A GEOLOGIC STUDY OF LITTLE GOBI DESERT, POTTAWATOMIE COUNTY, KANSAS

by

ROBERT JAMES ARDELL

B. A., Monmouth College, 1962

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Geology and Geography

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1965

Approved by:

Major Professor

LD
2668
.T4
1965
A67
c.2

TABLE OF CONTENTS

Abstract

The "Little Gobi Desert" of Pottawatomie County, in northeastern Kansas, has long been considered a Pleistocene dune deposit, although it has received only cursory attention with no attempt at a detailed study being made.

The primary object of the study was to postulate the origin of the sand, mode and time of deposition.

A detailed topographic map was constructed by use of a plane table and alidade and diagrammatic cross sections were assembled from data collected through augering.

Field observations of the area proved most valuable. A concentration of erratic gravel was found at the base of the sand immediately above a residual chert gravel formed on the Florence Limestone Member of the Barnseton Formation, Chase Group, Gearyan Series, Permian System. No cross bedding was observed in the sand, but a peculiar lamination of iron-enriched bands was observed occurring at intervals of two to four inches. The deposit, where dissected by erosion, exhibited layers of clay and silt with the characteristic blocky structure common to loess.

Samples collected were studied for fossils, grain size distribution, mineralogy, grain roundness, and surface textures. Roundness varied from rounded to well rounded for the median grain size of all samples. All sand of median grain size was well frosted to frosted. All samples studied were barren of fossils.

The mineralogical composition was determined by standard mineral separation techniques and microscopic examination. The heavy mineral

assemblage of four selected samples averaged .81% of the total sample weight. A pronounced enrichment of opaques (magnetite and ilmenite), 30%, and garnets, 12.5%, was found in the heavy mineral fraction. The light fraction of the samples studied displayed a low concentration, 3.75%, of chert. The opaque and garnet enrichment and chert deficiency are characteristic of known glacially derived sediments in the area.

It can be concluded from the combination of field observations and laboratory study that the "Little Gobi Desert" is late Kansas or early Yarmouth in age and an eolian deposit derived for the outwash plain of the Big Blue River.

INTRODUCTION

Purpose

The purpose of this investigation is to describe and determine the nature and origin of a deposit of sand locally known as "Little Gobi Desert" east of Big Blue River in Pottawatomie County, Kansas. The hypothesis on the history and method of deposition of the sediments in this deposit shall be proposed and supported by use of quantitative data accumulated through laboratory procedures and field observations.

The Pleistocene and Recent sediments of river valleys in Northeastern Kansas have been studied extensively, but little work has been done on sand deposits above the valley floors. Such deposits are of interest and should fit into the over-all Pleistocene history of Northeastern Kansas.

Emphasis in the study is placed upon the geomorphic history of the deposit, supported by petrological relationships and grain size analysis within the deposit. A detailed map of the area and cross sections have been included.

Geography

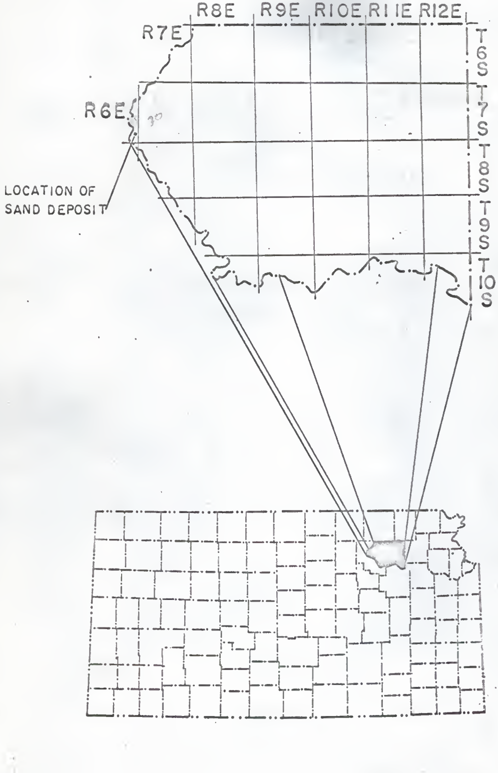
The sand deposit is located in the westernmost extension of Pottawatomie County, in northeast Kansas (Plate I). It is in Section 25, T7S, R6E, on a limestone bench approximately 180 feet above the conservation level of Tuttle Creek Reservoir and is some 225 feet above the channel of Big Blue River.

The climate is typical humid continental with an annual precipitation of 32.1 inches (Flora, 1948, p. 26, 81). Prevailing winds are from the

EXPLANATION OF PLATE I

Base map showing location of deposit in Pottawattomie County, Kansas.

PLATE I


R8E
R9E
R10E
R11E
R12E
R7E
R6E
T 6 S
T 7 S
T 8 S
T 9 S
T 10 S
LOCATION OF
SAND DEPOSIT

southwest. The land supports only light grazing.

Topographic expression of the deposit reflects the hummocky nature of a stationary dune and the vegetation, a short grass, is typical of other known dune deposits found at lower elevations. (Fig. 1)

The area is drained by the Big Blue River with only tertiary gully and rill-type tributaries associated with the deposit.

Fig. 1. Typical topography and vegetation of the deposit.

The Pleistocene classification used in this paper is that adopted by the U. S. Geological Survey and correlated with the Pleistocene units of Kansas (Frye and Leonard, 1952, p. 24).

Standard Time Scale		Deposits in Kansas	
Stage	Substage	Formation	Member
Recent			Modern soil
Wisconsinian	Mankatoan	Sanborn Fm.	Bignell Mem.
	Caryan		
	Bradyan		Brady soil
	Tazewellian		Peoria Mem.
	Iowan		
Sangamon			Sangamon soil
Illinoisian			Loveland Mem.
			Crete Mem.
Yarmouthian			Yarmouth soil
Kansan		Meade Fm.	Sappa Mem.
			Grand Island Mem.
		Kansas till	
		Atchison Fm.	
Aftonian			Afton soil
Nebraskan		Blanco Fm.	Fullerton Mem.
			Holdrege Mem.
		Nebraska till	
		David City Fm.	

Previous Investigations

That pertinant literature reviewed has been listed in chronological order for the sake of organization and simplicity.

Glacial deposits in Kansas were first recognized by B. F. Mudge in 1866 in his "First Annual Report of the Geology of Kansas" (Frye, 1946, p. 403).

Hay (1892) determined the southernmost extension of glacial advance in Kansas at the southern bluffs of the Kansas River.

Smyth (1896) described glacial Kaw Lake and indicated that it extended from Wabaunsee County on the east to Salina on the west and Blue Rapids on the north. Todd (1916a, p. 119) indicated that Kaw Lake was one mile wide six miles north of Manhattan in Big Blue River valley and diminished rapidly in width farther north. Todd (p. 197), in the same study, concluded that the channel of the Pliocene Kaw River was three miles north of the present channel and at no time passed near the sand deposit. Todd (1916b, p. 41) indicated that Kaw Lake reached a maximum elevation of 1175 feet.

The glacial drift border in Kansas was reestablished by Schoewe (1930) at several miles south of Kansas River. Schoewe (1939), in relocating the western drift border in northeast Kansas, indicated by a rough map that the drift border was within one mile of the sand deposit. By remapping the border, Schoewe was able to match the drift border in Kansas to the drift border in Nebraska.

