A PRELIMINARY STUDY OF THE PHYSICAL PROPERTIES AND REACTION OF SOIL MANTLE MATERIAL IN OKLAHOMA

A PRELIMINARY STUDY OF THE PHYSICAL PROPERTIES AND REACTION OF SOIL MANTLE MATERIAL IN OKLAHOMA

By
GEORGE M. HERRON
Bachelor of Science
Oklahoma Agricultural and Mechanical College
Stillwater, Oklahoma
1949

Submitted to the Faculty of the Graduate School of
the Oklahoma Agricultural and Mechanical College
in Partial Fulfillment of the Requirements
for the Degree of
MASTER OF SCIENCE
1950

APPROVED:

H. F. Murphy
Chairman, Thesis Committee

Lester W. Reed
Member, Thesis Committee

H. F. Murphy
Head of the Department

D. C. McIntosh
Dean of the Graduate School

ACKNOWLEDGEMENT

The author wishes to express his sincere appreciation to Dr. Horace J. Harper, Professor of Soils, Oklahoma A. & M. College, for guidance and encouragement during the progress of this Study. For constructive criticism concerning the preparation of the manuscript, the author is grateful to Dr. H. F. Murphy, Head Department of Agronomy, Oklahoma A. & M. College.

For typing the manuscript the author is indebted to Mrs. Norma L. Prentice.

G. M. H.

TABLE OF CONTENTS

A PRELIMINARY STUDY OF THE PHYSICAL PROPERTIES AND REACTION OF SOIL MANTLE MATERIAL IN OKLAHOMA

INTRODUCTION

The early soil scientists recognized the importance of the parent material in determining the characteristics of the mature soil profile developed under the influence of a given topographic, biologic and climatic condition. The older systems of soil classification were based largely on the type of parent material from which the soil was formed. As the science of Pedology advanced, it was realized that the materials were generally of less importance than the processes in determining the characteristics of the mature soil profile.

The early Russian Pedologists, working almost entirely in an area of continental climate, recognized the constant existance of a climatic-plant relationship, and the coexistence of an almost constant climatic-soil relationship. Thus, they were unable to completely distinguish between the effects produced by the climatic and biologic factors on the mature soil profile. This resulted in the Russian Pedologists accepting the climate as the dominant factor responsible for the modifications occurring in the parent material during the processes of soil profile development (19)*.

---

*Numbers in parentheses refers to literature cited on pages 60, 61 and 62.

In America there are areas where the constant climatic-plant relationship is absent, e.g. Region of Prairie Soils, as well as other areas where the effects of parent material has subdued the effects of climate and vegetation, e.g. Hagerstown series of New Jersey. Recognizing these conditions, the American soil scientists attempt to evaluate each, and the summation of, the various factors of soil genesis in determining the characteristics of a soil profile.

The young soils are often dominated by the properties of the parent material. A large percentage of the total crop production in Oklahoma is from soils formed on parent material that is geologically young and in many instances the soil profiles are immature. This study was planned in order to obtain some preliminary information concerning the properties of some of the soil mantle material in this state. The pedologic and agronomic phases of the problem must await future investigations. Most of the present study has been confined to soil mantle material with a fluviatile origin.

REVIEW OF LITERATURE

Physical Geography of the Area

A study of the paleogeography of Oklahoma reveals that almost every geological system from Pre-Cambrian to Recent is represented in the state. Practically all of the surface of eastern and central Oklahoma is of Paleozoic age, principally Mississippian, Pennsylvanian, and Permian. Western Oklahoma is composed chiefly of Cretaceous, Tertiary and Quaternary deposits (5). In the eastern part of the state the **rocks** are tilted to the west away from the Ozark, Ouachita and **Arbuckle** Mountain Ranges. This dip becomes less toward the west and about the longitude of Alva and Arapaho it becomes level. Beyond this longitude the dip of the strata is slightly to the east (29). These conditions have influenced the movement of soil material indirectly by its influence on the drainage pattern of the state. Oakes (23) postulated a Carboniferous stream flowing from southeastern Oklahoma into the central portion of the state, which is the opposite direction of the present drainage system.

Oklahoma is located largely in the Southern Great Plains Region. The drainage is principally from the northwest to the southeast, with a difference in elevation of approximately 4000 feet between the high and low portions of the state. However the gradient is not uniform throughout this distance. A large portion of the difference in elevation occurs west of the central part of the state. This has resulted in coarse sediment being deposited in western Oklahoma stream valleys and fine sediments in eastern Oklahoma valleys.

Almost all of the drainage water from Oklahoma is carried by two rivers and their tributaries; namely, the Red River System draining the southern portion, and the Arkansas River System draining the northern portion (29). The Arkansas River and its tributaries drain three-fourths of the surface area of Oklahoma. Three important tributaries; namely, Salt Fork, Canadian, and Cimarron, parallel the Arkansas River for a considerable distance and join it in the eastern part of the state. These rivers are typical streams of the Great Plains. All of them start in the Rocky Mountains, have few tributaries and they have narrow flood plains in proportion to their length. Their channels are filled with sand and sand dunes are prevalent along the north side of each of them in western part of Oklahoma (29).

The system of streams as described has transported a considerable amount of sediments into Oklahoma from the dry areas in the west. In some places the stream channels are filled with as much as 100 feet of alluvium of Recent age and the deposition is still in progress (12). Not all of the transported sediments are confined to the stream channels. Considerable areas of high terrace deposits are found in central Oklahoma, and in some instances these high terraces are not associated with the present stream valleys.

A criterion whereby the age of the terrace deposits and the eolian deposits could be accurately ascertained would be of immense value in correlation work. Unfortunately the terrace and eolian deposits do not yield many fossils, especially in the high rainfall areas. Some fifty years ago, it was postulated that the terraces along the Canadian River in McClain County were of Pleistocene age (12). In 1936, Williams (35) reported the findings of elephant remains in the surface of terrace deposits two and one-half miles south of the Norman Bridge, which strongly suggested that the terraces were no older than Pleistocene. The calcareous nodules found in the surface were believed to be of Recent age.

"Fossil soils" have been widely used as a stratigraphic datum in loess deposits of Kansas (10). Harper (15) studied the "buried soils" in central Oklahoma stream valleys and found the "fossil" profiles to be mature soils while the alluvium overlying these soils had immature profiles developed on them. He established the relative age of the soils by comparing them with the profiles developed on Pleistocene glacial material. The Wisconsin drift has immature soil profile while the Kansan drift has mature profile developed. Assuming that the forces of weathering had not been drastically different in the two areas, he postulated the upper layer of alluvium was younger than Kansan glaciation. Recent observation on the rate of weathering would indicate that he did not underestimate the age of the upper alluvium (1). Harper (15) also observed only one buried soil in the valleys of central Oklahoma. He interpreted this as an indication that only one period of drought had been severe enough to reduce the vegetation on the upland to the point where severe erosion could occur.

In some areas the sand dunes along the north bank of the Cimarron River extend for a distance of fifteen miles from the stream (29). Much of this material has been assumed to be of eolian origin. Harper and Hollopeter (13) studied the sandy lands along the Cimarron and Salt Fork Rivers and could find no evidence of a "buried soil" at the contact between the sandy land and the adjacent prairie soils. They concluded that wind was not the agent responsible for the deposition of this material. The principal effect of the wind had been local translocation of soil material and modification of the topography.

Harper (14) studied the zones of clay in the sandy lands along the Cimarron River and concluded they were the result of water deposition. Gould (12) considered the present stream channels might have contributed a small amount of sand, however, he postulated that in general the sands along the north side of the streams in western Oklahoma had their origin in the late Tertiary deposits that covered much of this area, and that the present sandy areas represent that part which has not eroded away.

Loess Origin and Distribution

The term loess was first used to describe the silty deposits in the Valley of the Rhine (6). Since this time large areas of fine-grained sediments in North and South America, Europe, Russia and China have been classified as loess. Regardless of where the loessial deposits may occur they show many similarities wherever found. Practically all of the deposits are of a very uniform silt loam texture, are calcareous in most instances, show no stratification, and the unweathered portion is usually a yellowish-brown or buff color. These deposits of loess have a high porosity, due to the angular loosely arranged particles. Very often they tend to split in vertical planes, producing a perpendicular cliff.

Since the time when the geologists recognized the contact between the loess and the underlying sediments as an unconformity there have been numerable theories advocated for the origin of this mantle material. Smith (28) states that in 1934, Scheidig listed some twenty hypotheses that had been presented to explain the presence and distribution of the loesses. The most popular hypotheses have been those that in some way or other would have the loess deposited by water and those that would attribute its present location to deposition by the wind. Each of the theories have some supporting evidence. A brief review of the voluminous literature concerning the origin and distribution of the loesses will be presented.

Aqueous Theory. It is reported that Cornelius writing in the first volume, first series, of the American Journal of Science and Arts in 1818 regarded the "clays" (now known as loess) of Natchez, Mississippi, as alluvial. Until recently this was the accepted view; swollen streams being regarded as the agent of transportation and deposition. The association of the Mississippi River system, and the decrease in depth and increase in fineness of particles away from the stream valley, resulted in an almost unanimous acceptance of the aqueous theory, in one form or another, for over fifty years (32).

In 1870, when the aqueous theory was challenged by the eolian theory, Todd formulated a theory which proposed a vast Lake Missouri in which the loess of Iowa and Missouri was deposited. Todd proposed varying levels of the lake as being responsible for the loess occuring at different elevations. Many of the leading scientist of the day had strongly objected to the eolian theory and they quickly approved of Todd's proposal. The greatest evidence in support of this hypothesis was the presence of fossil fauna which were identified as aquatic in habit and habitat. Later Shimek stated these fossil fauna were terrestrial rather than aquatic and they were far from being abundant (32).

