# A STUDY OF THE RELATION OF CERTAIN LOESSIAL SOILS OF NORTHEASTERN KANSAS TO THE TEXTURE OF THE PARENT MATERIAL

by

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TABLE OF CONTENTS

# INTRODUCTION

A large proportion of the soils of northeastern Kansas have developed in geologic materials thought to be of eolian origin. The purpose of this work was to study the relationship of the textural nature of the eolian deposits to the soils developed therein. This wind-borne material, loess as it is more commonly called, was believed to have been blown from the alluvial deposits left in the Missouri River flood plain during and after the retreat of the Pleistocene glaciers.

The deposition of eolian Pleistocene sediments in Kansas was directly controlled by glaciation, because alluvial materials are thought to be the source of most of these eolian deposits. With the retreat of the glacier, broad alluvial flats were being continuously replenished with sediments that were subject to the action of the wind.

It has been observed in other areas of loess deposits, that the soils developed in the thick loess close to the river differ from those soils developed in the thinner loess deposits occurring at some distance from the river. In Brown County it has been observed that the most permeable loessial soils occur on the deepest loess deposits near the suspected source of the loess, the post glacial Missouri River Valley. Because of their permeable nature, these soils are frequently considered to be the most productive. The unpublished soil survey of Brown County by the Soil Conservation Service not only revealed this soil variation with increased distance from the river bluff, but it also showed the loessial soils occurred in bands more or less parallel with the Missouri River. For example, it was found that a band of Knox soils occurred immediately adjacent to the Missouri River, with bands of Marshall, Sharpsburg, and Grundy soils occurring in sequence with distance from the river.

The uniform manner in which these four soil series occur in bands adjacent to the Missouri River in northeastern Kansas provides an opportunity to study the nature of these soils, determine the particle size composition of each of their horizons, and compare it with the textural composition of the parent loess.

## REVIEW OF LITERATURE

### Origin and Deposition of Missouri Valley Loess

The Pleistocene deposits of Kansas (12) are entirely nonmarine, but represent the full range of depositional environment that occurs on the Continental interior. Deposits made by glaciers are present in northeastern Kansas and have generally lent distinction to the Pleistocene Series. Deposits formed by streams occur widely over the state, as do sediments produced by the action of winds. It is these sediments that have been deposited by the wind to which this study has been devoted. The recognition and understanding of these deposits requires some knowledge of the loess and the processes that produce it. According to Mark Baldwin, (Thorp, 35) formerly Chief Inspector of the Division of Soil Survey, loess has been defined as,

> An unconsolidated or weakly consolidated deposit of calcareous fine earth material, dominantly silt throughout, with a lesser content of very fine sand or clay or both. Each deposit is practically homogeneous as to physical composition. The mineral composition of loess is variable, depending on the source of material, but there is everywhere an appreciable content of calcium carbonate or calcium-magnesium carbonate. Most of the material effervesces in cold dilute hydrochloric acid, indicating the presence of calcium carbonate. Secondary nodules (concretions) and tubes of calcium carbonate are present in many deposits. Most geologists and geomorphologists now agree that true loess deposits have been accumulated by the action of wind; in fact eolian origin

(mode of accumulation) is regarded as a definitive feature. Residuum from loess is generally very silty, although deposits of loess high in clay forming minerals, weathering in humid climates may form residuum with relatively high proportion of clay. In humid climates free carbonates are leached out to considerable but variable depths, depending upon kind and degree of impress of factors and processes of weathering. Some confusion has arisen among soil scientists owing to failure to distinguish between geological formation or deposits properly called loess and very silty residuum which may or may not have been formed by the weathering of loess. Distinction should be made between loess and dune sand on the one hand and between clayey wind-laid deposits or 'clay dunes' on the other.

One of the better sources of information concerned with glaciation and glacial deposits is the studies carried on by the University of Michigan. Their station at Mount Evans, Greenland, has studied climatic and geological conditions near the border of an ice sheet of the kind that once lay over northern North America. According to Hobbs (16) in one of his reports from this station, strong surface winds blow outward off the inland ice attaining at times hurricane velocities. The force of these surface winds decreases rapidly after passing the ice margin. During the summer season this glacial ice melts and the melt water flows in braided streams in the valleys. In early fall when thawing of the ice comes to an end, streams cease to flow leaving an area covered with outwash material. The fine material on drying out at the surface becomes an easy prey of the wind and causes sand storms which are comparable to those of deserts. Although severe in summer, the storms are much more violent during the winter months. The sands and silts removed from the valley flats collect in large deposits.

There have been many theories presented as to the origin of loess. Smith (34) stated that Scheidig in 1934 in his review of the literature lists some twenty hypotheses to explain the presence and distribution of loess. While loess may vary from one area to another with respect to source and method of deposition, there seems to be fairly general agreement that in the Mississippi

Valley, including the Missouri River, loess was deposited by wind and that its source area was the flood plains of the Pleistocene rivers.

Hobbs' (16) work in Greenland compares very closely to Chamberlain's hypothesis as to the origin of loess. Chamberlain (8) reasoned that after the water had retreated from the melting ice and snow, the extensive silt covered flats would become exposed to the sweeping influence of the wind, and when they had dried, the silt would be borne in great quantities over the adjoining uplands.

Tuck (36) also presented a modern example of the deposition of loess that was suggested by Chamberlain. In Matanuska Valley, Alaska, Tuck reports that glaciers stand 20 to 45 miles up valleys, and that the glacial rock flour is deposited down the valley in the many and constantly changing channels or on the broad flood plains. In dry weather it is reported that a pall of dust is visible over the surrounding country.

There have been theories offered that loess had its origin in violent fluviatile floods and lacustrine origin and that it formed in ponds and lakes (31). Although it is probable that certain limited portions of unmodified loess was deposited in this manner it does not account for the most extensive deposits which usually cap the highest hills along streams.

Shimek (33) presented the following five reasons why loess could not be of aquatic origin:

1. The land area during the period of formation of loess was large as shown by remains of a great number of terrestrial mollusca.

2. The occurrence of dry region mollusca in the deposits.

3. Deposits occur high above the surrounding region.

4. Particles of the silicates present are generally angular and often show

freshness of fracture which could hardly appear in water carried particles.

5. Distribution of loess is better accounted for by considering the action of winds and by the distribution of forest areas.

Some have thought the greater loess deposits date from interglacial times as reported by Visher (37). Penck (30) concluded that the loess was formed shortly before the commencement of the glacial epochs. According to Visher's report many American geologists have held that most of the loess accumulated while the ice sheets were at approximately their maximum size.

There is evidence to support each of these hypotheses, but it seems well to consider the possibility that a large portion formed immediately following the retreat of the ice. It appears that unless the retreat of the ice sheets were as slow as the advance of vegetation, a barren area must have bordered the retreating ice and formed an ideal source of loess.

In support of interglacial origin of loess Shimek (33) and others state that the glacial drift which lies beneath the loess gives evidence that some time elapsed between the disappearance of the ice and the deposition of the loess. Snail shells found in loess are not similar to the type found in cold regions but resemble those of dry regions.

## Age and Time of Deposition

The earliest known deposits of Pleistocene age in northeastern Kansas are those deposits associated with Nebraskan glaciation. Studies of surface exposures (10) have shown that the Nebraskan glacier entered the northeastern corner of Kansas and may have advanced as far as southern Nemaha County and northern Jackson County.

The second, and also last glacier to enter the state was the Kansan glacier which overrode remnants of Nebraskan till and advanced to a point well beyond the earlier glacial margin. The maximum advance of the Kansan glacier was a few miles south of the Kansas River (10). Glacial outwash and till filled many existing stream valleys.

Following the deposition of late Kansan and Yarmouthian sediments, erosion again became more active, and streams cut valleys below bed rock (10). After this cutting of valleys they were again alluviated in late Illinoian time. It was during this alluvial cycle that Loveland loess was deposited, but it is generally less than 10 feet thick in extreme northeastern Kansas and is absent over large areas. The last major alluvial cycle was initiated early in Wisconsin time (10). During this time, great amounts of loess were deposited. Along the bluffs of the Missouri River in Doniphan County, Peoria loess, deposited during Wisconsin time, has a maximum thickness of more than 100 feet. PLATE I. The loess thins rapidly away from the Missouri River. This study was made on soils developed in the Peoria loess. Loess deposition along the river flood plain could conceivably have taken place during the advance or the retreat of the ice.

Antevs (2) concluded from his studies of the varved clays that the last ice sheet began to diminish about 40,000 years ago. This figure may be 10,000 years too large or too small. The retreat of the ice, started about 40,000 years ago, may have lasted for 29,000 years, according to his counts of the varved clays. During the retreat of the ice, the residue left in the flood plains of the Missouri River furnished a source for the loess deposits of this study. The deposition of loess being a slow process is brought out by Shimek (33) in his studies of the loess fossils. He concluded that the deposition was slow and continued through a period of considerable time.

EXPLANATION OF PLATE I

Cut in the West Valley Wall of the Missouri River Valley Which Shows the Depth to Which Loess May Accumulate Near Its Source.

PLATE I

## Characteristics of Loess and Soils Developed From This Wind-Borne Material

In general the coarse unweathered to slightly weathered loess and loessial soils absorb water more readily, occur on steeper slopes, are more resistant to sheet erosion, but gully more readily than the finer textured loess and loessial soils. Loess is unstratified and a characteristic feature is its ability to stand in vertical or nearly vertical slopes, PLATE I. Being of a porous nature, raw loess will take up a greater portion of the water falling upon it and hold it, giving it up gradually during dry seasons.

Plant roots penetrate the loess to great depths and have a tendency to go farther down than to spread out. In decaying, the extensive corky layers of the rootlets last much longer than the other portions. As the interior disappears the outer tube finally collapses, leaving a flat band or ribbon-like film that long resists further decay and finally only the more stable minerals remain (23). These small cylindrical masses are composed of lime and in some instances are made up of iron. This feature has not been reported as a characteristic of loess in all cases but is characteristic of some deposits.

Another type of concretionary mass is found in some loess and loess devel-loped soils, and is composed primarily of iron and manganese. Humbert and Marshall (18) found this type of concretion to be prominent in the upper soil horizons of some Missouri soils. A study by Whiteside and Marshall (38) of the gumbo till underlying the Cowden silt loam of Missouri showed no iron-manganese concretions in the sand fraction, although they were abundant throughout much of the overlying soil. It was also brought out in a study by Haseman and Marshall (15) that iron-manganese concretions were found to exist from the surface to a depth of 38 inches in a Missouri soil which they were investigating.

The origin of the iron-manganese concretions seems to have been overlooked. According to Keyes (23) roots decay, accumulating around them crystalline coatings of pyrite which finally forms small concretions. The pyrite soon changes to limonite. Whether pyrite is only deposited on certain plants is not known. The facts that the concretions are abundant in certain areas and sparingly distributed or absent in others suggests that the nature of the plant or soil has something to do with their occurrence. The concretions of the soils studied in the investigation were prominent in the lower horizons as well as the upper in most cases. Their form is usually spherical although somewhat irregular. Color variations ranges from reddish brown to nearly black. They vary in size from greater than 0.5 mm. to 0.05 mm. Some were slightly magnetic. A chemical test of these concretions showed the presence of iron and manganese.