Harned (1940, p. 114), in his study of the mineralogy of selected rocks in the Manhattan area, concluded that mineral analysis could be relied upon to distinguish between transported and residual mantle in the Manhattan area and that field observation and physical appearances are insufficient criteria for establishing the origin of mantle rock in the area.

Beck (1949), in his study "The Quaternary Geology of Riley County, Kansas", found all sand dune deposits in Riley County to be located in the Kansas River valley and none west of the study area.

Seiler (1951) found, in his study of alluvial lenses along the Kansas River, that correlation based on age was possible to the extent that lenses could be identified as "pre volcanic ash", "volcanic ash", and "post volcanic ash". The volcanic ash was thought to be the Pearlette ash of Late Kansan age.

Frye and Leonard (1952, p. 29-30) related techniques in general use for the classification and correlation of Pleistocene deposits. They were physiographic expression, fossil vertebrates, stratigraphic succession, fossil molluscan faunas, morphology, continuity of buried soils, and petrographically distinctive volcanic ash.

Metz (1954, p. 32), in a petrographic study of Peoria and Loveland loesses in northern Kansas, found the most reliable single index for determining differences between Peoria and Loveland loess was the volcanic ash present in the Peoria loess.

Prevailing winds during the Pleistocene Epoch were persistant and strong. Flint (1957, p. 176) concluded this from the evidence of a higher proportion of wind-worn sand during the Pleistocene than sands of pre-Pleistocene age. Flint also felt that those prevailing winds of the Pleistocene Epoch were westerly, much like our prevailing winds of the present.

Flint (p. 180) explains the source and history of many Pleistocene dunes as follows:

> ...neither lack of vegetation nor arid climate required for the accumulation of the commonest form of dune...
>
> A sufficiently dry surface is all that is necessary. Most of the ancient dunes recorded in the literature of the Pleistocene were built in the lee of outwash bodies and other rich sources of sand. Some accumulated during deglaciation; others did not form until post-glacial dissection of the outwash had begun. Later both source and dunes became fully clothed with vegetation and dune building came to an end.

Scott <u>et al</u>. (1958, p. 136) described the deposit in their study as having "...the hummocky topographic form of dunes..." "The deposits consist of well graded loose fine sand that is composed predominantly of well rounded frosted quartz grains."

Three theories of the origin of this deposit were presented by Scott <u>et al</u>.

> ...Kansas glacial outwash that was reworked by the wind. The glacier lay only a short distance east of the dune and melt water might have brought sand from the glacier and

> deposited it on the bench. Another possibility concerns Kaw Lake, which occupied the valley of the present Big Blue River during the time the Kansas River was dammed. Melt water from the glacier may have filled the valley with outwash to a depth of 200 feet and because the dune sand lies on a high bench cut in bedrock, subsequent erosion only partly removed it while entirely removing the outwash in the valley. The most probable theory is that the sand is pre-Kansas and represents the deposit of the stream that cut the channel.

Husain (personal communication) concluded after a thorough statistical study of both dune and river sand of Hunter's Island, near Manhattan, that the only reliable parameter in his study was the variation in median grain size; the dune sand was finer than the river sand.

PROCEDURES

Field Procedure

Reconnaissance of the area was accomplished by use of aerial photos. Those photos used were ZB-5R-94, ZB-5R-95, and ZB-5R-96, of Group II, Pottawatomie County, Kansas. The photos were the property of the Geology Section of the State Highway Commission of Kansas and were flown in July of 1956. The scale of the photos was 1:20,000, and were not used in any mapping procedures.

After checking all suspected locations of sand deposition, this deposit was chosen for more thorough consideration. Other areas of suspected deposits of sand were not as extensive or as accessible for study.

Samples for study were collected by use of a bucket-type auger, a shovel, and a power auger. The bucket-type hand auger was used when the overburden was too great to dig to the desired depth. A shovel was used to construct a trench in the side of the deposit (Samples T.1-T.5) and to collect samples from near the surface. The power auger, furnished by the

State Highway Commission of Kansas, was used to collect samples from a depth greater than six feet and to collect data as to the nature of the underlying Permian limestone (Samples 2.1-4.3). Of the three methods, the shovel was the most accurate for sample collection because a true representative sample of a single lamina could be collected. The power auger was invaluable for rapid drilling and for collecting data for cross-sections, but the samples collected by using the power auger were subject to contamination due to slumping of the unconsolidated material higher in the drill hole.

Samples of clay were also collected from below the sand and from lenses in the sand, assuming a possible characteristic feature in the clay might prove diagnostic in determining the age of the sediment.

Field notes were taken and descriptions, diagrams, and sample numbers recorded. All sample locations were marked for later reference.

A contour map of the area (Plate II) was made by use of a plane table and alidade and sample locations were placed on the map. The altitude of the deposit was determined using the water level of Tuttle Creek Reservoir as a datum. The approximate boundary of the deposit was located with a small hand auger, three feet in length, at the time of mapping.

Laboratory Procedure

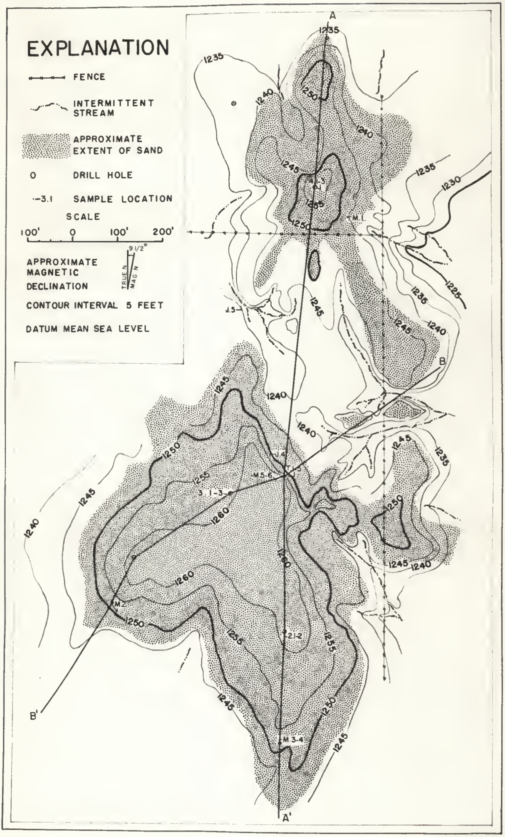
The laboratory procedure consisted primarily of size analysis, with secondary emphasis placed on mineralogical analysis and study of surface features of the sand grains.

The samples were allowed to air dry. After an adequate period of time for thorough drying had elapsed, the poorly indurated sand was disaggregated by crushing with a rubber pestle and the better indurated silt and

EXPLANATION OF PLATE II

Topographic map of study area
showing approximate extent of sand.

PLATE II


EXPLANATION
FENCE
INTERMITTENT STREAM
APPROXIMATE EXTENT OF SAND
DRILL HOLE
SAMPLE LOCATION
SCALE
100' 0 100' 200'
APPROXIMATE MAGNETIC DECLINATION
TRUE N
MAG N
CONTOUR INTERVAL 5 FEET
DATUM MEAN SEA LEVEL
A
A'
B
B'

clay by use of a wood pestle. The samples were then seived to pass through a No. 10 seive. The coarser fragments were hand-picked and placed with that portion of the sample that passed through the seive.

