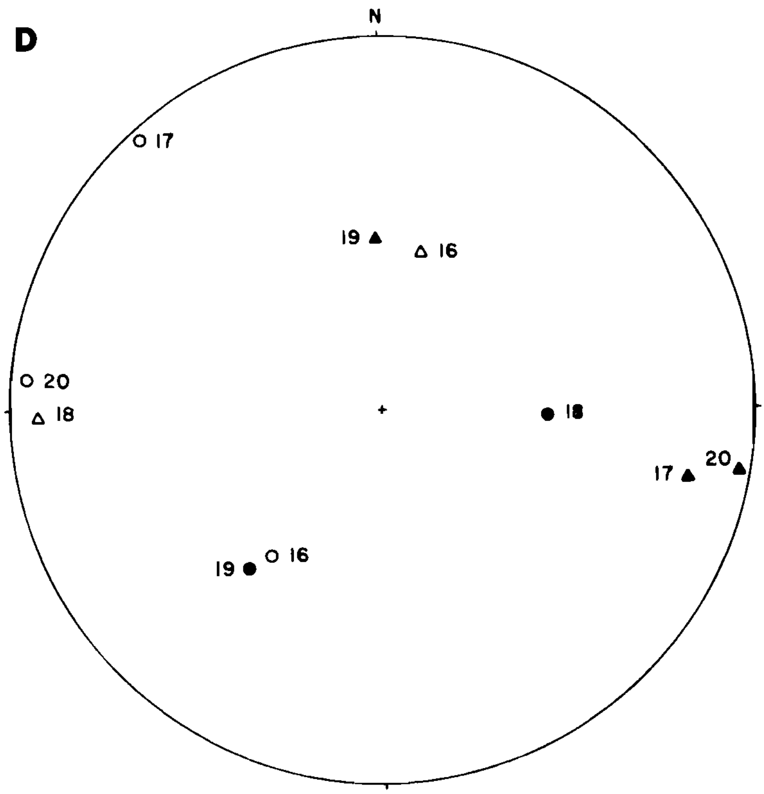
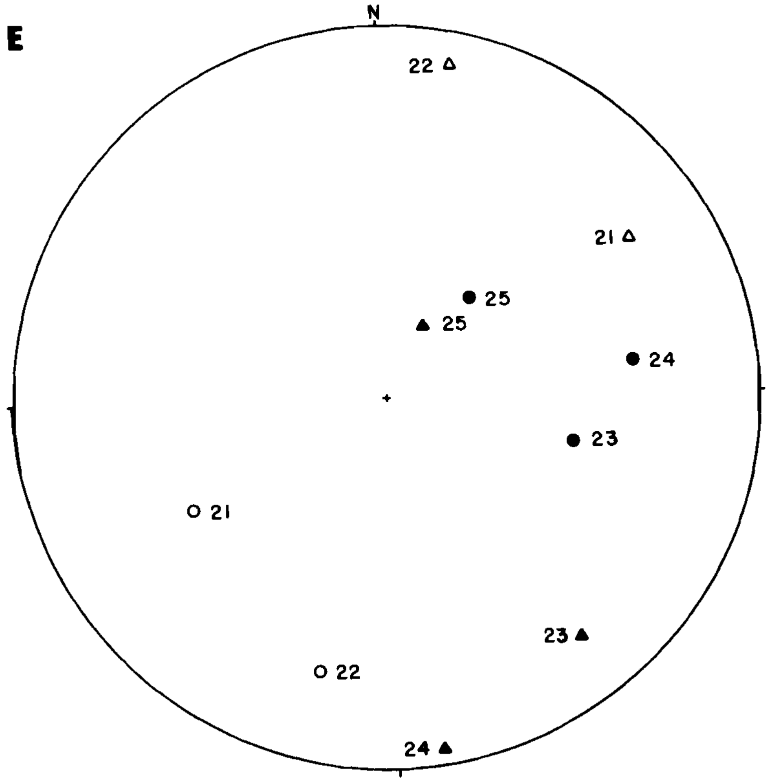


Figure 11. Continued from previous page.