Fertility of loess, because of which it is sometimes miscalled soil, is its most valuable property for mankind. Some refer to loess as soil, but this is erroneous because true loess is but soil material on which soil is developed (11). Typical loess contains an average of about 20 percent of feldspar in a more or less advanced stage of decomposition.

Soils developed from loess vary widely, because of great variation in a combination of factors involved in soil formation (35). Climate, biological activities, relief and time as well as the character of the loess from which they are formed have had an influence upon their development. Where profile development kept pace with deposition it is hard to determine that loess was ever present. Some distance from the source, soil development was as fast as deposition but adjacent to the source area the loess accumulated so rapidly that leaching, hydrolysis and soil formation could not proceed as fast as the material collected. The fact has been brought out by Thorp, (35), Smith, (34) and Leighton, (26) that with distance from the source of parent material (loess) the soils have a higher clay content and have a stronger profile development, compared to a lesser amount of clay and less profile development near the source of loess.

The characteristics of the soils of Brown County are relatively the same as found by other workers, working with soils developed from loess material, under similar conditions that prevailed in this area. The Peoria loess in the northeastern area of Kansas is a fine textured soil material consisting predominantly of particles of silt and clay size. Near its source where it is deepest, the loess is commonly calcareous at lower depths. With increasing distance from its source the loess becomes thinner, finer textured, more weathered and less calcareous, which has had a definite influence upon the soils developed from it.

## METHODS OF INVESTIGATION

### Field Methods

A traverse at right angles to the Missouri River was made from the northwestern part of Doniphan County, (PLATE II, Fig. 2), extending in a southwesterly direction to the southwestern part of Brown County, to the vicinity of Powhattan. Beginning at a point two miles from the Missouri River and at one and one half mile intervals therefrom, ten sampling sites were established, (PLATE II, Fig. 1). Pits were dug to a depth of five feet in order to sample adequately the significant soil horizons at each site. At sampling sites, 1, 3, 5, 7, 9, and 10 samples were taken by use of an extension soil auger at depths of 204, 156, 102, 96, 72, and 63 inches respectively.

EXPLANATION OF PLATE II

Fig. I. Location of Traverse Along Which Soil Profiles were Sampled For This Investigation.

Fig. II. Portion of State Where Study Was Made.

PLATE II

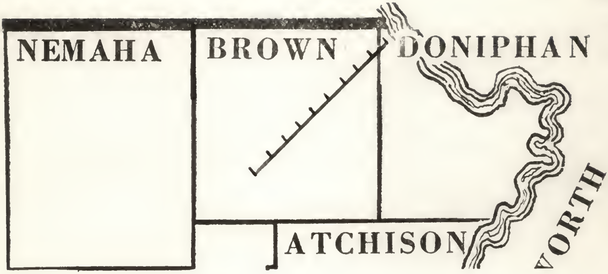


Fig. 1

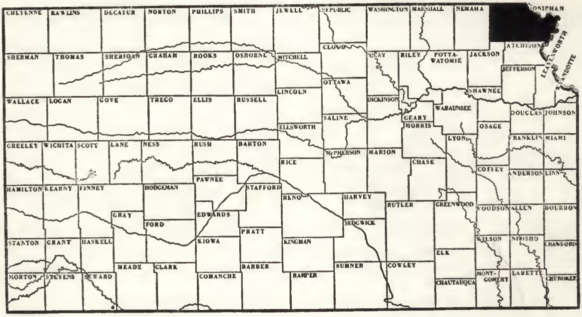


Fig. 2

The relief along the traverse varied from hilly near the Missouri River, where tributary streams had caused extensive dissection, to nearly level at the southwestern extremity of the traverse. The sampling sites were chosen on ridge tops in order to obtain as uniform slope and erosion characteristics as possible. It was felt that by shifting slightly from the point of sampling on the traverse when the position was in a draw or on a steep slope, a better comparison of the soils could be carried out. The advantages in selecting a site on a ridge over weighed those of taking the sample at the predetermined points on a straight line.

Soil samples were obtained from each horizon of the ten profiles. It was found that the surface horizon varied slightly in depth, depending upon the depth the soil had been cultivated. The auger samples were taken at the base of the loess except at the first location where the loess was of a greater thickness than 17 feet.

## Laboratory Methods

The samples were air dried, crushed with a rolling bottle, and screened through a 2 mm. number 10 Tyler sieve to eliminate any stones or large particles of foreign material. The samples were then tabled and placed into containers.

The pipette method of particle size analysis as described by Kilmer and Alexander (24) was used, with the following exceptions, (1) Use of dialysis bags in place of Pasteur-Chamberlain filters to remove free salts. (2) Two hundred-fifty ml. Erlenmeyer flasks were used rather than nursing bottles. (3) The sand fraction was treated with 6 normal hydrochloric acid to remove iron-manganese concretions. (4) The sand fraction was sieved in absence of a mechanical shaker, by raising the nest of sieves approximately an inch and dropping it sixty times.

The pH of the soils was determined with a Beckman pH meter. Ten ml. of distilled water were added to a 10 gm. sample of soil material. The mixture was stirred and allowed to stand for 30 minutes and then stirred again before immersing the glass electrodes.

The results of the particle size analyses of the soils based on percentage by weight of each size fraction are given in the APPENDIX. The mean particle size analyses and pH for each horizon are summarized in Tables 1-10. Soil profile descriptions and the summary of the laboratory data for each of the profiles follow:

Description of Soil Profile I. This soil resembles the Knox Series: The Knox Series consists of soils developed from calcareous loess in the timbered area of the Prairie soil region. They differ from the associatied Marshall soils in their much lighter color; and from Hamburg soils in being more advanced in development. (U.S.D.A. Description)

Soil Profile I

1. $A_1p$ 0-6.5" Very dark grayish brown (10YR 3/2) silt loam; soft, friable, very weakly granular, pH 6.0.
2. $A_1$ 6.5-13" Very dark grayish brown (10YR 3/2-4/2) silt loam, slightly hard, friable, very weakly granular, pH 5.7.
3. $A_3$-$B_1$ 13-17" Dark grayish brown to dark brown (10YR 4/2-4/3) silty clay loam, slightly hard, friable, weakly granular, pH 5.9.
4. $B_2$ 17-22" Dark grayish brown (10YR 4/2.5) silty clay loam, slightly hard, friable, weakly granular, pH. 5.6.

5. $B_3$ 22-32" Dark brown (10YR 4/3) silty clay loam, slightly hard, friable, very weakly granular, pH. 5.3.

6. $C_1$ 32-48" Dark grayish brown (10YR 4/2.5) silt loam, slightly hard, friable, very weakly granular, pH. 5.4.

7. $C_2$ 48-60" Brown (10YR 5/3) and light brownish gray (10YR 6/2) silt loam, soft, friable, very weakly granular, pH 5.9.

8. $C_{3ca}$ 85-90" Brown to pale brown (10YR5/3-6/3) silt loam, soft, friable, massive, moderately calcareous, pH 7.7.

9. 204"+ Yellowish brown and pale brown (10YR 5/6 and 6/3) silt loam, soft, friable, massive, moderately calcareous, pH 7.5.

Relief: Gently sloping to hilly uplands, some areas occupy relatively low smooth rounded hills. Sampling site location on area of B slope.

Vegetation: Area in cultivation, crop, alfalfa.

Location: NE¼, SW¼, Sec. 6, TIS, R19E.

Remarks: Color notations are for the moist soil.

Table 1. Particle size analyses of profile 1 (2 miles from Missouri River bluff).

| Horizon | Sampling Depth | pH | Sand >0.25 mm. | Sand 0.25-0.10 mm. | Sand 0.10-0.05 mm. | Silt 0.05-0.002 mm. | <0.005 mm. | Clay: <0.002 mm. | Textural Classification |
|---|---|---|---|---|---|---|---|---|---|
| | Inches | | Perct. | Perct. | Perct. | Perct. | Perct. | | |
| $A_{1p}$ | 0.6-5 | 6.0 | —— | 0.14 | 2.82 | 70.31 | 29.13 | 26.73 | Silt loam |
| $A_1$ | 6.5-13 | 5.7 | - —— | 0.11 | 3.22 | 68.13 | 33.83 | 28.54 | Silty clay loam |
| $A_3$-$B_1$ | 13-17 | 5.9 | —— | 0.11 | 3.11 | 66.10 | 31.54 | 30.68 | Silty clay loam |
| $B_2$ | 17-22 | 5.6 | —— | 0.14 | 3.21 | 65.91 | 34.29 | 30.74 | Silty clay loam |
| $B_3$ | 22-32 | 5.3 | —— | 0.12 | 3.72 | 66.24 | 32.34 | 29.92 | Silty clay loam |
| $C_1$ | 32-48 | 5.4 | —— | 0.13 | 2.86 | 75.05 | 28.02 | 21.96 | Silt loam |
| $C_2$ | 48-60 | 5.9 | —— | 0.45 | 4.39 | 71.20 | 28.22 | 24.96 | Silt loam |
| $C_3$ | 85-90 | 7.7 | —— | 0.59 | 3.73 | 73.03 | 25.15 | 22.65 | Silt loam |
| | 204 | 7.5 | —— | 0.33 | 3.81 | 75.43 | 21.28 | 20.43 | Silt loam |

Description of Soil Profile II. This soil resembles the Marshall Series: The Marshall Series includes a group of Prairie soils developed on land from Peoria loess. These soils differ from those of the Tama Series in having lime in the parent loess or a pH range from 7.8-8.5 in the lower part of the solum. They have much darker surface layers and are more advanced in development than the associated Knox soils.

Soil Profile II.

| | | | |
|---|---|---|---|
| 1. | ABp | 0-6" | Very dark gray (10YR 3/1) silty clay loam, soft, friable, weakly granuler, pH 5.6. |
| 2. | $B_{21}$ | 6-16" | Very dark gray and very dark grayish brown (10YR 3/1 and 3/2) silty clay loam, hard, firm, fine weakly block, pH 5.6. |
| 3. | $B_{22}$ | 16-225 | Very dark grayish brown to very dark brown (10YR 3.5/2) silty clay loam, slightly hard, slightly firm, fine weakly blocky, pH 5.7. |
| 4. | $B_3$ | 225-40" | Dark grayish brown to dark brown (10YR 4/2.5) silty clay loam, slightly hard, fine weakly block, pH 5.9. |
| 5. | $C_1$ | 40-60" | Brown, yellowish brown and dark brown (10YR 5/3, 5/6, and 4/3) silt loam, slightly hard, friable, massive, pH 6.5. |

Relief: Undulating to strongly rolling upland, sampling location located on area of B slope.

Vegetation: Area in cultivation, crop growing corn.

Location: NW¼, SE¼, Sec. 14, T1S, R18E

Remarks: Color notations are for the moist soil.

Table 2. Particle size analysis of profile 2 (3.5 miles from Missouri River bluff).

| Horizon | Sampling Depth | pH | Sand >0.25 mm. | Sand 0.25-0.10 mm. | Sand 0.10-0.05 mm. | Silt 0.05-0.002 mm. | <0.005 mm. | Clay <0.002 | Textural Classification |
|---|---|---|---|---|---|---|---|---|---|
| | Inches | | Perct. | Perct. | Perct. | Perct. | Perct. | Perct. | |
| $AB_p$ | 0-6 | 5.6 | --- | 0.14 | 2.65 | 66.99 | 32.39 | 30.22 | Silty clay loam |
| $B_{21}$ | 6-16 | 5.6 | --- | 0.05 | 2.16 | 62.71 | 36.23 | 35.08 | Silty clay loam |
| $B_{22}$ | 16-22.5 | 5.7 | --- | 0.07 | 1.61 | 66.33 | 35.37 | 31.99 | Silty clay loam |
| $B_3$ | 22.5-40 | 5.9 | --- | 0.13 | 2.30 | 68.06 | 34.16 | 29.51 | Silty clay loam |
| C | 40-60 | 5.5 | --- | 0.29 | 2.88 | 72.52 | 29.18 | 24.31 | Silt loam |

Marshall Series:

Soil Profile III.