The samples were then split until about 100 gm. of sample was obtained. Several sand samples were carefully weighed and placed in HCl to determine the percentage of carbonate present. This procedure yielded less than .5 per cent carbonate and was discontinued.

Because several samples were so well sorted, silt and clay size analysis of these samples was not undertaken. These samples were weighed on an analytical balance and placed in a nest of nine seives, graded in intervals of .5ϕ. The sample was then shaken in a mechanical shaker for 15 minutes. The sand retained on each seive was then weighed on the analytical balance and the data recorded.

Samples containing an appreciable portion of silt- and clay-sized particles were first analyzed by the hydrometer method of Bouyoucos. The samples were dried in an oven at 105°C for 24 hours, and then a 50 gm. portion of each was placed in a 600 ml. beaker and covered with distilled water. The samples were allowed to soak and slake for 15 hours.

Each sample was then transferred to a dispersion cup and 5 ml. of 1N solution of sodium metahexaphosphate (Calgon) was added to the sample. The sample was then stirred for five minutes in a blender and poured into a 1000 ml. sedimentation tube and placed in a constant temperature bath of 68°F. The soil hydrometer was placed in the sample two hours after a final hand stirring of the sample to determine the percentage of clay in suspension in the sample.

Following the determination of clay present, the samples were wet-seived through a 230 mesh seive, discarding the clay and silt and retaining the coarser sizes for dry-seive analysis. The coarse fraction was rinsed into large watch glasses and oven dried at 85°C for 24 hours and weighed after the samples were allowed to cool to room temperature. The difference between the initial weight minus the weight of clay present plus the remaining sand equaled the weight of silt present in the sample.

W_i = initial weight
W_c = weight of clay
W_s = weight of sand
W_z = weight of silt

$$W_i-(W_c + W_s) = W_z$$

The remaining sand was then seived in the manner explained earlier.

Consultation with C. F. Crumpton, State Research Geologist for the State Highway Commission of Kansas, indicated that any clay analysis would prove unfruitful as an aid to determining the relative age of the deposit. The clay content could be safely assumed to be a mixture of montmorillonite, illite, and kaolinite.

Upon completion of the size analysis, the samples were studied for surface features of grains by use of a binocular microscope, and estimated data of degree of roundness and frosting of the individual grains were recorded.

Four of the samples that were considered representative of the sand were sorted, retaining the fraction from 1/4mm. to 1/16mm., which was placed in concentrated HCl (30%) to remove any limonite stains present. The value of 1/4mm. was set as an upper limit because of the resolving power of the petrographic microscope, and the 1/16mm. lower limit was used because of the habit of silt size particles of coagulating (Haun and Leroy, 1958, p. 104).

After having been washed and dried, the samples were weighed and transferred to funnels containing tetrabromoethane (acetylene tetrabromide), specific gravity 2.95, for mineral separation. Tetrabromoethane was used rather than bromoform because of its lower toxicity, low volatility, and relatively inoffensive odor (Collinson, 1963, p. 14).

The samples were stirred at one-half hour intervals and allowed to stand over night before the heavy fraction was removed and washed. Both the heavy and light fractions were weighed after washing to determine the percentage of heavy minerals and the percentage of sand lost.

The method of mounting the samples was basically that of Azmon (1963) and included the following steps:

1) A small area of the slide was moistened with water.
2) A split of the heavy minerals was placed in the center of the moist area.
3) A drop of water was placed in the center of the heavy minerals. The drop of water spread the minerals.
4) The slide was heated until the water had evaporated. The minerals stuck to the slide.
5) Cadex cement (Index of refraction 1.54) was placed on the heavy minerals and heated.
6) The slide was removed from the stove and allowed to cool until the Cadex became tacky.
7) The edge of a cover slip was pressed into the Cadex so that the slip hung over the mineral grains.
8) The slide was placed back on the stove and the Cadex was remelted. The slip settled over the minerals and drove any bubbles from the slide.

9) The Cadex was cooked until it hardened sufficiently upon cooling.

The slides were then studied identifying 100 mineral grains on each slide with the aid of a petrographic microscope equipped with a mechanical stage to avoid recounting the same mineral. Azmon's (Ibid.) Appendix A was used as a guide to identification of the minerals. The same process was used with the light fraction.

Fourteen 1500 gm. samples of loess were collected and inspected for paleontological remains. The samples were soaked and wet seived (No. 10 seive), but no evidence of gastropods or other useful fossils was found. A second method incorporated in this search was that one recommended by Jones (1956, p. 10) for the removal of Foraminifera from poorly consolidated mud stones. The sample was slowly boiled in a strong solution of detergent and a dispersant (Calgon). The suds were periodically skimmed from the surface and examined for gastropods. This method also proved unsuccessful.

RESULTS OF INVESTIGATION

Field Observations

The sand deposit lies unconformably upon a bench of the Florence Limestone Member of the Barneston Formation, Chase Group, Gearyan Series, Permian System.

The sand was found to be interlayered with lenses of light brown clay and silt. This interlayering was probably a result of a change in the character of the source material or a variation in the velocity of the depositing agent (Bagnold, 1937, p. 438).

The sand deposit was highly dissected by intermittant drainage completely denuding the bedrock in several locations. In those locations, a residual chert gravel in a matrix of light brown clay was observed upon the Florence Limestone Member (Fig. 2).

Fig. 2. An exposure of the residual chert gravel developed upon the Florence Limestone Member.

Small ingeous rock fragments and quartzite pebbles, well rounded by transport, were found immediately east of the original deposit and were thought to be glacial outwash deposits of Kansan age. All such occurrences were at a lower altitude and, when found near the deposit, appeared to be under the sand. However, no occurrence of the erratics was found incorporated in the sand (Fig. 3).

Immediately north of sample location 4.1-3, a large blowout has developed. This feature was approximately 13 feet deep and 90 feet wide and was entirely covered with short grass. It appeared to be an ancient feature but actually was formed in 1955 during a dry period when the area was heavily grazed by cattle (personal communication, Glenn Burwell). The large denuded area in the central region of the deposit was reported to have been deflated within the past 60 years. The sand was removed from this site and deposited in the valley immediately east of its former location (Fig. 4).

Fig. 3. Typical igneous erratic found at base of the sand deposit (pen for scale).

Other dune-type features of this area include a small vegetated blowout, 20 feet east of sample location M.3-4. This feature is four feet deep and crescentic-shaped, with the horns of the blowout pointing in a windward direction.

Fig. 4. The large denuded area in the central region of the deposit.

Although no apparent movement was taking place at the time of study, the rejuvenation of movement apparently required only a small variation in precipitation or farming practice. It can safely be assumed that movement took place between 1933 and 1937 during an extended drought (Flora, 1948, p. 78).

The loess, where exposed, exhibited the typical blocky, columnar weathering of eolian silt and clay deposit and contained many carbonate nodules to a depth of three feet.

Cross sections AA' and BB' (Plate III) illustrate that fore and lee slopes were formed by prevailing southwest winds. Although these sections indicate a prevailing wind, the present shape of the deposit can be considered Recent, because of the evidence of reworking of the deposit.

EXPLANATION OF PLATE III

Diagrammatic cross sections of the deposit.