The early theories regarding the loess of Europe ascribed it to flood waters when a sudden change of drainage or of sea level occured (6). In this country the aqueous theory was, and is, favored because of unmistakable relation of the loess to the stream valleys and rivers. The loessial deposits are parellel to the streams, and are deeper and have a coarser texture near the streams, than at some distance away. The natural levee, or bluff, near the stream may be quite coarse and it is a well established fact that the floods of the present day will deposit coarse material near the stream and the finer material at some distance away. Shimek, however, believes that wind deposited material would be of the same nature because the greater growth of vegetation near the channel would tend to entangle and retain it (6).

Free (6) states that more certain indication of aqueous deposition is the occurence of loess of well developed strata and the intergradation of finer and coarser material. He was referring to Hilgard's report on the "Geology and Agriculture of Mississippi".

Eolian Theory. Richthofen, in 1870, suggested the eolian origin for loess in China (19). Richthofen based his eolian hypothesis on; (a) varying altitudes of loessial deposits, (b) absence of stratification, (c) land fossil fauna, (d) presence of plant root marks, and (e) the presence of large desert areas to the west of China which would be the source of supply for the loessial material. According to him desert mineral dust was carried eastward by the wind to a more humid climate where it settled to the ground and was entrapped by the beating rain and entanglement with the vegetation. He considered the dust to partially cover the grass, resulting in the aerial parts being greatly extended and the parts buried to undergo oxidation. This gave rise to vertical channels, on the walls of which lime has precipitated from the percolating waters. These limed filled cavities have been considered to be responsible for the loess standing in perpendicular cliffs with the appearance of vertical jointing planes. However, Willis (6) has suggested that vertical jointing planes are due to the horizontal spaces being very compact while the vertical spaces between the particles have never been compacted.

According to Free (6), the greatest evidence of eolian origin is the terrastrial fossil fauna. He states that it would not be so unusual to find land fauna in alluvial or marine deposits, but the absence of aqueous forms would be very unusual. Free concludes, "It is not the occurrence of terrestrial forms but the non-occurrence of any other form that seem to favor so strongly the deposition of loess over a dry land surface". The absence of stratification, no traces of water action, and the remarkable uniformity in particle size lends strong appeal to the eolian theory. The deposition in sluggish streams or lakes could account for the lack of stratification, but there is an absence of fresh water fauna to substantiate this. Free believes that intermittent flood plain deposition is inconsistent with absences of traces of water action.

Other Theories. Russell (26) studied the loess of the lower Mississippi Valley and hypothesized a new origin for this type of material. He concluded these silty materials were deposited during Pleistocene time as backswamp deposits or alluvium, and later acquired their loessial properties by a "loessification process" which was essentially weathering and colluvial movement. This hypothesis has not had wide acceptance. Recent observation of these loess deposits by Wascher, Hambert and Cady (34) indicate they are not different from those deposits found further north.

Joffe (19) reports that Berg considers all loess to have a common origin in that it is formed in situ from calcareous rock which were deposited during Pleistocene time and has weathered under the influence of a dry climate. At the symposium or loess held in Nebraska in 1945, Obruchev (24) presented a summary of the Russian's ideas concerning loess. He stated that they recognized a typical or primary loess which is an eolian formation, and a secondary loess which is a material very similar to that of definite eolian origin.

In 1897, Chamberlain (32) presented his fluvio-eolian hypothesis concerning the origin of loess, which has since gained the widest acceptance in America. According to Chamberlain silty glacial flood waters, the fluvio agent, overflowed their channels depositing vast mud flats. Upon drying and before stabilization by the vegetation these mud flats served as a source of supply of material for distribution by the prevailing westerly and northwesterly winds, the eolian agent. Chamberlain did not believe the narrow glacial streams were adequate to explain the wide distribution of the loesses. He also believed the presence of terrestrial fauna, loess at different elevations, and well preserved coniferous vegetation argued against a purely fluvio hypothesis. He postulated that there should be some relationship between the breadth of fluvio deposits and the extent and massiveness of the adjacent upland deposits. When Smith (28) investigated the Illinois loess more than forty years later he found there was a relationship between the width of the valley and the adjacent upland deposit. Smith also pointed out that Chamberlain's hypothesis was substantiated by the fact that the major deposits of loess are adjacent to the streams which are believed to have carried the glacial melt waters.

Some of the more recent investigations have offered support to Chamberlain's hypothesis. Tuck (31) described a modern example of loess deposition in the Matanuska Valley of Alaska. A mountain glacier is some twenty or more miles up the valley, and the rock flour is deposited down the valley in the stream channel and flood plains. He describes a pall of dust over the area during dry weather. Section corners staked in 1913 were covered several inches by 1935. The loess is thicker and of coarser texture near the stream than at some distance away.

In Greenland, Hobbs (16) described the deposition of loess from glacial outwash plains. The outwash plains dry up during the winter, which is the period of severe wind storms off of the ice sheet. The dust greatly reduces the visibility at Mt. Evans Observatory, twenty-five miles from the ice front. Hobbs (17, 18) believes the glacial anticyclones are the dominant agent in loess deposition.

Beavers and Albrecht (2) collected recently deposited alluvia in the Missouri-Mississippi River system between Rockport, Missouri, and Vicksburg, Mississippi. They found the sediments to be very uniform in chemical composition, indicating that running water could be relied on to produce homogeneous deposits. Vanderford and Albrecht (33) studied the soils along the river bluff from Iowa to Vicksburg, Mississippi. The C-horizon of the loessial soils were very uniform but the soils developed from this material was very different. They attributed the difference to climate.

That the wind is an effective agent in the fractionation of soil material was shown by Swineford and Frye (30). Mechanical analysis of dust collected in a third floor window during a dust storm at Meade, Kansas, showed the same particle size distribution as Sanborn loess. Dunesands are of uniform particle size because they are drifted and not lifted by the wind (6). Chepil (4) found that the drifted material along the border of fields subject to wind erosion to be of uniform particle size. Free (6) states that the material from "dust-falls" and volcanic ash are of uniform particle size. The uniformity of particle size has been advocated as a means of separating material of eolain origin from material of some other origin.

The sources of material for loessial deposits have been debated much less than the method of deposition. Long-continued secular decay of rocks in desert areas or the grinding of moving ice is usually considered as an adequate explanation. In China the desert areas are considered as the major source of the material. In America and Europe most of the loessial material seems to have had its origin during pleistocene glaciation (6). However, Hobbs (18) and Frye (7) believe that some of the loess of western Kansas had its origin in the desert to the southwest.

Distribution of Loess. Loess is most widespread in the

States of Illinois, Iowa, Nebraska, Kansas, and Missouri. Smaller deposits are found in Ohio, Indiana, Kentucky, Tennessee, Arkansas, Louisiana, and Mississippi. These latter deposits are restricted largely to areas near the streams. Some areas of Colorado, North and South Dakota, Montana and Wyoming are mapped as loess. In the Pacific Northwest a large area of the Palouse Region is mantled with loess. All of these areas were covered by glacial ice during Pleistocene time, or the streams carrying the water of the melting ice flowed through them.

Three distinct loess formations are recognized in the central States, the Loveland or Sangamon, the Peorian or Iowan, and the Bignell. The Loveland, or Sangamon as it is called in Illinois, was named at Loveland, Iowa (8). It is a reddish or pinkish colored silt usually found on Illinoian or Kansan till in the areas covered by glaciation (22). In Iowa, and especially in Kansas and Nebraska, the silt formation equivalent to the Sangamon of Illinois is called the Loveland silt member of the Sanborn Formation (7, 8, 9, 10, 11). The Loveland silt usually has a well developed soil profile.

The term Peorian was first used by Frank Laverett in 1898 to designate a weathering interval between Iowan loess and Tazewell glacial drift as he observed it near Peoria, Illinois (32). Later Shimek (27) proposed the interpretation that Iowan loess was not contemporaneous with Iowan drift sheet but was deposited continuously throughout the Wisconsin glacial substages. This interpretation was generally accepted and the Peorian loess now refers to all of the loess deposited during Wisconsin time. The Peorian loess can be traced across Illinois and Iowa into the states of Nebraska, Kansas and Missouri. In Nebraska and Kansas it is known as the Peoria silt member of the Sanborn formation (8, 9, 10, 11). The Peoria is usually found overlying Wisconsin drift or Loveland loess. It is usually more calcareous than Loveland loess and has a buff or yellowish color. The soil profile is well developed in most areas.

The least member of the loess family occurs in scattered areas overlying the Peorian loess. Along the Platte River of western Nebraska it was called the Bignell silt member of the Sanborn formation (8, 10). It has a young soil profile and probably represents reworked deposits of Loveland and Peoria loess (10).

SOURCE AND COLOR DESCRIPTION OF SOILS STUDIED

Three local areas in Oklahoma were selected for field and laboratory study. The Tulsa County and Kay County Areas are located adjacent to the Arkansas River in North Central Oklahoma. The McClain County area is located in Central Oklahoma on the south side of the Canadian River. All samples in these areas were collected by Dr. Horace J. Harper, Professor of Soils, and the author.

Soil samples from Northwestern and Northeastern Oklahoma were collected in the spring of 1950 by a member of the Advanced Soils Morphology Class under the supervision of Dr. Harper.

For the loess samples from North Central United States and the information concerning the location of these samples, the author is indebted to Professor J. E. Gieseking, University of Illinois; Professor H. H. Krusekoph, University of Missouri; Professor J. E. McClelland, Iowa State College; and Mr. B. H. Williams, U. S. D. A. Lincoln, Nebraska.

For the sample of loess from Vicksburg, Mississippi, the author is indebted to Dr. M. J. Plice, Oklahoma Agriculture and Mechanical College, Stillwater, Oklahoma.

