A GLACIO-FLUVIAL TERRACE IN MARSHALL AND WASHINGTON COUNTIES, KANSAS

by

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INTRODUCTION

The Pleistocene glacial deposits of Northeastern Kansas have received much attention in general, with the exception of detailed work upon the glacio-fluvial deposits which occur usually along the stream valley walls of that area.

It is the purpose of this work to describe in as much detail as possible, one such deposit placing particular emphasis upon the mineralogical relationships encountered as an aid in fixing the age of the sediments, with attention being focused secondarily upon the geomorphology, areal extent, and geologic relation of the deposit to the strata and topography of the surrounding area.

The material for the research conducted consisted of "spot" samples of the sediments involved, especially collected with the end view of showing particular mineralogical associations, and sedimentary relationships.

Aerial photographs of the region were furnished by the personnel of the Agricultural Conservation Association offices of Marshall and Washington counties. These photographs were used in mapping the deposit, see Plate III, and were found to be essential in working out its various ramifications since the restrictions of time and personnel were not conducive toward making a detailed topographic survey of the area by means of the plane table and alidade.

The excellent equipment made available by the Kansas

State Highway Department's Geologic Research Laboratory, recently established at the College, made possible the analyses of the clay minerals that are presented in this report.

Field Methods

Field work was accomplished by automobile, and consisted primarily of reconnaissance, the collection of samples, and the taking of field notes. During this period several sections of the glacio-fluvial terrace were measured, its extent and method of deposition noted, and its relation to the underlying Permian strata fixed. Topographic photographs were taken at this time in order that the most important of the features of the deposit could be revealed to greater advantage.

Laboratory Procedure

The laboratory research accomplished was threefold; consisting of a mechanical analysis, mineralogical analysis, and clay analysis of the samples collected.

Mechanical Analysis. The mechanical analysis was accomplished by means of Bouyoucos sedimentation tubes (1), and Tyler graded sizing screens.

The samples were first thoroughly mixed and quartered in the Jones-Riffle sampler. Fifty grams from one of the quarters of each of the samples was then weighed out on the analytical balance and placed in dispersion bottles. To each of the fifty gram samples in the bottles was added 20 cc. of a 2.5% solution of sodium silicate, a dispersion agent. The remainder of each bottle was filled with distilled water.

The average dispersal time for the samples was approximately five hours, although some of the clay samples were shaken for as long as ten hours before a complete dispersal was obtained.

Upon completion of the dispersion, the samples were placed in the sedimentation tubes and hydrometer readings were taken at the proper intervals for obtaining the size frequency distribution presented in the histograms.

The samples were then carefully washed through the 250 mesh screen, the clay fraction being saved for future analysis, dried, and again sized through a series of Tyler graded screens to obtain the size frequency distribution of the larger particles. Each fraction obtained by this screening was weighed on the analytical balance, and filed for future reference.

Mineral Analysis. This was accomplished by preparing permanent slides, mounted in Canada Balsam, of the 1/16 mm. fraction obtained from the mechanical analysis.

The heavy fraction of minerals was separated from the light by means of suspending the sample in bromoform and drawing off the heavy minerals that descended to the bottom of the separation funnel. These two fractions were washed in ethyl alcohol to remove all excess bromoform, but none of the samples were treated with hydrochloric acid since the removal of limonite and hematite stains was not found necessary. The samples were again dried and the slides prepared.

After the prepared slides had dried sufficiently to permit examination, they were placed under the polarizing microscope and a percentage mineral analysis was made by counting each grain that touched the cross hairs of the microscope as the slide was moved across the field of view. In every case a complete coverage of each slide was made, but the total number of grains counted in each instance was not the same. Enough grains were counted, about 200 per slide, however, to allow an accurate percentage analysis to be made.

Clay Mineral Analysis. The identification of the clay minerals was accomplished by determining the refractive index under the petrographic microscope, by thermal dehydration, and by thermal analysis.

Thermal dehydration was carried out by mounting an analytical balance over an automatically controlled, vertical, combustion furnace. The method used in this analysis was taken from Nutting (2), who has shown that the dehydration properties of clays bear a definite relationship to their identity.

As practiced by Nutting, this method requires that the clay, which has been suspended in the furnace from one arm of the analytical balance, be weighed periodically at 50 degree temperature intervals until the clay has reached a constant weight at each temperature.