(approximately north-south and east-west)

PLATE III

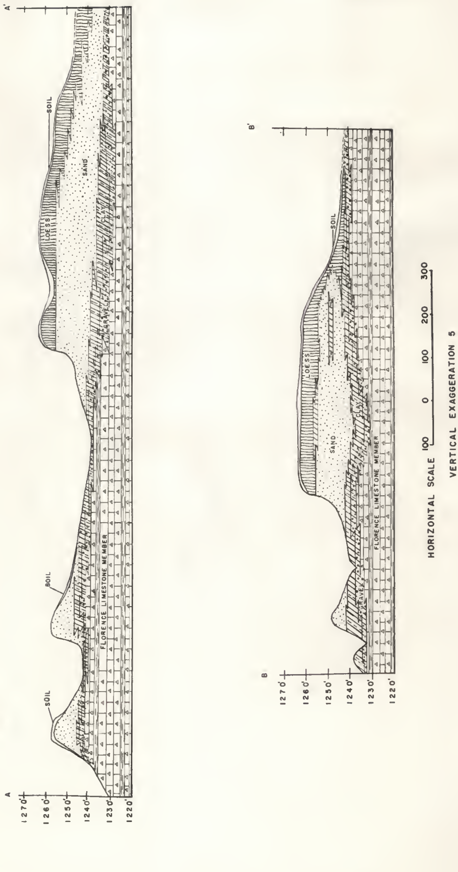

A
A'
1270'
1260'
1250'
1240'
1230'
1220'
SOIL
SOIL
SOIL
LOESS
SAND
CLAY
GRAVEL
FLORENCE LIMESTONE MEMBER
B
B'
1270'
1260'
1250'
1240'
1230'
1220'
SOIL
LOESS
SAND
CLAY
GRAVEL
FLORENCE LIMESTONE MEMBER
HORIZONTAL SCALE
100 0 100 200 300
VERTICAL EXAGGERATION 5

Fig. 5. Iron-enriched lamina found in a freshly exposed portion of the deposit (hammer for scale).

A peculiar lamination was found in the sand deposit when freshly exposed (Fig. 5 and 6). The banding in the sand consisted of layers of limonite enrichment one-quarter to one-half inch thick at two to four inch intervals. The layers were essentially horizontal but exhibited some minor crenulations. They were thought to have been formed as a percolating ground water phenomenon and as a result of a minor change in the degree of sorting in the deposit. Each lamina was enriched in silt and clay sized particles and consequently trapped a greater percentage of the limonite. Snow (1963, p. 23, 28), in a study of a sand deposit near Wamego, Pottawatomie County, Kansas, found similar banding in the SW $\frac{1}{4}$, NW $\frac{1}{4}$, NW $\frac{1}{4}$, Sec. 7, T10S, R9E. Scott et al. (1959, p. 113) described another such feature in the NW $\frac{1}{4}$, NE $\frac{1}{4}$, Sec. 25, T9S, R9E, Pottawatomie County, Kansas, and attributed it to leaching of material above the banding. These bands may be extremely low angle backset bedding as described by Smith (1940, p. 161), but no impressions of ancient plant roots were found incorporated with the bands.

Fig. 6. A close-up view of iron-enriched lamina in the deposit.

The light brown residual clay, where exposed, exhibited a blocky structure due to the contraction of the clay upon dessication. Frequently the cracks in the clay were partially filled with sand. These sand veinlets were thought to have been formed by percolating ground water and introduced from the sand directly overlying the clay.

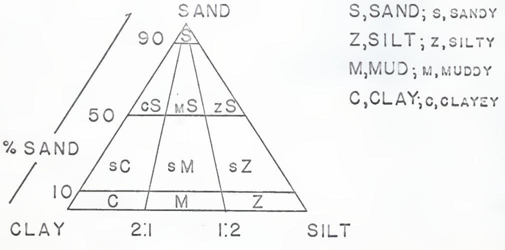
Method of Presentation of Data

The presentation of size analysis was accomplished through the use of cumulative percentages graphed on semi-log log paper as cumulative curves. Quartile measurements were determined graphically, the first quartile (Q_1) being that point of intersection of the 25 per cent line and the cumulative curve. The second quartile (Q_2) was that size associated with the intersection of the 50 per cent line and the cumulative curve and was the median grain size. The third quartile (Q_3) was the diameter determined by the intersection of the 75 per cent line and the cumulative curve. The coefficient of sorting (S_o) was established by using the formula of Trask (1930).

$$S_o = Q_3/Q_1$$

The sand portion of the deposit fell within the size range of seive analysis and all size relationships were derived for these samples. The silt-clay samples of the deposit (loess and residual clay) exhibited a size distribution that was a finer grade fraction than the capacity of the dry seive apparatus. Because of this, size analysis of the loess and residual clay samples was not displayed as cumulative curves and quartile measurements were not made.

The sediment nomenclature was determined from the clay-silt-sand percentages gained by the combined seive and sedimentation analysis. This data was applied to Folk's (1954, p. 349) triangular diagram (Fig. 7).



All colors described were determined by use of the Rock Color Chart (1951), comparisons being made with the dry sample.

Sample Description

Samples J.4-5, T.1-5 were collected by use of a shovel.

Sample J.4 was a moderate pale yellowish brown (10YR 6/4) silty sand collected from a four inch horizon in an exposure along a partially vegetated bluff. As with most of the samples collected near the surface, organic material was present and the decay of such material, along with normal decomposition of the rock, contributed to the percentage of material in the clay and silt size range. The median grain size (Q_2), determined from the cumulative curve, was .256mm. and the coefficient of sorting (S_o) was 1.41. The percentage of clay present was 2.00; silt, 10.80; and sand, 87.20.

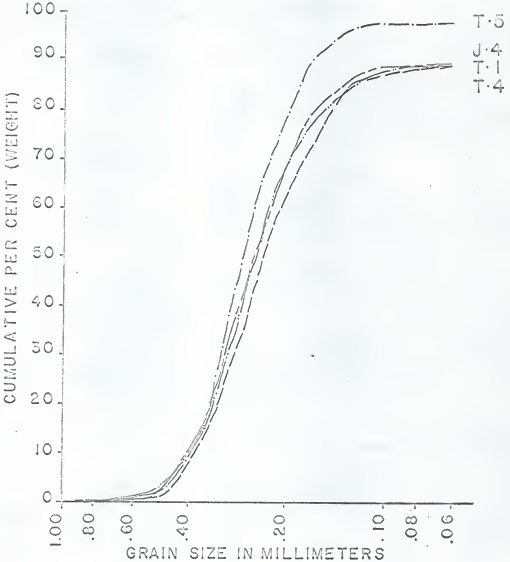
Sample J.5 was a dark yellowish orange (5YR 5/2) sandy silt collected two feet above the outcropping Florence Limestone Member and two feet below the sand. This sample had small veinlets of sand running through it that had moved down from the sand immediately above the sample and lodged in the cracks that were formed by the dessiccation of the silt. The percentage of clay present was 26.00; silt, 60.70; and sand, 13.30.

Sample T.1 was a light olive grey (5Y 6/1) silty sand collected from a two inch layer four inches below the surface. This sample was filled with root fragments and other organic remains. It was probably a Recent deposit of reworked sand from another portion of the deposit. The median grain size (Q_2) was .255mm. and the coefficient of sorting (S_o) was 1.34. The percentage of clay present was 2.50; silt, 10.52; and sand, 86.98.

EXPLANATION OF PLATE IV

Cumulative curves for samples J.4, T.1, T.4, T.5.