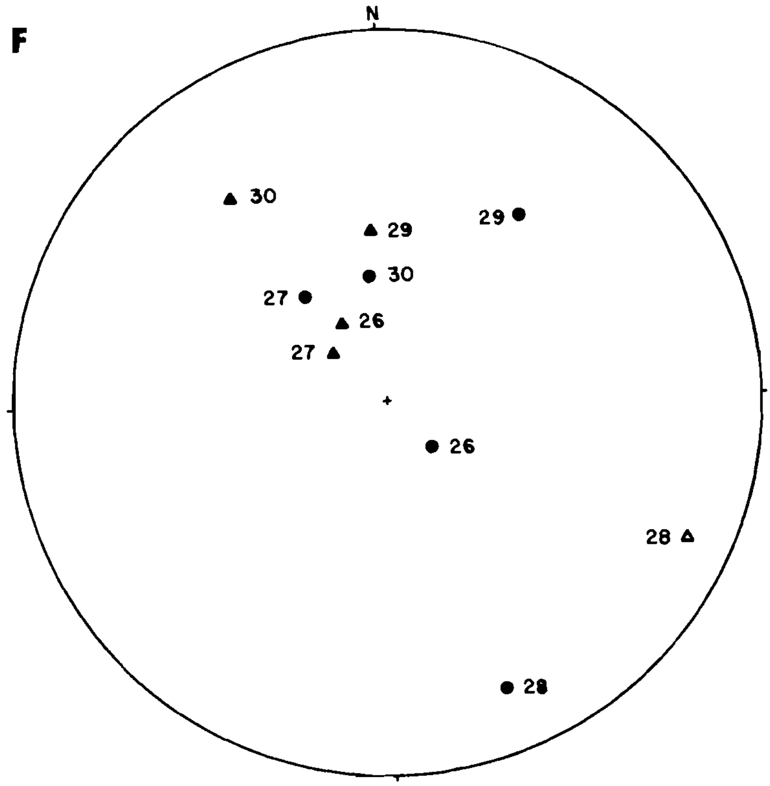


Figure 11. Continued from previous page.

Sample remnant magnetism from site C is shown in Figure 11C. Each sample retains the same polarity before and after demagnetization; two samples are normally polarized and three have reverse polarity. Four samples (11, 12, 13, and 14) have near-horizontal inclinations after demagnetization. This demonstrates that till has been deformed at this site.

Sample sites D and E are located toward the bottom of the main diapir. Sample remnant magnetism is widely scattered before and after demagnetization (fig. 11D and E). Many inclinations are nearly horizontal, and about half the samples show reverse polarity. These scattered orientations in remnant magnetism are clearly related to noticeable deformation at these sites.

As an area between the main and the small diapirs, site F reflects its unique position in the section as shown in Figure 7. Site F might be referred to as a site with little or no ice-pushed structures. Most samples from this site tend to retain their polarity and to cluster in a small zone with northwest or northeast declination and an intermediate positive inclination.

Site G, located in the head of the main diapir, represents maximum till deformation. However, orientation of sample remnant magnetism is not random; the data points form a well-defined band trending about 100-280 degrees (fig. 12). Paleomagnetic vectors (with exception of 33) are contained within planes having approximately this strike and dipping at >65 NE. This corresponds to the orientations of

