A STUDY OF THE PHYSICAL AND CHEMICAL CHARACTERISTICS OF SOME NORTH CENTRAL KANSAS BURIED SOILS AND THEIR PARENT MATERIALS

by

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INTRODUCTION

Purpose of Investigation

For several years geologists with the State Highway Commission of Kansas have noted a marked correlation between areas containing the buried Sangamon soil and failures in flexible pavements composed of bituminous surfacing materials. Those failures were observed in several of the northern and western counties of the state where the Sangamon soil occurs widely. The exact causes of these failures is unknown, but it has been thought that water movements within the loess units and the clay mineral composition of those units were the two major contributing factors to the failures.

The purpose of this investigation was to obtain information regarding the clay mineral composition of different loessial deposits and also serve as a guide for future research by the Highway Geology Research Laboratory.

Area of Investigation

Most of the loess samples were collected along Highway U. S. 36, in Decatur, Norton, Phillips, Smith, Jewell and Republic Counties. In addition, samples were collected along highway 283 in Norton County, highway 9 in Phillips County, highways 28 and 14 in Jewell County, and along an east-west county road east of Scandia in Republic County. Samples also were collected from Iowa Point in Doniphan County for correlation purposes. The above counties were chosen because they contained good exposures of the Sangamon soil as well as numerous highway failures. Washington, Marshall,

Nemaha and Brown Counties were omitted from the study principally because of limited exposures of the Sangamon soil.

Fig. 1 consists of an index map of Kansas showing the area covered by this investigation. Table 1 lists the geographic location of exposures from which samples were obtained.

Table 1. Geographic location of samples.

Sample No.	Legal description of sampled site	Counties
	Samples of Sangamon soil	
59DC36L	NW¼NE¼ sec. 2, T. 3S., R. 29W.,	Decatur
62NT283L	NW¼SW¼ sec. 14, T. 4S., R. 23W.,	Norton
33PL36L	NE¼NE¼ sec. 35, T. 3S., R. 17W.,	Phillips
34PL36L	NE¼NE¼ sec. 35, T. 3S., R. 17W.,	Phillips
65PL9L	SW¼SW¼ sec. 24, T. 4S., R. 19W.,	Phillips
66PL9L	SW¼SW¼ sec. 24, T. 4S., R. 19W.,	Phillips
28SM36L	NW¼NE¼ sec. 16, T. 3S., R. 4W.,	Smith
30SM36L	NW¼NE¼ sec. 16, T. 3S., R. 4W.,	Smith
86SM36L	NW¼NE¼ sec. 26, T. 3S., R. 14W.,	Smith
87SM36L	NW¼NE¼ sec. 26, T. 3S., R. 14W.,	Smith
71JW14L	SE¼SE¼ sec. 25, T. 3S., R. 8W.,	Jewell
74JW28L	NW¼NW¼ sec. 2, T. 2S., R. 9W.,	Jewell
90JW36L	NE¼NE¼ sec. 21, T. 3S., R. 9W.,	Jewell
91JW36L	NE¼NE¼ sec. 21, T. 3S., R. 9W.,	Jewell
92JW36L	NE¼NE¼ sec. 21, T. 3S., R. 9W.	Jewell
95JW36L	NE¼NE¼ sec. 23, T. 3S., R. 9W.,	Jewell
96JW36L	NE¼NE¼ sec. 23, T. 3S., R. 9W.,	Jewell
100JW36L	NW¼NW¼ sec. 20, T. 3S., R. 8W.,	Jewell
101JW36L	NW¼NW¼ sec. 20, T. 3S., R. 8W.,	Jewell

Table 1. (cont.) Geographic location of samples.

Sample No.	Legal description of sampled site	Counties
102JW36L	NW¼NW¼ sec. 20, T. 3S., R. 8W.,	Jewell
106JW36L	SW¼SW¼ sec. 14, T. 3S., R. 8W.,	Jewell
107JW36L	SW¼SW¼ sec. 14, T. 3S., R. 8W.,	Jewell
108JW36L	SW¼SW¼ sec. 14, T. 3S., R. 8W.,	Jewell
112JW36L	SE¼SE¼ sec. 14, T. 3S., R. 8W.,	Jewell
113JW36L	SE¼SE¼ sec. 14, T. 3S., R. 8W.,	Jewell
114JW36L	SE¼SE¼ sec. 14, T. 3S., R. 8W.,	Jewell
77RP36L	NE¼NE¼ sec. 16, T. 3S., R. 4W.,	Republic
117RP36L	SW¼SW¼ sec. 4, T. 3S., R. 1W.,	Republic
118RP36L	SW¼SW¼ sec. 4, T. 3S., R. 1W.,	Republic
119RP36L	SW¼SW¼ sec. 4, T. 3S., R. 1W.,	Republic
83DP36L	NE¼SE¼ sec. 6, T. 3S., R. 20E.,	Doniphan
	Samples of Loveland loess	
60DC36L	NW¼NE¼ sec. 2, T. 3S., R. 29W.,	Decatur
63NT283L	NW¼SW¼ sec. 14, T. 4S., R. 23W.,	Norton
67PL9L	SW¼SW¼ sec. 24, T. 4S., R. 19W.,	Phillips
68PL9L	SW¼SW¼ sec. 24, T. 4S., R. 19W.,	Phillips
69PL9L	SW¼SW¼ sec. 24, T. 4S., R. 19W.,	Phillips
35PL36L	NE¼NE¼ sec. 35, T. 3S., R. 17W.,	Phillips
36PL36L	NE¼NE¼ sec. 35, T. 3S., R. 17W.,	Phillips
29SM36L	NW¼NE¼ sec. 21, T. 3S., R. 12W.,	Smith
88SM36L	NW¼NE¼ sec. 26, T. 3S., R. 14W.,	Smith
70JW14L	SE¼SE¼ sec. 25, T. 3S., R. 8W.,	Jewell
75JW28L	NW¼NW¼ sec. 2, T. 2S., R. 9W.,	Jewell
93JW36L	NE¼NE¼ sec. 21, T. 3S., R. 9W.,	Jewell

Table 1. (cont.) Geographic location of samples.

Sample No.	Legal description of sampled site	Counties
97JW36L	NE¼NE¼ sec. 23, T. 3S., R. 9W.,	Jewell
103JW36L	NW¼NW¼ sec. 20, T. 3S., R. 8W.,	Jewell
109JW36L	SW¼SW¼ sec. 14, T. 3S., R. 8W.,	Jewell
110JW36L	SW¼SW¼ sec. 14, T. 3S., R. 8W.,	Jewell
115JW36L	SE¼SE¼ sec. 14, T. 3S., R. 8W.,	Jewell
78RP36L	NE¼NE¼ sec. 16, T. 3S., R. 4W.,	Republic
	Samples of Peorian loess	
58DC36L	NW¼NE¼ sec. 2, T. 3S., R. 29W.,	Decatur
61NT283L	NW¼SW¼ sec. 14, T. 4S., R. 23W.,	Norton
31PL36L	NE¼NE¼ sec. 35, T. 3S., R. 17W.,	Phillips
32PL36L	NE¼NE¼ sec. 35, T. 3S., R. 17W.,	Phillips
64PL9L	SW¼SW¼ sec. 24, T. 4S., R. 19W.,	Phillips
27SM36L	NW¼NE¼ sec. 16, T. 3S., R. 4W.,	Smith
84SM36L	NW¼NE¼ sec. 26, T. 3S., R. 14W.,	Smith
85SM36L	NW¼NE¼ sec. 26, T. 3S., R. 14W.,	Smith
72JW14L	SE¼SE¼ sec. 25, T. 3S., R. 8W.,	Jewell
73JW28L	NW¼NW¼ sec. 2, T. 2S., R. 9W.,	Jewell
121JW36L	NW¼NW¼ sec. 20, T. 3S., R. 8W.,	Jewell
122JW36L	NW¼NW¼ sec. 20, T. 3S., R. 8W.,	Jewell
123JW36L	NW¼NW¼ sec. 20, T. 3S., R. 8W.,	Jewell
89JW36L	NE¼NE¼ sec. 21, T. 3S., R. 9W.,	Jewell
94JW36L	NE¼NE¼ sec. 23, T. 3S., R. 9W.,	Jewell
99JW36L	NW¼NW¼ sec. 20, T. 3S., R. 8W.,	Jewell
105JW36L	SW¼SW¼ sec. 14, T. 3S., R. 8W.,	Jewell
111JW36L	SE¼SE¼ sec. 14, T. 3S., R. 8W.,	Jewell

Table 1. (concl.) Geographic location of samples.

Sample No.	Legal description of sampled site	Counties
76RP36L	NE¼NE¼ sec. 16, T. 3S., R. 4W.,	Republic
116RP36L	SW¼SW¼ sec. 4, T. 3S., R. 1W.,	Republic
82DP36L	NE¼SE¼ sec. 6, T. 2S., R. 20E.,	Doniphan
	Samples of Brady soil	
79PL9L	SW¼SW¼ sec. 24, T. 4S., R. 19W.,	Phillips
80PL9L	SW¼SW¼ sec. 24, T. 4S., R. 19W.,	Phillips
81PL9L	SW¼SW¼ sec. 24, T. 4S., R. 19W.,	Phillips
	Samples of weathered bedrock	
98JW36	NE¼NE¼ sec. 23, T. 3S., R. 9W.,	Jewell
104JW36	NW¼NW¼ sec. 20, T. 3S., R. 8W.,	Jewell
120RP36	SW¼SW¼ sec. 4, T. 3S., R. 1W.,	Republic

REVIEW OF LITERATURE

It has been exceedingly difficult both for geologist and soil scientists, to define loess precisely. Typically, deposits of loess are very silty but contain significant amounts of clay and fine sand. Usually, but not always, the material is calcareous. In Kansas these loess deposits are included in the Sanborn formation. This formation consists of the Bignell, Peorian, and Loveland loess members, the crete sand and gravel member, and early and late Wisconsin alluvial deposits.