Inasmuch as time would not permit such procedure, experiments were conducted in which samples were weighed at 100 degree Centigrade intervals over 12, 3, and 1 hour periods. It was discovered by this experimentation that no alarming variations were introduced into the weights obtained. As a result, it was decided to weigh the clays at 1 hour periods, with temperature intervals of 100 degrees Centigrade. Weights were taken up to and including a temperature of 700 degrees, for as shown by Nutting, no essential variations in weight occur after that temperature has been reached. For this reason, the weight of the sample at 700 degrees was taken as the base weight, rather than the weight at room temperature, where weights of clays are subject to great variation with both temperature and humidity.

A thermal analysis of the clays was conducted for the purpose of obtaining additional information for use in identifying the clay minerals. A chemical analysis of the clays as such, was not made. The form of the thermal curve alone was used as an aid in identification.

For the identification, a Leeds and Northrup Automatic Recording Micromax was used, see Plates I and II. This

EXPLANATION OF PLATE I

Photograph of Leeds and Northrup Automatic Recording Micromax

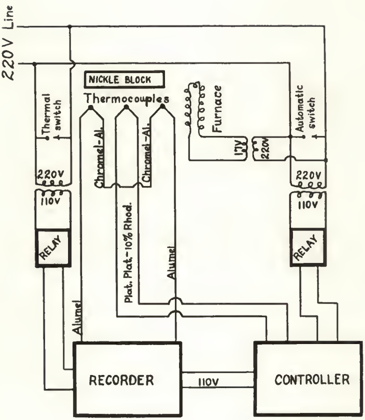
1. Recorder
2. Controller
3. M. E. C. Unit
4. Recorder Switch
5. Controller Switch
6. Controller Switch

PLATE I

EXPLANATION OF PLATE II

Schematic drawing of Micromax and Combustion Furnace

Plate II



220V Line
NICKLE BLOCK
Thermocouples
Thermal switch
Furnace
Automatic switch
Chromel-Al.
Chromel-Al.
17V
220V
220V
110V
220V
110V
RELAY
RELAY
Plat. Plat.-10% Rhod.
Alumel
Alumel
RECORDER
110V
CONTROLLER

machine required essentially the same procedure as that employed by Speil, Berkelhamer, Pask, and Davies (3) in which a prepared sample of the material to be analyzed was placed in one cup of a nickel block with a standard sample of calcined alumina being placed in the other. Differential thermocouples of chromel-alumel were then inserted in the two samples, while a third thermocouple of platinum-platinum 10% rhodium was inserted into the nickel block. The results of the temperature variations in the samplo were picked up by its thermocouple and recorded automatically as a continuous graph.

The essential differences between the Micromax and the equipment employed by the above referenced workers are: (a) the Micromax contains a built in "cold junction" thus obviating the necessity of using an ice pack for maintaining a constant external temperature between the thermocouples; (b) the Micromax incorporates a temperature controller, as well as a recorder, by means of which the rate of temperature increases up to and including 1,000 degrees Centigrade per hour, is automatically controlled by presetting. This feature also introduces a means for allowing the material being tested to remain at any one temperature for lengths of time up to and including several hours, and for varying the final heating rate after the "soak" time has been completed; and (c) the recorder has incorporated a device which allows the installation of either chromel-alumel, or platinum-platinum 10% rhodium differential thermocouples as desired.

In the thermal analysis curves shown as Figs. 31, 32, and 33, the downward deflections of the curve indicate endothermic reactions within the sample. (A lower temperature having occurred in the sample than in the standard alumina.) Upward deflections are exothermic and are caused by a higher temperature being reached in the sample than in the standard alumina with which it is compared by the two thermocouples.

It is possible to obtain a quantitative analysis of the material tested by employing the method of thermal analysis. For the purposes required here, the form of the curves obtained was sufficient for obtaining a fairly accurate identification of the clays, therefore the quantitative analysis was not undertaken.

