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DIFFERENTIATION OF PLEISTOCENE DEPOSITS IN NORTHEASTERN KANSAS BY CLAY MINERALS

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Abstract – Seventy-four samples from eight stratigraphic sections of lower Pleistocene glacial and glaciofluvial deposits in Doniphan County, extreme northeastern Kansas, were analyzed using X-ray diffraction techniques. Clay-mineral assemblages of the $<2\,\mu$ fraction of these deposits are nearly identical, consisting of a mixed-layer clay mineral associated with minor amounts of kaolinite and illite.

An attempt was made to differentiate units of till and nontill deposits by using the relative intensities of 001 reflections of "mixed-layer mineral," kaolinite, and illite. At least two tills were recognizable. Associated nontill deposits, could not be differentiated from one another, although the nontills are easily distinguished from tills.

INTRODUCTION

Nebraskan and Kansan glacial and glaciofluvial deposits occur only in the northeastern part of Kansas (Schoewe, 1930, 1939; Frye, 1946; Frye and Leonard, 1949, 1952). Major criteria used to differentiate stratigraphic units of these deposits in northwestern Doniphan County where Pleistocene sections are well exposed were (a) well-developed weathering profile in the middle part of the till section, (b) lithologic characters observable in the field, and (c) regional relationships. In Nebraska, regional correlation of Pleistocene glacial deposits is based on recognizable interglacial soils and major unconformities. Further subdivisions within glacial deposits of each stage are based on the recognition of interstadial soils and minor unconformities (Reed and Dreeszen, 1965). Subdivisions within glacial and glaciofluvial deposits of the two ages, however, are recognized (Dort, 1965) but have not been adequately described in Kansas because of lack of detailed studies. This investigation was designed to (1) determine the clay mineralogy of the glacial and glaciofluvial deposits in northeastern Kansas, and (2) test limitations of clay mineralogy for correlation.

The value of clay mineralogy in the interpretation of source and environmental history and in correlation of Pleistocene deposits has been demonstrated in many areas of the Midwest (Fanning and Jackson, 1966; Ruotsala, Koons, and Nordeng, 1966; Frye, Willman, and Glass, 1960; Johnson, 1965; Kempton, 1963; Willman, Glass and Frye, 1963, 1966; Harrison, 1959, 1960; Droste, 1956 and Droste and Tharin, 1958).

Good exposures of Pleistocene deposits are found in quarries and pits along the bluffs of the Missouri River Valley in Doniphan County, Kansas (Fig. 1). Detailed geographic locations, lithologic types, and relative stratigraphic positions of samples and other data are given in the Appendix.

METHOD OF STUDY

Seventy-four samples, both weathered and relatively fresh, were collected from eight stratigraphic sections. Clay particles of less than $2\,\mu$ in size were analyzed using an X-ray diffraction technique. About 50 g of raw sample were prepared for analysis by soaking in 100 ml of distilled water followed by gentle shaking until completely dispersed. Samples having a tendency to flocculate were repeatedly washed with distilled water until they remained in suspension. The clay fraction finer than $2\,\mu$ was separated by sedimentation. Onto each of four glass slides 4 ml of $<2\,\mu$ clay-water suspension was pipetted and evaporated to dryness at room temperature. One slide was treated with a 1 : 2 glycerine–water mixture; a second was heated to 450° and allowed to cool slowly to room temperature in the furnace; a third slide was heated to 575° for $\frac{1}{2}$ hr and allowed to cool gradually; a fourth slide was untreated.

X-ray diffraction data was obtained with a North American Philips (Norelco) X-ray diffractometer. Nickel-filtered copper radiation, 1° beam slits, and 0·003 in detector slit were used. Patterns were run at a scanning rate of one degree 2θ per min. The X-ray unit was operated at 35 kV and 18 mA. The relative humidity in the laboratory ranged from 50 to 60 per cent.