PLATE IV


100
90
80
70
60
50
40
30
20
10
0
CUMULATIVE PER CENT (WEIGHT)
T·5
J·4
T·1
T·4
1.00
.80
.60
.40
.20
.10
.08
.06
GRAIN SIZE IN MILLIMETERS

Sample T.2 was a dark yellowish brown (10YR 4/2) sandy silt collected from a four inch layer one foot below the surface. This sample had all indications of being a Recent buried soil and contained some carbonate nodules. Median grain size fell within the silt-clay range: the percentage of clay present was 24.00; silt, 50.96; and sand, 25.03.

Sample T.3 was a grayish orange (10YR 7/4) silt collected from a six inch horizon three feet below the surface. The sample had a blocky structure and contained many carbonate nodules. This sample was thought to be loess. The median grain size was within the silt range and the percentage of clay present was 22.00; silt, 68.22; and sand, 9.78.

Sample T.4 was a pale yellowish brown (10YR 6/2) sand collected from a six inch horizon six feet below the surface. The sample was well cemented with clay and silt particles and was more resistant than any other strata of sand encountered. Sample T.4 was the first true sand collected from the trench sequence and was unaltered by soil forming processes. The median grain size (Q_2), determined from the cumulative curve, was .240mm. and the coefficient of sorting (S_o) was 1.34. The percentage of clay present was 1.12; silt, 8.64; and sand, 90.24.

Sample T.5 was a dark yellowish orange (10YR 6/6) sand collected from a six inch horizon eight feet below the surface. The sample was poorly cemented and moist, and it exhibited limonite enriched lamina. The median grain size (Q_2) was .277mm. and the coefficient of sorting (S_o) was 1.24. The percentage of clay and silt present was 2.09, and sand, 97.91.

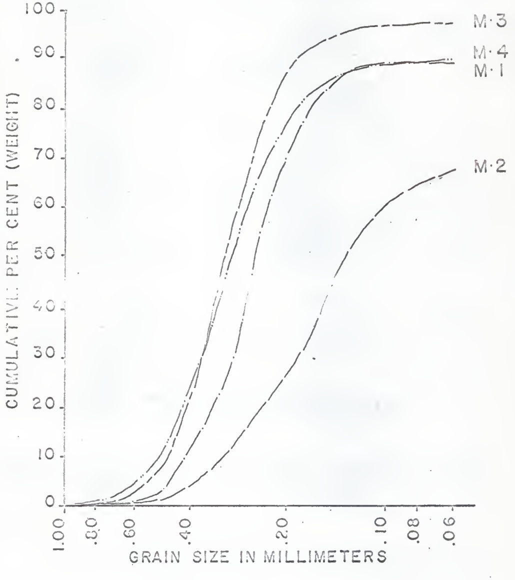
Samples M.1-M.6 were collected with a bucket-type hand auger.

Sample M.1 was a moderate dark yellowish brown (10YR 5/2) sand collected one and one-half feet below the surface. No soil was present at this

EXPLANATION OF PLATE V

Cumulative curves for samples M.1, M.2, M.3, M.4.

PLATE V



CUMULATIVE PER CENT (WEIGHT)
100
90
80
70
60
50
40
30
20
10
0
M·3
M·4
M·1
M·2
1.00
.80
.60
.40
.20
.10
.08
.06
GRAIN SIZE IN MILLIMETERS

location indicating the recency of deposition. The median grain size (Q_2) was .256mm. and the coefficient of sorting (S_o) was 1.29. The percentage of clay present in the sample was .20; silt, 9.70; and sand, 90.10.

Sample M.2 was a moderate yellowish brown (10YR 5/4) silty sand collected four and one-half feet below the surface. The sample was moderately well indurated with a clay-silt matrix and resisted disaggregation. The median grain size (Q_2) was .134mm. and the percentage of clay present was 6.20; silt, 26.41; and sand, 67.39.

Sample M.3 was collected from a depth of three feet. M.3 was a pale yellowish brown (10YR 6/2) sand with a median grain size (Q_2) of .318mm. and a coefficient of sorting (S_o) of 1.24. The percentage of clay and silt present was 2.64, and 97.36 per cent was sand.

Sample M.4 was a pale yellowish brown (10YR 6/2) sand collected one foot below M.3 (four feet down) and two feet above the residual clay-gravel bed that rests upon the Florence Limestone Member. The median grain size (Q_2) of M.4 was .300mm. and the coefficient of sorting (S_o) was 1.35. The percent of clay present was .15; silt, 9.75; and 90.10 per cent was sand.

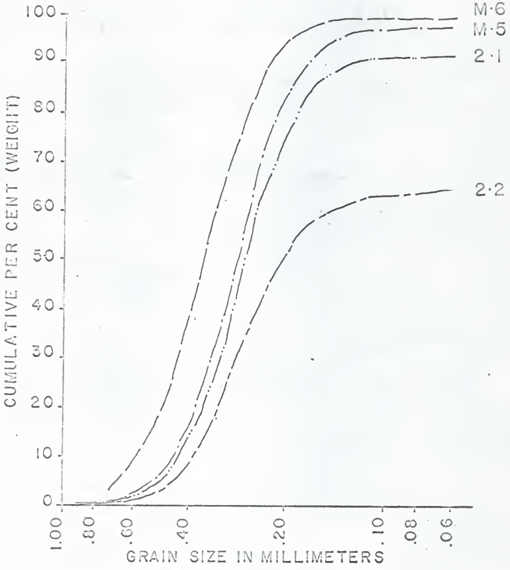
Sample M.5 was a grayish orange (10YR 7/4) sand collected 10 feet below the surface. The median grain size (Q_2), obtained from the cumulative curve, was .285mm. and the coefficient of sorting (S_o) was 1.25. The percentage of clay and silt was 1.82; sand, 98.18.

Sample M.6 was a dark yellowish orange (10YR 7/4) sand with a median grain size (Q_2) of .365 and a coefficient of sorting (S_o) of 1.27. The sample was one-half foot above the clay associated with the Florence Limestone Member and 13.5 feet below the surface. It consisted of 99.67 per cent sand and .33 per cent silt and clay.

EXPLANATION OF PLATE VI

Cumulative curves of samples M.5, M.6, 2.1, 2.2.

PLATE VI


M·6
M·5
2·1
2·2
100
90
80
70
60
50
40
30
20
10
0
CUMULATIVE PER CENT (WEIGHT)
1.00
.80
.60
.40
.20
.10
.08
.06
GRAIN SIZE IN MILLIMETERS

Samples 2.1-2.2, 3.1-3.3, 4.1-4.3 were collected by the use of a power auger, eight feet below the surface. Sample 2.1 was a grayish orange (10YR 7/4) sand collected eight feet below the surface with a median grain size (Q_2) of .275mm. and a coefficient of sorting (S_o) of 1.09. The percentage of clay and silt present was 8.36, and that of sand was 91.64.

Sample 2.2 incorporated a thin clay-silt lense in the sample. The sample was a light brown (5YR 5/6) silty sand and was taken from a depth of 13 feet. The median grain size (Q_2) was .210mm. The percentage of clay present was 7.20; silt, 27.70; and sand, 65.10.

Sample 3.1 was a light olive gray (5Y 6/1) silt collected from a depth of six feet. This sample had appeared much like T.3 in the field and was considered to be loess. The percentage of clay present in Sample 3.1 was 24.50; silt, 70.00; and sand, 5.50. These percentages corresponded favorably with those representing the composition of Sample T.3.