Bignell Member

This loess, as described by Schultz and Stout (26), is considered to be late Wisconsin in age. They stated the Bignell loess

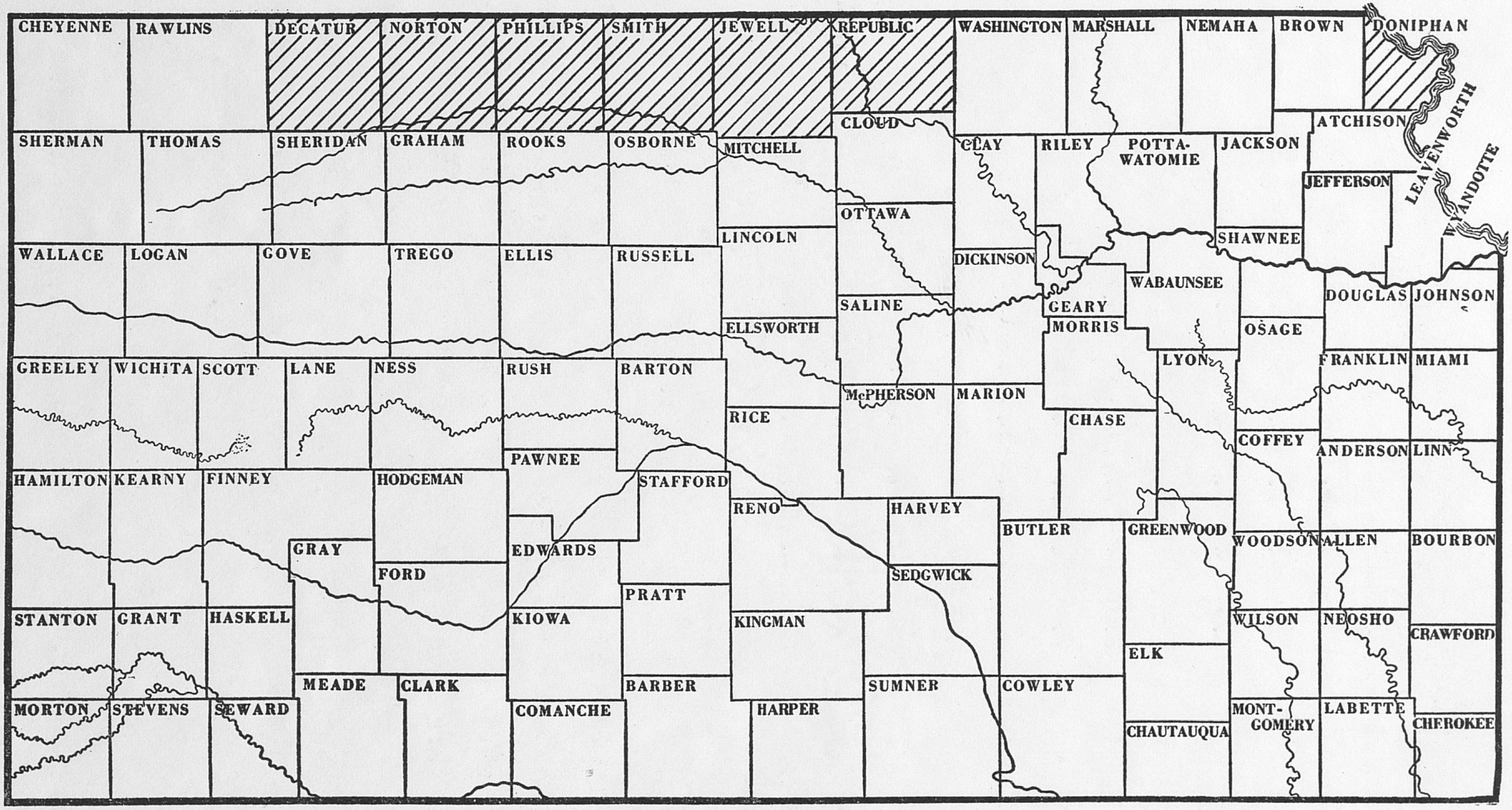


Fig. 1. Map of Kansas showing counties from which samples were taken for this investigation.

is, in part, re-worked Peorian loess. Frye and Leonard (9) stated that in Kansas the Bignell loess is so similar to the Peorian loess that it can not be distinguished without the Brady soil stratigraphically below it.

The Brady soil was formed during a short interglacial interval known as the Bradyan substage. Frye and Leonard (9) stated that the Brady soil developed in Peorian loess. They stated that the Brady profile is moderately to poorly drained, and that the depth of leaching ranges from one to three feet. They also stated that the A horizon is generally dark and the B horizon shows some clay accumulation. However, in some locations they found little or no textural difference between the A and B horizons. The Brady soil, where developed on Peorian loess, has been described by Thorp, et al., (31) as a Chernozem-like silt loam without textural variation throughout the profile. In other locations they observed the subsoil to be mottled, suggesting a Wiesenboden or Humic-Gley condition.

Peorian Member

Condra, et al., (7) stated that the Peorian loess was deposited during the time interval between the Iowan and Mankato glacial substages in Iowa. The deposition of the Peorian loess was suggested to have occurred during the relatively dry cycle following the melting of the ice sheet. They suggested that the source area for this material was the exposed silty alluvium along the large river valleys. Swineford and Frye (30) also stated that the silty alluvium along the major river valleys contributed most of the material for the Peorian loess.

The Peorian silt member ranges in texture from coarse silt and very fine sand along the Republican river in northwestern and northcentral areas of Kansas, to medium silt and silty clay in northeastern Kansas. The thickness of the Peorian member ranges from 90 feet at the Sanborn type section in Cheyenne County, to over 100 feet in Doniphan County (Frye and Walters, 12).

The Peorian loess is uniform in texture and general appearance from Jewell County westward to the Kansas-Colorado border. This material is usually highly fossiliferous, calcareous, and exhibits a massive or structureless appearance. Commonly developed at the base of the Peorian loess is an "inverted" A soil horizon. It has been suggested that the rate of deposition of Peorian loess was so slow at the beginning that this material was incorporated into the top of the Sangamon soil.

Loveland Member

The Loveland loess was named in 1909 by Shimek (27). The type location for this material was the Missouri River bluffs northeast of Loveland, in Pottawattamie County, Iowa. Kay and Apfel (18) re-described this and other Loveland deposits and suggested two phases of deposition, alluvial and eolian. Frye and Leonard (11) stated that the Loveland member in Kansas contains both the waterlaid silts in valley situations and the loess of the uplands.

The Loveland loess has been recognized along the Missouri and Kansas River valleys. This material has been encountered in test holes and has been studied in road cuts in northcentral, central,

and southwestern parts of Kansas. In the northwestern Kansas counties, widespread deposits classed as Crete or Crete-Loveland have been encountered. The Loveland loess is not recognized as such east of the Flint Hills area or in the Smoky Hill region of western Kansas.

Condra, et al., (7) stated that the Loveland loess consists of wind reworked alluvial deposits, also wind reworked dunesand and exposed older Pleistocene and Pliocene deposits such as the Ogallala and other High Plains bed rock formations.

The soil developed on the Loveland loess is referred to as the Loveland soil in Nebraska and Iowa. However, in Kansas and Illinois this buried soil has been termed the Sangamon soil by Frye and Leonard (11). This buried soil occurs from the Missouri River valley to the Colorado state line and has been used successfully as a stratigraphic datum. Thorp, et al., (31) stated the following about the character and environment of the Sangamon soil:

> On the Great Plains, it appears from the dark-colored A horizons and thick, reddish-brown clayey B horizons that the dominant vegetation probably was grass, and that the dominant well-drained soils were Reddish Prairie soils and reddish Chernozems with maximal textural contacts between the A and B horizons.

Clay Mineralogy of the Loesses

Considerable work has been done on the clay mineralogy of the loessial materials and the soils developed from them. Davidson and Handy (8) in their studies of the clay fraction from Peorian and Bignell loess in southwestern Iowa, reported a predominance of an interstratified mixture of montmorillonite and illite with minor amounts of quartz and kaolinite. They also found that the

clay in the loess occurred in two distinct kinds of coatings on larger grains: (1), minute specks adhering either individually or in clusters to a host grain; (2), a continuous coating covering the surface of larger grains. They report that the continuous coating of grains is less common than the speck type of clay coating. Swineford and Frye (30) and Mielenz, et al., (21) also observed the clay coatings. They stated that these clay coatings are predominantly montmorillonite or a mixed layer of montmorillonite and illite.

Russell and Haddock (25) investigated some Iowa soils developed on Peorian loess. They concluded that, on the average, the minerals present were in the amounts of 60 percent montmorillonite, 30 percent illite and 10 percent kaolinite.

Peterson (22) also analyzed the same soils developed on Peorian loess. He found that the clay fraction consisted mostly of montmorillonite and little or no illite. He reported that there was little difference in the clay mineral composition between the A and B horizon of the soils studied.

Bray (4) in his studies of Peorian loess of Illinois, stated that the colloid fraction is essentially a mixture of sericite-like and beidellite-type minerals. The coarse colloids gave the sericite-like X-ray pattern, whereas "super-fine colloids" gave the beidellite-type of pattern. He said that the mica loses its potassium and magnesium and becomes a beidellite-type mineral.

Beavers, et al., (1) in analyzing some soils developed from Peorian loess in Illinois, found that the clay fraction of the B and C horizons consisted predominantly of montmorillonite and minor amounts of illite and chlorite. The illite and chlorite

were about equal in amounts. The A horizon of these soils often contained a greater percentage of illite than montmorillonite. The percent of chlorite in the A horizon was often greater than that found in the B or C horizon. No kadinite was reported for any of these soils. They deduced that the clay fraction of the Peorian loess probably came from the same source area as that of the Peorian loess in Kansas, namely the montmorillonitic and bentonitic soils and sediments of the Great Plains region.

Swineford and Frye (29) studied loess from Italy, France, Germany, Belgium and Kansas. They found that the loesses of Italy contained muscovite, calcite, antigorite, chlorite, montmorillonite and a mixed layer mineral in the less than two micron size fraction. Those of France were found to contain illite, montmorillonite, kaolinite and quartz in the same size fraction. The clay fraction of the loesses from Germany contained calcite, illite, kaolinite, montmorillonite, chlorite and a mixed layer mineral. In the less than two micron fraction of loess from Belgium they found montmorillonite, illite, kaolinite and quartz. They found loess samples from Rawlins, Gove, Marshall and Doniphan Counties in Kansas to contain a predominance of montmorillonite, with illite and kaolinite present in smaller amounts. They found no evidence of chlorite or vermiculite in those samples.

They observed that these materials from widely separated regions possessed much similarity in field appearance, topographic relationships, soil profile development, texture and stratigraphy, but displayed strong differences in mineralogy. They concluded that the source area of the loess was the controlling factor in

both the clay and nonclay mineral composition. They believed that the observed minerals reflected mainly the weathering stages of the parent or source material, and not the post depositional weathering of the loess.

Metz (20) reported that the 0.2 to 0.08 micron size material from the Peorian loess, Sangamon soil and Loveland loess from Phillips County Kansas contained a predominance of montmorillonite and minor amounts of illite.

Kaufman (17) studied three soil profiles developed from Peorian loess in Kansas under varying climatic conditions. The classification of these soils was: Sierozem-like, Chestnut and Gray-Brown Podzolic. He found that the less than five micron size material of all three soils contained montmorillonite, illite and a mixed layer or beidellite-like mineral with smaller amounts of kaolinite and quartz and trace amounts of halloysite, feldspar and vermiculite.

FIELD INVESTIGATION PROCEDURE

Field Observations

It was noted during the field investigation of the loesses that three different conditions existed. The first, and most easily recognized, was the development of the Sangamon soil on thick deposits of Loveland loess. The second condition was the development of the Sangamon soil on thin and discontinuous areas of Loveland loess. The third condition occurred where the Sangamon soil had developed on residual material, such as the Greenhorn limestone. Field investigations are sufficient in determining the

origin of the material for the first condition, however, additional laboratory information is usually needed for the second and third conditions.

An example of condition number 2 is shown in Plate I. This plate shows a well developed Sangamon soil which developed from thin Loveland loess, overlying Smoky Hill chalk. Approximately seven feet of Peorian loess overlays the Sangamon soil.

It was also noted in fresh exposures that the Peorian loess was usually structureless. The B_2 horizon of the Sangamon soil showed moderate subangular blocky structure, whereas the structure of the C horizon of the Loveland loess was usually weak subangular blocky to structureless. It was further noted that the maximum development of the Sangamon soil occurred in the west-central part of the state.

Numerous calcium carbonate concretions were noted in the Peorian loess. These concretions occurred mostly above the contact with the underlying Sangamon soil. Calcium sulfate crystals often were observed to occur at or near the contact of these two units. Since calcium sulfate is much more soluble than calcium carbonate, this condition suggests that there is a restrictive zone or a difference in permeability between these two units.