1. $A_p$ 0-7" Very dark grayish brown (10YR 3.5/2) silty clay loam, slightly hard, slightly firm, weakly very fine granular, pH 5.3.

2. $B_{21}$ 7-14" Dark brown (10YR 4/3) silty clay loam, slightly hard, slightly firm, moderately medium blocky, pH 5.4.

3. $B_{22}$ 14-28.5" Dark brown (10YR 4/3) silty clay loam, slightly hard, slightly firm, weakly fine blocky, pH 5.4.

4. $B_3$ 28.5-41.5" Dark brown (10YR 4.5/3) silty clay loam, slightly hard, slightly firm, weakly coarse and medium blocky, pH 5.7.

5. $C_1$ 41.5-50" Brown (10YR 5/3) and dark brown (7.5YR 4/4 and 3/2) silty clay loam, slightly hard, slightly firm, weakly coarse and medium blocky, soil of (7.5YR 4/4 and 3/2) are mottled with manganese coating, pH 5.8.

6. $C_2$ 50-60" Brown, pale brown and brownish yellow (10YR 5/3, 6/3, and 6/6) and dark brown mottling (7.5Yr 4/4) and very dark grayish brown manganese stain (10YR 3/2) silty clay loam, slightly hard, slightly firm, coarse to medium blocky, pH 5.9.

7. 104-108" Light brownish gray and pale brown (10YR 6/2 and 6/3) and dark brown mottling (7.5YR 4/4) silt loam, pH 6.1.

Relief: Undulating to strongly rolling, upland, sampling location was on an area of B slope.

Vegetation: Area in cultivation, crop, corn.

Location: SW¼, NW¼, Sec. 28, T1S, R18E.

Remarks: Color notations are for moist soil.

Table 3. Particle size analysis of profile 3(5 miles from Missouri River bluff).

| Horizon | Sampling Depth | pH | Sand >0.25 mm. | Sand 0.25–0.10 mm. | Sand 0.10–0.05 mm. | Silt 0.05–0.002 mm. | <0.005 mm. | Clay <0.002 mm. | Textural Classification |
|---|---|---|---|---|---|---|---|---|---|
| | Inches | | Perct. | Perct. | Perct. | Perct. | Perct. | Perct. | |
| $AB_p$ | 0–7 | 5.3 | — | 0.08 | 1.16 | 64.73 | 35.35 | 34.03 | Silty clay loam |
| $B_{21}$ | 2–14 | 5.4 | — | 0.09 | 0.93 | 60.79 | 39.37 | 38.19 | Silty clay loam |
| $B_{22}$ | 14–28.5 | 5.4 | — | 0.12 | 0.90 | 65.48 | 35.39 | 33.50 | Silty clay loam |
| $B_3$ | 28.5–41.5 | 5.7 | — | 0.14 | 0.81 | 69.79 | 34.70 | 29.26 | Silty clay loam |
| $C_1$ | 41.5–50 | 5.8 | — | 0.16 | 0.65 | 69.47 | 34.64 | 29.72 | Silty clay loam |
| $C_2$ | 50–60 | 5.9 | — | 0.22 | 0.99 | 70.32 | 31.46 | 28.47 | Silty clay loam |
| | 84–96 | 6.1 | — | 0.15 | 1.33 | 73.94 | 27.36 | 24.58 | Silt loam |

Marshall Series:

Soil Profile IV.

| | | | |
|---|---|---|---|
| 1. | $A_{1p}$ | 0-7.5" | Very dark gray (10YR 3/1) silty clay loam, soft, friable, weakly fine granular, pH 5.1. |
| 2. | $A_1$ | 7.5-12" | Very dark gray (10YR 3/1) silty clay loam, slightly hard, slightly firm, weakly fine granular, pH 5.3. |
| 3. | $B_{21}$ | 12-17.5" | Very dark grayish brown (10YR 3/2) silty clay loam, hard, firm, weakly medium blocky, pH 5.2. |
| 4. | $B_{22}$ | 17.5-23.5" | Very dark grayish brown and very dark gray (10YR 3.5/2 and 3/1) silty clay, hard, firm, weakly medium blocky, pH 5.2. |
| 5. | $B_{23}$ | 23.5-30.5" | Dark grayish brown (10YR 4/2.5) silty clay loam, slightly hard, slightly firm, weakly fine blocky, pH 5.2. |
| 6. | $B_{24}$ | 30.5-37" | Dark brown (10YR 4/3) and dark brown (7.5YR 4/4) silty clay loam, slightly hard, slightly firm, very weakly fine blocky to massive, pH 5.4. |
| 7. | $B_{25}$ | 37-42" | Dark brown and grayish brown (10YR 4/3 and 5/2) and dark brown mottling (7.5YR 4/4) silty clay loam, slightly hard, slightly firm, weakly fine blocky to massive, pH 5.5. |
| 8. | $C_1$ | 42-51" | Brown, dark brown and dark grayish brown (10YR 5/3, 4/2, and 4/3) and dark brown mottling (7.5YR 4/4) silty clay loam, slightly hard, slightly firm, massive, pH 5.6. |
| 9. | $C_2$ | 51-60" | Brown, dark brown and pale brown (10YR 5/3, 4/3, and 6/3) and dark brown mottling (7.5YR 4/4) silty clay loam, slightly hard, slightly firm, massive, pH 5.9. |

Relief: Gently sloping, sampling location on an area of B slope.

Vegetation: Area in cultivation, crop corn.

Location: SW¼, NE¼, Sec. 6, T2S, R18E.

Remarks: Color notations are for the moist soil.

Table 4. Particle size analysis of profile 4 (6.5 miles from Missouri River bluff).

| Horizon | Sampling Depth | pH | Sand >0.25 mm. | Sand 0.25-0.10 mm. | Sand 0.10-0.05 mm. | Silt 0.05-0.002 mm. | <0.005 mm. | Clay <0.002 mm. | Textural Classification |
|---|---|---|---|---|---|---|---|---|---|
| | Inches | | Perct. | Perct. | Perct. | Perct. | Perct. | Perct. | |
| $A_{1p}$ | 0-7.5 | 5.1 | --- | 0.08 | 1.12 | 64.96 | 38.71 | 33.84 | Silty clay loam |
| $A_1$ | 7.5-12 | 5.3 | --- | 0.06 | 0.87 | 57.87 | 42.04 | 41.20 | Silty clay loam |
| $B_{21}$ | 12-17.5 | 5.2 | --- | 0.07 | 0.94 | 56.65 | 46.05 | 42.34 | Silty clay loam |
| $B_{22}$ | 17.5-23.5 | 5.2 | --- | 0.08 | 0.88 | 54.69 | 46.42 | 44.35 | Silty clay |
| $B_{23}$ | 23.5-30.5 | 5.2 | --- | 0.13 | 0.92 | 61.00 | 44.82 | 37.95 | Silty clay loam |
| $B_{24}$ | 30.5-37 | 5.4 | --- | 0.17 | 1.02 | 61.96 | 42.80 | 36.85 | Silty clay loam |
| $B_{25}$ | 37-42 | 5.5 | --- | 0.22 | 1.00 | 62.99 | 42.20 | 35.79 | Silty clay loam |
| $C_1$ | 42-51 | 5.6 | --- | 0.21 | 0.92 | 68.47 | 36.53 | 30.40 | Silty clay loam |
| $C_2$ | 51-60 | 5.9 | --- | 0.28 | 0.88 | 61.92 | 39.67 | 36.92 | Silty clay loam |

Marshall Series:

Soil Profile V.

| | | | |
|---|---|---|---|
| 1. | $AB_p$ | 0-5.5" | Very dark gray (10YR 3/1) silty clay loam, soft, friable, very weakly granular, pH 4.8. |
| 2. | $B_{21}$ | 5.5-13" | Very dark grayish brown (10YR 3/2) light silty clay loam, slightly hard, slightly firm, weakly granular, pH 4.9. |
| 3. | $B_{22}$ | 13-21.5" | Dark grayish brown (10YR 4/2 and 4/2.5) silty clay, hard, firm, medium fine blocky, pH 5.1. |
| 4. | $B_{23}$ | 21.5-28.5" | Dark grayish brown and brown (10YR 4/2 and 5/3) silty clay, hard, firm, weakly fine blocky, pH 5.2. |
| 5. | $B_{24}$ | 28.5-38" | Dark brown, brown and pale brown (10YR 4/3, 5/3, and 6/3) dark brown mottling (7.5YR 4/4) silty clay loam, slightly hard, slightly firm, weakly fine blocky, pH 5.2. |
| 6. | $C_1$ | 38-51" | Dark brown, brown and pale brown (10YR 4/3, 5/3, and 6/3) dark brown mottling (7.5YR 4/4) silty clay loam, slightly hard, slightly firm, massive, pH 5.7. |
| 7. | $C_2$ | 51-60" | Brown and pale brown (10YR 5/3 and 6/3) dark brown mottling (7.5YR 4/4) silty clay loam, slightly hard, slightly firm, massive, pH 5.9. |
| 8. | $D_1$ | 102-156" | Brown and pale brown (10YR 5/3 and 6/3) dark brown mottling (7.5YR 4/4) silty clay loam, slightly hard, slightly firm, massive, pH 6.1. |
| 9. | $D_2$ | 156" | Glacial Till |

Relief: Gently sloping, sampling location on about 1 percent slope.

Vegetation: Area in cultivation, crop, alfalfa.

Location: SE¼, SE¼, Sec. 12, T2S, R17E.

Remarks: Color notations are for the moist soil.

Table 5. Particle size analysis of profile 5 (8 miles from Missouri River bluff).

| Horizon | Sampling Depth | pH | Sand >0.25 mm | Sand 0.25-0.10 mm | Sand 0.10-0.05 mm | Silt 0.05-0.002 mm | <0.005 mm | Clay <0.002 mm | Textural Classification |
|---|---|---|---|---|---|---|---|---|---|
| | Inches | | Perct. | Perct. | Perct. | Perct. | Perct. | Perct. | |
| $AB_p$ | 0-5.5 | 4.8 | 0.10 | 0.21 | 1.07 | 64.64 | 42.50 | 33.98 | Silty clay loam |
| $B_{21}$ | 5.5-13 | 4.9 | 0.06 | 0.13 | 0.97 | 59.36 | 47.91 | 39.48 | Silty clay loam |
| $B_{22}$ | 13-21.5 | 5.1 | 0.07 | 0.10 | 0.65 | 57.73 | 51.72 | 41.45 | Silty clay |
| $B_{23}$ | 21.5-28.5 | 5.2 | 0.02 | 0.14 | 0.69 | 58.74 | 46.84 | 40.41 | Silty clay |
| $B_{24}$ | 28.5-38 | 5.2 | 0.03 | 0.14 | 0.83 | 62.65 | 43.02 | 36.95 | Silty clay loam |
| $C_1$ | 38-51 | 5.7 | 0.06 | 0.19 | 0.67 | 66.55 | 39.56 | 32.53 | Silty clay loam |
| $C_2$ | 51-60 | 5.9 | 0.07 | 0.18 | 0.64 | 68.56 | 38.09 | 30.55 | Silty clay loam |
| $D_1$ | 108 | 6.1 | 0.14 | 0.31 | 0.72 | 73.79 | 31.71 | 25.04 | Silty clay loam |

Marshall Series.