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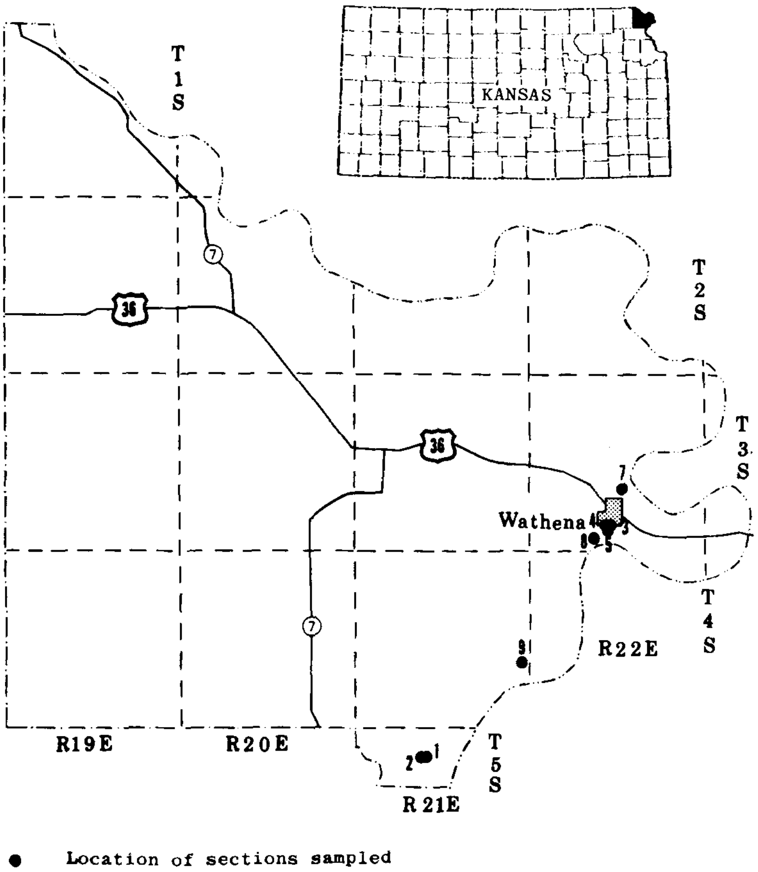

Fig. 1. Map of Doniphan County, Kansas, showing locations of sections sampled.

No quantitative analysis of clay mineral constituents was attempted. The relative intensity (peak height) of the 001 basal reflections of each clay-mineral constituent in the sample, however, was measured in terms counts per sec. Counts/sec were measured on the diffractometer chart of the untreated air-dried slide. The diffraction intensity (D.I.) ratio, which is the ratio of 001 basal reflections of illite to kaolinite, was also calculated (Frye, Glass and Willman, 1962). These measurements are not intended to be an assessment of quantitative mineral composition, but serve only as a means of comparison among samples. Relative intensities of 001 basal reflections of clay-mineral constituents and D.I. ratio for each sample are listed in Table 1 (See Appendix).

X-RAY ANALYSIS AND RESULTS

X-ray diffraction data indicate that the $<2\,\mu$ fraction clay-mineral assemblages of the samples are almost identical. All samples consist predominately of "mixed-layer mineral" and various amounts of illite and kaolinite. Chlorite may be present in trace amounts in some nontill samples, but its identification is tentative. Nonclay mineral components in the $<2\,\mu$ fraction of some samples include quartz, calcite, and dolomite. Dolomite is restricted to tills.

"Mixed-layer mineral" includes all clay materials with a broad basal reflection occuring at approximately 5·8° $2\theta(d = 15{\cdot}2\,\text{Å})$. Their basal spacing expands and the basal reflection shifts to about 4·9° $2\theta(d = 18\,\text{Å})$ after glycerine treatment. Higher order basal reflections of this mineral are too weak to be recognized on the diffraction patterns from air dried samples. Some high order basal reflections can be detected from glycerine-treated samples, but they are not in rational series. After heating to 450°, the first order basal reflection collapses and shifts to about 8·9° $2\theta(d = 9{\cdot}9\,\text{Å})$, and higher order basal reflections shift correspondingly. All basal reflections are intensified in samples heated to 575° for ½ hr. These characteristics suggest that the mineral is composed of randomly interstratified layers of montmorillonite and mica (Kodama and Brydon, 1966).

Illite was identified by a series of basal reflections that occur at 8·8°, 17·8°, and 26·8° 2*θ*, corresponding to *d* values of 10, 5, and 3·3 Å respectively. They are not changed by glyceration or heating. Kaolonite was identified by two basal reflections that occur at 12·3° and 24·9° 2*θ*, corresponding to *d* values of 7·2 and 3·6 Å. These peaks do not change upon glyceration or heating to 450°, but completely disappear when heated to 575° for ½ hr. Selected examples of diffractometer traces of oriented samples after treatments are given in Fig. 2.