Sample 3.2 was a grayish orange (10YR 7/4) sand collected from 12 feet below the surface. The median grain size (Q_2), determined from the cumulative curve, was .259mm. and the coefficient of sorting (S_o) was 1.22. The percentage of clay and silt particles present was 2.40 and the balance, 97.60 per cent, was sand.

Sample 3.3 was a light brown (5YR 5/6) silty sand collected 18 feet below the surface. The median grain size (Q_2) of Sample 3.3 was .208mm. and the percentage of clay present was 6.00; silt, 25.70; and sand, 68.30.

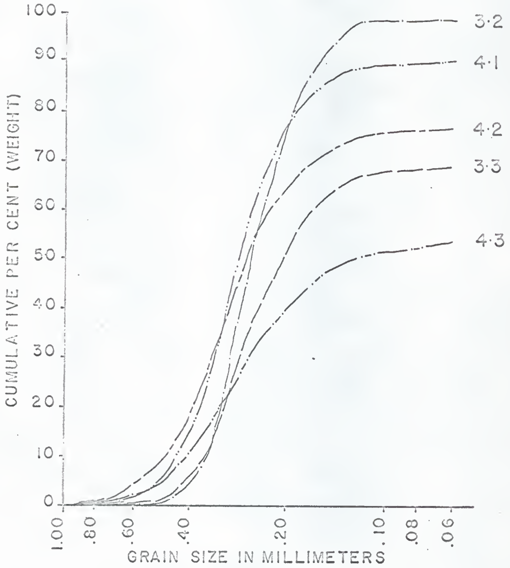
The following sequence of samples was collected with the power auger from one of the higher elevations on the deposit.

Sample 4.1, collected from three and one-half feet below the surface, was a moderately dark yellowish brown (10YR 4/3) sand with a median grain

EXPLANATION OF PLATE VII

Cumulative curves for samples 3.2, 3.3, 4.1, 4.2, 4.3.

PLATE VII


100
90
80
70
60
50
40
30
20
10
0
CUMULATIVE PER CENT (WEIGHT)
3·2
4·1
4·2
3·3
4·3
1.00
.80
.60
.40
.20
.10
.08
.06
GRAIN SIZE IN MILLIMETERS

size (Q_2) of .289mm. and a coefficient of sorting (S_o) of 1.30. The percentage of clay present was .20; silt, 9.14; and sand, 90.66.

Sample 4.2 was sampled eight feet below the surface and was a light brown (5YR 5/6) silty sand. The median grain size (Q_2) was .270mm. and the coefficient of sorting (S_o) was 1.76. The percentage of clay present was 5.20; silt, 16.20; and sand, 78.60.

Sample 4.3, collected eleven feet below the surface, was a light brown (5YR 5/6) sandy silt. The median grain size (Q_2) was .140mm. and the percentage of clay present was 13.20, while the balance of the sample consisted of 40.90 per cent silt and 45.90 per cent sand.

Heavy Mineral Analysis

The percentage by weight of heavy minerals (specific gravity greater than 2.95) present in the samples selected for heavy mineral analysis averaged less than one per cent (.81 per cent).

Table 1. Percentage by weight of heavy minerals in four samples.

Sample number	Percentage by weight of heavy mineral
4.1	1.09
M.6	.78
T.4	.60
T.5	.82

The percentage count of heavy minerals identified on each slide is shown in Table 2. Biotite and muscovite are probably anonymously low due to higher specific gravity of the liquid used (tetrabromoform 2.95; bromoform 2.89). The specific gravity of biotite ranges from 2.8 to 3.2, and muscovite from 2.76 to 3.10 (Hurlbut, p. 519, 526). This range in specific gravity as well as the erratic settling properties of the flakey minerals would appear to make any correlation using micas in a heavy mineral separation subject to careful examination (Folk, 1959, p. 94; Metz, 1954, p. 33).

Table 2. Percentage distribution of heavy minerals present in four samples.

Mineral	Sample number			
	4.1	M.6	T.4	T.5
Hornblende	27	26	42	23
Basaltic hornblende	2	3	2	1
Garnet	10	16	12	12
Tourmaline	4	4	3	2
Epidote	12	9	8	9
Muscovite	1	-	-	-
Biotite	-	-	2	2
Apatite	1	-	-	2
Zircon	6	10	6	9
Magnetite (Ilmenite)	35	30	21	36
Staurolite	1	-	1	2
Enstatite	2	2	1	2
Sphene	-	-	1	-

Of the heavy minerals present in these four samples, the average percentage of hornblende was 29.50; basaltic hornblende, 2.00; garnet, 12.50; tournaline, 3.25; epidote, 9.50; muscovite, .25; biotite, 1.00; apatite, .75; zircon, 7.75; magnetite (ilmenite), 30.50; staurolite, 1.00; enstatite, 1.50; and sphene, .25.

The dominance of hornblende, garnet, epidote, and magnetite (ilmenite) is consistant for all four samples studied. Hornblende and epidote were the most angular (sub-rounded to angular) of the dominant heavy minerals. This angularity can be attributed to the cleavage present in both minerals. Some of the garnet exhibited fresh fractured surfaces, but this was exceptional.

Those grains too thick or too heavily coated with limonite stains were not counted. Tourmaline overgrowths that were found were small, clear, and colorless. These overgrowths were not counted as separate grains. The overgrowths were frequently attached to those minerals too thick to be identified or those coated with limonite stain. Krynine (1946) considers these overgrowths to be secondary and formed incorporating the boron available in the ground water.

Zircon, apatite, and sphene were the only minerals that exhibited euhedral crystal outline.

Because of the dominance of the relatively unstable minerals hornblende, epidote, and garnet, it was concluded that the source material for the deposit had not been exposed to weathering action for an extended period of time.

The enrichment of opaques in the deposit correlated well with the analysis given by Lill (1946) of a glacial-fluviatile terrace in Washington and Marshall Counties, to the north of the study area. Holcomb (1957) and Seiler (1951) also show an increase in the percentage of garnet and magnetite (ilmenite) present in glacially derived sediments when compared to sediments derived from the mantle rock in the Manhattan area.

The light fraction (specific gravity less than 2.95) of the mineral analysis showed a marked predominance of quartz (Table 3).

Table 3. Percentage distribution of light minerals present in four samples.

Mineral	Sample number			
	4.1	M.6	T.4	T.5
Quartz	83	79	86	86
Orthoclase	7	9	6	8

Table 3 (concl.)

Mineral	Sample number			
	4.1	M.6	T.4	T.5
Microcline	3	7	1	1
Plagioclase	2	3	2	2
Chert	5	2	5	3

The average percentage of quartz present in the samples was 83.50; orthoclase, 8.00; microcline, 3.00; plagioclase, 2.25; and chert, 3.75. The predominance of quartz and marked deficiency of chert indicates a source other than the cherty mantle rock of the area. The quartz grains were generally rounded to well rounded and frequently exhibited many inclusions. Orthoclase and plagioclase were the most angular of the light minerals and they were sub-angular to sub-rounded.

Studies by Holcomb (1957), Seiler (1951), and Harned (1940), of material more distant from the edge of glacial advance, all indicate a marked increase in the percentage of chert present in the sediments.