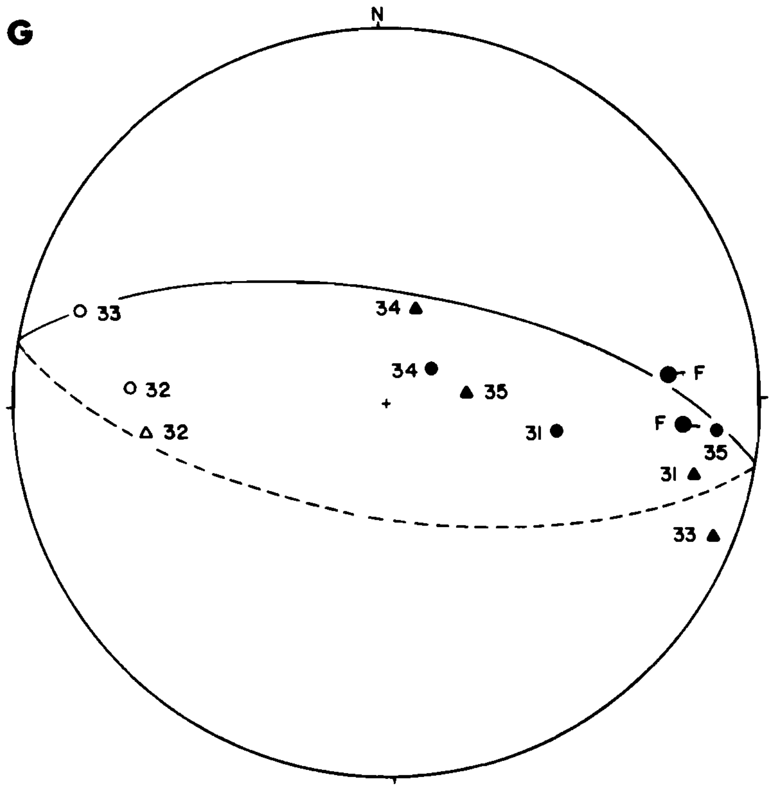


Figure 12. Remnant magnetism of samples from site G plotted on an equal-area stereonet. F = fold axes measured in the head of the main diapir (from Aber 1985, fig. 5). Solid arc represents a plane with strike = 100 and dip = 65 NE; dashed arc is upward (reversed) extension of plane toward southwest. Symbols same as Figure 11.

fold axes from the nose and upper part of the main diapir measured in 1981 (Aber 1985). The remnant magnetism at site G is obviously controlled by structural development of the diapir.

Subsurface Samples:

A second approach in the analysis was to plot inclinations for subsurface samples, as their declinations could not be determined. Samples collected from NM9-4 and NM9-5 all show normal polarities before and after demagnetization (fig. 13A). The demagnetized inclinations fall in the +60 to +80 degree range. This means that no till disturbance took place in this part of the section at depths between 40 and 50 m.

Figure 13B, shows inclinations for samples collected from NM10-2, NM10-4, NM10-5. The lowest portion of the section (NM10-5) shows typical normal polarities. However, moving up in the section, scatter of sample orienations increases. Wide scatter in orientations and reversed polarity reach a maximum in NM10-2 at a depth between 16.2-16.5 m. This is similar to diapir positions and remnant magnetism in the Lower Kansas Till section at West Atchison.

Combined surface and subsurface data indicate that the Lower Kansas Till is normally polarized except where obvious structural disturbance has occurred. There is no evidence for till with primary reversed polarity in northeastern Kansas.