Review of the Literature

In accordance with the current United States Geological Survey's classification, as taken from Thwaites (4), the glacial stages of the United States have been fixed as follows:

Epoch	Stage	
Recent	Wisconsin	Later Mankato, or late Wisconsin (5th Wisconsin). Early Mankato, or late Wisconsin (4th Wisconsin). Cary, or Middle Wisconsin (3rd Wisconsin). Tazewell, or Early Wisconsin (2nd Wisconsin). Iowan (1st Wisconsin).
. . .	. . .	. . . .
	Sangamon	Interglacial interval
	Illinoian	
Pleistocene	Yarmouth	Interglacial interval
	Kansan	
	Aftonian	Interglacial interval
	Nebraskan	

Of the above, it is generally conceded by most authorities that the only glacial ice to reach the state of Kansas was that which moved down during the Kansan, and possibly the Nebraskan, stage.

Proof that glacial ice actually reached as far south as Kansas is furnished by many observations that have been made during the past fifty or sixty years. Chief among the observers were Hay (5) who recognized clearly the true existence of morainic deposits, and who cites one in particular to the west of the Little Blue River, in Washington county, where glacial erratic boulders (not a very extensive deposit) rest upon the Dakota Sandstone; Todd (6) who has also recognized the existence of glacial deposits in the State, but has stated that true moraines do not exist in this area but that deposits, sometimes mistaken for moraines, really owe their origin to stream deposition as indicated by the drainage lines of the region; Schoewe (7) who has recognized the existence of glacial drift in Kansas and has accomplished much toward fixing the true border of the maximum extent of the "drift" in the State. In this work, he has fixed the western border of the drift in Kansas as running from Wamego north and west to Randolph, thence north and west to Washington, and from there northeast and north to the state of Nebraska. This boundary includes all of the Blue and Little Blue River valleys, with the exception of the lower end of the Big Blue from Randolph south to Manhattan.

Schoewe (8) has also contributed other reports which have gone far toward describing and classifying the glacial drift and other deposits of the State. According to him, the present topography of the area is largely bedrock controlled except along the Missouri River, which indicates that the drift deposits are not of enough significance to have affected the topography to any extent. The thickness of the drift has been placed by Schoewe as varying between 30 to 100 feet in Central and Northeastern Kansas to less than five feet at the borders of the glaciated area.

There are, again according to Schoewe (9), evidences of ice invasion to the south of the Kansas River. He discovered an exposure of glacial till at the Haskell Institute near the southern city limits of Lawrence, and another deposit 3/4 of a mile south and one mile east of the Haskell location in the northeast corner of NE 1/4, S17, T13S, R20E.

The southern border of the glacial drift in Kansas has been placed as follows: From Wabaunsee trending southeast almost to Alma, southeast to Douglas, east to Wakarusa, east by southeast to Vinland, and northeast to Kansas City. This takes the southern border of the maximum extent of the ice through Wabaunsee, Shawnee, Osage, Douglas, Johnson and Wyandotte counties.

Other positive evidences of the one time presence of glacial ice in Kansas consist of a buried moraine described by Smyth (10) along Shunganunga Creek in Shawnee county, and the existence of numerous glacial striae and grooves listed by Schoewe (11) as being located in Brown, Doniphan, Douglas, Leavenworth, Nemaha, and Wyandotte counties.

The existence of glacial lakes in Kansas has been pointed out by Smyth who lists the following lakes with some indication as to their maximum extent: Wakarusa Lake, which stretched from Richland to Auburn with a width of 3/4 of a mile; Mission Creek Lake, which existed in Wabaunsee county with a maximum extent of 15 miles; Mill Creek Lake, stretching from Maple Hill to Alma and then south for approximately seven miles; and Kaw Lake, the largest of them all, which filled the Kansas River Valley from Wabaunsee west to Manhattan, up the Smokey Hill River as far as Salina, and up the Big Blue River almost to Blue Rapids.

Todd (12) has indicated, upon rather incomplete evidence, that another lake, Lake Washington, was formed in Washington county by the ice shutting off the Big Blue River at Irving. He uses this mechanism to explain the distribution of glacial erratics west of the Little Blue River in Washington county. In connection with his remarks upon the existence of this lake, Todd has also stated:

> The culmination of Kansas stage did not last very long. The ice was not stationary long enough to form a moraine, and the till deposited was very thin.

Todd places the thickness of the ice in Northeastern Kansas at between 3,375 and 5,600 feet.

Flint (13) has covered the maximum extent of the glacial ice in Kansas with his recent glacial map of North America. On this map the general boundaries of the ice, as outlined above, were adhered to very closely considering the larger scale required in making a glacial map of the United States.