Summary and Conclusions

1) The sand grains are well frosted above the .125mm size and, according to Twenhofel (1945, p. 67), eolian traction transportation can produce frosted grains. Although some of each sample was unfrosted, the unfrosted grades were, almost without exception, in the very fine sand range (.125-.061mm). This can be expected and, according to Bagnold (1949, p. 12), finer grains seldom collide with an obstruction but conform to air currents. This conformity of the sand grains to the air currents is the cause of the greater angularity and lower degree of frosting found in the finer (less than .125mm) range.

2) The degree of roundness of the sand grains is well rounded for the coarser fraction (more than .246mm), with a gradational change to subangular to angular in the finer fraction (.125-.061mm). The median grain size (Q_2) for all sand samples exhibited a degree of roundness ranging from rounded to well rounded.

3) The coefficient of sorting (S_o) of the sand samples ranged from 1.02 to 1.76 with an average of 1.39, easily within Trask's (1930) "well sorted" verbal classification. The median grain size (Q_2) of the sand samples ranged from .140mm to .365mm with an average of .255mm. The coefficient of sorting and median grain size were affected somewhat by natural soil formation processes and the infiltration of silt and clay size particles from dust falls. Sampling methods probably induced some error, particularly to those samples collected with the power auger.

4) The silt and clay samples contributed little to the determination of the period of deposition. No fossil gastropods were found after a thorough search and individual samples inspected for volcanic ash shards

yielded only sporadic occurences of glass fragments. The carbonate nodules present in the upper portion of the loess could not be used for age correlation because of the variables of climate, vegetation, topography, primary carbonate and the position of the water table (Flint, 1949, pp. 298-300).

5) The heavy mineral analysis yielded data indicating a glacial source for the sand deposit. The enrichment of magnetite (ilmenite) (30 per cent) and garnet (12.5 per cent) correlated with other studies of glacially derived sediments in the Manhattan area (Lill, 1946; Holcomb, 1957; Seiler, 1951). The light fraction yielded a very low concentration of chert (3.75 per cent). Harned (1940), Seiler (1951), Holcomb (1957), an d Husain (1964) also found this deficiency in glacially derived sediments.

6) It is concluded that the source for this sand in this deposit is the Big Blue River and the period of deposition was late Kansas or early Yarmouth. The erratic gravel found at the base of the deposit is Kansan outwash gravel: the Kansan ice sheet was the only possible source for the gravel. Frye and Leonard (1952, p. 192) indicate that the Big Blue River was formed in the late stages of the Kansan glacial retreat by the abandonment of spillways across Republic and Washington Counties, Kansas, north of the sand deposit. In that prevailing winds were from the west at the time of deposition, the only possible source was the Big Blue River outwash plain. The tremendous stream load carried by the Big Blue River at the time of glacial retreat most probably clogged the valley with sediments, forming a braided outwash plain of some areal extent. The deposit is probably a border or river bed dune (Lobeck, 1939, p. 385), the source being the braided outwash plain developed following the retreat of the Kansan ice sheet.

Acknowledgements

The author wishes to acknowledge Dr. Henry V. Beck, supervisor of the study, for his guidance and counsel throughout the preparation of this paper.

Special thanks go to C. F. Crumpton, Research Geologist, and Wallace K. Taylor, Regional Geologist, both of the Kansas State Highway Commission. Their aid in grain size analysis by sedimentation methods and collection of field data by use of the power auger was invaluable.

Also acknowledged are Darrell Huber and Gary Herren, fellow graduate students, for their help in constructing the topographic map.

Mr. Richard A. Hooker, The Pure Oil Company, deserves mention for his patience and aid, without which this paper would not have been possible.

Added thanks go to the author's wife Donna for her patience and understanding throughout the period of this study and for her typing and proofreading of the manuscript.

References

Azmon, Emanuel. (1963), Heavy minerals in sediments of southern California. Ann Arbor, Michigan: University Microfilms, 145 pp.

Bagnold, R. A. (1937), The transport of sand by wind. Geog. Four., V. 89, pp. 409-438.

_________. (1941), The physics of blown sand and desert dunes. London: Methuen and Co., 265 pp.

Beck, H. V. (1949), The Quaternary geology of Riley County, Kansas. Unpublished M. S. thesis, Kansas State College of Agriculture and Applied Sciences, Manhattan, Kansas, 70 pp.

Bouyoucos, G. J. (1930), Comparison of the hydrometer method and the pipette method for making mechanical analysis of soils, with new directions. Am. Soc. Agron. Jour., V. 22, pp. 747-751.

Climatological data - Kansas, annual summary. (1950), U. S. Dept. of Commerce, Luther H. Hodges, Sec., Weather Bureau, F. W. Reichelderfer, Chief. 1950-51, 1958-59, 1961-63.

Collinson, Charles. (1963), Collection and preparation of conodonts through mass production techniques. Ill. State Geol. Survey circ. 343, 16 pp.

Davis, Stanley N. (1951), Studies of Pleistocene gravel lithologies in northeastern Kansas. Kansas Geol. Survey Bull. 90, pt. 7, pp. 173-192.

Doeglas, D. J. (1946), Interpretation of results of mechanical analysis. Jour. Sed. Petrology, V. 16, pp. 19-40.

Fenneman, Nevin M. (1938), Physiography of eastern United States. New York: McGraw-Hill Book Co., 714 pp.

Flint, R. F. (1949), Leaching of carbonates in glacial drift and loess as a basis for age correlation. Jour. Geol., V. 57, No. 3, pp. 297-303.

_________. (1957), Glacial and Pleistocene geology. New York: John Wiley & Sons, 553 pp.

Flora, S. D. (1948), Climate of Kansas. Rept. of Kansas State Board of Agri., V. 57, No. 285, pp.

Folk, Robert L. (1961), Petrology of sedimentary rocks, Austin, Texas: Hemphill's, 154 pp.

Frye, John C. (1946), Review of studies of Pleistocene deposits in Kansas. Am. Jour. Sco., V. 244, No. 6, pp. 403-416.

Frye, John C., Ada Swineford, and A. Byron Leonard. (1948), Correlation of Pleistocene deposits of the central Great Plains with the glacial section. Jour. Geol., V. 56, pp. 501-525.

________ and Ada Swineford. (1949), The plains border physiographic province. Kansas Acad. Sci. Transactions, V. 52, No. 1, pp. 71-81.

________ and A. Byron Leonard. (1949), Pleistocene stratigraphic sequence in northeastern Kansas. Am. Jour. Sci., V. 247, No. 12, pp. 883-899.

________________. (1952), Pleistocene geology of Kansas. Kansas Geol. Survey Bull. 99, 230 pp.

Harned, Charles H. (1940), The mineralogy and mechanical analysis of the mantle rock in the Manhattan area. Unpublished M. S. thesis, Kansas State College of Agriculture and Applied Science, Manhattan, Kansas, 119 pp.

Haun, John D. and L. W. LeRoy. (1958), Subsurface geology in petroleum exploration. Golden, Colorado: Colorado School of Mines, 887 pp.

Hay, Robert. (1892), Some characteristics of the glaciated area of northeastern Kansas. Kansas Acad. Sci. Trans., V. 13, pp. 104-106.

Holcombe, Walter B. (1957), Petrology of the 1951 Kaw River flood deposits between Ogden and Manhattan, Kansas. Unpublished M. S. thesis, Kansas State College of Agriculture and Applied Science, 75 pp.

Hurlbut, Cornelius S., Jr. (1952), Dana's manual of mineralogy, 16th edition. New York: John Wiley and Sons, 530 pp.