McNeal (19) reported that a difference in permeability between the Peorian loess and the underlying Sangamon soil effected the water movement through these units.

Where highway construction has exposed the Peorian loess and Sangamon soil on vertical slopes to surface weathering, the Sangamon soil tends to spall in small angular blocks about 2" x 1" x 1" in

EXPLANATION OF PLATE I

Photograph of Peorian loess underlaid by a well developed Sangamon soil developed in thin Loveland loess overlying the Smoky Hill chalk in Jewell County. ($NW\frac{1}{4}NE\frac{1}{4}$ sec. 20, T. 3S., R 8W.)

PLATE I



size. This spalling gradually continues until the overlying Peorian loess has been undercut. When this condition occurs the Peorian loess caves off in large triangular shaped blocks that range in size from about 2' x 2' x 6' and upward.

The presence of the Sangamon soil at or near the surface is often reflected in the surface topography. There is usually a change in slope where the Sangamon soil outcrops at the surface. The Sangamon tends to stand at a steeper slope than either the overlying Peorian or underlying Loveland loesses when exposed by normal geological weathering processes. This slope relationship is often reflected on the surface by a "cat-step" type of topography. Thus the presence of the Sangamon soil can often be detected in grassland slopes even though no soil is exposed to view.

Sampling Procedure

Since this investigation was concerned principally with the difference in clay minerals as related to the type of loess present, spot samples were collected from the major horizons of the loess members.

A recent excavation, prior to construction, on proposed U. S. Highway 36 near Mankato, Kansas, provided several excellent exposures of the loess units. The samples collected at those exposures were usually obtained in the vicinity of highway failures. Soil descriptions were taken at the sites in Jewell County to ascertain the properties of the loessial material not affected by present surface weathering. The sample sites from which the other samples were obtained were not described in detail but samples were collected

in the same manner as those from along U. S. Highway 36 in Jewell County.

Description of Soil Profile I

NE¼NE¼ sec. 21, T. 3S., R. 9W., Jewell County, Kansas

1. C_2 0-12" Light gray (10YR 7/2), pale brown (10YR 6/3) moist, light silty clay loam, structureless, vesicular, friable, soft, pH 8.1.
2. A_{1b} 12-26" Gray (10YR 5/1 and 6/3), very dark gray (10YR 3/1) moist, silty clay loam, structureless, vesicular, friable, slightly hard, pH 7.9.
3. B_{1b} 26-37" Dark gray (10YR 4/1 and 3/2), very dark gray (10YR 3/1) moist, light silty clay, structureless to weak granular, vesicular, friable, hard, pH 7.9.
4. B_{2b} 37-63" Dark gray (10YR 4/1), very dark gray (10YR 3/1) moist, silty clay, fine subangular blocky, less vesicular than above, occasional 3.5 mm. gypsum concretions present, friable to firm, hard to very hard, pH 7.5.
5. C_b 63-69" Reddish yellow (7.5YR 7/6), reddish yellow (7.5YR 6/6) moist, light silty clay loam, weak subangular blocky to structureless, friable to firm, hard, pH 7.8.

A cross section of the loessial material in relation to the bedrock and topography at this location is shown in Fig. 2.

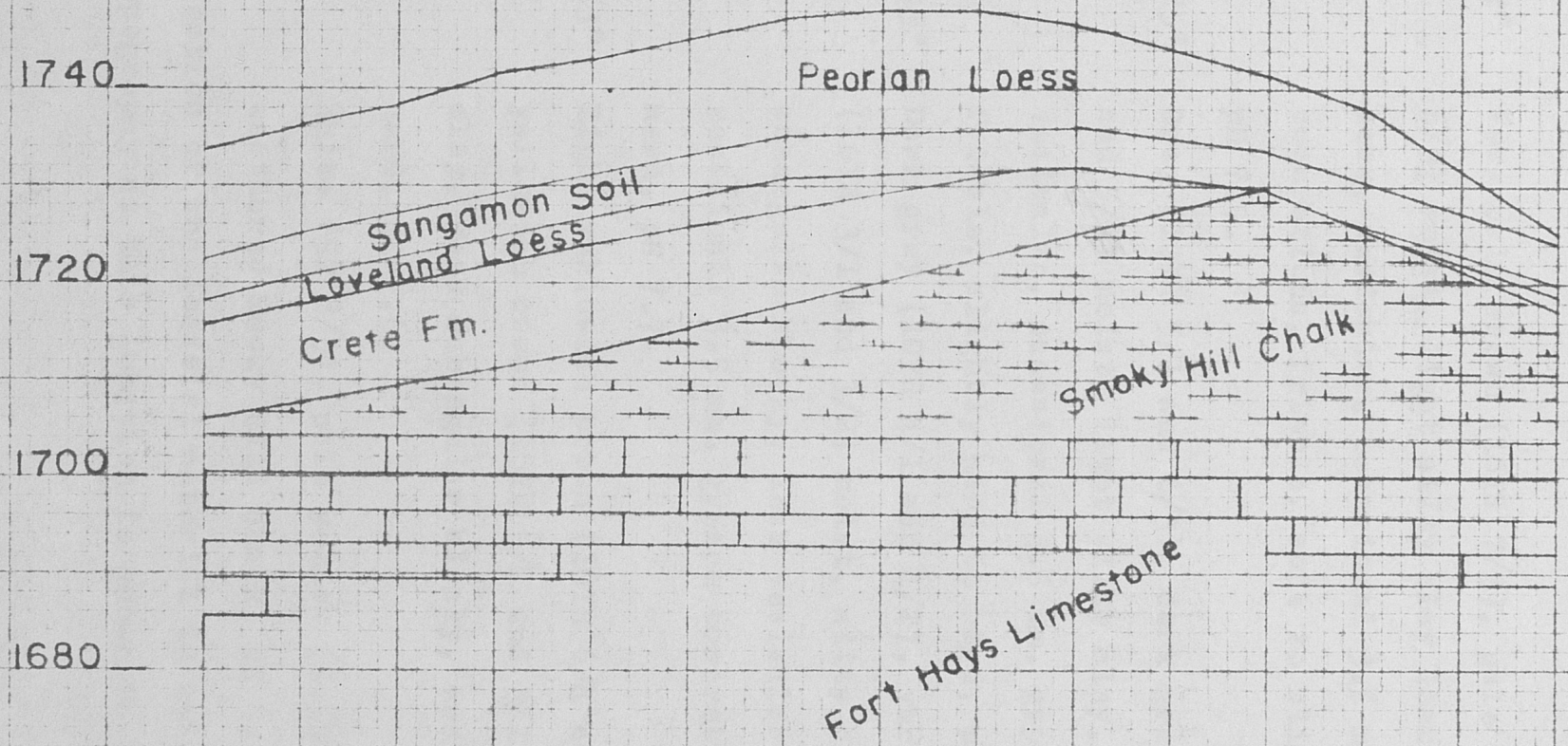


Fig. 2. A cross section of the loessial materials.

Description of Soil Profile II.

NE¼NE¼ sec. 23, T. 3S., R. 9W., Jewell County, Kansas

1. C_2 0-12" Very pale brown (10YR 7/3), pale brown (10YR 6/3) moist, light silty clay loam, structureless, vesicular, occasional 3.5 mm. gypsum concretions, friable, soft to slightly hard, pH 7.9.

2. A_{1b} 12-25" Gray (10YR 5/1 and 6/3), dark gray (10YR 4/1 and 5/3) moist, light silty clay, structureless, vesicular, occasional 3.5 mm. gypsum concretions, friable, slightly hard to hard, pH 7.7.

3. B_{2b} 25-43" Dark gray (10YR 4/1 and 4/2), very dark gray (10YR 3/1 and 3/2) moist, silty clay, fine subangular blocky, less vesicular than above, occasional 3.5 mm. gypsum concretions, firm, hard, pH 7.7.

4. C_b 43-53" Light yellowish brown (10YR 6/4 and 3/1), yellowish brown (10YR 5/4 and 3/1) moist, silty clay, weak subangular blocky, vesicular, firm, hard, pH 7.6.

5. D 53+ White (5Y 8/3), pale yellow (2.5Y 7/4) moist, weathered Smoky Hill chalk, pH 8.1.

A cross section of the loessial material in relation to the bedrock and topography at this location is shown in Fig. 3.

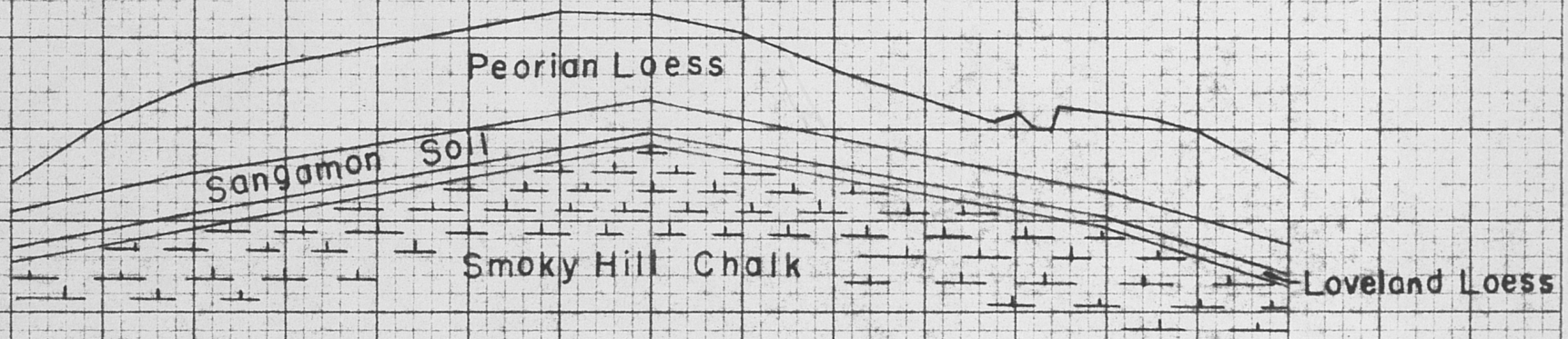


Fig. 3. A cross section of the loessial materials.

Description of Soil Profile III.

NW¼NW¼ sec. 20, T. 3S., R. 8W., Jewell County, Kansas

1. C_2 0-12" Very pale brown (10YR 7/3), pale brown (10YR 6/3) moist, heavy silt loam, few fine faint mottles, structureless, vesicular, friable, soft to slightly hard, pH 7.8.

2. A_{1b} 12-26" Light gray (10YR 7/2), pale brown (10YR 6/3 and 6/2) moist, light silty clay loam, few fine faint mottles, structureless, vesicular, friable, slightly hard to hard, pH 7.7.

3. B_{1b} 26-40" Dark gray (10YR 4/1), very dark gray (10YR 3/1 and 3/2) moist, heavy silty clay loam, common medium distinct mottles, weak granular to structureless, firm, hard, pH 7.6.

4. B_{2b} 40-61" Dark gray (10YR 4/1), very dark gray (10YR 3/1) moist, silty clay, few fine faint mottles, fine subangular blocky, firm, hard to very hard, pH 7.7.

5. C_b 61-72" Yellowish brown (10YR 5/4 and 4/1), yellowish brown (10YR 5/4 and 4/1) moist, light silty clay, few fine faint mottles, weak to fine subangular blocky, firm, hard, pH 7.7.