Concerning the drift gravels found in Kansas, Schoewe has stated that:

> The common drift gravels are composed entirely of northern erratics, and undoubtedly are outwash deposits some of which were formed while the glacier was advancing and others while it retreated. In some instances, as east of Seneca, in Nemaha county, these gravels represent delta deposits laid down in ponded rivers.

From the foregoing, it has been indicated that there is some evidence in Kansas for the existence of moraines, and glacial outwash deposits, with positive proof of the existence of glacial till. There has also been given some indication of the presence of glacial lakes formed by the stoppage of normal stream drainage by the encroachment of the ice.

DESCRIPTION OF THE TERRACE

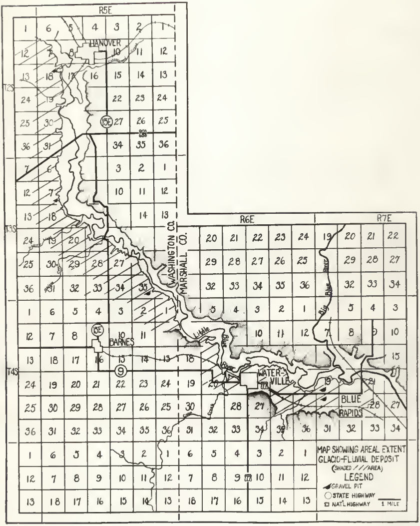
General. The region surrounding the terrace lies in Marshall and Washington counties, principally along the Little Blue River on the south and west sides, and extends from just to the east of Blue Rapids, where the main part of the terrace begins, to a few miles north of Hanover in Washington county, see Plate III.

The area has reached early maturity in the fluvial cycle

EXPLANATION OF PLATE III

Section Line Map Showing Areal Extent of Glacio-Fluvial Deposit in Marshall and Washington counties, Kansas.

PLATE III


R5E
R6E
R7E
T2S
T3S
T4S
HANOVER
BARNES
WATER-VILLE
BLUE RAPIDS
WASHINGTON CO.
MARSHALL CO.
Little Blue River
Big Blue River
MAP SHOWING AREAL EXTENT GLACIO-FLUVIAL DEPOSIT
(SHADED ///AREA)
LEGEND
GRAVEL PIT
STATE HIGHWAY
NAT'L HIGHWAY
1 MILE

of erosion, as evidenced by the wide floodplains, and numerous meanders of the streams comprising the chief drainage system of the region; the well developed dendritic drainage pattern, accompanied by paired terraces, that is invariably found in localities which are capped entirely by sedimentary rocks once the region has arrived at the stage of maturity.

The largest part of the area, to the north and south of the Little Blue is capped by the Winfield Limestone formation of the Chase Group, while the Odell Shale of the Sumner Group is the principal formation at the surface lying close to the Little Blue on the west and east. Farther to the west, only a few miles, the chief cap rock of the area is the Dakota Sandstone formation of the Dakota Group.

The elevation of the area varies between 1,250 and 1,350 feet to the north and east of the Little Blue, to 1,400 and 1,450 feet to the south and west (14).

Surface Features. The terrace, which lies along the south and west valley walls of the Little Blue, and which in places comprises the valley wall, shows the typical swell and swale type of topography encountered in other glaciated areas. Part of this topography is undoubtedly due to post-glacial erosion, since there are numerous intermittent streams that flow across the terrace, but for the most part the topography was determined by the manner in which the sediments of the terrace were deposited, which subsequently has tended to control the local, post-glacial drainage.

Figures 1 and 2 show the inner face, i.e., toward the stream, of the terrace. Figure 1 is the terrace just six miles directly south of Hanover, in Washington county, on the west valley wall of the Little Blue. Figure 2 is located at the extreme northeast corner of the city limits of Blue Rapids, in Marshall county. The terrace here has been modified somewhat by the building of a road along its base, but this has also served to help show the relative height of the terrace above the floodplain of the Big Blue River.

Figure 3 is a cross section of the terrace taken in the Washington county gravel pits one mile west and one-half mile south of Hanover. The soil, and the till at the top of the stratified sand and gravel, are nicely shown, although the pebbles and boulders which are found elsewhere in the till are not evident in the figure.