Soil Profile VI.

| | | | |
|---|---|---|---|
| 1. | $AB_p$ | 0-7" | Very dark gray (10YR 3/1.5) silty clay loam, slightly hard, slightly firm, very weakly granular, pH 5.1. |
| 2. | $B_{21}$ | 7-13" | Very dark grayish brown (10YR 3/2) silty clay, hard, firm, moderate, fine blocky, pH 5.1. |
| 3. | $B_{22}$ | 13-18.5" | Very dark grayish brown and dark brown (10YR 3/2 and 4/3) silty clay, hard, firm, moderate, fine blocky, pH 5.2. |
| 4. | $B_3$ | 18.5-26.5" | Dark grayish brown (10YR 4/2) silty clay, hard, firm, moderate, fine blocky, pH 5.5. |
| 5. | $C_1$ | 26.5-34" | Dark brown (10YR 4/3) silty clay loam, slightly hard, slightly firm, weakly fine blocky, pH 5.6. |
| 6. | $C_2$ | 34-51" | Dark brown and brown (10YR 4/3 and 5/3) silty clay loam, slightly hard, slightly firm, weakly fine blocky, pH 6.1. |
| 7. | $C_3$ | 51-72" | Brown (10YR 5/3) silty clay loam, soft, friable, massive, pH 6.2. |
| 8. | D | 72-120" | Sangamon soil in Loveland Loess. |
| 9. | | 120"+ | Glacial Till. |

Relief: Gently sloping, sampling location on about 2 percent slope.

Vegetation: Area in cultivation, crop, corn.

Location: NW¼, NW¼, Sec. 13, T2S, R17E.

Remarks: Color notations are for the moist soil.

Table 6. Particle size analysis of profile 6 (9.5 miles from Missouri River bluff).

| Horizon | Sampling Depth | pH | Sand >0.25 mm | Sand 0.25–0.10 mm | Sand 0.10–0.05 mm | Silt 0.05–0.002 mm | <0.005 mm | Clay <0.002 mm | Textural Classification |
|---|---|---|---|---|---|---|---|---|---|
| | Inches | | Perct. | Perct. | Perct. | Perct. | Perct. | Perct. | |
| $AB_p$ | 0-7 | 5.1 | 0.04 | 0.07 | 0.89 | 59.35 | 46.28 | 39.65 | Silty clay loam |
| $B_{21}$ | 7-13 | 5.1 | 0.04 | 0.04 | 0.41 | 52.58 | 52.50 | 46.93 | Silty clay |
| $B_{22}$ | 13-18.5 | 5.2 | 0.02 | 0.04 | 0.52 | 53.93 | 53.13 | 45.49 | Silty clay |
| $B_3$ | 18.5-26.5 | 5.5 | —— | 0.05 | 0.49 | 55.62 | 49.73 | 43.84 | Silty clay |
| $C_1$ | 26.5-34 | 6.6 | —— | 0.04 | 0.52 | 59.25 | 46.52 | 40.29 | Silty clay loam |
| $C_2$ | 34-51 | 6.1 | —— | 0.05 | 0.49 | 62.66 | 44.36 | 36.77 | Silty clay loam |
| $C_3$ | 51-60 | 6.2 | —— | 0.01 | 0.60 | 66.51 | 41.28 | 32.88 | Silty clay loam |

Description of Soil Profile VII. This soil resembles the Sharpsburg Series 1. The Sharpsburg Series includes very dark colored granular well-drained Prairie soils developed from silty material of loessial origin. They occupy crests of ridges in upland areas ranging in gradient in most cases from two to six percent. They have B horizons higher in clay content than Marshall soils and less clay than the Haig soils. A tentative proposal has been made to recognize a new soil catena including Stuart, Sharpsburg, and Shelmar soils occupying the range in relief from the level areas to those having gradients of 12 to 15 percent. The soils or this catena would be intermediate in character with respect to color, structure, and texture, particularly of their B horizons between the proposed Minden, Marshall, Mills Catena and Grundy, Haig Catena. The surface and subsoil is medium to strongly acid in reaction and the deep substratum is neutral or alkaline in places where the silt deposits are thickest. The silty clay loam and silt loam types occur. (U.S.D.A. description)

Soil Profile:

| | | | |
|---|---|---|---|
| 1. | $A_{1p}$ | 0-7.5" | Black (10YR 2.5/1) silty clay loam, slightly hard, friable, very weakly fine granular, pH 4.8. |
| 2. | $A_1$ | 7.5-19" | Black (10YR 2.5/1) silty clay loam, slightly hard, friable, moderate, fine granular, pH 4.8. |
| 3. | $A_3$-$B_1$ | 19-24" | Very dark gray (10YR 3/1) silty clay, hard, slightly firm, plastic, moderate fine granular, pH 5.1. |
| 4. | $B_{21}$ | 24-28.5" | Very dark gray and dark grayish brown (10YR 3/1 and 4/2) silty clay, hard, firm, moderate fine blocky, pH 5.0. |
| 5. | $B_{22}$ | 28.5-43.5" | Very dark grayish brown (2.5Y 3.5/2) silty clay, hard, |

| | | |
|---|---|---|
| | | firm, moderate, medium blocky, pH 5.9. |
| 6. $B_3$ | 43.5-54" | Dark grayish brown (2.5Y 4.5/2) and brown (10YR 5/3) silty clay loam, hard, firm, moderate, medium blocky, pH 5.4. |
| 7. $C_1$ | 54-60" | Grayish brown (2.5Y 5/2) and dark brown (7.5YR 4/4) silty clay loam, mottled, slightly hard, firm, very weakly medium blocky to massive, pH 5.0. |
| 8. D | 144" | Old soil developed in lacustrine clays. |

Relief: Gently sloping, sampling location on about 1 percent slope.

Vegetation: Area cultivated, crop corn.

Location: NE¼, NW¼, Sec. 33, T2S, R17E.

Remarks: Color notations are for the moist soil.

Table 7. Particle size analysis of profile 7 (11 miles from Missouri River bluff).

| Horizon | Sampling Depth | pH | Sand >0.25 mm | Sand 0.25–0.10 mm | Sand 0.10–0.05 mm | Silt 0.05–0.002 mm | <0.005 mm | Clay <0.002 mm | Textural Classification |
|---|---|---|---|---|---|---|---|---|---|
| | Inches | | Perct. | Perct. | Perct. | Perct. | Perct. | Perct. | |
| $A_{1p}$ | 0–7.5 | 4.8 | 0.05 | 0.11 | 1.50 | 65.67 | 38.90 | 32.67 | Silty clay loam |
| $A_1$ | 7.5–19 | 4.8 | 0.04 | 0.14 | 1.45 | 59.29 | 43.26 | 39.08 | Silty clay loam |
| $A_3B_1$ | 19–24 | 5.1 | 0.04 | 0.11 | 1.15 | 55.46 | 49.06 | 43.24 | Silty clay |
| $B_{21}$ | 24–28.5 | 5.0 | 0.04 | 0.13 | 0.89 | 53.36 | 52.47 | 45.58 | Silty clay |
| $B_{22}$ | 28.5–43.5 | 5.9 | —— | 0.04 | 0.47 | 49.30 | 54.12 | 50.19 | Silty clay |
| $B_3$ | 43.5–54 | 5.8 | —— | —— | 0.35 | 56.76 | 50.14 | 42.89 | Silty clay |
| $C_1$ | 54–60 | 5.0 | —— | 0.02 | 0.60 | 60.07 | 45.76 | 39.31 | Silty clay loam |
| D | 144 | 5.7 | —— | —— | 0.52 | 61.36 | 45.11 | 38.12 | Silty clay loam |

Description of Profile VIII. This soil resembles the Grundy Series: The Grundy soils include dark lime-free Planosols on level or undulating loess covered uplands within the Prairie region. They have a heavier subsoil than the Muscatine soils, and are less calcareous than the Marcus soils. They lack the well-developed gray subsurface layer characteristics of the Edina and Putman soils. The surface soil is strongly acid; the deeper layers are less acid. (U.S.D.A. Description)

Soil Profile VIII.

| | | | |
|---|---|---|---|
| 1. | $A_{1p}$ | 0-5" | Black (10YR 2.5/1) silty clay loam, soft, friable, very weakly granular, pH 4.9. |
| 2. | $A_1$ | 5-13" | Black (10YR 2.5/1) silty clay, slightly hard, slightly firm, moderate, fine granular, pH 4.8. |
| 3. | $A_3$-$B_1$ | 13-18" | Very dark gray and dark grayish brown (10YR 3/1 and 4/2) silty clay, hard, firm, moderate, fine granular, pH 4.8. |
| 4. | $B_{21}$ | 18-22.5" | Very dark grayish brown and dark gray (10YR 3/2 and 4/1) silty clay, hard, firm, moderate medium blocky, breaking into moderate fine granules, pH 4.8. |
| 5. | $B_{22}$ | 22.5-28.5" | Dark gray (10YR 4/1) silty clay, hard, firm, moderate, medium blocky, breaking into moderate, fine granules, contains manganese concretions, pH 5.1. |
| 6. | $B_{23}$ | 28.5-36.5" | Gray and brown (10YR 5/1 and 5/3) and dark brown (7.5YR 4/4) silty clay, hard, firm, moderate medium blocky, breaking into moderate fine granules, contains manganese concretions, pH 5.1. |
| 7. | $C_1$ | 36.5-48" | Grayish brown and brown (10YR 5/2 and 5/3) and dark brown (7.5YR 4/4) silty clay loam, slightly hard, slightly firm, |

| | | |
|---|---|---|
| | | weakly medium blocky to massive, contains manganese concretions, pH 5.4. |
| 8. $C_2$ | 48-60" | Grayish brown (2.5Y 5/2) and yellowish brown (10YR 5/6) silty clay loam, slightly hard, slightly firm, weakly medium blocky to massive, contains manganese concretions, pH 5.6. |
| 9. $D_1$ | 108-132" | Sangamon soil in Loveland loess. |
| 10. $D_2$ | 132"+ | Glacial Till. |

Relief: Gently sloping, sampling location on about 1 percent slope.

Vegetation: Area cultivated, crop, red clover.

Locations: NW¼, NW¼, Sec. 8, T38, R17E.

Remarks: Color notations are for the moist soils.