6. D 72+ Pale yellow (5Y 8/4), white (2.5Y 8/4) moist, weathered Smoky Hill chalk, pH 8.5.

A cross section of the loessial material in relation to the bedrock and topography at this location is shown in Fig. 4.

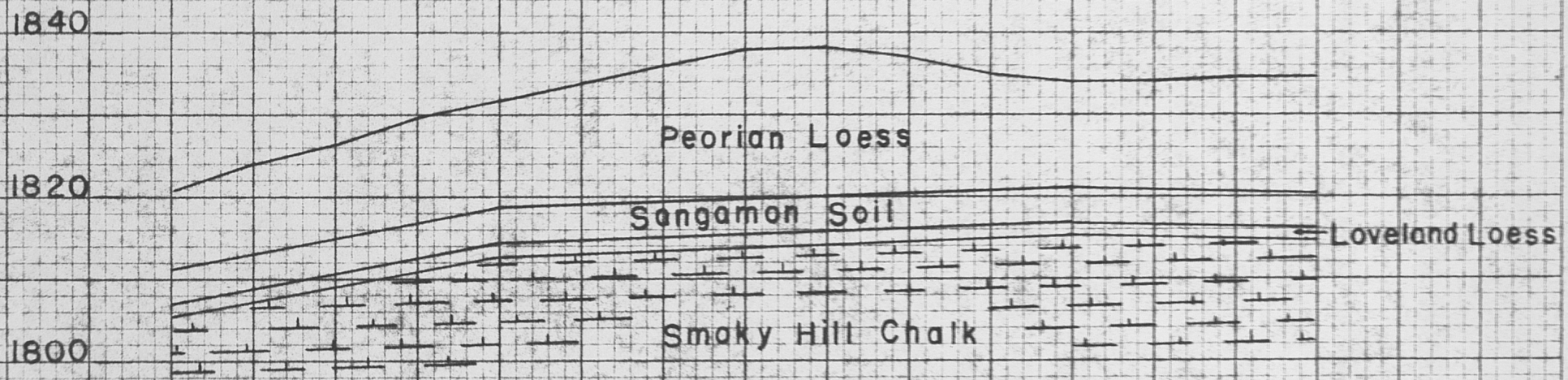


Fig. 4. A cross section of the loessial materials.

Description of Soil Profile IV.

SW¼SW¼ sec. 14, T. 3S., R. 8W., Jewell County, Kansas

1. C_2 0-12" Pale brown (10YR 6/3), brown (10YR 5/3 and 5/2) moist, silty clay loam, structureless, vesicular, friable, soft to slightly hard, slight effervescence with Hcl, pH 8.1.

2. A_{1b} 12-24" Dark gray (10YR 4/1 and 6/3), very dark gray (10YR 3/1 and 4/2) moist, light silty clay, structureless, vesicular, friable, slightly hard, pH 8.0.

3. B_{1b} 24-37" Dark gray (10YR 4/1 and 4/2), very dark gray (10YR 3/1 and 3/2) moist, silty clay, structureless, vesicular, friable, hard, pH 8.1.

4. B_{2b} 37-51" Very dark gray (10YR 3/1 and 4/2), very dark gray (10YR 3/1 and 3/2) moist, silty clay, fine subangular blocky, vesicular, occasional 3.5 mm. gypsum concretions, firm, hard to very hard, pH 8.3.

5. B_{3b} 51-75" Brown (10YR 5/3 and 5/2), yellowish brown (10YR 5/4 and 4/1) moist, light silty clay, weak subangular blocky to structureless, occasional 3.5 mm. gypsum concretions, firm, hard, pH 8.2.

6. C_b 75+ Light yellowish brown (10YR 6/4), yellowish brown (10YR 5/4) moist, light silty clay, structureless, firm, hard, pH 8.2.

A cross section of the loessial material in relation to the bedrock and topography at this location is shown in Fig. 5.

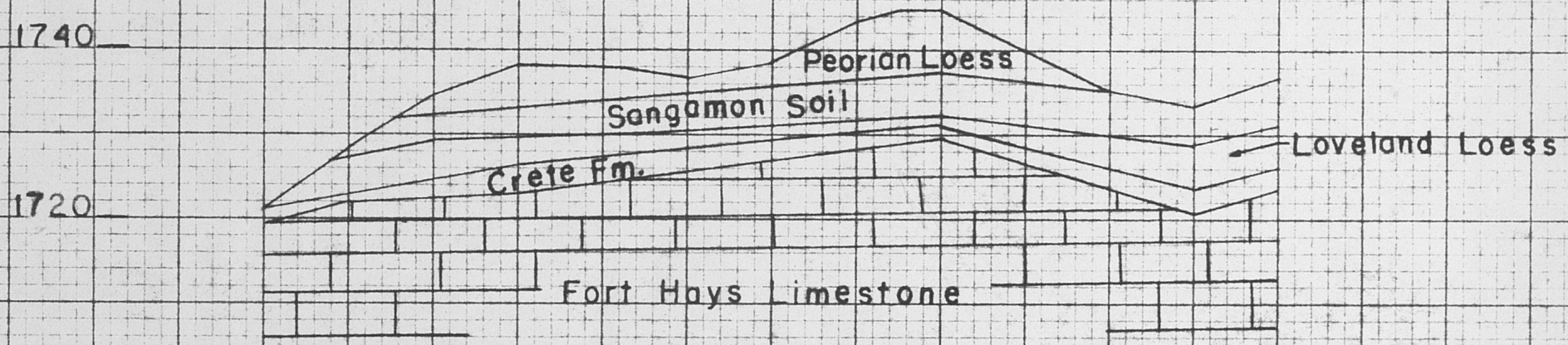


Fig. 5. A cross section of the loessial materials.

Description of Soil Profile V.

SE¼SE¼ sec. 14, T. 3S., R. 8W., Jewell County, Kansas

1. C_2 0-12" Very pale brown (10YR 7/3 and 5/1), light yellowish brown (10YR 6/4 and 4/1) moist, light silty clay loam, vesicular, friable, soft to slightly hard, slight effervescence with HCl, pH 8.0.

2. A_{1b} 12-41" Dark gray (10YR 4/1 and 6/3), dark gray (10YR 4/1) moist, light silty clay, structureless, vesicular, friable, slightly hard, slight effervescence with HCl, pH 7.9.

3. B_{2b} 41-50" Dark gray (10YR 4/1 and 5/3), very dark gray (10YR 3/1 and 5/4) moist, silty clay, fine subangular blocky, firm, hard to very hard, occasional 3.5 mm. gypsum concretions, pH 8.0.

4. B_{3b} 50-58" Dark grayish brown (10YR 4/2 and 4/3), dark gray (10YR 4/1) moist, silty clay, weak subangular blocky to structureless, firm, hard, pH 8.0.

5. C_b 58+ Light brown (7.5YR 6/4), brown (7.5YR 5/4) moist, light silty clay, structureless, vesicular, firm, hard, occasional 3.5 mm. gypsum concretions, pH 8.0.

A cross section of the loessial material in relation to the bedrock and topography at this location is shown in Fig. 6.

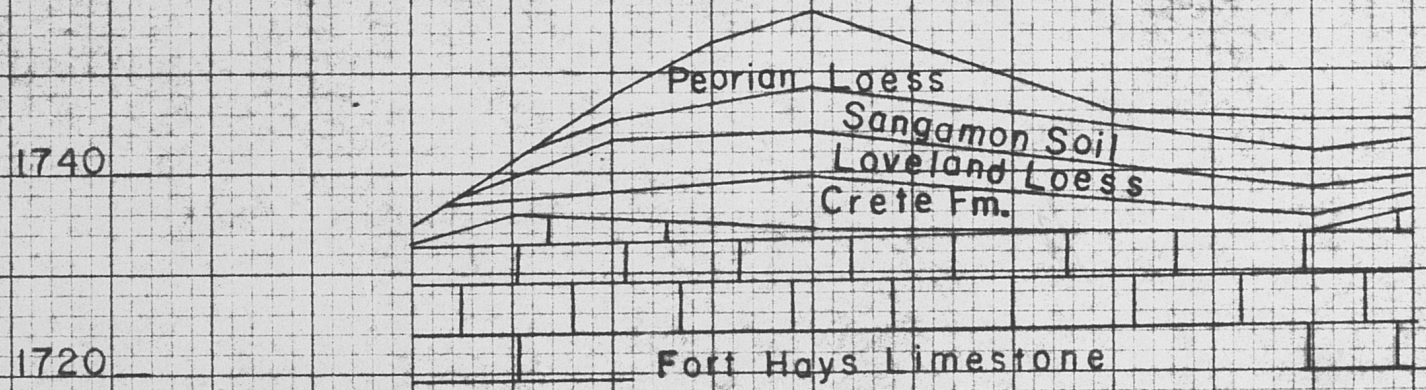


Fig. 6. A cross section of the loessial materials.

Description of Soil Profile VI.

SW¼SW¼ sec. 4., T. 3S., R. 1W., Republic County, Kansas

1. C_2 0-12" Light gray (10YR 7/2), light grayish brown (10YR 6/2 and 6/3) moist, silty clay loam, common medium distinct mottles, structureless, vesicular, friable, slightly hard, calcium carbonate concretions present, pH 7.9.

2. A_{1b} 12-25" Gray (10YR 5/1 and 6/3), dark gray (10YR 4/1) moist, silty clay, common medium distinct mottles, structureless, vesicular, firm, hard, pH 7.7.

3. B_{2b} 25-38" Dark gray (10YR 4/1), very dark gray (10YR 3/1) moist, silty clay, common medium distinct mottles, fine subangular blocky, firm, hard to very hard, pH 7.6.

4. B_{3b} 38-53" Light brown (7.5YR 6/4), brown (7.5YR 5/4) moist, silty clay, common medium distinct mottles, weak subangular blocky, firm, hard, pH 7.8.

5. C_b 53+ Pale yellow (2.5Y 8/4), yellow (2.5Y 8/6) moist, weathered Pfiefer shale, pH 8.5.

A cross section of the loessial material in relation to the bedrock and topography at this location is shown in Fig. 7.

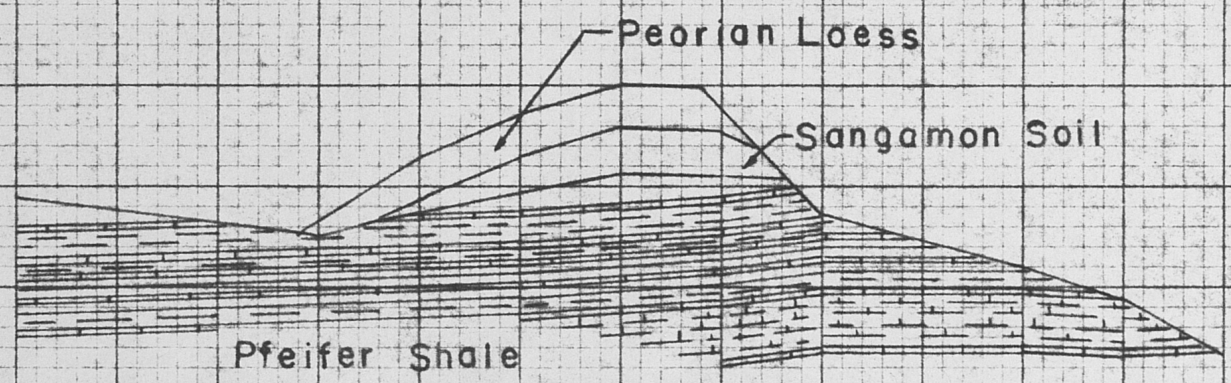


Fig. 7. A cross section of the loessial materials.