Figure 4 is a typical section of the cross-bedding found in the stratified sand and gravel of the terrace. Here, the torrential bedding of the deposit is plainly evident near the center of the photograph and is best shown by the coarser material of the section, while directly above and below is shown the horizontal bedding quite frequently found in the finer sands.

The alignment of the larger, elongated pebbles in the stratified gravels is in a north-south direction in the terrace on the south side of the river. On the west side of the river, in the Washington county gravel pits, the pebbles are aligned in an east-west direction. This indicates, as does the

EXPLANATION OF PLATE IV

Fig. 1. Glacio-Fluvial Terrace Six Miles South of Hanover, Washington county; SW 1/4, NE 1/4, S6, T3S, R5E.

Fig. 2. Glacio-Fluvial Terrace at Blue Rapids, Marshall county; NW 1/4, SW 1/4, S20, T4S, R7E.

PLATE IV

Fig. 1

Fig. 2

EXPLANATION OF PLATE V

Fig. 3. Cross Section of the Glacio-Fluvial Terrace South and West of Hanover, Washington county, SW 1/4. NE 1/4, S18, T2S, R5E.

Fig. 4. Cross Section of the Glacio-Fluvial Terrace Showing Cross-Bedding, Blue Rapids Gravel Pit, Marshall county. NE 1/4, SW 1/4, S19, T4S, R7E.

PLATE V

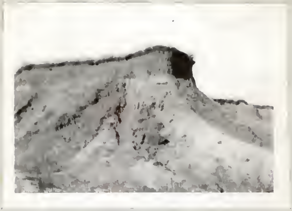


Fig. 3

Fig. 4

torrential cross-bedding seen at both localities, that the direction of stream flow was from north to south on the southern margin of the ice, and east to west on the western margin.

In the gravel pit at Blue Rapids, Fig. 4, the cross-bedding seen was all finely developed. Within a vertical distance of six inches as many as 69 different layers were counted. This fine bedding represented dark colored heavy mineral concentrations, chiefly of magnetite and hornblende, with the lighter colored minerals comprising the intervening beds.

At another location, in the same pit at Blue Rapids, four torrentially bedded layers were observed within a vertical distance of four feet. These beds were inclined at an angle of approximately 30 to 40 degrees with the horizontal, with horizontal layers of from one to two inches in thickness separating the torrentially bedded layers.

Figure 5 was taken one mile east of Irving in Marshall county along the east side of the Big Blue looking south from highway K-113. This terrace consisted only of undifferentiated drift in the form of a terrace remnant, and was included only for the purpose of showing how the sands and gravels of the main terrace pinched out to the south of the junction of the Big and Little Blue Rivers.

Figure 6 shows the working of the terrace at the Blue Rapids gravel pit for the purpose of obtaining aggregate. The discussion of the economic aspects of the deposit is deferred to a later portion of the report.

EXPLANATION OF PLATE VI

Fig. 5. Terrace one Mile east of Irving, Marshall county.

Fig. 6. Mining Operations at Blue Rapids Gravel Pit, Marshall county, SE 1/4, NW 1/4, S30, T4S, R7E.

PLATE VI

Fig. 5

Fig. 6

Figure 7 was taken approximately two miles south of Hanover along the west side of the Little Blue. This photograph shows the unconformable contact of the deposit with the Odell Shale in that locality. Here the stratified sand and gravel, including the till at the top of the deposit, is approximately 35 to 45 feet thick. At the extreme right hand side of the photograph, although it is not too readily apparent, there is a minor fault in the Odell Shale. This fault, with a maximum displacement of only six inches to one foot, is not apparent in the overlying sand and gravel.

Two measured sections of the till and stratified sand and gravel of the terrace are shown by Figs. 8 and 9 as being typical of the deposit in general. As presented by Fig. 8, the sequence of beds from finely cross bedded sand at the bottom, coarse gravel, silty clay, fine silt, gray clay, pebbly till and till at the top leaves little doubt but that the sediments were of glacio-fluvial origin. Whether or not the sediments were actually deposited in ponded water is, of course, a matter of conjecture. That the deposit was not of deltaic origin was evidenced by the absence of the typical topset, foreset and bottomset beds. On the other hand the sediments at this locality are quite suitably located being at the junction of the Big and Little Blue Rivers, with the hills to the south as shown in Fig. 6, to have been laid down in standing water.