Table 8. Particle size analysis of profile 8 (12.5 miles from Missouri River bluff).

| Horizon | Sampling Depth | pH | Sand >0.25 mm | Sand 0.25–0.10 mm | Sand 0.10–0.05 mm | Silt 0.05–0.002 mm | <0.005 mm | Clay <0.002 mm | Textural Classification |
|---|---|---|---|---|---|---|---|---|---|
| | Inches | | Perct. | Perct. | Perct. | Perct. | Perct. | Perct. | |
| $A_{1p}$ | 0–5 | 4.9 | ––– | 0.05 | 0.53 | 66.35 | 39.44 | 33.07 | Silty clay loam |
| $A_1$ | 5–13 | 4.8 | ––– | 0.04 | 0.56 | 57.23 | 47.04 | 42.17 | Silty clay |
| $A_3$–$B_1$ | 13–18 | 4.8 | ––– | 0.06 | 0.60 | 54.14 | 53.13 | 45.18 | Silty clay |
| $B_{21}$ | 18–22.5 | 4.8 | ––– | 0.15 | 0.85 | 49.07 | 56.23 | 49.93 | Silty clay |
| $B_{22}$ | 22.5–28.5 | 5.1 | ––– | 0.11 | 0.75 | 52.77 | 55.41 | 46.37 | Silty clay |
| $B_{23}$ | 28.5–36.5 | 5.1 | ––– | 0.10 | 0.88 | 54.32 | 53.29 | 44.70 | Silty clay |
| $C_1$ | 36.5–48 | 5.4 | ––– | 0.15 | 1.03 | 60.14 | 46.45 | 38.68 | Silty clay loam |
| $C_2$ | 48–60 | 5.6 | ––– | 0.27 | 1.61 | 61.09 | 44.97 | 37.03 | Silty clay loam |

Grundy Series:

Soil Profile IX.

| | | | |
|---|---|---|---|
| 1. | $A_{1p}$ | 0-6" | Black (10YR 2/1) silty clay loam, soft, friable, very weakly fine granular, pH 4.7. |
| 2. | $A_1$ | 6-14" | Black (10YR 2/1) silty clay loam, slightly hard, slightly firm, moderate, fine granular, pH 4.4. |
| 3. | $A_3$-$B_1$ | 14-22" | Black (10YR 2/1) silty clay, hard, firm, moderate fine blocky, pH 5.0. |
| 4. | $B_{21}$ | 22-29.5" | Very dark gray (10YR 3/1) silty clay, very hard, firm to very firm, prismatic structure breaking into weak medium blocks. Some Iron and Manganese concretions, few faint mottling areas, pH 5.1. |
| 5. | $B_{22}$ | 29.5-36" | Dark grayish brown (10YR 4/2) silty clay, very hard, very firm, prismatic structure breaking into weak medium blocks. Some Iron and Manganese concretions and some root channels causing dark spots, pH 5.3. |
| 6. | $B_{23}$ | 36-45 | Grayish brown and dark brown (10YR 5/2 and 4/3) silty clay loam, very firm, weakly medium prismatic structure, breaking into weakly medium blocks. Some Iron and Manganese concretions and some root channels causing dark spots, pH 5.4. |
| 7. | $C_1$ | 45-55" | Light brownish gray (10YR 6/2) and yellowish red (5YR 4/6) silty clay loam, hard, firm, massive to weakly medium blocky, mottled, pH 5.8. |
| 8. | $C_2$ | 55-60" | Light gray (10YR 7/2) and dark reddish brown (5YR 3/3) silty clay loam, slightly hard, slightly firm, massive |

structure, pH 5.9.

| | | |
|---|---|---|
| 9. | 72" | Glacial Till. |

Relief: Gently sloping, sampling location on relatively flat area.

Vegetation: Area cultivated, crop, barley.

Location: NE$\frac{1}{4}$, SE$\frac{1}{4}$, Sec. 14, T3S, R16E.

Remarks: Color notations are for the moist soil.

Table 9. Particle size analysis of profile 9 (14 miles from Missouri River bluff).

| Horizon | Sampling Depth | pH | Sand >0.25 mm | Sand 0.25–0.10 mm | Sand 0.10–0.05 mm | Silt 0.05–0.002 mm | < 0.005 mm | Clay <0.002 mm | Textural Classification |
|---|---|---|---|---|---|---|---|---|---|
| | Inches | | Perct. | Perct. | Perct. | Perct. | Perct. | Perct. | |
| $A_{1p}$ | 0–6 | 4.7 | ---- | 0.14 | 1.47 | 62.66 | 39.66 | 35.73 | Silty clay loam |
| $A_1$ | 6–14 | 4.4 | ---- | 0.06 | 1.29 | 56.72 | 46.60 | 41.93 | Silty clay |
| $A_3$ | 14–22 | 5.0 | ---- | 0.06 | 1.03 | 53.90 | 51.84 | 45.01 | Silty clay |
| $B_{21}$ | 22–29.5 | 5.1 | ---- | 0.13 | 0.90 | 49.10 | 54.89 | 49.87 | Silty clay |
| $B_{22}$ | 29.5–36 | 5.3 | ---- | 0.04 | 0.51 | 51.38 | 53.75 | 48.07 | Silty clay |
| $B_{23}$ | 36–45 | 5.4 | ---- | 0.01 | 0.48 | 58.14 | 47.86 | 41.37 | Silty clay |
| $C_1$ | 45–55 | 5.8 | ---- | 0.02 | 0.41 | 59.92 | 48.11 | 39.65 | Silty clay |
| $C_2$ | 55–60 | 5.9 | ---- | 0.01 | 0.37 | 62.35 | 44.97 | 37.27 | Silty clay |

Grundy Series:

Soil Profile X.

| | | | |
|---|---|---|---|
| 1. | $A_{1p}$ | 0-7" | Black (10YR 2/1) silty clay loam, soft, friable, weakly fine granular, pH 5.4. |
| 2. | $A_1$ | 7-10" | Black (10YR 2/1) silty clay loam, hard, firm, with moderate fine blocky structure, pH 5.2. |
| 3. | $A_3$-$B_1$ | 10-17" | Black (10YR 2/1) silty clay, very hard, very firm, with moderate fine subangular blocky structure, pH 4.8. |
| 4. | $B_{21}$ | 17-28" | Very dark gray (10YR 3/1) silty clay, very hard, very firm, with weakly medium prismatic structure breaking into weak blocks, fine faint mottling, Iron and Manganese concretions and some root channels causing dark spots, pH 5.2. |
| 5. | $B_{22}$ | 28-40" | Dark grayish brown (10YR 4/2) silty clay, very hard, very firm, with weak prismatic structure breaking into weak blocks, fine faint mottling, Iron and Manganese concretions, and some root channels causing dark spots, pH 5.5. |
| 6. | $B_{23}$ | 40-45" | Grayish brown (10YR 5/2) and dark brown (7.5YR 4/4) silty clay, very hard, very firm, weak medium blocky, Iron and Manganese concretions present, pH 6.0. |
| 7. | C | 45-60" | Light gray and light brownish gray (10YR 7/2 and 6/2) and dark brown (7.5YR 4/4) silty clay loam, hard, firm, with weak medium blocky to massive structure, pH 6.2 |
| 8. | D | 63" | Glacial Till. |

Relief: Gently sloping, sampling location on relatively flat area.

Vegetation: Area cultivated, crop corn.

Location: $NE\frac{1}{4}$, $NE\frac{1}{4}$, Sec. 28, T3S, R16E.

Remarks: Color notations are for the moist soils.

Table 10. Particle size analysis of profile 10 (15.5 miles from Missouri River bluff).

| Horizon | Sampling Depth | pH | Sand >0.25 mm | Sand 0.25–0.10 mm | Sand 0.10–0.05 mm | Silt 0.05–0.002 mm | <0.005 mm | Clay <0.002 mm | Textural Classification |
|---|---|---|---|---|---|---|---|---|---|
| | Inches | | Perct. | Perct. | Perct. | Perct. | Perct. | Perct. | |
| $A_{1p}$ | 0–7 | 5.4 | —— | 0.06 | 1.41 | 62.69 | 42.29 | 35.84 | Silty clay loam |
| $A_1$ | 7–10 | 5.2 | —— | 0.05 | 1.23 | 59.09 | 44.83 | 39.63 | Silty clay loam |
| $A_3$-$B_1$ | 10–17 | 4.8 | —— | 0.07 | 0.96 | 54.95 | 50.29 | 44.02 | Silty clay |
| $B_{21}$ | 17–28 | 5.2 | —— | 0.11 | 0.80 | 46.08 | 59.01 | 53.01 | Silty clay |
| $B_{22}$ | 28–40 | 5.5 | —— | 0.09 | 0.79 | 52.45 | 54.50 | 46.67 | Silty clay |
| $B_{23}$ | 40–45 | 6.0 | —— | 0.03 | 0.31 | 58.63 | 48.67 | 41.03 | Silty clay |
| C | 45–60 | 6.2 | —— | 0.03 | 0.33 | 59.96 | 47.95 | 39.68 | Silty clay loam |

# EXPERIMENTAL RESULTS

The results of the particle size analyses show that there is a decrease in the sand fraction and an increase in clay content in each profile with distance from the source area. Tables 1-10. The results of this investigation show that there is a higher percentage of sand in the C horizon of the soils occurring nearer the river than is present in the surface horizon, whereas those farther from the river have their higher percentage of sand in the surface horizon. Tables 1-10. It was found from this investigation that the clay content increased in all horizons with distance from the river. With an increase in distance from the Missouri River the loess material thins rapidly. It is on these thinner deposits that the soils have developed which contain the higher percentage of clay. This investigation has shown that there is a relationship of profile development with thickness of loess material in which the soil has developed and with the clay content of the soil. The thinning of the loess in a southwesternly direction away from the Missouri River is illustrated by Fig. 1, which shows the variation in maximum loess thickness along the traverse of this study.

In comparing the increase of clay content of the C horizons and the B horizon of the ten profiles studied it is realized that the increase in clay content of the B horizon is greater than the increase in the C horizons in relation to distance from the source of the parent material and conversely the decrease in silt is greatest in the C horizon.

The pH of the samples varied with depth in each profile studied, showing a slight increase with depth. Tables 1-10. The results of this investigation show that there is a gentle decrease in pH with distance from the Missouri River

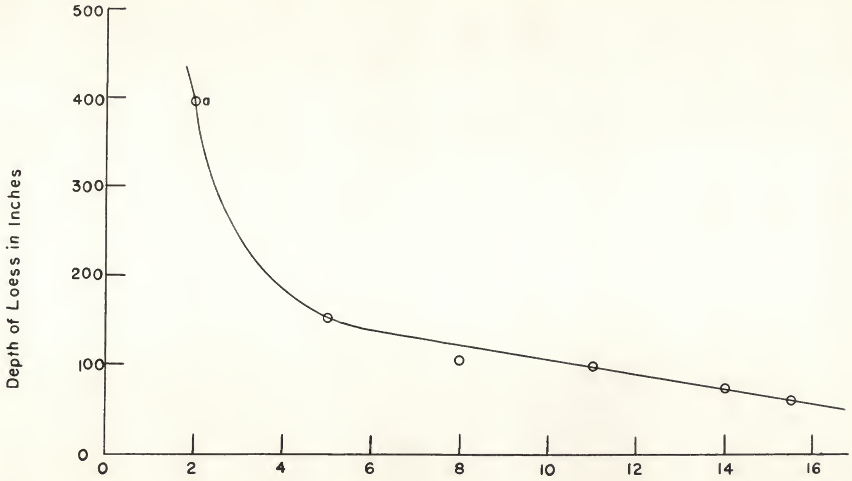


Figure 1. Miles From Missouri River Bluff
a Estimated

in all horizons. With a decrease in pH with distance, it is realized there is a relationship of thickness of loess, content of clay, profile formation, and distance from the source area.