LABORATORY INVESTIGATION PROCEDURE

The samples were air dried, gently crushed with a rolling bottle, and screened through a 2 mm number 10 Tyler sieve. The samples were labelled and placed in containers.

Particle Size Distribution

The Bouyoucos (2) procedure was used to determine the particle size distribution of the samples. The air dry equivalent of 50 grams of oven dry organic matter free material was used for this procedure. The air dry soil was carefully weighed and placed in 250 ml beakers. Enough distilled water was then added to each sample to cover the soil. Five ml of 1N solution of sodium hexametaphospate were added to each sample. The soil suspension was allowed to stand overnight for complete soaking and slaking. After standing overnight the material was quantitatively transferred to a malted milk mixing cup and stirred for four minutes to bring the soil into suspension. Each soil suspension was then transferred to a standard sedimentation cylinder. A hydrometer was placed in the suspension and the total volume brought to 1000 ml using distilled water. The hydrometer was removed and the suspension in the cylinder shaken vigorously by hand for one minute. The cylinder containing the suspension was placed in a constant temperature bath ($67^{\circ}F$). The hydrometer was placed back in the suspension and hydrometer readings and temperature of the suspension were recorded after the elapse of 40 seconds and again after two hours.

Determination of Soil pH

The pH of the soils was determined on a 1:1 soil-water suspension with a Beckman pH meter. The mixture was stirred and allowed to stand for 30 minutes and then stirred again before immersing the glass electrodes.

Determination of Cation Exchange Capacity

The exchange capacity values for the various soil horizons were determined with a Beckman flamephotometer using a modification of the method proposed by Rendig (23). Between one and two grams of air-dry soil were weighed to the nearest thousandth of a gram and transferred to a 100 ml plastic centrifuge tube. Fifty ml of 0.1 N hydrochloric acid were added to the sample and the material brought into suspension by the use of a rubber tipped electric stirrer. The suspension was centrifuged at 1800 r.p.m. for three minutes and the supernatant liquid decanted. This process was repeated until no effervescence could be observed. The soil was resuspended in 50 ml of 1 N calcium chloride. The suspension was recentrifuged at 1800 r.p.m. for three minutes and the supernatant liquid discarded. This procedure was repeated three times. After the washing with 1 N calcium chloride was complete, the soil was resuspended in 50 ml of ethyl alcohol, recentrifuged, and the supernatant liquid discarded. This procedure was repeated until no test for chlorides was obtained when silver nitrate was added to the decantate. The material was then resuspended in 1 N neutral ammonium acetate and centrifuged four times with this

solution. The supernatant liquid from each centrifuging was combined in a 250 ml volumetric flask and the total volume brought to 250 ml using ammonium acetate buffered to a pH of 7. The contents of the flask were then filtered through a Whatman number 42 filter paper. The calcium content of the filtrate was determined using a Beckman flamephotometer.

Determination of Soil Organic Matter

The soil organic matter was determined with a spectrophotometer, using a wave length setting of 620. Distilled water was used as a reference liquid.

One gram of soil was placed in a 250 ml erlenmeyer flask and 10 ml of 1 N potassium dichromate were added. After the addition of potassium dichromate, 20 ml of reagent grade sulfuric acid (sp. gr. 1.84) were added and the contents were mixed for ten seconds and then allowed to stand for 30 minutes. One hundred ml of distilled water were added and the total contents were mixed thoroughly. The suspension was filtered through a Whatman number 2 filter paper and the filtrate was caught in a funnel tube and allowed to cool. After cooling, the funnel tube containing the filtrate was placed in the photometer and readings were made and recorded.

Exchangeable Sodium and Potassium

Ten grams of sample were placed in a 125 ml erlenmeyer flask and 50 ml of 1 N neutral ammonium acetate solution were added. A rubber stopper was placed in the flask and its contents were mixed for ten minutes by means of an end over end shaker. The suspension

was filtered through a Whatman number 42 filter paper. Twenty ml of the filtrate were placed in a 125 ml erlenmeyer flask and 2 ml of a solution containing 1,100 p.p.m. of lithium in 1 N ammonium acetate were added. The solution then contained 100 p.p.m. of lithium and an unknown concentration of sodium.

The Perkin flamephotometer was standardized for sodium in ammonium acetate solution by adjusting it to give an internal standard dial reading of 100 with the standardizing solution of 100 p.p.m. of sodium and 100 p.p.m. of lithium in ammonium acetate. Then the internal standard dial readings for the ammonium acetate soil extracts containing 100 p.p.m. of lithium were recorded. The internal dial readings were converted to milliequivalents of sodium per hundred grams of soil by reference to the proper standardization curve.

The same procedure as described for exchangeable sodium was used for exchangeable potassium with the exception of standardizing the Perkin flamephotometer. The photometer was standardized for potassium in ammonium acetate solution by adjusting it to give an internal standard dial reading of 100 p.p.m. of lithium in ammonium acetate. Then the internal standard dial readings for the ammonium acetate soil extracts containing 100 p.p.m. of lithium were recorded.

Removal of Organic Matter

One hundred grams of air dry soil which had passed through a 2 mm sieve, were placed in a 600 ml beaker. Two hundred and fifty ml of distilled water were added to the soil and stirred with a

glass rod. Ten ml of 30 percent hydrogen peroxide were added and the beaker covered with a watch glass. Where a violent reaction occurred, the cold hydrogen peroxide treatment was repeated until more frothing occurred. The beaker was then heated to about 80 degrees centigrade on a steam plate. Hydrogen peroxide was added in 10 ml increments at 45 minute intervals until the organic matter was removed. Heating was then continued for about 30 minutes to remove any excess nascent oxygen.

A rubber policeman and a fine stream of distilled water were used to transfer the sample from the beaker to a Buechner funnel containing a Whatman number 42 filter paper. Small increments of distilled water were added to the material as it was vacuum filtered. Usually four washings were sufficient to remove any soluble salts.

Separation of the Clay Fraction

Approximately 100 grams of organic matter free material were placed in a Waring blender. Two hundred ml of distilled water and 10 ml of sodium hexametaphosphate were added to the blender, and the contents were mixed for five minutes.

After mixing, the samples were washed over a number 270 sieve to separate the sand from the silt and clay. The silt and clay that passed through the sieve were washed into a standard sedimentation cylinder. Distilled water was added to bring the total volume to 1000 ml. The suspension was mixed thoroughly by shaking vigorously for one minute. The cylinder containing the suspension was then placed in a 20 degree constant temperature bath.

The samples were allowed to stand eight hours for each ten centimeters of settling distance with an additional 50 percent settling time allowed for the first separation. At the end of 36 hours the upper 30 centimeters of suspension was siphoned off and saved. Distilled water was added to the cylinder to bring the total volume to 1000 ml. The suspension was shaken vigorously for one minute and returned to the constant temperature bath for 24 hours. At the end of that period a second separation was made. Two separations gave sufficient clay for analysis.

The clay suspension was mixed thoroughly and a 150 ml aliquot was taken for use in making oriented slides for X-ray diffraction analysis. The remaining suspension was flocculated by lowering its pH to 3.5 by the addition of 1 N hydrochloric acid. After flocculation was complete the clear supernatant liquid was decanted. The remaining clay suspension was vacuum filtered through a Buechner funnel using Whatman number 42 filter paper. The clay was allowed to air dry, was crushed with a mortar and pestle, and placed in a vial for later use in Differential Thermal Analysis and stain testing.

Separation of Clay into Size Fractions by Use of the Supercentrifuge

The method described by Jackson (14) was used in the separation of clay into size fractions. This was accomplished by using a Sharples laboratory model air-turbine supercentrifuge equipped with a clarifier bowl having a removable cellulose acetate liner.

The separation of the less than 0.08 micron clay fraction was made first. A supercentrifuge bowl speed of 25,000 revolutions per

minute and a suspension flow rate of 100 milliliters per minute was used. The total clay fraction was placed in a Waring blender and mixed for 15 minutes. The suspension was placed in an upper feed reservoir and allowed to flow into a lower feed reservoir. A constant level was maintained in the lower reservoir by adjusting the flow from the upper reservoir. The suspension was fed into the supercentrifuge from the lower reservoir. The outflow from the supercentrifuge which contained the clay that was less than 0.08 micron in diameter was collected. The clay fraction coarser than 0.08 micron was sedimented on the cellulose acetate liner. After the centrifuge had stopped, the cellulose acetate liner was removed from the clarifier bowl and the retained clay fraction was washed into the Waring blender. The suspension was mixed for 15 minutes in preparation for the second centrifuging. This procedure was followed until the outflow from the supercentrifuge was clear, usually requiring five separations.

The less than 0.08 micron material was flocculated by the addition of 1 N hydrochloric acid. The clear supernatant liquid was decanted, and the suspension containing the less than 0.08 micron clay was vacuum filtered using a number 42 Whatman filter paper. The less than 0.08 micron clay was not allowed to dry but was washed several times on the filter paper until no chlorides could be detected in the filtrate. The moist clay was then transferred to a bottle by the use of a small stream of distilled water, and set aside for X-ray diffraction analysis.

The same procedure was used for the separation of the 0.2 to 0.08 micron clay fraction. However, a bowl speed of 25,000

revolutions per minute and a flow rate of 382 ml per minute was used. The outflow from the supercentrifuge was collected and flocculated by the addition of hydrochloric acid. After the 0.2 micron separation was completed the material sedimented on the cellulose acetate liner was washed into a bottle and saved. This material was the coarse fraction with a diameter of less than two microns and larger than 0.2 microns.

X-ray Diffraction Analysis

The 150 ml aliquot saved after separation of the clay fraction was placed in a Waring blender and mixed for one minute. Approximately three ml of suspension were placed on a glass microscope slide and allowed to dry. When the suspension had dried, a thin film of clay minerals were left oriented on the glass slide. Clay minerals oriented in this manner give only the basal reflections in X-ray diffraction analysis. The oriented clay minerals present on the glass microscope slide were placed in the slide holder of a North American Phillips X-ray diffractometer. The specimen was exposed to nickel filtered copper radiation, utilizing 20 milliamps, 40 kilovolts, with a one degree slit opening, a rate scale factor of eight, and a time constant of four seconds. Each sample was X-rayed from 30 degrees to three degrees two theta. The sample was treated with ethylene glycol and X-rayed from 15 degrees to three degrees two theta. The angular spacings were recorded on a strip chart recorder in degrees two theta and d-spacings in angstrom units were obtained from "Tables for Conversion of X-ray Diffraction Angles to Interplanar Spacing"

Swanson (28). The d-spacings were compared with the theoretical and measured d-spacings of minerals that may be expected to occur in the clay size fraction to determine what clay minerals were present.

The use of organic complexes such as ethylene glycol, as described by Bradley (3), expanded the C dimension of montmorillonite and provided a sharp (001) reflection at 17.7 angstroms. The use of glycol permitted the detection of minerals such as chlorite or vermiculite that might otherwise be masked by montmorillonite.

Differential Thermal Analysis

The powdered sample saved for thermal analysis was placed in one hole, and calcined aluminum oxide was placed in the other hole of a nickel speciman holder. One junction of a differential double junction thermocouple was inserted in the sample, while the other was placed in the inert material. The heating rate was determined by a thermocouple placed in the nickel block just below and between the holes which held the sample and the aluminum oxide. The holder and thermocouples were placed in a Hoskins Hevi-duty oven and heated. When a physical or chemical change occurred in the sample, it showed up either as an exothermic or an endothermic reaction. The temperature and thermal reactions were plotted automatically by the use of Leeds and Northrup micromax recorders.