The official sample number, depth, location as near as possible, and Munsell color description are given in Tables 1 - 9, inclusive. The remark column is utilized to designate the soil series, topographic position or profile characteristics. In the column, giving the sample number, only the last two figures of the sample number are given for the lower horizons of the same profile. Samples within a profile are numbered consecutively from the surface downward. The Munsell color designations were determined by the author using the official color standards recommended by the Soil Science Society of America.

Table 1. 'Location and color of soil smaples collected from the Kay County area.

Sample Number	Depth inches	Location Collected	Munsell Color Designation Value	Color	Remark
11970	0-6	Sec.3,T.26N,R4E.	3/3 5YR	dr. reddish brown	Mapped as Derby silt loam. About 200 ft. above the stream bed.
71	6-20		5/4 5YR	reddish brown	
72	20-42		5/6 7.5YR	strong brown	
73	42-72		5/6 7.5YR	strong brown	
74	72-96		5/6 10YR	yellowish brown	
11975	0-10	Sec.30,27N,R.5E.	3/4 5YR	dr. reddish brown	Mapped as Derby silt loam. 170 ft. above the river.
76	60-72		4/4 5YR	reddish brown	
77	72-108		5/6 5YR	yellowish red	
78	108-120		5/8 5YR	yellowish red	
11979	82-84	Sec.9,T.27N,R.4E.	5/4 7.5YR	brown	150 ft. above stream.
11980	20-24	½mi.S.Fairfax, Okla. Highway 18	4/4 5YR	reddish brown	Arkansas River alluvium. Some stratification.
81	120-132		5/6 5YR	yellowish red	
11982	50-54	Sec.36,T.27N,R4E. Beaver Creek, E. of Washunga.	5/6 5YR	yellowish red	Mapped as Derby fine silt loam.
83	92-96		4/6 5YR	yellowish red	
11984	0-6	Sec.20,T.27N.,R4E.	6/2 7.5YR	pinkish gray	Mapped as Derby fine sandy loam same elevation as the Derby silt loam.
85	6-24		7/3 10YR	very pale brown	
86	24-36		6/6 10YR	brownish yellow	
87	36-48		5/4 5YR	reddish brown	
11988	3-6	Sec.29,T.28N.,R4E.	3/1 5YR	very dark gray	Summit silty clay loam.

Table 2. Location and color of soil samples collected from the Tulsa County area.

Sample Number	Depth inches	Location Collected	Munsell Color Designation		Remark
			Value	Color	
11996	360*	Sec.8,T.19N.,R10E.	5/6 5YR	yellowish red	Dougherty soil material. Position of slope alluvium.
97	216*		5/6 5YR	yellowish red	
98	96*		5/6 5YR	yellowish red	
99	0*		5/6 5YR	yellowish red	
12000	6-12	Sec.3,T.19N.,R12E.	6/4 7.5YR	light brown	Definite stratification.
01	118-122		6/3 10YR	pale brown	
02	236-240		5/8 5YR	yellowish red	
12003	0-12	Sec.36,T.18N.,R13E. N. of Bixby, Okla.	3/4 5YR	dr. reddish brown	Teller fine sandy loam. High alluvium.
04	12-30		4/6 5YR	yellowish red	
05	30-72		5/6 5YR	yellowish red	
06	72-102		5/6 5YR	yellowish red	
12007	66-90	Sec.30,T.19N.,R13E.	5/4 5YR	reddish brown	Lower horizons of the Lonoke very fine sandy loam.
08	90-120		6/4 5YR	lt. reddish brown	
09	120-144		6/4 7.5YR	lt. brown	
12010	84-132	Sec.29,T.19N.,R13E.	5/8 10YR	red	Stidham C horizon.
12011	12-24	Sec.28,T.19N.,R13E.	5/2 2.5YR	gray brown	Bates very fine sandy loam.
12	36-48		6/6 10YR	brownish yellow	
12013	0-18	Sec.13,T.18N.,R13E.	3/1 10YR	very dark gray	Mapped as deep phase Bates very fine sandy loam.
14	18-24		6/1 10YR	gray	
15	24-48		6/6 10YR	brownish yellow	

---

*Indicate the difference in elevation between the lower and upper part of a steep slope.

Table 3. Location and color of soils collected from the McClain County area.

Sample Number	Depth inches	Location Collected	Munsell Color Designation Value	Color	Remark
12016	0-6	Sec.14,T.8N.,R.3W. Road cut on Highway 74 S. of Norman bridge.	3/4 5YR	reddish brown	This would probably be mapped as Minco silt loam. The upper half seems quite different from the lower part.
17	58-62		6/4 7.5YR	light brown	
18	178-182		6/4 7.5YR	light brown	
19	262-266		4/4 5YR	reddish brown	
20	442-446		5/8 2.5YR	red	
21	500-504		5/8 2.5YR	red	
12022	84-102	Sec.23,T.8N.,R.3W. West of Goldsby School.	5/6 5YR	yellowish red	Water at 16 ft. Fe and Mn concretions at 12 ft.
23	102-114		4/6 2.5YR	red	
24	114-132		4/8 2.5YR	red	
25	132-168		4/8 2.5YR	red	
26	168-192		5/6 2.5YR	red	
12027	0-6	Sec.23,T.8N.,R.3W.	3/2 10YR	v. dr. gray brown	Probably alluvium.
28	58-62		5/6 5YR	yellowish red	
12029	0-12	Sec.22,T.8N.,R.3W. West of Goldsby School.	3/4 5YR	dr. reddish brown	Grant silt loam. Formed on sandstone.
30	54-78		4/8 10R	red	
31	78-96		4/6 10R	red	
32	96-102		4/8 10R	red	
12033	0-14	Sec.8,T.7N.,R.2W.	3/2 7.5YR	dark brown	Probably would be mapped as Minco silt loam. Calcareous at 72 in., about 80 ft. above river.
34	14-30		4/4 7.5YR	brown	
35	30-48		5/4 7.5YR	brown	
36	48-72		5/4 7.5YR	brown	
37	72-96		5/4 10YR	yellowish brown	
38	96-126		5/6 7.5YR	strong brown	
39	126-144		5/6 7.5YR	strong brown	

Table 4. Location and color of soil samples collected from Northwestern Oklahoma.

Sample Number	Depth inches	Location Collected	Munsell Color Designation Value	Color	Remark
12045	6-18	Sec.6,T.19N.,R.16W.	5/4 7.5YR	brown	St. Paul silt loam.
46	18-36	Dewey County, NW	4/3 10YR	dark brown	Located between the
47	36-48	of Seiling, Okla.	4/4 5YR	reddish brown	Canadian and the
48	92-96		5/8 5YR	yellowish red	North Canadian
49	118-122		5/8 5YR	yellowish red	Rivers.
12050	6-24	Sec.30,T.19N,R16W.	5/4 7.5YR	brown	St. Paul silt loam.
51	30-36	Dewey County N.	4/4 7.5YR	dark brown	North of the Canadian
52	48-60	Taloga, Okla.	4/4 5YR	reddish brown	River.
53	300-304		5/6 5YR	yellowish red	
12054	0-36	South of Freedom,	4/4 5YR	reddish brown	Pratt loamy sand
55	36-60	Okla. Woods County.	5/8 2.5YR	red	Quinlan parent material.
12056	0-4	Highway 283, Harper County.	6/4 10YR	lt. yellowish br.	Pratt sand, dune phase.

Table 5. Location and color of soils collected in Northeastern and Central Oklahoma.

Sample Number	Depth inches	Location Collected	Munsell Color Designation Value	Color	Remark
11990	10-14	Sec.1,T.19N.,R9E. Creek County	6/3 5YR	lt. reddish brown	Dougherty silt loam. Some indication of stratification.
91	20-24		4/4 5YR	reddish brown	
92	30-36		5/6 5YR	yellowish red	
93	36-78		5/6 5YR	yellowish red	
94	78-96		5/6 5YR	yellowish red	
95	120-144		5/6 5YR	yellowish red	
12040	54-58	Sec.21,T.13N.,R2W.	4/8 10R	red	Oklahoma County.
12041	0-16	Toby, Okla. Delaware County	7/2 5Y	light gray	Very deep A horizon.
12042	118-122	Zinc pit. Commerce, Okla. Ottawa County	8/4 5Y	pale yellow	
12043	0-12	Commerce, Okla. Ottawa, County	6/2 2.5Y	lt. brownish gray	Parsons silt loam.
12044		Cleveland, Okla. Pawnee County	8/1 5YR	white	Volcanic ash
12092	300-304	Vicksburg, Miss.	7/4 5Y	pale yellow	Loess

Table 6. Location and color of loess soil samples derived from Missouri.*

Sample Number	Depth	Location collected	Munsell Color Designation Value	Color	Remark
12057	Surface	Sec.7,T.50,R.26. 4mi.S.E. Lexington 4mi. from Mo.River.	4/1 10YR	dark gray	Marshall silt loam.
12058	Surface	About 8mi.S.W. of Columbia and 2mi. from Mo.River.	6/3 10YR	pale brown	Menfro silt loam.
12059	Surface	About 2mi.S. of Columbia and 6mi. from Mo.River.	4/1 10YR	dark gray	Seymour silt loam.

Table 7. Location and color of loess derived soil samples from Iowa.*

Sample Number	Depth	Location collected	Munsell Color Designation Value	Color	Remark
12060	Surface	3mi.SE of the edge Mo.River bluff SE Turin, Iowa, Monona County.	4/2 10YR	dark gray brown	Monona silt loam.
61	8 ft.		6/4 10YR	lt. yellowish brown	
12062	Surface	1mi. E. of Ute, Iowa. Monona County	4/2 10YR	dark gray brown	Monona silt loam.
63	12 ft.		6/4 2.5Y	lt. yellowish brown	

---

*Samples obtained through the courtesy of Professor H. H. Krusekopf, Columbia, Missouri.