All samples studied can be classified into three groups on the basis of relative intensities of the three clay-mineral components (Fig. 3; Table 1) and the D.I. ratios of illite to kaolinite. The groups and their distinguishing characteristics are briefly stated below.

Group A. This group is characterized by high relative intensity of kaolinite and low D.I. ratio (less than 1) of illite to kaolinite. The relative intensity of kaolinite ranges from 21 to 31. Relative intensities of mixed-layer mineral and illite range from 41 to 69 and 9 to 29. Fourteen samples classified in this group are from tills, which represent either the entire or upper portion of the till section.

Group B. Kaolinite in samples of this group shows moderate relative intensity. D.I. ratios of illite to kaolinite are relatively high (greater than 1). Relative intensities of kaolinite, mixed-layer mineral, and illite range from 15 to 21, 53 to 58, and 23 to 29. Seven samples classified in this group occur in the lower part of the till section.

Group C. All 51 nontill samples and 2 till samples are classified in this group, which is characterized by low relative intensity of kaolinite and high D.I. ratio (greater than 1) of illite to kaolinite. Relative intensities of kaolinite, mixed-layer mineral, and illite range from 4 to 14, 59 to 84, and 12 to 31. Nontill samples cannot be subdivided on the basis of clay mineralogy into meaningful stratigraphic groups.

Because no significant difference was found between weathered and relatively fresh samples within each group in terms of relative intensities of the three clay-mineral components, it is not likely that the clay minerals have been significantly affected by weathering after deposition. Therefore, correlation can be made between samples regardless of weathering condition.

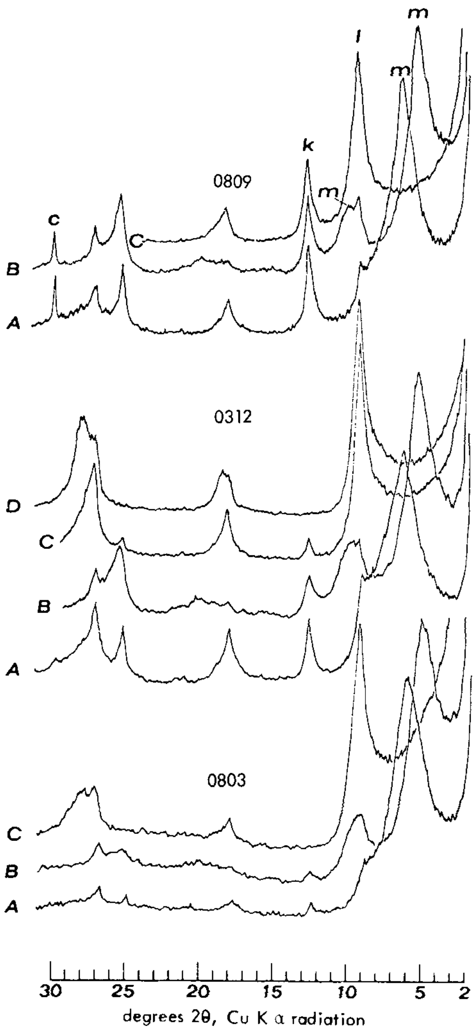

Fig. 2. X-ray diffraction patterns of three typical samples: *A*—untreated; *B*—glycerated; *C*—heated to 450°; *D*—heated to 575° for ½ hr; *m*—mixed-layer mineral; *i*—illite; *k*—kaolinite; *c*—calcite.

With one exception, all till samples are judged to be of Kansan age. Sample 0903 is presumed to be of Nebraskan age (C. K. Bayne and H. G. O'Connor, personal communication, 1966). At least two groupings in the Kansan tills can be recognized on the basis of the clay mineralogy (Fig. 3), but on the basis of one sample the Nebraskan till cannot be differentiated from Kansan tills in Group B. The classification of clay mineral data into two groups, A and B, supports the field identification of at least two Kansan tills in the sections sampled.