Husain, Athar. (1964), Differentiation between river and dune sand, Hunter's Island and vicinity, Riley County, Kansas. Unpublished M. S. thesis, Kansas State University, Manhattan, Kansas, 114 pp.

Keller, W. D. (1945), Size distribution of sand in some dunes, beaches and sandstones. Am. Assoc. Petroleum Geologists Bull., V. 29, Pt. 1, pp. 215-221.

________ and F. J. Pettijohn. (1938), Manual of sedimentary petrography. New York: D. Appleton-Century Company, 549 pp.

________ and L. L. Sloss. (1959), Stratigraphy and sedimentation. San Francisco: W. H. Freeman and Company, 497 pp.

Krynine, P. D. (1946), The tourmaline group in sediments. Jour Geol., V. 54, pp. 65-87.

Lill, Gordon Grigsby. (1946), A glacio-fluvial terrace in Marshall and Washington Counties, Kansas. Unpublished M. S. thesis, Kansas State College of Agriculture and Applied Science, Manhattan, Kansas, 84 pp.

Lobeck, Armin K. (1939), Geomorphology. New York: McGraw-Hill Book Company, 731 pp.

Metz, Harold Lloyd. (1954), A petrographic comparison of the loveland and peoria loesses of northern Kansas. Unpublished M. S. thesis, Kansas State College of Agriculture and Applied Science, Manhattan, Kansas, 45 pp.

Milner, Henry B. (1962), Sedimentary petrography. New York: Macmillan Company, V. 1, 643 pp.

Mudge, Melville R. (1955), Early Pleistocene geomorphic history of Wabaunsee, southeastern Riley, and southern Pottawatomie Counties, Kansas. Kansas Acad. Sci., V. 58, No. 2, pp. 271-281.

O'Connor, H. G. (1963), Changes in Kansas stratigraphic nomenclature. Am. Assoc. Petroleum Geologists Bull., V. 147, No. 10, pp. 1873-1877.

Pettijohn, F. J. (1941), Persistance of heavy minerals and geologic age. Jour. Geol., V. 49, pp. 610-625.

_________. (1957), Sedimentary rocks. New York: Harper and Brothers, 718 pp.

Rock Color Chart. (1951), New York: Geological Society of America.

Schoewe, W. H. (1930), Evidences for the relocation of the drift border in eastern Kansas. Jour. Geol., V. 38, No. 1, pp. 67-74.

_________. (1939), Evidences for the relocation of west drift border in eastern Kansas. Kansas Acad. Sci. Trans., V. 42, p. 367.

_________. (1930), Glacial erratics in Shawnee, Douglas, and Johnson Counties, Kansas. Kansas Acad. Sci. Trans., V. 31, pp. 106-109.

Scott, Glenn R., Frank W. Foster, and Carl F. Crumpton. (1958), Geology and construction materials of Pottawatomie County, Kansas. U. S. Geological Survey Bull. 1060-C. Washington, D. C.: Government Printing Office, 178 pp.

Seiler, C. D. (1951), Correlation of alluvial lenses along the Kansas River between Topeka and Ogden, Kansas. Unpublished M. S. thesis, Kansas State College of Agriculture and Applied Sciences, Manhattan, Kansas, 109 pp.

Smith, H. T. U. (1940), Geologic studies in southwestern Kansas. Kansas Geol. Survey Bull. 34, 212 pp.

Smyth, B. B. (1896), Buried moraine of the Shunganunga. Kansas Acad. Sci. Trans., V. 15, pp. 95-104.

Snow, Dale Loren. (1963), Study of the "sand" deposit between Manhattan and Wamego, Kansas. Unpublished M. S. thesis, Kansas State University, Manhattan, Kansas, 66 pp.

Thornbury, W. D. (1954), Principles of Geomorphology. New York: John Wiley and Sons, 618 pp.

Todd, J. E. (1916), Kansas during the ice age. Kansas Acad. Sci. Trans., V. 28, pp. 33-47.

________. (1916), History of Kaw Lake. Kansas Acad. Sci. Trans., V. 28, pp. 187-199.

Trask, P. D. (1930), Mechanical analysis of sediments by centrifuge. Econ. Geology, V. 25, pp. 581-599.

Trewartha, Glenn T. (1954), An introduction to climate. New York: McGraw-Hill Book Company, 402 pp.

Twenhofel, W. H. (1945), The rounding of sand grains. Jour. Sed. Petrology, V. 15, No. 2, pp. 59-71.

________ and S. A. Tyler. (1941), Methods of study of sediments. New York: McGraw-Hill Book Company, 183 pp.

von Engeln, Oscar D. (1942), Geomorphology. New York: Macmillan Company, 655 pp.

Woo, C. C. (1964), A new technique for petrographic analysis. Am. Mineralogist, V. 49, pp. 116-126.

Appendix. Collected weights of samples studied.

	Diameter in millimeters.										
	.991	.701	.495	.351	.246	.175	.125	.088	.061	silt	clay
Sample number	Weight retained in grams.										
J.4	.000	.037	1.137	8.115	18.027	10.413	4.622	.949	.300	4.142	1.000
J.5	.060	.130	.467	.807	1.042	.904	1.196	.924	1.120	30.350	13.000
T.1	.047	.136	1.584	7.316	16.251	11.283	4.010	1.814	.234	5.260	14.250
T.2	.008	.034	.176	1.405	4.425	4.135	1.811	.334	.168	25.480	12.000
T.3	.007	.022	.276	1.002	1.821	1.008	.341	.092	.164	34.110	11.000
T.4	.022	.074	1.294	7.035	15.420	12.563	6.808	1.441	.434	4.390	.560
T.5	.000	.049	1.941	8.654	22.241	11.816	3.762	.370	.106	----	----
M.1	.010	.138	1.870	7.503	18.591	12.021	4.311	.485	.119	4.850	.100
M.2	.058	.080	.722	2.840	6.115	7.023	9.406	5.156	2.290	13.210	3.100
M.3	.017	.387	4.324	14.186	19.089	8.042	2.354	.231	.050	----	----
M.4	.149	.656	4.332	11.944	16.728	7.597	2.848	.506	.280	4.870	.070
M.5	.000	.262	2.691	11.961	20.167	10.191	3.356	.374	.088	----	----
M.6	.000	1.417	7.933	18.010	16.209	5.201	1.011	.042	.012	--.165--	
2.1	.040	.171	1.957	8.883	20.832	10.417	3.030	.352	.140	7.160	1.200
2.2	.046	.113	1.393	6.323	12.820	7.552	3.098	.699	.506	13.850	3.600

Appendix. Collected weights of samples studied. (Conclu.)

	Diameter in millimeters.										
	.991	.701	.495	.351	.246	.175	.125	.088	.061	silt	clay
Sample number	Weight retained in grams.										
3.1	.040	.022	.056	.403	1.245	.780	.103	.068	.033	35.000	12.120
3.2	.000	.004	.103	5.092	22.087	15.687	5.335	.419	.073	--1.200--	
3.3	034	.066	.705	4.614	13.226	9.611	4.467	.921	.506	12.850	3.000
4.1	.028	.183	2.602	10.716	18.977	9.650	2.698	.349	.127	4.570	.100
4.2	052	.527	3.984	9.916	13.805	6.943	2.932	.693	.448	8.100	2.600
4.3	23	.438	1.002	4.220	7.460	4.507	2.923	1.173	.804	20.450	6.600