*Samples obtained through the courtesy of Professor J. E. McClelland, Ames, Iowa

Table 8. Location and color of loess derived soil samples from Nebraska and Kansas.*

Sample Number	Depth inches	Location Collected	Munsell Color Designation Value	Color	Remark
12070	0-11	SE¼SW¼Sec.12,T.9N, R6E. About 1mi. S. of city limits of Lincoln, Nebraska.	2/2 5Y	black	Originally called Sharpsburg silty clay loam but has recently been correlated with the Crete series.
71	11-18		4/1 5Y	dark gray	
72	18-40		6/3 5Y	pale olive	
73	40-70		7/3 5Y	pale yellow	
74	72-96		8/4 5Y	pale yellow	
75	108-126		8/4 5Y	pale yellow	
76	126-144		8/4 5Y	pale yellow	
12077	0-6	NW¼NE¼Sec.22,T.18N, R18W. 8mi.S.of Sargent Nebraska.	5/1 5Y	gray	Holdrege silt loam. This is a medial Chernozem soil developed on loess.
78	6-20		5/1 5Y	gray	
79	20-34		6/1 5Y	light gray	
80	34-48		7/1 5Y	light gray	
81	48-54		8/3 5Y	pale yellow	
82	54-70		8/3 5Y	pale yellow	
12083	0-4	SW¼SE¼Sec.32,T.3S. R24W. 8mi. W. of Norton, Kansas.	5/1 5Y	gray	Holdrege silt loam. This is a medial Chernozem soil developed on loess.
84	4-10		4/1 5Y	dark gray	
85	10-13		4/1 5Y	dark gray	
86	13-16		5/1 5Y	gray	
87	16-24		6/2 5Y	light olive gray	
88	24-28		6/3 5Y	pale olive	
89	28-42		7/3 5Y	pale yellow	
90	42-84		7/3 5Y	pale yellow	
91	84-120		8/4 5Y	pale yellow	

---

*Samples obtained through the courtesy of Mr. B. H. Williams, USDA, Lincoln, Nebraska.

Table 9. Location and color of loess derived soil samples from Illinois.*

Sample Number	Depth inches	Location Collected	Munsell Color Designation		Remark
			Value	Color	
12064	0-6	SW¼SW¼SW¼,Sec.2, T.18N,R7W.	3/1 10YR	very dark gray	19.5 miles from Illinois River.
65	52-58		7/6 2.5YR	yellow	
12066	0-6	SW¼SE¼SE¼,Sec.30, T.15N,R3W.	3/1 10YR	very dark gray	50.5 miles from Illinois River.
67	52-58		7/4 2.5YR	pale yellow	
12068	0-6	NW¼NE¼SE¼,Sec.32, T13N,R1W.	4/1 10YR	dark gray	68.5 miles from Illinois River.
69	52-58		7/6 2.5YR	yellow	

---

*Samples obtained through the courtesy of Professor J. E. Gieseking, Urbana, Illinois.

ANALYTICAL PROCEDURES

The clay content of all samples from Oklahoma were determined by the procedure recommended by Bouyoucos (3). It was found unnecessary to oxidize the organic matter since most of the samples came from the lower horizons. Sodium hydroxide and sodium oxalate were used as dispersing reagent. The total sand content was determined by washing the contents of the sedimentation cylinders through a 270 mesh sieve with square openings of 53 microns. The total sand was dried and weighed and the individual sand separates were determined by dry sieving. Very fine sand is considered that portion retained on the 270 mesh sieve but which passed through the 140 mesh sieve which has openings of 105 microns. The fine sand was considered as the material retained on the 140 mesh sieve but which passed through the 60 mesh sieve with openings of 250 microns. Material retained on the 60 mesh sieve is considered as medium sand although some samples contained coarse sand and concretions which were retained on this sieve. Duplicate determination were made of all samples.

Since most of the mechanical analyses reported on loessial soils have been by the Pipette Method, it was believed that analyses by this procedure would be more valuable for the soils developed on loess from North Central United States. The procedure recommended by Olmstead, Alexander and Middleton (25) was adapted with such modification as were necessary to fit the equipment available. Since this method is not in regular use in the Oklahoma laboratory it will be described.

Approximately 15 grams of soil was placed in a 500 ml. beaker and sufficient hydrogen peroxide added to oxidize the organic matter. Usually about 40 ml. of a 10% solution was sufficient, however, some samples required a second or a third treatement. Repeated additions of small amounts gave more complete oxidation and the sample was easier to handle than when a large amount was added at one time. The sample was stirred throughly to bring the soil in contact with the solution. Samples containing abundant manganese concretions were treated with a few milliliters of glacial acetic acid (25). After the reaction between the hydrogen peroxide and organic matter had quited down about 300 ml. of distilled water was added and the beaker was placed on the steam plate for several hours or overnight.

Calcareous samples were treated with about 10 ml. of one normal hydrochloric acid, or until the cessation of the rapid evolution of carbon dioxide indicated the decomposition of the secondary carbonates were complete. The soil suspension was then filtered through a heavy filter paper in a Buchner funnel connected with a suction pump. The sample was washed several times to remove the soluble chlorides and organic compounds. The sample was oven dried before being crushed and mixed throughly.

A ten gram sample of this oven dry, mineral fraction of the soil was used for analysis. The sample was dispersed by the regular laboratory procedure and washed into a cylinder about ten inches high and three and one-half inches in diameter. The volume of the soil suspension was made up to one liter. These short cylinders were adapted because they offered a better opportunity of controlling the temperture. The wide diameter of these cylinders seemed to be an advantage over the tall form sedimentation cylinders since the sand was not sieved out prior to the pipette sampling.

A special iron rod with a disc fastened to the lower end was used to thoroughly stir the soil suspension. At a time interval when all particles with an effective diameter greater than forty microns had settled below a depth of eight centimeters, the pipette was inserted to a depth of eight centimeters, and a twenty-five milliter aliquot was withdrawn. The calculation of the time interval was based on Stoke's Law. The twenty micron and the two micron aliquot was taken in the same manner.

The aliquots were drained into clean and previously weighed beakers. The pipette was filled with distilled water and this was allowed to drain into the beaker, thus washing the pipette. Aliquots were evaporated to dryness on the steam plate and the weight was determined to one-tenth milligram. The sand content was determined by washing the contents of the cylinder through a 270 mesh sieve and weighing the material retained on the sieve.

A correction was made for the weight of the dispersing agents. The coarse silt fraction was determined by difference, i.e., the difference between the sand as determined by sieving and the total material smaller than forty microns in diameter. Duplicate determinations were made on all samples.

The volume weight was obtained by collecting a sample of soil of definite volume with a core sampler designed so the natural structure would not be disturbed. The volume weight is based on the oven dry weight of core of soil.

The reaction of the soils were determined with a Leeds and Northrup pH meter using five grams of soil and ten milliliters of water.

RESULTS OF ANALYSES

The results of the analyses are recorded in Tables 10 - 17, inclusive.

Table 10. Mechanical composition and reaction of soil samples from the Kay County area.

Sample Number	Depth inches	% Sand larger than 250 microns	% Sand 250-105 microns	% Sand 105-53 microns	% Silt 53-2 microns	% Clay less than 2 microns	pH Value
11970	0-6	0.6	2.4	8.0	65.3	23.7	6.0
71	6-20	0.4	1.8	7.8	60.3	29.7	6.2
72	20-42	0.4	2.0	7.8	63.1	26.7	6.6
73	42-72	0.4	2.6	9.4	61.9	25.7	6.8
74	72-96	0.4	2.6	11.2	61.7	24.1	7.2
11975	0-10	0.8*	4.0	9.4	62.2	23.6	6.6
76	60-72	0.6*	1.4	4.8	56.6	36.6	6.6
77	72-108	0.6*	1.2	4.0	55.1	39.1	6.9
78	108-120	0.2*	1.0	4.8	53.7	40.3	6.9
11979	82-84	1.2	1.8	4.8	59.4	32.8	6.6
11980	20-24	0.2	1.0	6.6	58.9	33.3	6.7
81	120-132	0.1	0.6	5.1	66.4	27.8	7.2
11982	50-54	0.6	3.4	12.0	62.7	21.3	6.8
83	92-96	1.0	5.0	11.4	61.3	21.3	7.0
11984	0-6	48.4	22.6	2.6	19.1	7.3	6.9
85	6-24	58.6	18.8	2.6	15.2	4.8	6.7
86	24-36	35.4	15.2	2.6	21.3	25.5	6.0
87	36-48	47.4	20.0	2.8	14.3	15.5	5.0
11988	3-6	0.0	0.0	4.1	57.6	38.3	6.1

---

*Concretions.

Table 11. Mechanical composition and reaction of soil samples collected from the Tulsa County area.

Sample Number	Depth inches	% Sand Larger than 250 microns	250-105 microns	105-53 microns	% Silt 53-2 microns	% Clay less than 2 microns	pH Value
11996	360*	4.8	20.4	9.7	46.1	19.0	7.2
97	216*	2.0	5.0	8.1	58.4	26.5	6.9
98	96*	2.4	8.6	12.5	60.5	16.0	7.4
99	0*	1.0	3.8	11.3	66.9	17.0	7.3
12000	6-12	27.1	12.9	7.5	46.6	5.9	7.0
01	118-122	41.2	15.8	3.3	30.8	8.9	6.9
02	236-240	9.6	25.6	11.6	43.1	10.1	7.6
12003	0-12	7.4	22.6	10.0	46.0	14.0	6.5
04	12-30	6.3	20.8	10.3	38.8	23.8	6.7
05	30-72	8.5	26.0	10.3	31.4	23.8	6.5
06	72-102	7.5	27.7	11.8	28.7	24.3	6.3
12007	66-90	0.0	3.0	13.1	59.6	24.3	6.9
08	90-120	0.4	3.9	17.5	59.5	18.7	7.2
09	120-144	4.9	10.8	7.6	50.0	26.7	7.3
12010	84-132	32.1	43.9	3.4	6.0	14.6	6.3
12011	12-24	1.0**	7.7	11.1	62.5	17.7	6.1
12	36-48	0.7**	4.2	7.6	48.0	39.5	8.3
12013	0-18	1.8**	2.2	6.4	70.7	18.9	6.0
14	18-24	1.7**	2.2	6.1	69.3	20.7	5.8
15	24-48	0.6**	2.2	4.8	49.6	43.5	6.8

---

*<u>Ibid</u>. Table 2.