The grouping of samples shown on the ternary diagram (Fig. 3) was tested by two objective procedures as a check against possible bias. All samples were analyzed by the method of

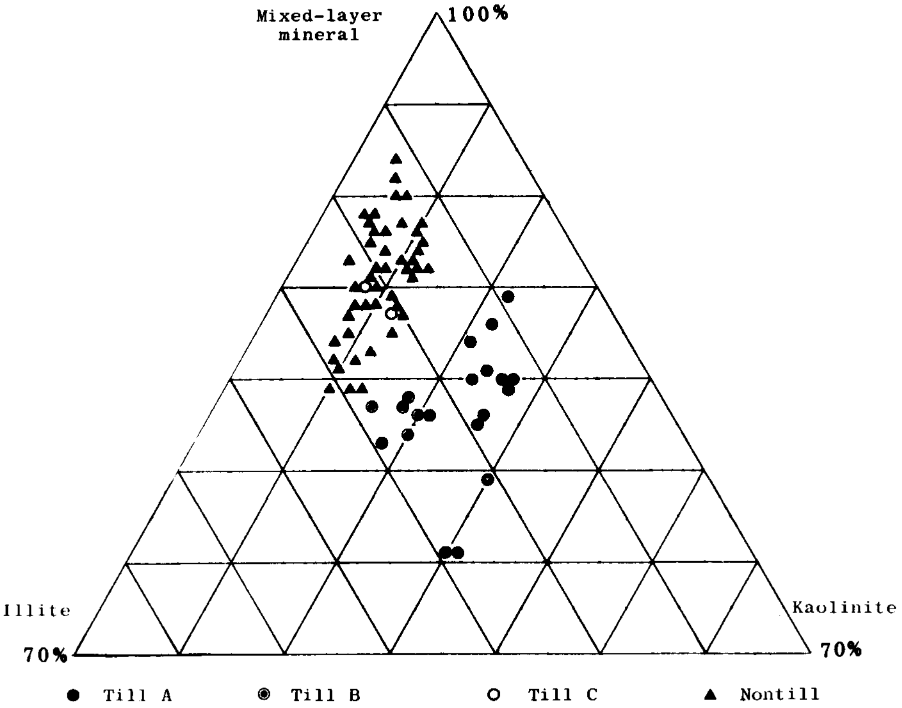

Fig. 3. Diagram showing relative intensities of three clay mineral components from till and nontills. Some sample points were omitted.

principal components, and the first two uncorrelated components were plotted. Tills and nontills were segregated into two distinct clusters, corresponding to those empirically derived from the ternary plot. Principal components analysis was then performed on till samples alone, producing a graph with two distinct clusters corresponding to Group A and Group B. Samples 0215 and 0216 appear as "rouges" outside the clusters. These samples are misclassified on the ternary diagram as well.

Discriminant analysis was performed to measure objectively the degree of distinctness between the groups chosen from the ternary diagram. The generalized distance (D^2) between the pooled group of tills and the group of nontills is 19·8, which is significant at levels exceeding 99·95 per cent. A second analysis was run on the two groups of tills. The generalized distance between these two groups is 24·2, which is also significant at levels exceeding 99·95 per cent. Statistics pertaining to these tests are listed in Table 2 of the Appendix.

Objective measures of the groupings indicate that they are statistically valid and suggest that clay-mineral assemblages are diagnostic features of these glacial and glaciofluvial deposits. The high significance levels associated with these tests indicates that it is unlikely that further sampling from these deposits would alter the results of this study.

SUMMARY

Clay-mineral assemblages of less than 2μ fractions from lower Pleistocene glacial and glaciofluvial deposits of northeastern Kansas are practically identical. Samples studied consist predominately of mixed-layer mineral and various amounts of illite and kaolinite. At least two Kansan tills are distinguishable in the sections studied. Nebraskan till, if present, could not be differentiated from Group B Kansan till. Nontill deposits could not be subdivided regardless of their stratigraphic position relative to tills. Tills can be differentiated into Groups A, B, or C, regardless of weathering condition.

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APPENDIX

Table 1. Relative X-ray diffraction intensities of clay minerals in samples. Sample locations, lithologic type, and color also are included