The author prefers to classify this part of the terrace,

EXPLANATION OF PLATE VII

Fig. 7. Glacio-Fluvial Terrace two Miles South of Hanover, Washington county, SE 1/4, SE 1/4, S19, T2S, R5E.

PLATE VII

Fig. 7

EXPLANATION OF PLATE VIII

Fig. 8. Cross Section of the Kame Terrace at Blue Rapids, Marshall county, SE 1/4, NW 1/4, S30, T4S, R7E.

Fig. 9. Cross Section of the Glacial Outwash Terrace, Hanover, Washington county, SW 1/4, NE 1/4, S18, T2S, R5E.

Plate VIII

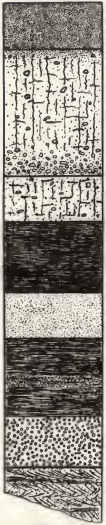


Fig. 8

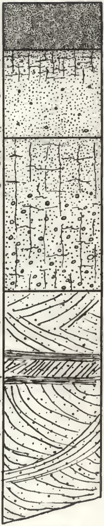


Fig. 9

(no scale)

from Blue Rapids west to just beyond Waterville, as a kame terrace. The structure of the sediments, and the locality are quite typical of described kame terraces. With respect to kame terraces, or kames, Chamberlin (15) has written the following:

> Kames are abundant in connection with deep, rapidly descending valleys, being especially abundant where they are joined by tributaries, or where they make a sharp turn in open portions of their valley..... In such instances, they are usually associated with gravel terraces and plains.....Precisely similar accumulations are very common associates, if not constituents of terminal moraines.

The above quotation lends some plausibility to the classification of this section of the terrace as a kame terrace. The valleys of the two rivers are deep enough, the river makes a sharp turn in the open portion of its valley at Blue Rapids, and the deposit is associated with, and comprises part of a sand and gravel terrace.

Brown (16), in his description of the kames and kame terraces of Central Massachusetts, has stated that:

> The upper 6 feet is composed of horizontally bedded coarse gravel with numerous pebbles and cobblestones 4 to 6 inches or more in diameter, all well rounded and fresh and nearly all of granite. Beneath this coarse gravel is at least 20 feet of intricately cross bedded sands and fine gravels. Many of the beds are lens-shaped; others dip at variable angles and in various directions. These dipping beds are frequently truncated and covered by others that are practically horizontal. Aside from the top bed of coarse gravel, no bed or series of beds shows any consistent or persistent dip in any direction for more than a few feet.

He later says:

> There is no dominant direction of dip as in the foreset beds of a delta; the bedding may better be

compared with that characteristic of kames, which has been graphically described as "tumultously" bedded.

With the exception of the till and clay which caps the kame terrace at Blue Rapids, and which was absent in the deposits described by Brown, the above description could be used, without variation, to describe that section of the terrace shown in Fig. 8.

Further evidence that the terrace was probably deposited in ponded water is added by the presence of the clay toward the top of the section. The two clay beds, shown diagrammatically in Fig. 8, are lens shaped in form, and cover an areal extent of approximately 1,000 square feet as closely as could be ascertained. Brown has covered this phase of deposition of kames by showing that deposition could occur in a small bay in a mass of temporarily stagnated ice. Further requisites being the presence of higher hills a short distance from the ice front with a narrow, marginal lake lying between.

In general, the remainder of the terrace from Waterville to Hanover, corresponds to the section shown in Fig. 9. At this particular locality, there are no higher hills to the west of the deposit which could have caught the sediments being washed out of the ice front. Instead, there seems to be no definite outer boundary to the deposit, as has been indicated on Plate III. The inner face of the terrace, see Fig. 1, is just as marked as that which is seen in the vicinity of Blue Rapids where the deposit has been referred to a kame terrace and follows the course of the Little Blue almost without variation.

This section of the deposit, from Waterville to Hanover, is referred to a glacial outwash terrace. Again the work of Chamberlin (17) and Hay (18) may be referred to. Hay has recognized that morainic deposits were probably in existence in Washington county, and Chamberlin has stated that kames are quite usually associated with gravel terraces and plains.

The cross-bedding that is indicated in the lower part of the section, Fig. 9, is primarily of the torrential type, with the inclination of the beds and the alignment of the pebbles indicating that the chief direction of stream flow was approximately from east to west, or perhaps from northeast to southwest.