From this investigation it was found that iron-manganese concretions began to occur in the samples taken from profile 5, (Marshall profile) and began to show up at a depth of approximately 36 inches, and were present in the remainder of the profiles. In profiles 6, 7, 8, 9, and 10 (Sharpsburg and Grundy profiles) concretions were present in each horizon, being highly concentrated in the B horizon, with almost as many present in the C horizon. It was noted that those samples containing a high amount of clay also had a large number of concretions. The concretions tend to increase in all horizons to a distance of approximately 11 miles from the river. From this point on the number of concretions were relatively constant for each profile.

## DISCUSSION

Although numerous hypotheses have been developed on the origin of loess, the parent material of these soils, it is generally accepted today that it was deposited by the wind and that the most common source area of the loess in this country was water deposited sediments. The fact that the maximum depth of the soil material occurs adjacent to the Missouri River with a gradual thinning of this material with distance from the river plus the fact that there is a decrease in the mean particle size of the coarse materials of the parent material with distance would seem to substantiate these hypotheses. Soils studied in this investigation indicate that both parent material, weathering and time had a great influence on their development.

There are soils derived from loess material occurring on many parts of the earth. Some have been shown to be functionally related to the loess from which they have developed. Bray (5) has shown in Illinois the weathering of loess and degree of differentiation in the soils are related to the distribution of the loess. Jenny (22)has described a sequence of soils in which time is the only genetic variable. Hutton (19) in his study showed that the characteristics of the soils in southwestern Iowa are related to the distribution pattern of the loess. The thick loess deposits near the river which contain an abundance of coarse particles and in which there has been little profile horizon differentiation indicates that the deposition of the loess was most rapid near the river, or that the loess here has been deposited more recently. In as much as no buried soil was observed in the first site to a depth of 204 inches it may be concluded that deposition of the material either occurred at a fairly rapid uniform rate, or that it is all recent deposition, which seems unlikely.

The presence of the iron-manganese concretions in the more clayey profiles seems to suggest that restrictions in drainage are an important factor in the formation of these secondary particles. Further work should be undertaken in order to determine whether the presence or absence of these concretions is also associated with minor changes in soil acidity as has been suggested by some authorities.

This study revealed the Knox soils, which had little horizon differentiation, to be developed in loess estimated to be 500 to 2000 inches thick. The Marshall soils, which have slight to moderate horizon differentiation, developed on loess material from 150 to 500 inches thick, approximately, and the Sharpsburg soils showed moderate to strong horizon differentiation, and were developed in loess from 100 to 150 inches thick. The Grundy soils showed strong horizon differentiation, having developed on less than 100 inches of loess. It has been concluded from this investigation that at the time of deposition the coarse materials were dropped near the source with the smaller particles being carried farther from the source, as is indicated by the particle size analyses of the C horizons. Tables 1-10.

The wind action which was responsible for these deposits, not only caused a differential thickness in the deposit with distance, but it also served to sort the materials to some extent. A comparison of the amount of sand and clay at sites 1 and 10 reveal this important difference.

The thin deposits of fine grained materials deposited at a relatively slow rate over a long time interval on an upland more or less undissected by encroaching stream tributaries has been responsible for the formation of the Grundy soils. As the parent material mean particle size increases and as the depth of the deposit increases there usually is a corresponding increase in the amount of dissection which occurred. For that reason, it is difficult to assess the importance or value of each of these factors. As the effect of each varies, however, the final soil product varies in proportion to the effect of each of these factors.

Although the texture of the parent material has an obvious importance in determining the nature of the soil developed in it, there is evidence in the area of the traverse that reduced drainage as influenced by limited dissection or reduced slopes may cause a soil to be more highly developed than would be normal for the given parent material. Small areas of Grundy in a larger Sharpsburg area for example, are quite prominent on the level interfluve areas, whereas the Sharpsburg soils occur on the more sloping areas in that vicinity.

In the development of a soil profile, if it is assumed that the development of the A horizon results from the eluviation of clay, it would be normal to assume that the concentration of the coarser materials would increase with development due to the removal of the clay which tends to have a diluting effect on the sand, providing, of course, that the sand fraction is assumed to weather slowly. One would expect then, that the comparison of the sand in the A horizon with that of the C horizon might give a rough approximation of the amount of weathering and profile differentiation which has taken place in a given profile. The immature soil would be expected to have a fairly uniform distribution of sand in the profile, assuming uniform deposition. With increased weathering, increased loss of clay from the A, and an enrichment of clay in the B horizon it would be expected that the sand concentration would increase in the A, and decrease in the B, compared to the C horizon.

The data for the ten profiles seem to substantiate this hypothesis, at least in a rough way, for in the first four profiles there appears to be no decided concentration of sand in the A, although there does appear to be a decrease in the B horizon due to the dilution effect of the clay enrichment. The fact that there is an actual decrease in the sand fraction in the A compared to the C horizon in the four profiles located in the more rolling part of the traverse seems to suggest that erosion may have removed a greater proportion of the surface than has been realized, and in so doing, it has altered the expected proportions of sand to silt and clay.

The remaining profiles with the exception of profile 8, show the ratio of the sand fraction in the A to that in the C to increase with increased profile development. If this thinking is valid, the data would seem to suggest that there has been little deposition since the beginning of the soil formation processes since there has been no, or very little, sand dilution.

In considering the development of each of the profiles it should be pointed out that the total clay in the B horizon does not necessarily give a true picture of the degree of development. Instead, the difference between that value and the amount of clay in the C horizon gives a better estimation of the amount of clay which has accumulated in the B horizon. A comparison of these values shows that with the exception of the first four profiles in which there is some variation, the amount of clay which has accumulated in the B, over and above what was already there, is approximately the same value for each of the profiles. The large value for the clay in the B horizons of profiles 5, 6, 7, 8, 9, and 10 is not so great when one compares the amount of clay in the B with the amount which is present in the C horizon. One possible fallacy with this line of reasoning should be pointed out. If the material were deposited over a considerable time interval as was suggested by Smith (34), and underwent severe weathering during the time of its deposition, it is conceivable that the texture of the lower horizons of the deposit may have been altered prior to the completion of the deposition. If this is true, a comparison of the clay content of the B and the so-called C horizon would be less meaningful.

# CONCLUSIONS

From this investigation it was concluded that:

1. The post-glacial Missouri River Valley was the source of the loess which covers the extreme northeastern part of Kansas. This is based on the following:

   a. The texture of the loess decreases in mean particle size with increased distance from the Missouri River Valley.

   b. The depth of the deposit decreases with distance from the river.

2. There appeared to be a close relationship between the amount of clay present in the parent loess and the amount of clay present in the B horizon of the soil developed in it.

3. The abundance of the iron-manganese concretions in the soils developed from the more clayey loess suggested the possibility that restriction in drainage may be a factor in their development.

4. The texture of the parent loess appeared to be the most important factor in the development of the Knox, Marshall, Sharpsburg, and Grundy soils, although it is recognized that the depth of the loess and the relief may alter the importance of the loess texture in its effect on the final end product.

5. The ratio of the quantity of sand in the A horizon to that of the C horizon tended to increase with distance from the river, suggesting that the A horizon developed through eluviation of clay. It would seem to indicate that there has been very little deposition since the beginning of the development of those soils at a distance of 8 miles and more from the river.

6. The pH of each of the ten soil profiles increased with depth, and there

was a tendency for the pH of the solum and the parent material to decrease with distance from the river.

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# APPENDIX

Particle size analysis of profile 1.

| | Per cent | | | | | |
|---|---|---|---|---|---|---|
| Sample | > 0.25 mm | 0.25–0.10 mm | 0.10–0.05 mm | 0.05–0.002 mm | < 0.005 mm | < 0.002 mm |
| 1-1 | | 0.08 | 2.27 | 69.41 | 28.24 | 28.24 |
| 1-2 | | 0.15 | 2.38 | 71.02 | 27.83 | 26.45 |
| 1-3 | | 0.18 | 2.81 | 71.51 | 31.32 | 25.50 |
| 2-1 | | 0.03 | 2.28 | 70.70 | 34.52 | 26.99 |
| 2-2 | | 0.16 | 3.77 | 67.26 | 32.41 | 28.81 |
| 2-3 | | 0.13 | 3.61 | 66.24 | 34.57 | 29.82 |
| 3-1 | | 0.11 | 3.25 | 65.85 | 30.80 | 30.79 |
| 3-2 | | 0.12 | 3.45 | 66.21 | 32.82 | 30.22 |
| 3-3 | | 0.10 | 3.22 | 65.66 | 31.02 | 31.02 |
| 4-1 | | 0.13 | 3.39 | 65.86 | 33.68 | 30.62 |
| 4-2 | | 0.09 | 3.10 | 64.98 | 35.05 | 31.82 |
| 4-3 | | 0.21 | 3.14 | 66.87 | 35.92 | 29.78 |
| 5-1 | | 0.14 | 3.51 | 67.77 | 33.27 | 28.58 |
| 5-2 | | 0.08 | 3.76 | 70.49 | 32.94 | 25.67 |
| 5-3 | | 0.14 | 3.88 | 60.48 | 30.80 | 35.50 |
| 6-1 | | 0.11 | 2.58 | 73.76 | 27.83 | 24.55 |
| 6-2 | | 0.10 | 2.96 | 70.81 | 18.75 | 26.13 |
| 6-3 | | 0.19 | 4.03 | 70.57 | 28.20 | 25.21 |
| 7-1 | | 0.44 | 4.36 | 69.90 | 28.73 | 25.30 |
| 7-2 | | 0.53 | 4.58 | 70.28 | 28.38 | 24.57 |
| 7-3 | | 0.39 | 4.23 | 70.37 | 27.55 | 25.01 |
| 8-1 | | 0.56 | 3.63 | 72.80 | 25.22 | 23.01 |
| 8-2 | | 0.46 | 2.93 | 76.26 | 25.21 | 20.35 |
| 8-3 | | 0.74 | 4.64 | 70.04 | 25.02 | 24.58 |
| 9-1 | | 0.34 | 3.98 | 74.52 | 21.16 | 21.16 |
| 9-2 | | 0.29 | 3.28 | 74.62 | 21.79 | 21.81 |
| 9-3 | | 0.35 | 4.16 | 77.17 | 20.88 | 18.32 |

Particle size analysis of profile 2.

| | Per cent | | | | | |
|---|---|---|---|---|---|---|
| Sample | Sand > 0.25 mm | Sand 0.25-0.10 mm | Sand 0.10-0.05 mm | Silt 0.05-0.002 mm | < 0.005 mm | Clay < 0.002 mm |
| 1-1 | | 0.14 | 2.38 | 67.75 | 32.98 | 29.73 |
| 1-2 | | 0.13 | 2.95 | 66.64 | 31.27 | 30.38 |
| 1-3 | | 0.14 | 2.62 | 66.70 | 32.92 | 30.54 |
| 2-1 | | 0.03 | 1.86 | 62.30 | 35.91 | 35.91 |
| 2-2 | | 0.05 | 2.22 | 62.95 | 35.21 | 34.78 |
| 2-3 | | 0.06 | 2.40 | 62.99 | 37.57 | 34.55 |
| 3-1 | | 0.10 | 2.04 | 63.79 | 35.27 | 33.07 |
| 3-2 | | 0.07 | 1.78 | 65.93 | 34.37 | 32.22 |
| 3-3 | | 0.05 | 1.96 | 67.31 | 36.48 | 30.68 |
| 4-1 | | 0.14 | 2.65 | 67.50 | 32.68 | 29.61 |
| 4-2 | | 0.13 | 1.90 | 67.63 | 33.76 | 30.34 |
| 4-3 | | 0.12 | 2.34 | 69.05 | 36.04 | 28.49 |
| 5-1 | | 0.34 | 2.67 | 74.04 | 29.75 | 22.95 |
| 5-2 | | 0.20 | 2.86 | 74.19 | 28.44 | 22.75 |
| 5-3 | | 0.32 | 3.12 | 69.33 | 29.35 | 27.23 |