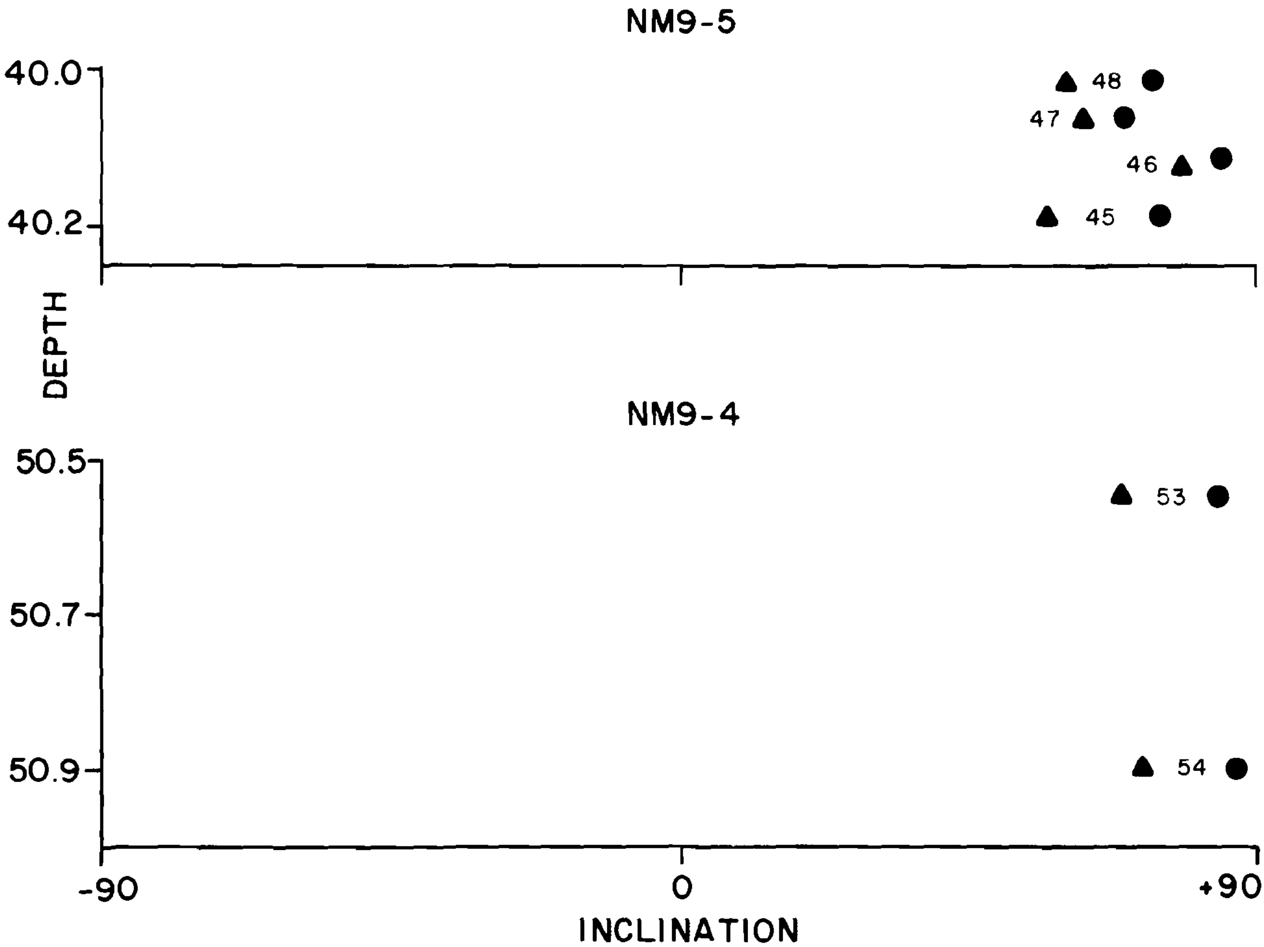


Figure 13A. Variations in remnant magnetism direction (inclination) of subsurface samples versus depth. See Fig. 9 for location. Scale in m; symbols same as Fig. 11.