**Fe and Mn concretions.

Table 12. Mechanical composition and reaction of soil samples collected from the McClain County area.

Sample Number	Depth inches	% Sand larger than 250 microns	% Sand 250-105 microns	% Sand 105-53 microns	% Silt 53-2 microns	%Clay less than 2 microns	pH Value
12016	0-6	1.0	4.4	18.3	64.0	12.3	7.6
17	58-62	0.4	2.0	9.7	71.1	16.8	8.3
18	178-182	0.4	2.0	8.3	69.0	20.3	8.3
19	262-266	0.8	6.8	18.2	56.4	17.8	8.1
20	442-446	0.4	2.2	30.2	51.9	15.3	8.0
21	500-504	1.4	3.8	13.6	57.6	23.6	8.2
12022	84-102	1.5	4.6	15.7	47.4	30.8	8.1
23	102-114	1.4	4.6	17.2	48.0	28.8	8.1
24	114-132	1.4	4.0	13.2	50.0	31.4	8.1
25	132-168	1.2	3.0	12.9	52.0	30.9	8.2
26	168-192	0.0	4.0	23.3	41.8	30.9	8.5
12027	0-6	0.2	1.7	8.5	63.7	25.9	6.7
28	58-62	0.3*	4.4	16.6	40.3	38.4	7.1
12029	0-12	0.2*	2.1	11.8	57.5	28.4	6.1
30	54-78	0.2*	5.6	23.5	39.3	31.4	6.8
31	78-96	0.2*	6.6	26.8	37.0	29.4	7.0
32	96-102	0.2*	6.8	36.2	33.1	23.7	7.7
12033	0-14	0.1*	1.0	12.6	70.6	15.7	6.7
34	14-30	0.1*	0.6	11.8	70.5	17.0	6.3
35	30-48	0.1*	0.4	9.9	72.9	16.7	6.6
36	48-72	0.1*	0.4	5.0	72.3	22.2	7.6
37	72-96	1.4*	1.8	4.5	65.1	27.2	8.3
38	96-126	1.6*	2.5	9.6	61.6	24.7	8.2
39	126-144	0.4*	2.6	11.1	59.7	26.2	8.1

---

*Calcium carbonate, iron and manganese concretions.

Table 13. Mechanical composition and reaction of soil samples from Northwestern and Northeastern Oklahoma area.

Sample Number	Depth inches	% Sand			% Silt	% Clay	pH Value
		larger than 250 microns	250-105 microns	105-53 microns	53-2 microns	less than 2 microns	
St. Paul silt loam							
12045	6-18	0.2	3.0	25.8	56.2	14.8	7.5
46	18-36	0.2	3.6	24.4	50.0	21.8	7.0
47	36-48	0.2	6.2	39.8	36.0	17.8	7.5
48	92-96	1.2*	9.2	42.8	36.4	10.4	8.5
49	118-122	0.4*	7.4	45.8	38.0	8.4	8.6
St. Paul silt loam							
12050	6-24	0.2	2.2	13.0	54.8	29.8	7.9
51	30-36	0.2	2.3	11.5	55.2	30.8	8.0
52	48-60	0.4*	4.2	14.2	50.4	30.8	8.2
53	300-304	0.2*	8.2	23.0	56.2	12.4	8.1
Pratt loamy sand and Quinlan parent material							
12054	0-36	48.6	32.6	6.8	8.6	3.4	7.2
55	36-60	11.4	9.6	17.8	39.8	21.4	6.9
Pratt sand, dune phase							
12056	0-4	44.6	48.8	4.8	1.8	0.0	8.4

---

*Calcium carbonate concretions.

Table 14. Mechanical composition and reaction of soil samples from Central and Northeastern Oklahoma area.

Sample Number	Depth inches	% Sand larger than 250 microns	% Sand 250-105 microns	% Sand 105-53 microns	% Silt 53-2 microns	% Clay less than 2 microns	pH Value
11990	14-14	1.8	6.0	18.5	62.6	11.1	6.6
91	20-24	1.0	5.0	15.9	49.5	28.6	6.1
92	30-36	1.0	6.6	20.7	51.1	20.6	6.6
93	36-78	1.0	7.2	21.4	50.3	20.1	6.6
94	78-96	1.0	7.4	21.1	50.4	20.1	6.8
95	120-144	1.0	6.2	20.9	53.3	18.6	7.1
12040	54-58	1.0	12.7	13.4	54.7	18.2	6.3
12041	0-16	---	---	5.9	83.4	10.7	5.2
12042	118-122	---	---	10.9	80.2	8.9	6.6
12043	0-12	---	---	9.7	78.2	12.1	5.5
12044	---	---	---	8.6	71.6	19.8	7.2
12092	300-304	0.0	0.0	1.7	88.5	9.8	7.6

Table 15. Volume weight of soil materials collected in various areas of Oklahoma

Sample Number	Location	Depth Feet	Volume Weight
11982	Beaver Creek, east of	4.5	1.457
83	Washunga, Oklahoma	8	1.414
11979	N.W. of Washunga, Oklahoma	7	1.502
11981	South of Fairfax, Oklahoma	8	1.645
12002	West Tulsa, Oklahoma	20	1.631
12019	Highway 74, South of	22	1.451
20	Norman Bridge	37	1.503

---

*The exact location of soil samples is given in the tables of description.

Table 16. Mechanical composition of soils developed from Peorian loess in Missouri, Iowa and Illinois as determined by the Pipette method of analyses.

Sample Number	Depth inches	% Sand	% Coarse, medium, and fine silt			% Clay
			53-40 microns	40-20 microns	20-2 microns	
			Marshall silt loam			
12057	Surface	0.9	14.1	36.0	30.4	18.6
			Menfro silt loam			
12058	Surface	4.3	20.4	36.4	26.9	11.9
			Seymour silt loam			
12059	Surface	2.5	12.0	37.7	32.4	15.4
			Monona silt loam			
12060	Surface	3.0	24.4	30.0	23.2	19.4
61	96	2.0	20.4	36.7	28.9	12.1
12062	Surface	1.7	14.5	30.4	26.3	27.3
63	144	1.9	21.8	34.6	25.9	15.8
	Illinois Samples - 19.5 miles from Illinois River					
12064	0-6	2.0	11.3	28.4	37.8	20.5
65	52-58	1.0	16.7	32.4	40.1	9.8
	Illinois Samples - 50.5 miles from Illinois River					
12066	0-6	1.2	9.7	28.8	42.4	17.9
67	52-58	0.7	6.4	25.1	46.5	21.3
	Illinois Samples - 68.5 miles from the Illinois River					
12068	0-6	2.8	6.5	24.6	46.8	19.3
69	52-58	0.9	8.7	30.4	45.0	15.0

Table 17. Mechanical composition of soils developed from Peorian loess in Kansas and Nebraska as determined by the Pipette Method of analyses.

Sample Number	Depth inches	% Sand	% Coarse, medium and fine silt			% Clay
			53-40 microns	40-20 microns	20-2 microns	
Sharpsburg or Crete silty clay loam						
12070	0-11	2.0	14.7	27.0	22.3	34.0
71	11-18	1.4	10.1	20.8	21.8	46.1
72	18-40	1.0	10.4	23.6	26.3	38.7
73	40-70	1.2	11.7	27.6	29.3	30.2
74	72-96	1.3	9.9	26.6	30.5	31.7
75	108-126	3.3	10.5	29.6	31.9	24.7
76	126-144	1.6	12.5	30.5	33.1	23.3
Holdrege silt loam						
12077	0-6	18.3	32.3	20.1	10.1	15.8
78	6-20	13.0	28.2	22.6	12.8	23.4
79	20-34	12.3	26.4	20.1	15.3	25.9
80	34-48	11.7	22.9	20.8	17.9	26.7
81	48-54	8.8	23.3	24.9	21.1	21.9
82	54-70	9.0	28.8	23.6	23.3	15.3
Holdrege silt loam						
12083	0-4	5.0	24.5	30.6	18.6	21.3
84	4-10	4.9	24.1	27.5	19.3	24.2
85	10-13	3.6	21.0	24.7	17.9	32.8
86	13-16	3.7	15.6	26.3	16.5	37.9
87	16-24	4.6	17.4	25.8	15.4	36.8
88	24-28	4.9	21.5	25.7	20.2	27.7
89	28-42	5.2	23.1	26.0	25.6	20.1
90	42-84	5.0	20.5	28.1	26.3	20.1
91	84-120	5.3	21.5	30.9	27.0	15.3

DISCUSSION OF RESULTS

In discussing the results it will be necessary to mention certain visual observations[*] made in the field which are not recorded in other sections of this paper. For simplicity the results will be discussed on the basis of individual soil areas, without excluding comparisons between areas when this seems to be justified by the preliminary observations and analyses.

Kay County Area. All soil samples from Kay County were collected in the east central part of the county in the vicinity of the Kaw and Washunga communities. The Arkansas River has deposited a large volume of sediments in this area which are quite variable in age and origin of material. In 1915, when the soil survey of this county was conducted, extensive areas on the high terraces and adjacent uplands were mapped with the Derby series. At that time the soil surveyors recognized that a considerable part of this material had blown up from the flood plains of the Arkansas River (20).