Particle size analysis of profile 3.

| | Per cent | | | | | |
|---|---|---|---|---|---|---|
| Sample | > 0.25 mm | 0.25–0.10 mm | 0.10–0.05 mm | 0.05–0.002 mm | < 0.005 mm | < 0.002 mm |
| 1-1 | | 0.09 | 1.19 | 64.33 | 37.96 | 34.39 |
| 1-2 | | 0.08 | 1.10 | 65.99 | 34.28 | 32.49 |
| 1-3 | | 0.06 | 0.89 | 63.83 | 33.82 | 35.21 |
| 2-1 | | 0.09 | 0.95 | 59.54 | 47.30 | 39.42 |
| 2-2 | | 0.08 | 0.93 | 60.33 | 29.11 | 38.66 |
| 2-3 | | 0.11 | 0.90 | 62.51 | 41.69 | 36.48 |
| 3-1 | | 0.12 | 0.60 | 66.45 | 36.33 | 32.83 |
| 3-2 | | 0.12 | 0.96 | 64.03 | 34.56 | 34.89 |
| 3-3 | | 0.13 | 1.13 | 66.05 | 35.27 | 32.69 |
| 4-1 | | 0.18 | 0.98 | 68.91 | 34.89 | 30.03 |
| 4-2 | | 0.14 | 0.74 | 70.30 | 34.13 | 28.82 |
| 4-3 | | 0.11 | 0.71 | 70.24 | 35.08 | 28.94 |
| 5-1 | | 0.22 | 0.89 | 70.67 | 32.55 | 28.15 |
| 5-2 | | 0.17 | 0.76 | 68.58 | 36.51 | 30.49 |
| 5-3 | | 0.08 | 0.29 | 69.12 | 34.87 | 30.51 |
| 6-1 | 0.04 | 0.24 | 0.85 | 70.88 | 29.69 | 27.99 |
| 6-2 | 0.03 | 0.20 | 1.08 | 70.32 | 35.08 | 28.67 |
| 6-3 | 0.04 | 0.23 | 1.03 | 69.95 | 29.62 | 28.75 |
| 7-1 | 0.04 | 0.13 | 0.85 | 73.49 | 26.34 | 25.49 |
| 7-2 | 0.03 | 0.15 | 1.39 | 74.12 | 28.96 | 24.13 |
| 7-3 | 0.03 | 0.16 | 1.15 | 74.55 | 26.78 | 24.11 |

Particle size analysis of profile 4.

| Sample | > 0.25 mm | 0.25–0.10 mm | 0.10–0.05 mm | 0.05–0.002 mm | < 0.005 mm | < 0.002 mm |
|---|---|---|---|---|---|---|
| | Per cent | | | | | |
| 1-1 | | 0.07 | 1.00 | 63.87 | 39.33 | 35.06 |
| 1-2 | | 0.09 | 1.33 | 67.13 | 39.98 | 31.45 |
| 1-3 | | 0.09 | 1.04 | 63.87 | 36.82 | 35.00 |
| 2-1 | | 0.06 | 0.92 | 56.00 | 38.90 | 43.02 |
| 2-2 | | 0.06 | 0.90 | 57.83 | 44.80 | 41.21 |
| 2-3 | | 0.05 | 0.80 | 59.78 | 42.43 | 39.37 |
| 3-1 | | 0.08 | 0.93 | 57.85 | 47.84 | 41.14 |
| 3-2 | | 0.08 | 0.77 | 56.87 | 45.80 | 42.28 |
| 3-3 | | 0.06 | 1.12 | 55.22 | 44.50 | 43.60 |
| 4-1 | | 0.07 | 0.73 | 55.31 | 47.03 | 43.89 |
| 4-2 | | 0.08 | 1.05 | 53.64 | 46.13 | 45.23 |
| 4-3 | | 0.08 | 0.86 | 55.13 | 46.10 | 43.93 |
| 5-1 | | 0.09 | 1.04 | 59.20 | 47.86 | 39.67 |
| 5-2 | | 0.15 | 0.89 | 59.85 | 40.83 | 39.11 |
| 5-3 | | 0.15 | 0.83 | 63.94 | 45.74 | 35.08 |
| 6-1 | 0.02 | 0.18 | 1.07 | 62.43 | 43.74 | 36.30 |
| 6-2 | 0.02 | 0.17 | 1.15 | 61.67 | 41.34 | 36.99 |
| 6-3 | 0.02 | 0.15 | 0.84 | 61.74 | 43.31 | 37.25 |
| 7-1 | 0.04 | 0.23 | 0.87 | 63.29 | 40.77 | 35.57 |
| 7-2 | 0.03 | 0.21 | 1.17 | 62.84 | 44.04 | 35.75 |
| 7-3 | 0.04 | 0.22 | 0.96 | 62.72 | 41.78 | 36.06 |
| 8-1 | 0.02 | 0.18 | 1.04 | 66.91 | 38.30 | 31.85 |
| 8-2 | 0.02 | 0.22 | 0.85 | 69.60 | 36.96 | 29.31 |
| 8-3 | 0.02 | 0.23 | 0.88 | 68.84 | 34.32 | 30.03 |
| 9-1 | 0.02 | 0.32 | 0.78 | 61.89 | 38.73 | 36.99 |
| 9-2 | 0.04 | 0.30 | 0.88 | 61.43 | 40.87 | 37.35 |
| 9-3 | 0.04 | 0.22 | 0.98 | 62.27 | 39.41 | 36.41 |

Particle size analysis of profile 5.

| Sample | > 0.25 mm | 0.25–0.10 mm | 0.10–0.05 mm | 0.05–0.002 mm | < 0.005 mm | < 0.002 mm |
|---|---|---|---|---|---|---|
| | Per cent | | | | | |
| 1-1 | 0.16 | 0.19 | 0.86 | 63.12 | 40.06 | 35.73 |
| 1-2 | 0.12 | 0.22 | 1.39 | 63.82 | 42.76 | 34.48 |
| 1-3 | 0.15 | 0.23 | 0.97 | 66.95 | 44.69 | 31.73 |
| 2-1 | 0.04 | 0.11 | 0.99 | 58.28 | 49.74 | 40.57 |
| 2-2 | 0.05 | 0.11 | 0.97 | 60.42 | 46.51 | 38.44 |
| 2-3 | 0.08 | 0.16 | 0.95 | 59.40 | 47.48 | 39.42 |
| 3-1 | 0.06 | 0.09 | 0.72 | 59.87 | 51.27 | 39.26 |
| 3-2 | 0.03 | 0.08 | 0.67 | 57.56 | 51.96 | 41.66 |
| 3-3 | 0.12 | 0.12 | 0.57 | 55.76 | 51.94 | 43.43 |
| 4-1 | 0.02 | 0.12 | 0.69 | 58.95 | 45.91 | 40.22 |
| 4-2 | 0.02 | 0.13 | 0.68 | 58.97 | 46.00 | 40.20 |
| 4-3 | 0.02 | 0.17 | 0.69 | 58.39 | 48.61 | 40.80 |
| 5-1 | 0.03 | 0.15 | 0.85 | 61.19 | 42.50 | 37.78 |
| 5-2 | 0.04 | 0.15 | 0.87 | 61.38 | 44.93 | 37.52 |
| 5-3 | 0.03 | 0.13 | 0.76 | 63.42 | 41.64 | 35.56 |
| 6-1 | 0.07 | 0.20 | 0.55 | 66.69 | 40.74 | 32.51 |
| 6-2 | 0.06 | 0.18 | 0.74 | 66.41 | 38.26 | 32.61 |
| 6-3 | 0.04 | 0.18 | 0.72 | 66.60 | 39.69 | 32.48 |
| 7-1 | 0.06 | 0.21 | 0.61 | 70.54 | 39.64 | 28.56 |
| 7-2 | 0.08 | 0.16 | 0.50 | 67.58 | 42.38 | 31.68 |
| 7-3 | 0.05 | 0.16 | 0.82 | 67.58 | 32.25 | 31.40 |
| 8-1 | 0.29 | 0.27 | 0.68 | 73.51 | 31.63 | 25.30 |
| 8-2 | 0.49 | 0.39 | 0.76 | 74.13 | 31.83 | 24.40 |
| 8-3 | 0.57 | 0.34 | 0.71 | 73.18 | 31.65 | 25.41 |

Particle size analysis of profile 6.

| | Per cent | | | | | |
|---|---|---|---|---|---|---|
| Sample | > 0.25 mm | 0.25-0.10 mm | 0.10-0.05 mm | 0.05-0.002 mm | < 0.005 mm | < 0.002 mm |
| 1-1 | 0.04 | 0.10 | 0.84 | 59.12 | 44.64 | 39.90 |
| 1-2 | 0.05 | 0.05 | 1.06 | 60.62 | 47.77 | 38.58 |
| 1-3 | 0.04 | 0.06 | 0.77 | 58.70 | 46.44 | 40.46 |
| 2-1 | 0.05 | 0.03 | 0.55 | 52.80 | 50.19 | 46.57 |
| 2-2 | 0.03 | 0.05 | 0.58 | 51.46 | 52.75 | 47.88 |
| 2-3 | 0.03 | 0.04 | 0.76 | 52.83 | 54.55 | 46.34 |
| 3-1 | 0.02 | 0.04 | 0.51 | 53.47 | 37.91 | 45.96 |
| 3-2 | 0.02 | 0.04 | 0.46 | 55.81 | 52.69 | 43.67 |
| 3-3 | | 0.03 | 0.59 | 52.54 | 52.76 | 46.84 |
| 4-1 | | 0.06 | 0.53 | 65.26 | 50.47 | 34.14 |
| 4-2 | | 0.05 | 0.51 | 55.35 | 50.14 | 44.09 |
| 4-3 | | 0.03 | 0.43 | 55.23 | 48.57 | 44.31 |
| 5-1 | | 0.04 | 0.55 | 57.70 | 45.54 | 41.71 |
| 5-2 | | 0.04 | 0.43 | 61.16 | 46.50 | 38.37 |
| 5-3 | | 0.03 | 0.51 | 58.66 | 47.52 | 40.80 |
| 6-1 | | 0.06 | 0.50 | 61.50 | 43.48 | 37.94 |
| 6-2 | | 0.05 | 0.53 | 61.54 | 47.22 | 37.78 |
| 6-3 | | 0.05 | 0.54 | 66.98 | 42.38 | 32.43 |
| 7-1 | | 0.02 | 0.65 | 63.85 | 41.61 | 35.48 |
| 7-2 | | 0.01 | 0.49 | 67.59 | 40.85 | 31.91 |
| 7-3 | | 0.01 | 0.65 | 68.08 | 41.39 | 31.26 |