Stain Techniques

The procedure by Hambleton and Dodd (13) was used for the identification of clay minerals by stain techniques. In this

procedure, Eastman reagent grade p-amino phenol in absolute alcohol was prepared in 0.1, 0.5, 2, and 4 percent concentrations and stored in brown glass dropper bottles. A bottle of 1:1 hydrochloric acid was also prepared.

Dry bulk samples of the loess were ground to pass the 50 and be retained on the 100 mesh screen. Three to five cubic mm. of such material were placed in the depressions on a white porcelain spot plate, four separate spots being used for each sample. Two drops of p-amino phenol reagent of the various concentrations were added to the samples in the separate depressions (only one concentration was added to any one depression). The samples in each depression were then thoroughly mixed and allowed to stand until the alcohol solvent had evaporated. The dried grains were mixed thoroughly with a thin glass stirring rod and one drop of 1:1 HCl was added. The color of the wet sample was observed under a stereoscopic microscope and the color compared to that in a standard chart. Fluorescent light was found to be suitable for observing the colors.

Montmorillonites give blue colors which are frequently seen only on the edges or corners of grains when treated with 0.1 percent reagent solution.

Illites when observed wet after the addition of acid to a sample which had previously been treated with 0.5 percent or 2 percent reagent solutions give green or brown colors.

Kaolin minerals when treated with 4 percent reagent solution give colors ranging from light tans to pinks. The presence of 25 percent or more of montmorillonite or illite often caused the pink

or tan kaolin colors to be masked by the blue or green colors of those minerals.

Soil Moisture Determination

Numerous samples of Peorian, Sangamon and Loveland loess were collected for soil moisture determination. A four inch bucket auger was used for collecting the samples which were placed in weighed aluminum moisture cans and tightly sealed with masking tape. A soil description was taken at each site.

The weighed samples were allowed to dry at 105 degrees C in a drying oven for several days. After the samples were completely dry they were reweighed and the loss in weight determined. The loss in weight represented the free water that each sample contained.

RESULTS OF THE INVESTIGATION

Particle Size Distribution

The results of the particle size analysis are shown in Table 2. The analysis indicated that the lower portion of the Peorian was a silty clay loam. The total sand content of the Peorian samples described in Jewell and Republic Counties ranged from 2.0 to 11.2 percent. The silt fraction from these locations ranged from 56.1 to 67.3 percent. The clay fraction for the same samples varied from 25.5 to 37.8 percent.

The B_{2b} horizon of the Sangamon soil from the same locations showed a total sand content range from 4.0 to 7.2 percent, with

the silt ranging between 45.6 and 50.3 percent. The clay fraction of the Sangamon soil ranged from 42.5 to 50.4 percent. The B_{2b} horizon of the Sangamon soil is a silty clay.

The Loveland C_b horizon at these locations showed a variation in sand content between 5.6 to 10.4 percent. The silt ranged between 48.3 and 53.6 percent. The clay fraction varied between 41.3 and 45.7 percent. The C_b horizon of the Loveland loess is classed as a light silty clay to silty clay in texture.

Soil pH

The pH results are shown in Table 2. The pH of the Peorian loess from the locations in Jewell and Republic Counties ranged from 7.8 to 8.1, while the pH of the Sangamon soil ranged from 7.5 to 8.3. The pH of the Loveland samples ranged from 7.6 to 8.2.

The pH of the lower portion of the Peorian loess was slightly higher than the A_{1b} horizon of the underlying Sangamon soil. In most cases there was little change in the pH between the B_{2b} of the Sangamon and the C_b of the Loveland loess.

Soil Organic Matter

The results of the organic matter determination are shown in Table 2. The organic matter content of the Peorian loess varied between 0.0 and 0.3 percent. The organic matter content in the Sangamon soil varied between 0.05 and 0.9 percent. The organic matter content of the Loveland loess ranged from 0.0 to 0.1 percent.

Table 2. Results for soil profiles.

Member	Horizon	Thickness	Total Sand*	Total Silt*	Total Clay*	Textural Class	pH	% Organic Matter	Exchange Cations Na (Meq per 100 g of soil)	Exchange Cations K (Meq per 100 g of soil)	Cation Exchange Capacity
						Profile 1.					
Peorian	C_2	0-12"	8.4	61.5	30.1	SiCL	8.1	0.1	1.74	1.43	32.3
Sangamon	A_{1b}	12-26"	8.2	57.8	34.0	SiCL	7.9	0.6	1.90	1.06	32.2
Sangamon	B_{1b}	26-37"	9.6	47.6	42.8	SiC	7.9	0.9	1.97	1.01	35.5
Sangamon	B_{2b}	37-63"	5.6	49.2	46.2	SiC	7.5	0.7	2.40	0.92	38.6
Loveland	C_b	63-69"	10.4	48.3	41.3	SiC	7.8	0.0	1.93	0.67	33.1
						Profile 2.					
Peorian	C_2	0-12"	11.2	56.1	32.7	SiCL	7.9	0.1	1.93	0.98	34.0
Sangamon	A_{1b}	12-25"	5.2	53.1	41.7	SiC	7.7	0.5	0.95	0.92	39.0
Sangamon	B_{2b}	25-43"	7.2	50.3	42.5	SiC	7.7	0.3	1.18	0.81	39.1
Loveland	C_b	43-53"	6.5	48.5	45.0	SiC	7.6	0.1	1.45	0.90	40.0
Shale	D	53+					8.1	0.1	0.85	0.48	34.5

Table 2. (cont.) Results for soil profiles.

Member	Horizon	Thickness	Total Sand*	Total Silt*	Total Clay*	Textural Class	pH	% Organic Matter	Exchange Cations Na (Meq per 100 g of soil)	Exchange Cations K (Meq per 100 g of soil)	Cation Exchange
						Profile 3.					
Peorian	C_2	0-12"	7.2	67.3	25.5	SiL	7.8	0.0	1.08	0.92	37.7
Sangamon	A_{1b}	12-26"	4.1	68.7	27.2	SiCL	7.7	0.2	1.27	0.70	39.0
Sangamon	B_{1b}	26-40"	3.6	58.6	37.8	SiCL	7.6	0.5	1.37	0.61	39.0
Sangamon	B_{2b}	40-61"	6.4	46.6	47.0	SiC	7.7	0.5	1.23	0.53	38.9
Loveland	C_b	61-72"	7.8	49.7	42.5	SiC	7.7	0.0	1.35	0.62	38.8
Shale	D	72+					8.5	0.0	0.36	0.12	26.7
						Profile 4.					
Peorian	C_2	0-12"	2.0	65.2	32.8	SiCL	8.1	0.3	0.96	0.67	38.8
Sangamon	A_{1b}	12-24"	3.2	55.4	41.4	SiC	8.0	0.7	0.78	0.57	42.5
Sangamon	B_{1b}	24-37"	3.4	52.4	44.2	SiC	8.1	0.7	0.96	0.65	39.0
Sangamon	B_{2b}	37-51"	5.6	46.0	48.4	SiC	8.3	0.4	1.61	0.63	38.4
Sangamon	B_{3b}	51-75"	5.2	52.0	42.8	SiC	8.2	0.2	1.57	0.64	38.1
Loveland	C_b	75+	5.2	54.0	40.8	SiC	8.2	0.1	1.35	0.64	36.2

Table 2. (concl.) Results for soil profiles.

Member	Horizon	Thickness	Total Sand*	Total Silt*	Total Clay*	Textural Class	pH	% Organic Matter	Exchange Cations Na (Meq per 100 g of soil)	Exchange Cations K (Meq per 100 g of soil)	Cation Exchange
						Profile 5.					
Peorian	C_2	0-12"	4.8	64.2	31.0	SiCL	8.0	0.3	0.70	0.84	38.2
Sangamon	A_{1b}	12-41"	4.8	51.9	43.3	SiC	7.9	0.4	0.87	0.78	39.6
Sangamon	B_{2b}	41-50"	4.8	49.2	46.0	SiC	8.0	0.5	1.77	0.63	39.3
Sangamon	B_{3b}	50-58"	4.4	52.0	43.6	SiC	8.0	0.4	2.32	0.69	40.3
Loveland	C_b	58+	6.4	51.6	42.0	SiC	8.0	0.1	1.62	0.69	37.0
						Profile 6.					
Peorian	C_2	0-12"	3.2	59.0	37.8	SiCL	7.9	0.1	1.55	0.60	40.0
Sangamon	A_{1b}	12-25"	2.0	53.6	44.4	SiC	7.7	0.3	1.55	0.48	42.0
Sangamon	B_{2b}	25-38"	4.0	45.6	50.4	SiC	7.6	0.4	1.77	0.53	43.6
Sangamon	B_{3b}	38-53"	6.0	48.3	45.7	SiC	7.8	0.0	2.00	0.66	40.6
Shale	C_b	53+					8.5	0.0	0.55	0.29	28.6

*Sand 2.0 - 0.05 mm
*Silt 0.05 - 0.002 mm
*Clay Less than 0.002 mm

Exchangeable Sodium and Potassium

The exchangeable sodium and potassium data are listed in Table 2. There appeared to be no apparent relationship between the exchangeable sodium content and the Peorian, Sangamon, and Loveland loess because the percentage of sodium in these members was quite variable. Within the Sangamon itself however, the B horizon contained more exchangeable sodium than the A horizon. This difference may be due to the higher clay content of the B horizon.

The exchangeable potassium was higher in the Peorian loess than in either the Sangamon or Loveland members. Within the Sangamon the B_{2b} horizon had a lower amount of exchangeable potassium than the A_{1b}, B_{1b} or the B_{3b}.

Cation Exchange Capacity Determination

The cation exchange determination results are shown in Table 2. These data show a close relationship in the different horizons of the loessial materials. It was noted that the exchange values of the Peorian C_2 and the Loveland C_b were usually quite similar. The greatest variation occurred within the Sangamon soil.

Soil Moisture Determination

The Sangamon soil showed higher moisture content than the overlying Peorian loess. The Sangamon contained from 14 to 36 percent moisture whereas the overlying Peorian ranged from 9 to

30 percent. The Peorian usually showed an increase in moisture with depth. The greatest quantities of water in the Peorian was usually located just above the top of the Sangamon soil.

Over 200 soil moisture determinations were made during this study. Many of the determinations were made on samples from areas not included in this investigation. The results for all the moisture studies are on file in the Highway Geology Research Laboratory at Kansas State College.

Stain Techniques

Montmorillonite and illite occurred in all of the samples tested by the stain technique. Kaolinite was not observed in any of these samples by this method. However, the presence of kaolinite colors are masked by 25 percent or more of illite or montmorillonite.

The presence of organic matter often masked the montmorillonite and illite. The removal of the organic matter with hydrogen peroxide allowed the blue colors of montmorillonite to occur.

Differential Thermal Analysis

Differential thermal analysis were obtained for many fractionated and nonfractionated clay size samples. All the samples showed endothermic reactions between 100°C. and 200°C. An endothermic reaction occurred between 590°C. and 750°C. However, most of these second endothermic peaks occurred between 600°C. and 620°C. A third endothermic reaction occurred between 800°C. and 900°C.