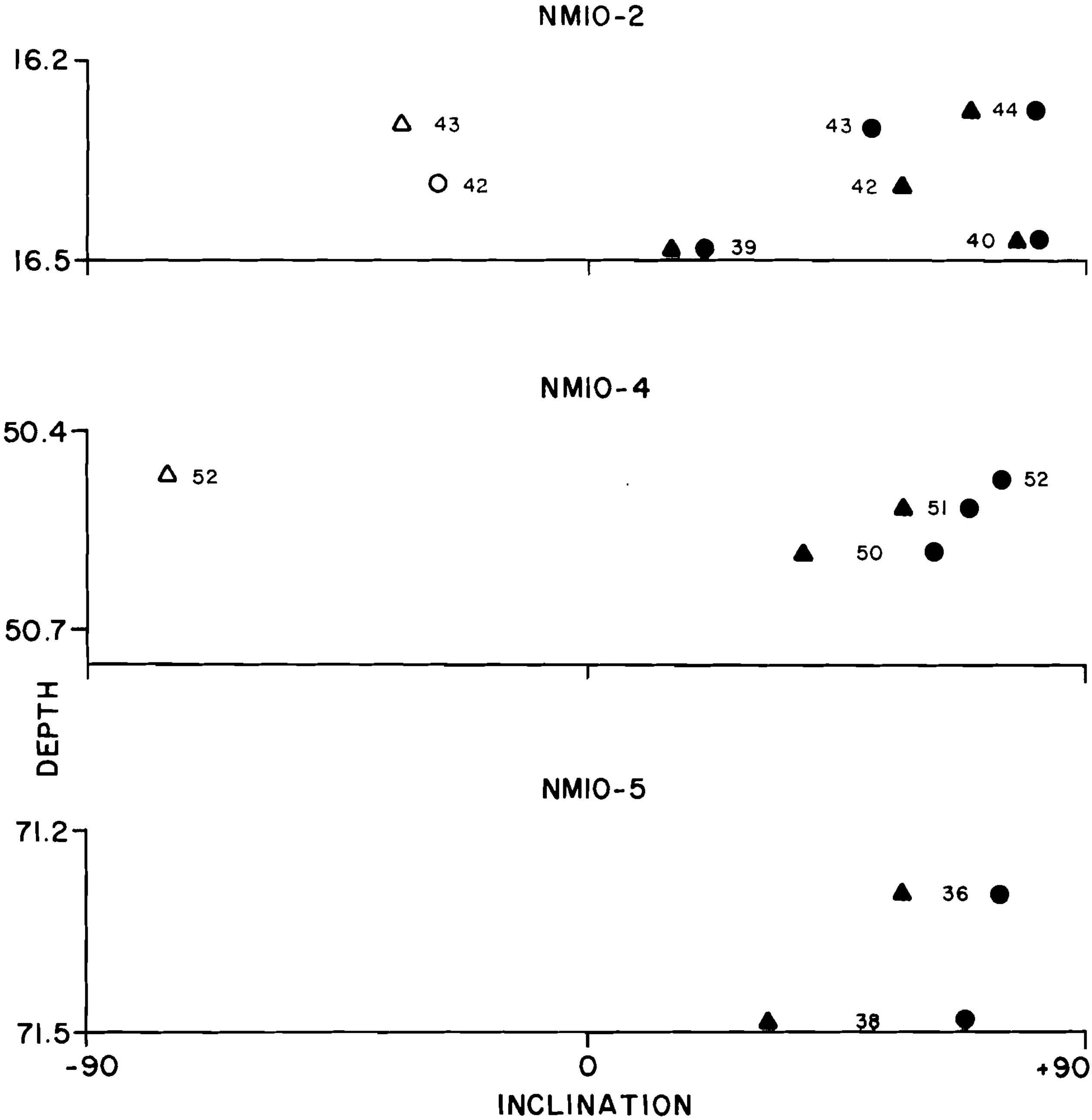


Figure 13B. Variations in remnant magnetism direction (inclination) of subsurface samples versus depth. See Fig. 9 for location. Scale in m; symbols same as Fig. 11.

Chapter 5. STRATIGRAPHY AND AGE IMPLICATIONS

Volcanic ash dates and biostratigraphy provide minimum and maximum ages for the Kansas Drift. Volcanic ash is contained in post-Kansan alluvium within the Kansas River valley, near Desoto. This ash was identified by Geil (1987) as the Pearlette ash, about 600,000 years old. This date fixes the minimum age of the Kansas Drift. Near Wathena, Kansas (fig. 1), the Lower Kansas Till rests on alluvium in which a rich fossil assemblage, called the Wathena local fauna, is found. Martin and Schultz (1985) judged the age of this fauna to be around 1.0 million years BP, based on comparison with other dated faunas of the Great Plains region. As the Wathena local fauna lies beneath the lowest till in the type Kansan region, this fixes a maximum age for the Kansas Drift.