Particle size analysis of profile 7.

| | Per cent | | | | | |
|---|---|---|---|---|---|---|
| Sample | > 0.25 mm | 0.25-0.10 mm | 0.10-0.05 mm | 0.05-0.002 mm | < 0.005 mm | < 0.002 mm |
| 1-1 | 0.05 | 0.10 | 1.57 | 66.27 | 37.52 | 32.01 |
| 1-2 | 0.05 | 0.12 | 1.50 | 65.58 | 39.93 | 32.75 |
| 1-3 | 0.05 | 0.11 | 1.43 | 65.17 | 40.24 | 33.24 |
| 2-1 | 0.04 | 0.11 | 1.56 | 56.79 | 41.94 | 41.50 |
| 2-2 | 0.05 | 0.18 | 1.37 | 59.13 | 43.91 | 39.27 |
| 2-3 | 0.04 | 0.14 | 1.42 | 61.84 | 43.93 | 36.46 |
| 3-1 | 0.04 | 0.10 | 1.11 | 56.61 | 46.92 | 42.14 |
| 3-2 | 0.04 | 0.10 | 1.19 | 53.15 | 48.10 | 45.52 |
| 3-3 | 0.03 | 0.14 | 1.15 | 56.61 | 52.15 | 42.07 |
| 4-1 | 0.05 | 0.20 | 0.85 | 52.80 | 54.71 | 46.10 |
| 4-2 | 0.04 | 0.09 | 0.90 | 56.83 | 53.11 | 42.04 |
| 4-3 | 0.04 | 0.10 | 0.92 | 50.23 | 52.59 | 48.61 |
| 5-1 | | 0.04 | 0.46 | 48.88 | 53.62 | 50.62 |
| 5-2 | | 0.04 | 0.49 | 48.19 | 57.03 | 51.28 |
| 5-3 | | 0.03 | 0.45 | 50.85 | 51.72 | 48.67 |
| 6-1 | | | 0.48 | 57.30 | 49.18 | 42.22 |
| 6-2 | | | 0.48 | 56.23 | 50.57 | 43.29 |
| 6-3 | | | 0.58 | 56.25 | 50.66 | 43.17 |
| 7-1 | | | 0.61 | 59.41 | 43.89 | 39.98 |
| 7-2 | | | 0.52 | 59.38 | 46.63 | 40.10 |
| 7-3 | | | 0.66 | 61.76 | 46.76 | 37.58 |
| 8-1 | | | 0.60 | 60.68 | 44.37 | 38.72 |
| 8-2 | | | 0.48 | 61.89 | 43.68 | 37.63 |
| 8-3 | | | 0.47 | 61.52 | 47.29 | 38.01 |

Particle size analysis of profile 8.

| | Per cent | | | | | |
|---|---|---|---|---|---|---|
| Sample | > 0.25 mm | 0.25-0.10 mm | 0.10-0.05 mm | 0.05-0.002 mm | < 0.005 mm | < 0.002 mm |
| 1-1 | | 0.05 | 0.45 | 67.14 | 40.78 | 32.36 |
| 1-2 | | 0.05 | 0.56 | 67.24 | 38.41 | 32.15 |
| 1-3 | | 0.04 | 0.59 | 64.64 | 39.13 | 34.73 |
| 2-1 | | 0.03 | 0.38 | 58.56 | 46.44 | 41.03 |
| 2-2 | | 0.04 | 0.69 | 55.64 | 49.17 | 43.63 |
| 2-3 | | 0.04 | 0.61 | 57.51 | 45.52 | 41.84 |
| 3-1 | | 0.08 | 0.65 | 54.54 | 52.47 | 44.73 |
| 3-2 | | 0.07 | 0.59 | 53.75 | 52.82 | 45.59 |
| 3-3 | | 0.08 | 0.57 | 54.12 | 54.10 | 45.23 |
| 4-1 | 0.06 | 0.19 | 0.97 | 48.30 | 55.86 | 50.54 |
| 4-2 | 0.05 | 0.13 | 0.81 | 48.56 | 58.34 | 50.50 |
| 4-3 | 0.05 | 0.13 | 0.77 | 50.35 | 59.49 | 48.75 |
| 5-1 | | 0.12 | 0.76 | 52.59 | 55.15 | 46.53 |
| 5-2 | | 0.07 | 0.67 | 53.98 | 54.42 | 45.28 |
| 5-3 | | 0.14 | 0.81 | 51.76 | 56.66 | 47.29 |
| 6-1 | | 0.12 | 1.01 | 53.92 | 54.28 | 44.95 |
| 6-2 | | 0.09 | 0.76 | 54.89 | 52.53 | 44.26 |
| 6-3 | | 0.09 | 0.87 | 54.16 | 53.07 | 44.88 |
| 7-1 | | 0.14 | 0.82 | 60.24 | 45.86 | 38.80 |
| 7-2 | 0.08 | 0.15 | 1.04 | 60.64 | 46.49 | 38.17 |
| 7-3 | 0.07 | 0.17 | 1.23 | 59.72 | 47.00 | 38.88 |
| 8-1 | 0.08 | 0.25 | 1.60 | 51.90 | 45.95 | 36.25 |
| 8-2 | 0.08 | 0.25 | 1.67 | 51.82 | 44.76 | 36.26 |
| 8-3 | 0.07 | 0.31 | 1.55 | 59.66 | 44.21 | 38.58 |

Particle size analysis of profile 9.

| | Per cent | | | | | |
|---|---|---|---|---|---|---|
| Sample | > 0.25 mm | 0.25-0.10 mm | 0.10-0.05 mm | 0.05-0.002 mm | < 0.005 mm | <0.002 mm |
| 1-1 | | 0.14 | 1.45 | 63.29 | 38.86 | 35.12 |
| 1-2 | | 0.13 | 1.41 | 62.11 | 39.53 | 36.35 |
| 1-3 | | 0.14 | 1.56 | 62.57 | 40.58 | 35.73 |
| 2-1 | | 0.06 | 1.26 | 56.82 | 45.31 | 41.86 |
| 2-2 | | 0.09 | 1.38 | 55.13 | 46.41 | 43.40 |
| 2-3 | | 0.04 | 1.23 | 58.21 | 48.08 | 40.52 |
| 3-1 | | 0.07 | 0.94 | 53.54 | 50.86 | 45.45 |
| 3-2 | | 0.06 | 1.10 | 53.76 | 51.57 | 45.18 |
| 3-3 | | 0.06 | 1.06 | 54.49 | 53.10 | 44.39 |
| 4-1 | | 0.13 | 1.02 | 48.91 | 57.25 | 49.94 |
| 4-2 | | 0.14 | 0.76 | 47.64 | 54.47 | 51.46 |
| 4-3 | | 0.13 | 0.93 | 50.74 | 52.94 | 48.20 |
| 5-1 | | 0.04 | 0.36 | 51.26 | 53.48 | 48.34 |
| 5-2 | | 0.04 | 0.48 | 52.00 | 54.45 | 47.48 |
| 5-3 | | 0.04 | 0.69 | 50.88 | 53.32 | 48.39 |
| 6-1 | | 0.01 | 0.45 | 58.78 | 46.77 | 40.76 |
| 6-2 | | 0.01 | 0.50 | 57.73 | 47.88 | 41.79 |
| 6-3 | | 0.01 | 0.49 | 57.93 | 48.93 | 41.57 |
| 7-1 | | 0.03 | 0.51 | 58.54 | 45.18 | 40.92 |
| 7-2 | | 0.02 | 0.36 | 59.89 | 47.34 | 39.73 |
| 7-3 | | 0.01 | 0.35 | 60.99 | 51.81 | 38.65 |
| 8-1 | | 0.01 | 0.42 | 63.91 | 44.05 | 35.66 |
| 8-2 | | 0.01 | 0.35 | 61.12 | 44.66 | 38.52 |
| 8-3 | | 0.01 | 0.35 | 62.02 | 46.21 | 37.62 |

Particle size analysis of profile 10.

| | Per cent | | | | | |
|---|---|---|---|---|---|---|
| Sample | > 0.25 mm | 0.25–0.10 mm | 0.10–0.05 mm | 0.05–0.002 mm | < 0.005 mm | < 0.002 mm |
| 1-1 | | 0.07 | 1.28 | 62.68 | 43.52 | 35.97 |
| 1-2 | | 0.05 | 1.26 | 62.24 | 41.91 | 36.45 |
| 1-3 | | 0.06 | 1.68 | 63.17 | 41.43 | 35.09 |
| 2-1 | | 0.04 | 1.26 | 60.49 | 46.56 | 38.21 |
| 2-2 | | 0.04 | 1.15 | 58.65 | 43.77 | 40.46 |
| 2-3 | | 0.06 | 1.29 | 58.13 | 44.17 | 40.52 |
| 3-1 | | 0.09 | 0.88 | 54.49 | 49.38 | 43.54 |
| 3-2 | | 0.04 | 0.90 | 54.95 | 51.24 | 44.11 |
| 3-3 | | 0.08 | 1.110 | 54.49 | 50.25 | 44.42 |
| 4-1 | | 0.09 | 0.82 | 45.61 | 57.49 | 53.43 |
| 4-2 | | 0.16 | 0.81 | 45.12 | 59.52 | 53.91 |
| 4-3 | | 0.07 | 0.76 | 47.52 | 60.03 | 51.65 |
| 5-1 | | 0.11 | 0.81 | 52.36 | 53.57 | 46.72 |
| 5-2 | | 0.06 | 0.84 | 53.31 | 53.78 | 45.79 |
| 5-3 | | 0.10 | 0.71 | 51.77 | 56.15 | 47.51 |
| 6-1 | | 0.04 | 0.28 | 58.11 | 49.63 | 41.57 |
| 6-2 | | 0.03 | 0.26 | 58.86 | 48.51 | 40.85 |
| 6-3 | | 0.02 | 0.39 | 58.93 | 47.86 | 40.66 |
| 7-1 | | 0.04 | 0.37 | 59.98 | 47.82 | 39.71 |
| 7-2 | | 0.02 | 0.36 | 59.87 | 49.16 | 39.75 |
| 7-3 | | 0.03 | 0.25 | 60.15 | 46.88 | 39.57 |

# A STUDY OF THE RELATION OF CERTAIN LOESSIAL SOILS OF NORTHEASTERN KANSAS TO THE TEXTURE OF THE PARENT MATERIAL

by

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AN ABSTRACT OF A THESIS

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ABSTRACT

A study was conducted on ten soil profiles represented by four soil series on a traverse from the Missouri River Bluff in northwestern Doniphan County to a point in southwestern Brown County near the vicinity of Powhattan. The first sampling site occurred at a point two miles from the Missouri River and subsequent sampling sites occurred at distances of one and one half miles apart.

Particle size analyses were conducted on the ten profiles which were selected on the traverse to determine the textural composition of each horizon. The depth of the loess was determined at alternate sites at the time of sampling and the pH of each horizon was determined in the laboratory.

From this investigation it was concluded that the Missouri River Valley flood plain was the chief source of the loess material which was deposited in the northeastern part of Kansas. This is based on the fact that the deposit decreases with distance from the river and the texture of the C horizon became finer with distance from the river.

The textural variation of the loess material is concluded to be the major factor in determining the nature of the soil developed in it, although depth of loess and relief are acknowledged to have an effect on the final end product of soil development.