This was normally followed immediately by an exothermic reaction that occurred between 900°C. and 1000°C.

In the interpretation of the thermal curves of clay minerals, a differentiation between well organized montmorillonite and illite is made by the temperature of the midrange endothermic peak. Well organized montmorillonite normally gives a midrange peak around 700°C., whereas it occurs at approximately 600°C. for illite.

Only one sample (36PL36L) showed a midrange peak around 700°C., indicating a well organized montmorillonite. All the samples showed a midrange peak closer to 600°C., which is indicative of illite. However, the large size of the low temperature peak indicated the presence of montmorillonite in the samples. Rowland (24) pointed out that when the organization and order of stacking of montmorillonite crystals is poor, as is the case with most sediments containing montmorillonite, it is seldom possible to distinguish between montmorillonite and illite with differential thermal curves. This is thought to be the reason why montmorillonite is not indicated on the differential thermal curves of the loess samples.

Kaolinite was not identified by the thermal method in any of the samples. In general it was felt that the information gained by differential thermal analysis was of little value in this study. Therefore the thermal curves were not included in this thesis, they are on file in the Highway Geology Research Laboratory at Kansas State College.

X-ray Diffraction Analysis

The X-ray identification of montmorillonite was based on a 12 to 14 A basal reflection that expanded to 17.6 A after treatment with ethylene glycol.

Illite was identified on the basis of a 10 A basal reflection and other basal reflections with a 10 A periodicity that remained unchanged following glycolation.

The presence of kaolinite in these samples was based primarily on an integral series of orders related to a 7.1-7.2 A periodicity which did not change after glycolation or heating to 450°C. or treatment with warm hydrochloric acid.

An iron-rich chlorite was found to be present in all the samples. Its identification was based on a reduction in the intensity of the series of reflections based on a 7.1-7.2 A periodicity following heat treatment at 450°C. for 45 minutes.

The entire series of peaks based on the 7.1-7.2 A periodicity disappeared following heat treatment at 500°C. for 45 minutes. This led to the problem of determining whether the material was better crystalline chlorite than that which was destroyed at 450° C. or poorly crystalline kaolinite, since kaolinite is normally destroyed around 575°C. To differentiate between iron-rich chlorite and poorly crystalline kaolinite the samples were treated with warm hydrochloric acid. This acid treatment was designed to destroy any iron-rich chlorite that was present. X-ray diagrams of the acid-treated samples showed a series of kaolinite peaks with the same intensity as the samples that had been heated to

450°C. This indicated no further loss of chlorite. The acid-treated samples lost all of the reflections attributed to iron oxides.

To verify the presence of kaolinite, electron micrographs were obtained on some of the loess samples. These micrographs showed the presence of broken plates which appeared to have been hexagonal in shape in both the coarse and medium size fraction. No complete hexagonal crystals were noted in any of the micrographs.

The nonclay minerals that were found in the clay-size range were quartz, calcite and gypsum. Quartz was identified by the presence of 4.2 and 3.35 A reflections. The 3.03 A reflection of calcite and the 4.27 A reflection of gypsum was used to identify those minerals.

Montmorillonite was found to be the predominant clay mineral in the less than 0.08 micron size fraction. Illite and poorly crystalline iron-chlorite were the only other minerals found in this size fraction.

In the 0.2-0.08 micron size fraction, the Peorian and Loveland materials gave symmetrical peaks attributed to montmorillonite. The Sangamon in this size range showed a low intensity, broad reflection with its high point at 14.7 A, and upon glyoclation the spacing increased to 17.6 A. Illite, kaolinite, iron-rich chlorite, and in some cases, iron oxides, were also present in this size fraction.

Even though the weak, broad reflection expanded upon the addition of glycol much like montmorillonite, it was believed

that the line broadening and low intensity of the peak was due to a mineral other than montmorillonite.

Brindley (5) has discussed four factors that cause broad X-ray diffraction peaks. He summarized the cause as follows:

1. decreasing particle size
2. crystal strain
3. interstratification
4. decreasing degree of parallel orientation

The possibility of the line broadening being due to decreasing particle size can be eliminated because the material in the Sangamon is the same size range as that in the Peorian and Loveland which did not show this effect. A decrease in particle size should cause an increase in background intensity. The background intensity is actually lower for the Sangamon then either the Peorian or Loveland.

Crystal strain can not be ruled out as a possibility, particularly since line broadening is most pronounced in the A and B horizon of the Sangamon soil. The crystal strain, if present may be due to the weathering processes. However, it is felt this is not the major cause of line broadening because the B_2 horizon of the present day soil, developed on Peorian loess does not display this phenomenon. If this line broadening and low intensity were due to crystal strain caused by normal weathering, it should show the same characteristics in the B_2 of the present soil.

To check the possibility of a lesser degree of parallel orientation, the slides prepared for X-ray analyses were studied with a petrographic microscope. It was found that the Sangamon

samples in this size fraction gave interference figures that were as distinctive as those of the Peorian or Loveland. In addition, no peaks other than the basal peaks of any of the clays were observed in the diffraction pattern of the oriented sample.

This leaves interstratification as a probable cause for the broad diffused peaks of low intensity. According to Brown and MacEwan (6) there are three types of interstratification: (1) regular, (2) random and (3) with segregation into zones in the crystallites. They state that type (1) gives a high spacing reflection and a series of sharp higher order reflections with spacings which are strictly submultiples of this. The authors described type (2) by presenting a series of continuous curves showing the shifts and relative intensities encountered with various combinations of dioctahedral and trioctahedral binary components. They stated that type (3) gave rise to bands, of various shapes depending on the distribution of the different types of hydrates, and that it was more complicated than (1) or (2), since it may involve both of them. It is believed that the soil clays analyzed in the Sangamon soil more likely resemble type (3) since the authors point out that in general broad bands are not given by two-component interstratification. Such bands are, however, commonly given by soil clay minerals, and where they are present, we may suspect that some more complicated type of mixture is present, i.e one of type (3).

The coarse clay fraction composed of the 2 to 0.2 micron size material showed montmorillonite to be the major constituent of the Peorian and Loveland members. Illite, kaolinite, chlorite

and quartz were found in these samples. The same clay minerals were found in the coarse clay fraction of the Sangamon soil except that the interstratified clay was also present in that material.

The broad, diffuse, low intensity peak attributed to interstratification is also reflected in the total clay fraction (2 micron) of the Sangamon and Brady soils. This can be seen in Plates II and III.

X-ray data obtained on the clay and nonclay fraction of the series of samples collected from Republic County, Fig. 7 indicated that the Sangamon soil at this location was a residual soil developed on weathered Pfiefer shale. This soil had been previously described as having been developed from thin Loveland loess (10).

The X-ray diagrams of any horizon of the various loess units studied were quite similar for those same horizons throughout the area of the investigation. Therefore, only two profiles are included in the X-ray diagrams shown in Plates II and III in this thesis. All the X-ray patterns are on file in the Highway Geology Laboratory at Kansas State College.

Discussion of the Results

The B_2 horizon of the Sangamon soil was found to contain from 10 to 21.5 percent more clay than the C_2 horizon of the overlying Peorian loess. The difference in clay content between these horizons was not reflected in their cation exchange capacities. Because of the significant difference in clay content between these horizons and the minor differences in cation exchange capacity, there must have been a difference in clay mineral type.

EXPLANATION OF PLATE II

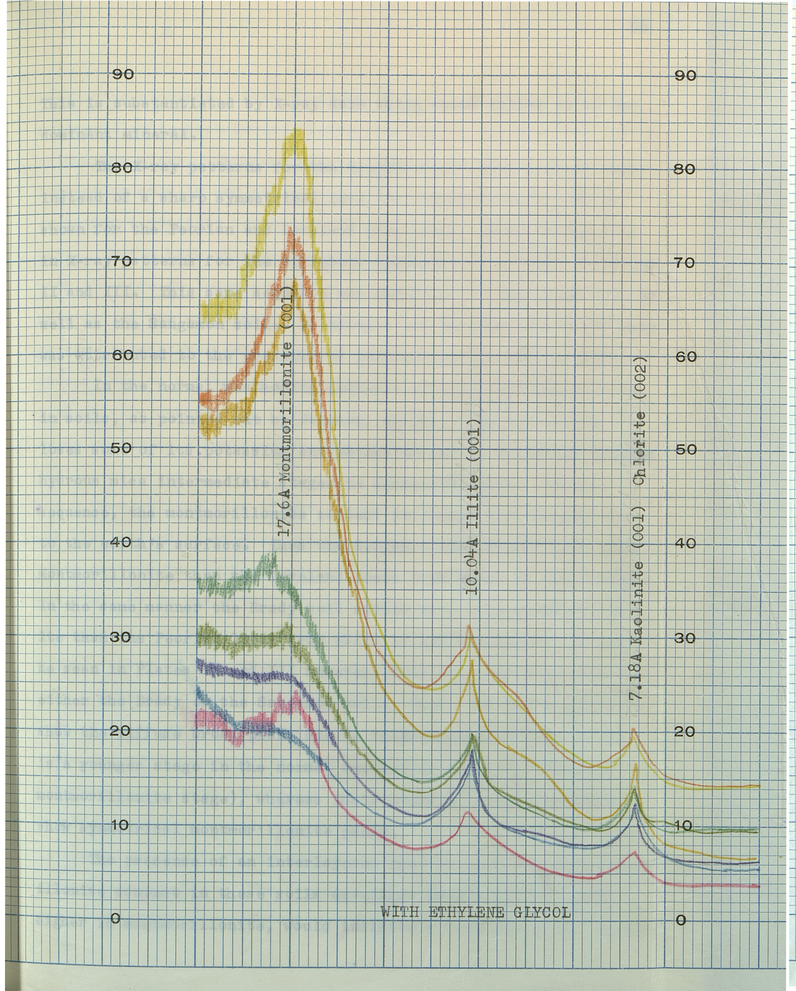
X-ray diffractometer tracings of oriented slides of the clay fractions (2 micron) of the Peorian loess, Sangamon soil, Loveland loess and Smoky Hill chalk, from soil profile III, NW¼NW¼ sec. 20, T. 3S., R. 8W., Jewell County, Kansas. The plate shows the symmetrical montmorillonite peaks of the Peorian and Loveland loesses and the broad diffuse peaks of the Sangamon soil both with and without ethylene glycol. The plate also shows the illite, kaolinite, chlorite, calcite, quartz and gypsum peaks of these loess units.