The time range in question covers the Late Matuyama and Early Brunhes Epochs, including oxygen-isotope stages 22-16 (fig. 14). The Matuyama-Brunhes reversal took place approximately 700,000 years ago, and the Jaramillo normal polarity event occurred roughly 950,000 to 890,000 years ago (Bowen 1978). All normal-polarity deposits from this time range must, therefore, date from the Jaramillo timespan or be younger than 700,000 years. As the Jaramillo falls within a long interglacial interval, it probably does not coincide with the Kansan glaciation. Therefore, normal polarity of the Lower Kansas Till indicates a Brunhes age for the Kansas Drift.

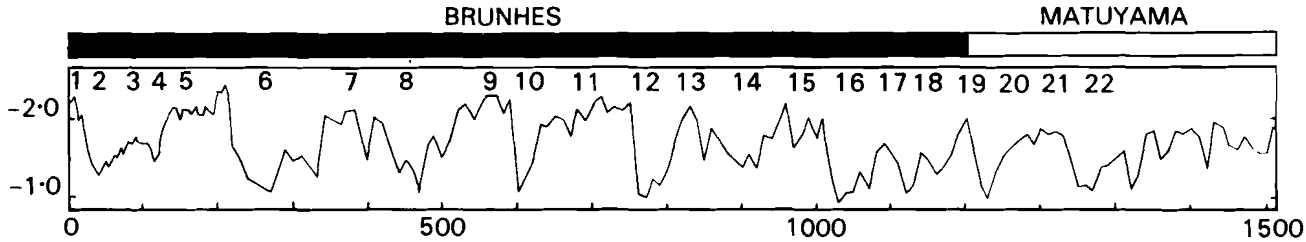


Figure 14. Oxygen isotope-stages 1-22 of core V-28-238 from Solomon Plateau, Pacific Ocean. This core has been proposed as a standard for the later Pleistocene. Brunhes-Matuyama reversal (700,000 years BP) occurs in stage 19 and is used as the basis for dating glacial stage boundaries. Taken from Bowen (1978, fig. 3-5). Horizontal scale is core depth in cm; vertical scale is per mil O-18 variations.

On this basis, the Kansan glaciation took place between 700,000 and 600,000 years ago (Aber et al. 1988). This corresponds to oxygen-isotope stages 18-16. Stage 16 is one of the largest glacial stages in the oxygen-isotope record, which is reasonable considering the Kansan glaciation was the greatest ice coverage in central North America. The 100,000-year timespan is comparable with later glaciations.

Normal polarity of the Lower Kansas Till supports its correlation with the Fremont Till at Cedar Bluffs, Nebraska (fig. 6), which Easterbrook and Boellstorff (1981) showed to be normal also. However, the Lower Kansas and Fremont Tills cannot be correlated with the reversely magnetized type Nebraskan Till (fig. 4). Although the Lower Kansas Till was considered Nebraskan by many geologists (Frye and Leonard 1952; Aber 1988), it is not. There is no evidence for Nebraskan Till in northeastern Kansas.

Chapter 6. CONCLUSIONS

1: The Lower Kansas Till (basal Kansas Drift) has stable primary remnant magnetism with normal polarity, in surface and subsurface samples, except where obvious structural deformation is present (Aber et al. 1988).

2: Normal polarity of the Lower Kansas Till restricts its age to the Brunhes Epoch, which began about 700,000 years ago.

3: Age of the Kansas Drift is between 600,000 and 700,000 years old (Aber et al. 1988).

4: As the Lower Kansas Till shows a positive polarity, the Fremont Till at Cedar Bluffs, which also has a positive polarity, should be of Kansan age.

5: Nebraskan Till with reversed polarity is not present in northeastern Kansas.

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