	Relative Intensities							
Sample no.	Mixed layer	Illite	Kaolinite	D.I. ratio	Group	Lithologic type	Color (Munsell system)	Distance above bottom of section (ft)
Section No.	1	NW NE	sec. 9,	T. 5 S.,	R. 21 E.			
0116	60	13	27	0·48	A	till	pale yel. 2·5Y 7/4	28·5
0115	55	19	26	0·73	A	till	pale yel. 2·5Y 7/4	25·5
0114	69	20	11	1·82	C	clay	pale brn. 10YR 6/3	24
0113	73	17	10	1·70	C	clay	pale brn. 10YR 6/3	19
0112	72	19	9	2·11	C	clay	pale brn. 10YR 6/3	18
0111	74	18	8	2·25	C	clay	pale brn. 10YR 6/3	13
0110	63	25	12	2·08	C	clay	brn. 7·5YR 5/2	10
0109	68	22	10	2·20	C	clay	brn. 7·5YR 5/2	9
0108	68	20	12	1·67	C	clay	lt. rd. brn. 5Y 6/4	7·5
0107	77	13	10	1·30	C	silt	lt. gy. 2·5Y 7/2	5·5
0106	72	17	11	1·55	C	silt	wh. 5Y 8/1	4·5
0105	71	17	12	1·42	C	silt	wh. 5Y 8/1	3·5
0104	75	14	11	1·28	C	silt	wh. 5Y 8/1	2·5
0103	76	14	10	1·40	C	silt	wh. 5Y 8/1	1·5
0102	73	16	11	1·45	C	silt	wh. 5Y 8/1	0·5

Table 1. (*cont.*)

	Relative Intensities							
Sample no.	Mixed layer	Illite	Kaolinite	D.I. ratio	Group	Lithologic type	Color (Munsell system)	Distance above bottom of section (ft)
Section No.	2*	NW NE	sec. 9,	T. 5 S.,	R. 21 E.			
0216	67	21	12	1·75	C	till	lt. brn. gy. 2·5Y 6/2	26
0215	70	22	8	2·75	C	till	lt. brn. gy. 10YR 6/2	24·5
0214	61	29	10	2·90	C	silt	gy. brn. 10YR 5/2	22·5
0213	62	27	11	2·45	C	silt	gy. brn. 10YR 5/2	21
0212	68	20	12	1·67	C	clay	gy. 10YR 1/5	15
0211	59	31	10	3·10	C	silt	gy. brn. 2·5Y 5/2	7
0209	65	26	9	2·89	C	silt	lt. brn. gy. 2·5Y 6/2	4
0208	62	29	9	3·22	C	silt	very pale brn. 10YR 7/3	2
0206	67	20	13	1·54	C	gravel	lt. yel. brn. 10YR 6/4	1
Section No.	3†	NW NE	sec. 33,	T. 3 S.,	R. 22 E.			
0313	60	17	23	0·74	A	till	pale yel. 2·5Y 7/4	35
0312	58	24	18	1·33	B	till	lt. gy. 2·5Y 7/2	33
0311	77	15	8	1·88	C	clay	lt. brn. gy. 2·5Y 6/2	30
0310	77	15	8	1·88	C	silt	lt. brn. gy. 2·5Y 6/2	25·5
0309	71	21	8	2·63	C	clay	pale brn. 10YR 6/3	17·5
0308	80	13	7	1·86	C	silt	lt. brn. gy. 2·5Y 6/2	10·5
0307	71	21	8	2·63	C	clay	gy. 10YR 5/1	7
0306	75	19	6	3·17	C	silt	gy. 10YR 5/1	6
0305	76	17	7	2·43	C	silt	gy. brn. 2·5Y 5/2	4·5
0304	72	20	8	2·50	C	sand	lt. brn. gy. 2·5Y 6/2	4
0303	84	12	4	3·00	C	gravel	lt. brn. gy. 2·5Y 6/2	3·5
0302	82	13	5	2·60	C	silt	lt. brn. gy. 2·5Y 6/2	2·5
0301	78	18	4	4·50	C	f. sand	lt. gy. 2·5Y 7/2	1
Section No.	4†	NW NE	sec. 33,	T. 3 S.,	R. 22 E.			
0406	57	28	15	1·87	B	till	lt. brn. gy. 2·5Y 6/2	28·5
0405	54	26	20	1·30	B	till	lt. brn. gy. 2·5Y 6/2	26·5
0404	72	16	12	1·33	C	clay	lt. brn. gy. 2·5Y 6/2	25·5
0403	74	15	11	1·36	C	clay	lt. brn. gy. 2·5Y 6/2	23·5
0402	70	23	7	3·29	C	silt	wh. 2·5Y 8/2	15
0401	68	24	8	3·00	C	silt	wh. 2·5Y 8/2	11

Table 1. (*cont.*)