The topography of this section of the terrace displays some swell and swale characteristics. Here too some of the profile is caused by the post-glacial drainage which has developed across the terrace, but in the main it is the manner in which the terrace was deposited that controls the drainage. This situation is, of course, quite local and applies only to the terrace and not to the surrounding area.

The till at the top of the terrace along its entire extent may be explained by the fact that the ice again became reactivated, after temporary stagnation, and over-rode the outwash gravel which was probably sufficiently frozen to prevent its eradication. Brown (19) has again lent plausibility to such an explanation in his discussion of the late Wisconsin ice movements in Massachusetts in which he stated that the outwash sands may have been frozen and that the ice rode over the deposit leaving the till on top.

It is suggested that the entire terrace could only have been deposited from advancing ice that had become temporarily stagnated with later movements occurring in which the ice overrode the sediments already deposited. The presence of the till at the top of the outwashed sands and gravels seems to preclude any other explanation.

No evidence is presented by the section of the terrace lying in Washington county that the sediments were deposited in ponded water. In all of the sections examined there were no foreset, or topset beds in evidence, nor were there any clay lenses, or other clay deposits of any sort present. The entire deposit along the western side of the Little Blue consisted only of outwash sand and gravel at the bottom with a capping of till at the top. If a glacial lake existed in Washington county during the time of deposition of the terrace, it must certainly have been farther to the west, however, the possibility is not excluded that there could have been a narrow, shallow, marginal lake close along the front of the ice in which the sediments composing the terrace could have been deposited without leaving much trace of their shallow lacustrine origin.

THE MINERALOGY OF THE TERRACE

The number of papers in existence on the mineralogy of the glacial deposits of Kansas is very small considering that the glacial character of the surface deposits of Northeastern Kansas has been known for a considerable length of time.

A clue to the minerals which might be found in any of the glacial sediments of Kansas may be obtained from an examination of the rocks which are to be found in such deposits. Schoewe (20) lists the following rocks as occurring in the drift materials of the State:

Quartzites	Granites
Gabbros	Diorites
Cherts	Iron bearing rocks
Basalts	Gneisses
Schists	Local limestone, sandstone and shale

In addition to the above the author has noted considerable petrified wood in the terrace under consideration. One piece, the largest found, measured approximately one foot long by six inches wide by four inches thick.

Harned (21) has presented actual mineral counts in his study of the mantle rocks of the Manhattan area. The average counts for the glacial sediments treated by him are presented as follows:

Mineral	Per cent
Augite & Diopside	1.0
Basaltic Hornblende	2.0
Biotite	0.5
Chlorite	5.7
Epidote	14.6
Garnet	4.5
Hornblende	19.6
Kyanite	1.0
Magnetite	18.0
Muscovite	8.0
Other Opaques	11.8
Rutile	0.3
Sillimanite	1.0
Titanite	1.5
Topaz	1.0
Tourmaline	1.8
Zircon	7.0
Chalcedony	24.4
Plagioclase	1.8
Orthoclase	5.1
Quartz	62.9

The chief purpose of making the mineral analysis of the terrace was in order that it might be compared with that of a till deposit located in Pottawatomie county, see Table 1, which is believed to be older, possibly of the Nebraskan glacial stage. Differences between the two deposits would aid in identifying the age of the terrace with that of the Kansan glacial stage.

The older deposit is shown in cross section on Plate VIII-A. It lies exposed at the bottom of a creek, and consists of a buried moraine of till and large limestone boulders interspersed with a few smaller quartzite boulders.

Field evidences for believing the deposit in Pottawatomie county to be of older age than the terrace lie in the fact that the till is associated with a boulder moraine consisting primarily of limestone rocks; the deposit is partially covered by a till which appears to be of later origin; and the deposit is located well toward the southern extremity of the Kansas glaciated area.