Samples 11975-78, 11982-83, and 11979 were collected on the north side of the River in the vicinity of Washunga in soil areas mapped as Derby silt loam. These samples were taken at similar topographic positions. All of them have

---

[*] Many of the basic observations were made in the field by Dr. Horace J. Harper and the author, however, the interpretations of the observations and analyses are the work of the author.

similar reddish colors and a reaction which is slightly acid to neutral. Samples 11982-83 were collected near Beaver Creek, east of Washunga. The higher sand and lower clay content of these samples indicate the proximity of faster moving water when deposition occurred, however, its origin is apparently the same as the other samples of Derby silt loam collected in this area. According to the soil survey map (20) this material extends for some two miles up the Beaver Creek valley from the point where Beaver Creek enters the Arkansas River. Beaver Creek drains an area where the soils were formed from calcareous shales and limestone. Had these sediment been eroded from the uplands which are drained by Beaver Creek they would have been dark brown or a very dark gray color, e.g. Osage series.

The profile represented by samples 11975-78 was collected east of Beaver Creek, but a high limestone escarpment was between the two locations. Mechanical analyses in Table 10 show the lower horizons to be very high in clay content, and also a slight increase in clay content with depth. Since the profile has a higher pH with depth it is probable that this clay was not formed <u>in situ</u>, but was transported to this area by back water when the Arkansas River was flowing at a much higher level than it is today. Sample 11979, collected four miles northwest of Washunga, is of similar nature. Contour lines on the topographic map of this area show the elevation is some 70 feet above the river channel.

No stratification of these sediments was observed at any of the locations mentioned, however, these deposits of silty material can be laterally traced down the small stream valleys to the Arkansas River. This lack of stratification was observed in other areas studied.

Density cores were taken at the Beaver Creek location and northwest of Washunga. These cores are given the number of the corresponding samples taken at these locations. Volume weight results are shown in Table 15, but apparently they are of little significance. The samples from Beaver Creek, which contained more sand and less clay, showed the lower volume weight.

A large area northwest of Washunga mapped as Derby fine sandy loam is of particular interest because of its high topographic position and coarse texture. At some locations, this material is as much as 170 feet above the present river channel. Samples 11984-87 represent the A_1, A_2, B, and C horizons of a profile formed on this material. These samples were taken in a cultivated field but the most recent native vegetation was apparently scrub oak with a considerable undergrowth of grass, or at least this is the condition of some of the surrounding virgin area. From the mechanical analyses in Table 10, it can be seen that considerable clay has accumulated in the B horizon, probably a large part of it being eluviated from the light colored A_2 layer. Whether this soil material was deposited principally by wind or water in its present location cannot be definitely stated, however, the well developed profile indicates it has been weathering for a long period of time. At the present time this profile would probably be correlated as the Stidham sandy loam.

West of Kaw, in the middle of a large ox-bow of the Arkansas River, is a rather extensive area of Derby silt loam which definitely appears to be of eolian origin. At the location where Samples 11970-74 were collected the elevation is approximately 200 feet above the channel of the river. This is about the same elevation as much of the upland in this area. Mechanical analyses in Table 10 show that the profile is not so highly developed, and that the clay in the B horizon is the result of weathering of silt particles <u>in situ</u> rather than translocation from the A horizon. Although this area is almost surrounded by scrub oak forest, the immediate area where the sample was collected was probably influenced by grass vegetation. At the present time it is a cultivated field.

The configuration of the river channel at the above location is such that soil material from the flood plain could be picked up by either a northwest or a southwest wind and deposited on the upland area where the sample was taken. A large continuous area of Derby silt loam is mapped to the southwest along the north side of the river. This is suggestive that a large part of this material came across the ox-bow from this direction, although no sample were collected or observation made in the field to substantiate this statement. The high silt content and the relatively low sand content at the location site also indicates this material was carried a fairly long distance.

Tulsa County Area. Most of the alluvial deposits in Tulsa County are confined to the north side of the Arkansas River. This condition was not so apparent in the Kay County area because the Arkansas River flows in a general north-south direction, whereas in Tulsa County it flows in an eastern or southeastern direction. The large amount of alluvium on the north side of the river seems to have resulted from the river channel continually shifting to the south.

In general, all of the samples collected in Tulsa County are coarser textured and more acid in reaction than the Kay County samples. However, this is partly the results of selecting these areas for study and may not represent the conditions as they actually exist.

The location site of samples 12000-02 is a perpendicular bluff approximately forty feet high adjacent to the highway between Sands Springs and Tulsa. This bluff parallels the Arkansas River for a considerable distance. The upper five or six feet of the profile has well developed prismatic structure. When this location was first visited in the spring of 1950 there was no visual evidence of stratification in the exposed part of the bluff. In June, the location was visited again but in the meantime a large slice of the bluff had caved off, exposing several layers of well stratified sand, clay and gravel in the lower one-half of the bluff. Mechanical analyses recorded in Table 11 show the variation between the surface and a depth of 10 and 20 feet. Some people had insisted this material was deposited by the wind, however, the well stratified layer of coarse materials in the lower one-half must definitely be attributed to deposition by water.

Sample 12010 is the lower horizon of a Stidham profile which has the same topographic position as the Stidham soil in Kay County. Samples were not collected from the upper horizons, however, it was observed that the Tulsa County Stidham soil had a more strongly developed podsolized profile. The strongly developed profile may be in part the result of forest vegetation.

Between the Arkansas River and the high terrace where the Stidham profile is developed there is a considerable area of fine textured sediments mapped with the Lonoke series. These soils are above the ordinary flood level of the river but at a considerable lower elevation than the alluvium from which the Stidham soil was developed. Samples 12007-09 are the lower horizons of the Lonoke very fine sandy loam. To a depth of fifteen feet there is no visual evidence of stratification, although this silty deposit of alluvium can be traced laterally to the bank of the Arkansas River. The presence of stratification, even though it is not visible, is recorded in the Mechanical analyses, Table 11. This absence of stratification was observed in the fine textured sediments in Kay County.

The Teller fine sandy loam, samples 12003-06, is intermediate in texture and reaction, as compared to the Lonoke and Stidham soils. The Teller soil is rather extensive on the high terraces north of Bixby.

Samples 11996-99 occupies the position of slope alluvium, but apparently most of it is very high alluvium deposited by the Arkansas River. The increase in fine sand content in the upper sample indicates the influence of the sandstone hill it grades into further up the slope.

When the Tulsa County survey was conducted, field men recognized the possibility that a large inland lake may have existed in the vicinity of the Mingo and Bird Creek Valleys. They believed this occurred at a time when the Arkansas River was flowing at a much higher level. This conclusion was reached because of the basin-like valley topography and the existence of a large area with deep dark-colored surface soils (21).

As a result of the above condition, a new soil series was established and named after the town of Alsuma which is located in this area. The Inspector from the Division of Soil Survey objected to the establishment of a new soil series, therefore these areas were correlated with the established soil series of the area. Samples 12011-12 and 12013-15 were collected from areas mapped as the deep phase of Bates very fine sandy loam. In the field, it was noted that the latter profile was more like Parsons silt loam than Bates very fine sandy loam. In this area of Oklahoma the Bates and Parsons series are typically developed on sandstone and shale parent material, respectively. The development of the two profiles sampled is very similar, except that the "Parsons silt loam"

(Samples 12013-15) contained more gray and yellowish mottling in the A_2 horizon.

Mechanical analyses and reactions of the above profiles are recorded in Table 11. The mechanical composition of the profiles is more similar than would be expected had the two soils been developed on typical sandstone and shale formations. The Bates soil is only slightly coarser textured than the "Parsons" soil and the high pH value of the Bates subsoil is an unusual condition for this soil series. Whether these soils are developed on alluvium deposited by the Arkansas River cannot be definitely stated, however, the parallelism of some of the areas to the Arkansas River, and the adjacent Dougherty and Teller soils, is strongly suggestive of this origin.

Samples 11990-95, Table 14, collected in Creek County, are typical of the large areas of high alluvium found in this area of Oklahoma. In profile development, reaction and color these soils are similar to the Derby series found in Kay County. In Creek and Tulsa Counties these soils have been mapped as the Dougherty series. Both the Derby and the Dougherty soil material was probably transported from the "Redbeds" further up the Arkansas and Cimaron Rivers.

<u>McClain County Area</u>. In the McClain County Area, south of the Canadian River, is located one of the largest continuous deposits of alluvium in central Oklahoma. In the review of literature, it was mentioned that some evidence had been

presented that indicated some of this material was of Pleistocene age. Analyses of samples collected in this general area are recorded in Table 12.

On highway 74, about one and one-half miles south of the Norman Bridge, an excavation by the Highway Department has revealed approximately a 45-foot section of this material deposited on the high terrace of this area. For a reference point in discussing the other samples collected in McClain County, the above location will be referred to as the Highway exposure, samples 12016-21.

Some of the observations made at the Highway exposure were; (a) no visual evidence of stratification, (b) a zone near the center having the appearance of a "buried soil," (c) many crotovinas near the center of the exposure, (d) abundant nodules of lime concretions in the lower portion, (e) a large amount of pseudo-mycelium development in the upper one-half of the exposure, (f) brown colored in the upper one-half, and (g) a predominant red colored in the lower one-half.

The lack of visual stratification, while the mechanical analyses indicated that stratification was present, was observed in other areas. Characteristics in which the alluvium of these areas share are a high percentage of silt size particle (50-70%), only slight profile development, and a high pH value. They differ in geographic location and the topographic position in relation to the stream channel. The Lonoke profile in Tulsa County is just above flood level while the Highway exposure is some 100 feet above the present level of the Canadian River Channel. From the above observations it may be concluded that the absence of stratification does not exclude water deposition.