	Relative Intensities							
Sample no.	Mixed layer	Illite	Kaolinite	D.I. ratio	Group	Lithologic type	Color (Munsell system)	Distance above bottom of section (ft)
Section No. 5† SW NE sec. 33, T. 3 S., R. 22 E.								
0511	66	12	22	0·55	A	till	lt. gy. 2·5Y 7/2	45
0510	60	14	26	0·54	A	till	lt. gy. 2·5Y 7/2	40
0507	49	21	30	0·70	A	till	gy. N6	29
0505	56	23	21	1·10	B	till	gy. N6	21
0504	53	29	18	1·61	B	till	lt. olive gy. 5Y 6/1	13
0503	73	22	5	4·40	C	f. sand	lt. gy. 2·5Y 7/2	12
0502b	59	29	12	2·42	C	c. sand	wh.	8
0501	65	22	13	1·69	C	gravel	wh.	3·5
Section No. 7† SW SW sec. 22, T. 3 S., R. 22 E.								
0705	56	18	26	0·69	A	till	lt. yel. brn.	31
0704	56	24	20	1·20	B	till	lt. brn. gy. 2·5Y 6/2	24
0703	70	21	9	2·33	C	clay	brn. 7·5YR 5/4	18
0702	70	21	9	2·33	C	clay	brn. 7·5YR 5/4	6
0701	67	25	8	3·13	C	silt	pale brn. 10YR 6/3	1
Section No. 8† NW SW sec. 33, T. 3. S., R. 22 E.								
0811	69	9	22	0·41	A	till	lt. olive brn. 2·5Y 5/4	55·5
0810	64	15	21	0·71	A	till	olive brn. 2·5Y 4/4	49·5
0809	59	14	27	0·52	A	till	lt. yel. brn. 2·5Y 6/4	43·5
0808	68	23	9	2·56	C	clay	brn. 7·5YR 5/4	33·5
0807	70	21	9	2·34	C	silt	pale brn. 10YR 6/3	26·5
0806	76	18	6	1·13	C	clay	gy. 10YR 6/1	24
0805	73	22	5	4·40	C	silt	lt. brn. gy. 2·5Y 6/2	18
0804	77	18	5	3·60	C	silt	wh. 5Y 8/1	12
0803	78	17	5	3·40	C	silt	wh. 5Y 8/1	6
0802	72	15	13	1·15	C	sand	lt. brn. gy. 2·5Y 6/2	2·5
0801	80	14	6	2·33	C	silt	yel. brn. 5Y 7/2	2
Section No. 9† SE SE sec. 24, T. 4 S., R. 21 E.								
0909	61	15	24	0·63	A	till	pale yel. 2·5Y 7/4	51
0908	61	15	24	0·63	A	till	pale yel. 2·5Y 7/4	33
0907	41	28	31	0·90	A	till	gy. N5	18
0906	41	29	30	0·97	A	till	gy. N5	16
0903	58	25	17	1·47	B	till	lt. red brn. 2·5Y 6/4	6·5
0902	64	28	8	3·50	C	f. sand	pale yel. 2·5Y 7/4	6·5
0901	59	28	13	2·15	C	gravel	lt. olive brn. 2·5Y 5/4	2

*Section sampled by Habib, 1966.

†Sections sampled by Habib and Tien, 1966.

Table 2. Matrices of covariances and means and discriminant equations for tills and nontills. A = till group A; B = till group B; AB = pooled group of tills; C = nontill group

Covariance matrix

$$A = \begin{bmatrix} 70{\cdot}5274928 & -46{\cdot}4065876 & -24{\cdot}1208682 \\ -46{\cdot}4065876 & 32{\cdot}3791216 & 14.0274750 \\ -24{\cdot}1208682 & 14{\cdot}0274750 & 10{\cdot}0934119 \end{bmatrix}$$

$$B = \begin{bmatrix} 3{\cdot}6666667 & -2{\cdot}1666667 & -1{\cdot}5000000 \\ -2{\cdot}1666463 & 4{\cdot}9523824 & -2{\cdot}7857106 \\ -1{\cdot}4999796 & -2{\cdot}7857056 & 4{\cdot}2857208 \end{bmatrix}$$

$$AB = \begin{bmatrix} 47{\cdot}3286132 & -33{\cdot}3642696 & -13{\cdot}9642698 \\ -33{\cdot}3642696 & 39{\cdot}3904840 & -6{\cdot}0261841 \\ -13{\cdot}9642698 & -6{\cdot}0261841 & 19{\cdot}9904844 \end{bmatrix}$$

$$C = \begin{bmatrix} 35{\cdot}6335396 & -26{\cdot}1802234 & -9{\cdot}4358915 \\ -26{\cdot}1802234 & 23{\cdot}2168254 & 2{\cdot}9464590 \\ -9{\cdot}4358915 & 2{\cdot}9464566 & 6{\cdot}5082960 \end{bmatrix}$$