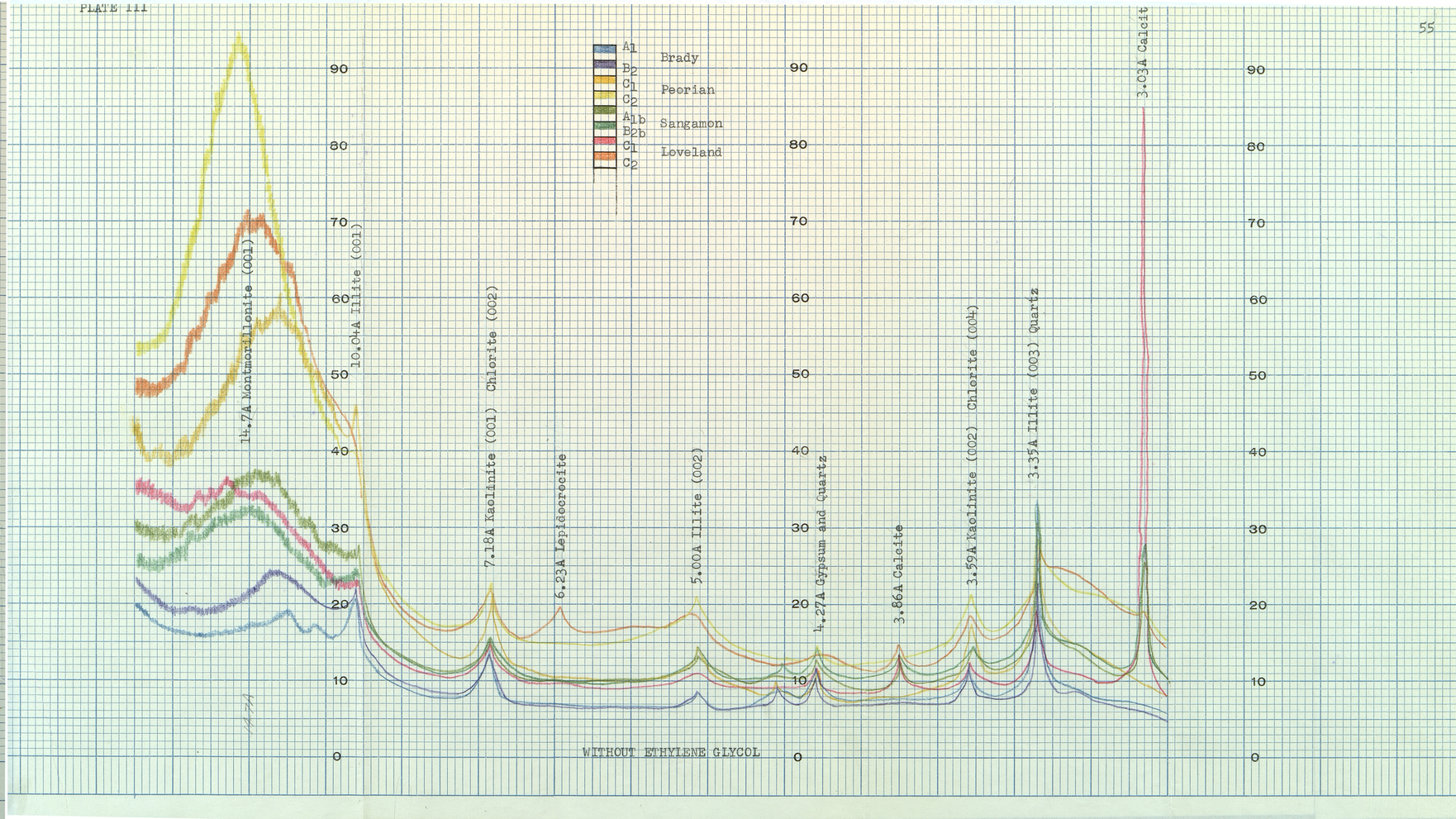
17.6A Montmorillonite (001)
10.04A Illite (001)
7.18A Kaolinite (001) Chlorite (002)
WITH ETHYLENE GLYCOL
14.7A Montmorillonite (001)
10.04A Illite (001)
7.18A Kaolinite (001) Chlorite (002)
5.00A Illite (002)
4.27A Gypsum and Quartz
3.86A Calcite
3.59A Kaolinite (002) Chlorite (004)
3.35A Illite (003) Quartz
3.03A Calcite
WITHOUT ETHYLENE GLYCOL
A
B2
C1
C2
A1b
B1b
B2b
Cb
D
Peorian
Sangamon
Loveland
Shale
0
10
20
30
40
50
60
70
80
90

EXPLANATION OF PLATE III

X-ray diffractometer tracings of oriented slides of the clay fractions (-2 micron) of the Brady soil, Peorian loess, Sangamon soil and Loveland loess from the SW¼SW¼ Sec. 24, T. 4S., R. 19W., Phillips County, Kansas. The plate shows the symmetrical montmorillonite peaks of the Peorian and Loveland loesses and the broad diffuse peaks of the Brady and Sangamon soils with and without ethylene glycol. The plate also shows the illite, kaolinite, chlorite, calcite, quartz, gypsum and lepidocrocite peaks of these loess units.

PLATE III


17.6A Montmorillonite (001)
10.0+A Illite (001)
7.18A Kaolinite (001) Chlorite (002)
WITH ETHYLENE GLYCOL


A1
B2
C1
C2
A1b
B2b
C1
C2
Brady
Peorian
Sangamon
Loveland
14.7A Montmorillonite (001)
10.0+A Illite (001)
7.18A Kaolinite (001) Chlorite (002)
6.23A Lepidocrocite
5.00A Illite (002)
4.27A Gypsum and Quartz
3.86A Calcite
3.59A Kaolinite (002) Chlorite (004)
3.35A Illite (003) Quartz
3.03A Calcit
WITHOUT ETHYLENE GLYCOL

This is substantiated by X-ray data which shows illite to be the dominant mineral.

The X-ray patterns for the Sangamon soil show a broad band instead of a sharp symmetrical peak for montmorillonite, as is shown for the Peorian and Loveland materials. These differences in X-ray patterns for the different horizons can be seen in Plates II and III. This same sequence was observed for the Brady soil as well as the Sangamon soil. As brought out earlier, the broad band was attributed to the presence of interstratified clay minerals.

In the normal weathering sequence of clay size minerals in in soils, as pointed out by Jackson, et al., (15, 16) illite loses some of its potassium and magnesium and is converted through hydrous mica intermediate stages to montmorillonite. In this sequence, the montmorillonite content increases with proximity to the earth's surface. Thus the Sangamon soil should have more montmorillonite than the Loveland loess from which it was formed. In the same manner the Brady soil should have more montmorillonite than the Peorian loess from which it has developed. As can be seen in Plates II and III however, this does not hold true for either the Brady or the Sangamon soil. These two buried soils show the diffuse broad peaks due to interstratification, (which is a younger stage in the normal weathering sequence than the montmorillonite stage), whereas their loessial parent materials show symmetrical montmorillonite peaks.

The presence of an interlayered type of clay of low montmorillonite content in these soils developed from parent material higher in montmorillonite, would indicate a reversal of the normal

weathering sequence. Such a reversal would tend to revert the montmorillonite back toward illite through the intermediate stages of hydrous micas. Jackson, et al., (16) state that in general, increasing acidity and increasing oxidation must be considered as having a positive sense, favoring increased weathering intensity. Thus a high pH such as those found in the loessial soils with the same or lower oxidizing potential would tend to cause reversal of the weathering sequence. Also leaching would tend to have a positive sense, whereas slowing down of the leaching process due to a zone of lower permeability, would tend to have a negativite sense. The higher clay content of the Sangamon soil tends to act as a restrictive zone retarding the leaching of this soil.

Chemical analyses of the Bignell, Brady, Peorian, Sangamon, and Loveland units by Frye, et al., (10) showed a higher potassium oxide content in the Sangamon and Brady soils than in their parent material, or in the material overlying them. In all cases there was more potassium oxide in the Brady soil than the overlying Bignell loess or the underlying Peorian loess. There was also more potassium oxide in the Sangamon soil than the overlying Peorian loess or underlying Loveland loess. As shown in Table 2 there was more exchangeable potassium in the Peorian than in the Sangamon soil. Since there was an increase in potassium oxide in the Sangamon accompanied by a decrease in exchangeable potassium, it can be assumed that the potassium was becoming fixed in the nonexchange position. The fixing of the potassium would increase the illitic type clay content and decrease the montmorillonitic

type clay. This was substantiated by the X-ray patterns.

To check this further, a sample of the B_2 horizon of a recent surface soil developed on Peorian loess which showed a strong symmetrical montmorillonite peak was treated with potassium chloride and washed free of chloride. The X-ray pattern of this treated sample gave a broad diffuse peak similar to those found in the Brady and Sangamon soils.

The clay minerals present in the C horizon of the Peorian and Loveland loesses probably reflect the weathering stages of the source material of these loesses rather than weathering since the time of Pleistocene deposition.

SUMMARY AND CONCLUSIONS

Numerous samples were collected from the Brady soil, Peorian loess, Sangamon soil, Loveland loess and weathered bedrock in north central Kansas. The fractions studied were the total clay (<2 micron) as well as the coarse, medium and fine clay subfractions. The methods used were: particle size distribution, X-ray diffraction, differential thermal analysis, cation exchange capacity, electron micrographs, stain techniques, organic matter, pH, soil moisture determination, field observations, and exchangeable sodium and potassium. The results of this investigation may be summarized as follows:

1. Differential thermal analysis and stain techniques were found to be of little value in this study.

2. Montmorillonite, illite, kaolinite, chlorite and quartz were found in all of the samples studied. The Peorian and Loveland

loess showed symmetrical montmorillonite peaks whereas the buried soils showed broad diffuse peaks attributed to the presence of interlayered clays.

3. The clay minerals present in the C horizon of the Peorian and Loveland loesses probably mainly reflect the weathering stages of the source material of these loesses rather than weathering since the time of Pleistocene deposition.

4. The buried soils contained more clay than the overlying loesses and thus acted as a zone of restriction to downward moving water.

5. The pH, cation exchange capacity, exchangeable potassium, total potassium and X-ray diffraction results indicated that there was a reversal of the weathering sequence in the buried soils developed from the Peorian and Loveland loesses.

6. It was concluded that there was an increase in the illite content of interlayered clay found in the buried soils. This increase was due to the leaching of potassium from the overlying loess units by downward percolating waters and its redeposition in the buried soils. The potassium content increased as a result of the restriction of downward moving waters because of the higher clay content of the buried soils.

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A STUDY OF THE PHYSICAL AND CHEMICAL CHARACTERISTICS OF SOME NORTH CENTRAL KANSAS BURIED SOILS AND THEIR PARENT MATERIALS

by

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The purpose of this investigation was to determine the clay mineralogy of the different horizons in the loess units.

Samples of Brady soil, Peorian loess, Sangamon soil, Loveland loess and bedrock were collected from along highway U. S. 36 in Decatur, Norton, Phillips, Smith, Jewell and Republic Counties. In addition, samples were collected from highway 283 in Norton County, highway 9 in Phillips County, and from a county road in Republic County.

Selected horizons of these units were studied in the field and in the laboratory. The methods used in this study included particle size analysis, pH, cation exchange capacity, exchangeable sodium and potassium, soil organic matter, X-ray diffraction analysis, differential thermal analysis, stain techniques, and soil moisture determination.

The results of this investigation may be summarized as follows:

1. Little value was ascertained by the use of the differential thermal analysis and the stain techniques in this study.

2. The Peorian and Loveland loess showed symmetrical montmorillonite peaks whereas the buried soils showed broad diffuse peaks attributed to the presence of interlayered clays. The other clay minerals present were montmorillonite, illite, kaolinite and chlorite. Quartz, which is a non-clay mineral, was also present.

3. The clay minerals present in the C horizon of the Peorian and Loveland loesses probably mainly reflect the weathering stages

of the source material of these loesses rather than weathering since the time of Pleistocene deposition.

4. The Brady and Sangamon soils contained more clay than the overlying loesses and thus acted as a zone of restriction to downward moving water.

5. The laboratory results indicated that there was a reversal of the weathering sequence in the Brady and Sangamon soils.

6. It is suggested that the high clay content of the buried soils restricted the downward moving water, causing an increased concentration of potassium. This is believed to have had an influence on the formation of interlayered clays that occur in the buried soils resulting in an increase in the illite content.