The difference of color in the lower and upper portions of the exposure, the presence of concretions in the lower part and the pseudo-mycelium in the upper portion seem to indicate a difference in source of sediments and a difference in age of the sediments. The crotovinas near the center of the exposure may indicate that a buried soil actually existed (19, page 155). A soil profile which apparently is developing on the same material as the upper layer of the Highway exposure is represented by samples 12033-39. The analyses are shown in Table 12. This profile shows very little B-horizon development and the basic reaction indicate it is not highly weathered. Calcium carbonate concretion were encountered by a depth of 72 inches. The location site is 70 feet above the channel of the Canadian River and about seven miles southwest of the Highway exposure.

Near the Goldsby School, about two miles south of the Highway exposure, samples 12022-26 were collected. At a depth of 16 feet water seeped into the auger hole and deeper samples could not be obtained. The water indicated an impervious stratum immediately below this level. The color of the lower horizons of this profile are the same as the lower horizons of the Highway exposure. The deepest sample collected, 12026, shows a remarkable increase in the content of very fine sand, however, all of the horizons have a uniform clay content. Samples of the A- and B- horizons were not collected, however, a well developed soil profile was observed. The strongly developed soil profile indicates an older age for the sediments at this location than for the surface of the Highway exposure near the Canadian River.

Whether the upper layer of the Highway exposure is discontinuous between the Highway excavation and two miles further from the Canadian River cannot definitely be stated; but if this is the condition, the surface soil profile near the Goldsby School would probably be equivalent to the "buried soil profile" in the Highway exposure. The basis for the above postulation is: (a) the depth from the surface of the soil to the impervious layer below is approximately 16 feet in the vicinity of Goldsby School; (b) the depth from the zone appearing to be a "buried soil" in the Highway exposure to the sandstone layer beneath is approximately 20 feet; and (c) the topography between the two locations is gently undulating and appears to be at a slightly higher elevation than the level area of the terrace beyond the Goldsby School to the south. The local drainage pattern near the Goldsby School indicates the difference in elevation by the water flowing to the southeast rather than to the north which would be the nearest distance to the Canadian River.

Samples 12029-32 were taken from a Grant silt loam or a Grant very fine sandy loam profile about one and three-fourths mile west of the Goldsby School. This soil is formed on sandstone and is at a slightly higher elevation than the terrace deposit. Samples 12027-28 were taken about two miles south of the Goldsby School near the southern extremity of the terrace deposit. The clay content is higher at this location than near the stream. The higher clay content further from the stream is probably the result of backwater deposition.

Two density cores were collected at the Highway exposure but the volume weights were very similar (Table 15).

Northwestern Oklahoma Area. The analyses of a few samples collected in northwestern Oklahoma are recorded in Table 13. Two profiles of St. Paul silt loam were collected in Dewey County between the Canadian and the North Canadian Rivers. Since these profiles have developed a deep silty surface soil under the influence of a semi-arid climate, they were suspected of having been influenced by soil material transported by the wind. The increasing sand content and decreasing silt content with depth seem to indicate that the texture of these soils resulted from the weathering of the fine-grained sandstone parent material. If the depth of the surface soils has been influenced by wind movement of soil material, it is probable the result of local material of the same texture. There is a considerable difference in the texture of the parent material from the two profiles.

The Pratt loamy sand is representive of considerable areas of this type of material in northwestern Oklahoma. It is apparent from the mechanical analyses that the surface soil could not have formed as the result of the weathering of the Quinlan parent material. Whether wind or water is responsible for the movement of the mantle material must be decided for each individual area. All soils mapped with the Pratt series are not necessarily mantle material.

Dune sand collected in Harper County merely shows the mechanical composition of this type of material. This material is continually shifted by the wind but it is never moved a long distance at any one time.

As would be expected, all of the samples from Northwestern Oklahoma were basic in reaction.

Central and Northeastern Oklahoma Areas. Several soil samples in widely scattered areas of central and northeastern Oklahoma were collected because of some unusual feature observed in the field. Time has not permitted a second visit to these areas for detail study in the field.

Sample 12041 was collected near Toby, Oklahoma, in Delaware County. Soils in this section are characteristically developed on cherty limestone. The limestone weathers away and leaves a stony loam surface soil. At the location site of the above sample a deep silty surface soil has developed with no evidence of chert for a considerable depth. At the present time this area is not associated with any stream terrace.

Sample 12042 was collected in a zinc pit near Commerce, Oklahoma in Ottawa County. The Parsons silt loam of this area is typically developed on shale formations. The analyses substantiate the field observation that this was not a typical shale. Sample 12043 is a surface soil of Parsons silt loam collected a short distance north of Commerce, Oklahoma. The analyses are recorded in Table 14.

Sample 12040 is a sample of the high alluvium deposited by Deep Fork Creek in Oklahoma County.

Sample 12044 is volcanic ash which is usually believed to have been transported to this area by the wind from the southwestern United States. This sample was taken from the soils laboratory supply which was collected in Pawnee County, Oklahoma.

The analyses of a sample of loess from Vicksburg, Mississippi is included in Table 14.

Loessial Soils. Samples of loess from Iowa, Illinois, Nebraska, Kansas and Missouri were obtained in order to secure some information on the texture of these deposits which are commonly considered to be of eolian origin. The mechanical composition of these samples as determined by the Pipette method is recorded in Tables 16 and 17. A lengthy discussion concerning these soils will not be presented since the author has only the analyses and the information obtained by letter from the collectors of the samples. From the present investigation, it would not be feasible to attempt to correlate the loess deposits of north central United States and the alluvial and eolian deposits of Oklahoma.

The Marshall, Menfro and Seymour silt loams are typical of the surface soils developed from loess in Northern Missouri.

Two surface samples and two subsurface samples of loessial soils collected at different distances from the Missouri River in Monona County, Iowa, show the effect of wind fractionation. Samples 12060-61 were collected about three miles from Missouri River bluff while samples 12062-63 had been transported some twenty-five miles by the northwest wind. The subsurface samples show the fractionation which occured in the parent material and the surface samples reflect both the fractionation of the parent material and the time interval it has been exposed to weathering.

Samples 12064-69 were collected at various distances from the Illinois River along the same traverse studies by Smith (28). The fractionation of the parent material is apparent between the first two locations but a secondary source of loess may have influenced the local area between the second and third locations.

The author is indebted to Mr. B. H. Williams for contributing the information concerning the soils from Nebraska and Kansas. The following information was abstracted from Mr. Williams' letter of January 10, 1950.

> The Sharpsburg silty clay loam* from near Lincoln, Nebraska, and the Holdrege silt loams

---

*Recent communication from Mr. B. H. Williams stated this soil had been correlated with the Crete series.

from Sargent, Nebraska, and Norton, Kansas, are all developed on Peorian loess which includes all of the eolian silts of this part of the plains region. This material is considered to have been deposited during early Wisconsin time. Williams reports that Professor E. C. Reed, Associate State Geologist for Nebraska, believes there has been a thin layer of Bignell loess deposited over the immediate surface but it is not readily identifiable at the sample sites.

The most probable sources for the parent loess of the Sharpsburg silty clay loam were suggested as the Platte River Valley located some 50 miles to the northwest, the Nebraska Sandhills more than 100 miles to the northwest, and the Missouri River Valley about 50 miles to the northeast. The Sharpsburg soil is leached free of lime carbonate to a depth of about 10.5 feet with relatively unleached loess below this depth. What appeared to have been a secondary accumulation of lime carbonate leaching downward from a late covering of Bignell loess. Williams believed that the late covering of Bignell loess was deposited over a moderately developed soil and become part of the thick dark A horizon of the present soil.

The Sharpsburg soil profile was collected in the Prairie-Chernozem transition belt of Nebraska and is not quite typical of true Sharpsburg soils. Williams reports the high clay content of the B-horizon seems to be approaching that of the Crete series while the presence of lime carbonate is characteristic of both Crete and Hastings soils. The latter two soils are the maximal and medial Chernozem soils, respectively, that are typically developed a few miles further west.

The Holdrege silt loam from near Sargent, Nebraska, is only seven miles south of the Middle Loup River and about twenty-miles south of a large area of the Nebraska Sandhills. Both of these areas are considered as major sources of loess. This profile is representative of a "medial" Chernozem soil developed on loessial parent material. It is near the median in range of profile development in the Chernozem great soil group.

The Holdrege silt loam from near Norton, Kansas, is about thirty miles south of the Republican River Valley, which is considered as a major source of loess. Two smaller streams are between the sample site and the Republican River Valley but they are not considered as major sources of loess. At the time this profile was collected, Williams observed that it contained the maximum clay content

> for Holdrege soils. In this respect it closely approaches the Hastings soils, but lacks the strong nuciform or fine blocky structure of the Hastings soils.

William's is in agree with Smith's conclusions (28) that there should be a direct correlation between the distance the loess is transported and the clay content. The increasing clay content with distance should be present in the soil developed as well as in the unweathered loess. Williams predicted that the Sharpsburg profile would be the highest in clay content, the Holdrege profile from Norton, Kansas, samples 12083-91, would be intermediate in clay content, and the Holdrege profile from Sargent, Nebraska, samples 12077-82, would contain the smallest amount of clay. The mechanical analyses show Williams prediction to be correct, except for the clay content of the deepest samples collected for the two Holdrege profiles. If the Holdrege profile from Sargent, Nebraska, had been sampled as deep as the profile from Kansas the exceptence would probably not have existed.

The fractionation of the sand and silt is just as apparent as the fractionation of the clay. The Sharpsburg profile contained a large amount of fine silt, a small amount of coarse silt and practically no sand, while the Holdrege soil from Nebraska contained a large amount of sand and coarse silt, but a small amount of fine silt. The Holdrege soil from Kansas is intermediate in respect to the fractionation of the sand and silt particles.