Matrix of means

$$\begin{array}{cccc} & \text{Mixed-layer} & \text{Illite} & \text{Kaolinite} \\ A & 57{\cdot}28571 & 17{\cdot}07143 & 25{\cdot}64286 \\ B & 56{\cdot}00000 & 25{\cdot}57143 & 18{\cdot}42857 \\ AB & 56{\cdot}85714 & 19{\cdot}90476 & 23{\cdot}23810 \\ C & 70{\cdot}88461 & 20{\cdot}13462 & 8{\cdot}96154 \end{array}$$

Discrimination equation between nontills and tills.

$R_{C:AB} = 0{\cdot}0056 \times (\text{mixed layer})\ 0{\cdot}0236 \times (\text{illite}) - 1{\cdot}3920 \times (\text{kaolinite})$

Generalized distance	Significance
$D^2_{C:AB} = 19{\cdot}800$	$F = 95{\cdot}948$ with $\nu_1 = 3, \nu_2 = 70$

Discrimination equation between till Group A and Group B.

$R_{A:B} = -0{\cdot}3369 \times (\text{mixed layer}) - 1{\cdot}4482 \times (\text{illite}) + 1{\cdot}7080 \times (\text{kaolinite})$

Generalized distance	Significance
$D^2_{A:B} = 24{\cdot}199$	$F = 33{\cdot}680$ with $\nu_1 = 3, \nu_2 = 17$

Résumé—Soixante-quatorze prélèvements de huit sections stratigraphiques de dépôts glaciaires et fluvio-glaciaires effectués à Doniphan County, dans l'extrême nord-est du Kansas, ont été analysés selon des techniques utilisant la diffraction des rayons X. Des assemblages de minéraux argileux de la fraction $<2\,\mu$ de ces dépôts sont presque identiques, et consistent en un minéral argileux interstratifie associé à de petites quantités de kaolinite et d'illite.

Un essai a été effectué pour différencier les dépôts argileux et non argileux en utilisant les intensités relatives de réflections 001 du "Mineral interstratifie", kaolinite et illite. Au moins deux argiles étaient reconnaissables. Il était impossible de différencier entre eux les dépôts associés non argileux, bien que ceux-ci se distingaient facilement des dépôts argileux.

Kurzreferat—Vierundsiebzig Proben aus acht stratigraphischen Abschnitten von Moränen- und Moränenflussablagerungen aus dem Unteren Pleistozän im Doniphan Kreis im nordöstlichen Kansas wurden unter Anwendung des Röntgenbeugungsmethoden analysiert. Der Aufbau der Tonminerale in den $<2\,\mu$ Brüchen dieser Ablagerungen ist beinahe identisch und besteht aus einem Mischschicht-Tonmineral in Verbindung mit kleineren Mengen von Kaolinit und Illit.

Es wurde versucht, zwischen Geschiebelehm und Nicht-Geschiebelehm zu unterscheiden, indem die relativen Stärken der 001 Reflexionen des "Mischschicht Minerals" Kaolinit und Illit verwendet wurden. Zum mindesten zwei Geschiebelehme wurden beobachtet. Die damit verbundenen Nicht-Geschiebelehme konnten nicht voneinander unterschieden werden, während jedoch die Nicht-Geschiebelehme sehr leicht von der Geschiebelehmen zu unterscheiden sind.

Резюме—Семьдесят четыре образца из восьми стратиграфических разрезов нижних плейстоценовых ледниковых и флювиогляциальных отложений в графстве донифан, на крайнем северо-востоке штата Канзас, были подвергнуты анализу пользуясь методами рентгеновской дифракции. Ассоциации глинистых минералов фракции 2μ этих отложений почти что идентичны и состоят из смещаннослойного глинистого минерала, ассоциированного с небольшими количествами каолинита и иллита.

Предпринимались пробы для различения ледниковых и неледниковых отложений, пользуясь относительной интенсивностью 001 отражений ‘смещаннослойного минерала” каолинита и иллита. Различено по крайней мере две валунные глины. Ассоциированные неледниковые отложения нельзя было отличить друг от друга, хотя ледниковые наносы легко отличаются от неледниковых.