William's postulation that a late covering of Bignell loess was deposited on a moderately developed soil at the location site of the Sharpsburg profile seem to be substantiated by the analyses. The transition zone between the leached and the calcareous material, 96-108 inches, was not sampled. This sample might lend more support to the presence of the buried soil.

SUMMARY AND CONCLUSIONS

A preliminary investigation of the soil mantle material in Oklahoma indicates that a more thorough study would be justified. Field observations and laboratory analyses of a reconnaissance type have revealed only the general conditions and the details must await future investigations.

Along the Arkansas River in Kay and Tulsa Counties, three general types of sediments have been studied: (a) a coarse textured material at a high elevation and a considerable distance from the stream; (b) a fine-textured silty deposit at an intermediate elevation and distance, with respect to the stream; and (c) a fine-textured silty deposit near the River and just above the flood level of the present stream channel.

In Kay County the coarse sediments have weathered less than the corresponding material in Tulsa County. This could be due to several factors such as; (a) forest vegetation predominating in Tulsa County resulting in the strongly podsolized profile being formed, while in Kay County the soil profile has been influenced by a grass vegetation at some past period of time*; (b) the Kay County soil has been influenced by the wind depositing fresh soil material on it from the flood plain of the Arkansas River; or, (c) both of the above conditions could have existed. Since the coarse sediments occupies the same

---

*While studying the Kay County profile in the field, Dr. Harper suggested it might have been influenced by a grass vegetation and the present scrub oak forest has recently become dominant.

topographic position, in both areas, with respect to the Arkansas River and the other alluvial material the time of deposition must have been the same, thus eliminating the age of the parent material as a variable factor. These coarse sediments must have been transported into this area from the west during an early period of severe erosion following the establishment of the Arkansas River at its present location. In Tulsa County the soils on this material have been mapped as the Stidham series while in Kay County they were mapped with the Derby series.

The fine-textured sediments of intermediate topographic positions are apparently of the same origin as the coarse sediments as indicated by their similar colors, In Kay County the soils on these sediments were mapped with the Derby silt loams. They occupy areas which appear to have been backwater deposits when the Arkansas River was flowing at a higher level. The high clay content of the lower horizons indicating slow moving water. They differ from coarse sediments by having a higher pH value.

In Tulsa County the soils of the Dougherty series are fine-textured, however, they may occupy a higher topographic position than did the Derby silt loams in Kay County. Soils of the Teller series are of a similar nature, being on the high alluvial terrace but they are of a slightly coarser texture than the Derby soils of Kay County. The profile is less weathered than Stidham soil.

The low terrace silty deposits are quite different from the previous types of deposits mentioned. The dark color of these deposits indicate a different origin than that of the reddish colored higher terrace deposits. The high pH value indicates they have not existed for a long period of time under their present environment. It probably that they represent the material eroded from the calcareous uplands adjoining the Arkansas River and its tributaries. The Lonoke soils the Tulsa County Area would be representative of this type of sediment.

The McClain County alluvium on the high terrace south of the Norman Bridge appear to be composed of material from two sources. A red colored alluvial material is covered with a brown colored mantle material. The upper brown-colored soil material may not extend as far over the terrace deposit as the underlying red sediments. At one location there appears to be a buried soil between the two deposits.

The Canadian River eroded a wide flat valley before beginning to deposit sediments. The clay content of the sediments increases from north to south across the terrace away from the river. This probably indicates that the channel was near its present location when the period of deposition began. As the water spread out across the flood plain the coarse particles were deposited first. The high, constant clay content in the lower horizons is suggestive of backwater deposition a considerable distance from the main stream channel.

The absence of stratification in silty alluvial deposits was observed several times in the field.

Analyses of maximal and medial Chernozem soils developed from loessial parent material show some of the characteristics of this type of soil mantle material.

LITERATURE CITED

1. Andrews, L. E. and Rhoades, H. F. 1947 "Soil Development from Calcareous Glacial Material in Eastern Nebraska during Seventy-five Years". Soil Sci. Soc. of Amer. Proc., 12: 407-408.

2. Beavers, A. H. and Albrecht, W. A. 1948 "Composition of Alluvial Deposits Viewed as Probable Sources of Loess". Soil Sci. Soc. Amer. Proc., 13: 468-470.

3. Bouyoucos, G. J. 1928 "The Hydrometer Method for Making a Very Detailed Mechanical Analysis of the Soil". Soil Sci. 26: 233-238.

4. Chepil, W. S. 1946 "Dynamics of Wind Erosion: VI. Sorting of Soil Material by the Wind. Soil Sci. 61: 331-340.

5. Dunbar, C. O. 1949 "Historical Geology". John Wiley & Sons, Inc., New York, New York.

6. Free, E. E. 1911 "The Movement of Soil Material by the Wind". U.S.D.A. Bureau of Soils, Bulletin No.68.

7. Frye, John C. 1945 "Problems of Pleistocene Stratigraphy in Central and Western Kansas". Jour. Geol., 53: 73-93.

8. Frye, John C. and Fent, O. S. 1947 "The Late Pleistocene Loesses of Central Kansas". State Geol. Survey of Kansas, Bulletin No. 70, Part 3.

9. Frye, John C. and Swineford, Ada 1948 "Correlation of the Pleistocene Deposits of the Central Great Plains with the Glacial Section". Jour. Geol. 56: 501-525.

10. Frye, John C. 1949 "Use of Fossil Soils in Kansas Pleistocene Stratigraphy". Trans. Kan. Acad. Sci. Vol. 52, No. 4.

11. Frye, John C. and Leonard, A. B. 1949 "Pleistocene Stratigraphic Sequence in Northeastern Kansas". Amer. Jour. Sci. 247: 883-899.

12. Gould, C. N. 1925 "Index to the Stratigraphy of Oklahoma". Okla. Geol. Survey, Bulletin No. 35.

13. Harper, H. J. and Hollopeter, C. A. 1932 "Buried Soils and Their Significance". Okla. Acad. Sci. Proc., 12: 63-66.

14. Harper, H. J. 1933 "Studies of the Origin of the Sandy Land Along the Cimarron River". Okla. Acad. Sci. Proc. 13: 24-27.

15. Harper, H. J. 1934 "Further Investigations of Buried Soils in Relation to the Climatic Change in Oklahoma". Okla. Acad. Sci. Proc., 14: 65-67.

16. Hobbs, W. H. 1931 "Loess, Pebblebands and Boulders from Glacial Outwash of Greenland Continental Glacier". Jour. Geol., 39: 381-385.

17. Hobbs, W. H. 1942 "Wind, the Dominant Transportation Agent Within Extravarginal Zones to Continental Glaciers". Jour. Geol., 50: 556-559.

18. Hobbs, W. H. 1943 "The Glacial Anticyclones and the Continental Glaciers of North America". Review by Frank Laverett. Jour. Geol., 51: 428-429.

19. Joffe, J. S. 1947 "Pedology". Pedology Publications. New Brunswick, New Jersey.

20. Kirk, N. M. and Jurney, R. C. 1917 "Soil Survey of Kay County, Oklahoma". U.S.D.A. Bureau of Soils.

21. Knobel, E. W. and Brensing, O. H. 1935 "Soil Survey of Tulsa County, Oklahoma". U.S.D.A. Bureau of Soils. Series, No. 22.

22. Leighton, M. M. 1926 "A Motable Pleistocene Type Section: The Farm Creek Exposure Near Peoria, Illinois". Jour. Geol., 34: 167-174.

23. Oakes, M. C. 1948 "Chert River, an Inferred Carboniferous Stream of Southeastern Oklahoma." Okla. Acad. Sci. Proc., 28: 70-71.

24. Obruchev, Vlandimir A. 1945 "The Loess Types and Their Origin". Amer. Jour. Sci., 243: 256-262.

25. Olmstead, L. B., Alexander, L. T. and Middleton, H. E. 1930 "A Pipette Method of Mechanical Analysis of Soils Based on Improved Dispersion Procedure." U. S. D. A. Technical Bulletin No. 170.

26. Russell, R. J. 1940 "Lower Mississippi Valley Loess". Bul. Geol. Soc. Amer., 55: 1-40.

27. Shimek, B. 1930 "Land Snails as Indicators of Ecological Conditions". Ecology, 11: 673-686.

28. Smith, G. D. 1942 "Illinois Loess. Variations in its Properties and Distribution: A Pedologic Interpretation". Ill. Agri. Exp. Sta. Bul. 490.

29. Snider, L. C. 1917 "Geography of Oklahoma". Okla. Geol. Survey Bul. 27.

30. Swineford, Ada and Frye, John C. 1945 "A Mechanical Analyses of Windblown Dust Compared with Analysis of Loess". Amer. Jour. Sci., 243: 249-255.

31. Tuck, Ralph 1938 "The Loess of the Matanuska Valley, Alaska". Jour. Geol., 46: 647-651.

32. Ulrich, Rudolph 1948 "Some Physical and Chemical Properties of Planosol and Wiesenboden Soil Series as Related to Loess Thickness and Distribution". Unpublished Ph.D. Thesis. Iowa State College, Ames, Iowa.

33. Vanderford, H. B. and Albrecht, W. A. 1942 "The Development of Loessial Soils in Central United States as it Reflects Differences in Climate". Missouri Agri. Res. Bul. No. 345.

34. Wascher, H. L., Hambert, R. P. and Cady, J. G. 1947 "Loess in the Southern Mississippi Valley: Identification and Distribution of the Loess Sheets". Soil Sci. Soc. Amer. Proc., 12: 389-399.

35. Williams, A. J. 1936 "A Drainage Change Involving the North and South Canadian Rivers". Okla. Acad. Sci. Proc., 16: 76-77.

Norma L. Prentice, Typist