The differences between the two deposits discovered by a mineralogical analysis of each consist of the following: (a) All of the mineral grains from the Pottawatomie till examined, particularly the hornblende, presented a much higher degree of weathering and rounding; (b) zircon was not as abundant in the Pottawatomie till as it was in the terrace deposit. In addition to not being as abundant, the zircon was of a different species being a decided pink in color, exhibiting marked pleochrism, and in some instances showing more rounding. The zircon of the terrace deposit was light brown to mauve in color and did not show pleochrism to any extent; (c) reference to Tables 2 and 3 shows that chlorite was more abundant in the Pottawatomie till than it was in the terrace; (d) the amount of muscovite in the till of the terrace is apparently less than that of the Pottawatomie till; (e) tourmaline was not discovered in the till at the top of the terrace deposit, but was found to be fairly abundant in the Pottawatomie till; (f) plagioclase is apparently more abundant in the terrace till than in the Pottawatomie till.

No differences were discovered in the clay minerals of the terrace and the Pottawatomie till.

Table 1. Location of samples.

Number	Date	Location	Material
1	8/10/46	SW1/4,S-19,T4S,R7E Marshall Co. North side US-77, Gravel pit	Glacial till
2	8/10/46	do	Cross-bedded gravel (see Fig. 8)
3	8/10/46	do	Gray clay lens (see Fig. 8)
4	2/10/46	NE1/4,S-17,T3S,R7E Marshall Co. 2.6 mi. SW Marysville on Big Blue	Cross-bedded gravel
5	2/10/46	same as #1	Clay geodes and vein fillings
6	2/10/46	NW1/4,S-30,T4S,R7E Marshall Co.	Gray silt clay
7	2/16/46	NE1/4,S-18,T4S,R6E Marshall Co.	Glacial till
8	2/16/46	SW1/4,S-35,T3S,R5E,Washington Co.	Cross-bedded sand
9	2/16/46	NW1/4,S-17,T3S,R5E,Washington Co.	do
10	do	do	do
11	do	same as #8	do
12	do	same as #9	Clay boulder
12-A	do	NE1/4,Sec-18,T3S,R5E,Washington Co.	do
13	2/25/46	2.5 mi. N. Cleburne E.side K-13 Riley Co.	Glacial till
14	do	do	Clay geodes and vein fillings
15	do	do	Cross-bedded sand
16	do	same as #1	Very fine sand well sorted
17	3/9/46	2 mi. S. Cleburne 1/4 mi. E. K-13 south side road cut. Riley Co.	Fine sand
1-A thru 6-A	3/9/46	SE1/4,SW1/4,NE1/4,S10,T10S,R8E Pottawatomie Co.	Glacial till, clay and stratified sand

EXPLANATION OF PLATE VIII-A

Cross section of a till deposit in Pottawatomie County, east of Manhattan. SE1/4, SW1/4, NE1/4, S10, T10S, R8E.

Plate VIII-A


soil
Recent Till #5
Stratified Till
#2 Vertical-walled Till #3
#6
Stratified
Sand
Limestone &
Quartzite
Boulders
#1 Hard Red Clay #4
Creek Level

Table 2. Mineral analysis for the glacio-fluvial terrace.

Minerals	Till: 1	Clay: 3	Silt: clay: 6	Till: 7	Sand: [illegible]	Sand: 9	Sand: 10	Sand: 11	Clay: ball: 12	Till: 13	Sand: 15	Sand: 16	Sand: 17	Clay ball 12A
							Heavy fraction							
Andalusite	2.3			1.6	0.6		1.9	0.4						
Basaltic Hndld	2.8	1.2	3.3					0.8	0.9	2.7	0.5	3.8	1.8	1.2
Biotite	5.2	9.6	7.9	3.5	1.9	16.2	5.6	2.3	27.0	4.3	1.6		2.5	6.0
Chlorite					0.6	1.1								
Epidote	10.0	6.0	14.5	5.0	7.1	5.9	3.7	9.4	3.0	18.1	7.8	9.5	11.3	19.1
Garnet	3.3	2.4	2.6	6.7	7.8	4.7	0.9	3.5	2.1	2.3	12.3	2.9	5.6	2.4
Kyanite		2.4			0.6			1.9		0.8	0.5	1.0	1.6	0.4
Muscovite	4.2	12.0	10.5	11.7	8.9	4.7	1.8	1.1	23.8	5.5		0.3	1.2	14.6
Opaque	32.0	45.1	23.4	38.9	45.0	46.4	33.0	28.4	17.3	23.7	40.4	14.4	31.4	29.6
Sillimanite	1.4	1.2	0.3			5.9			0.9	0.4	1.1	0.3		1.2
Titanite					5.0	3.5	2.7							
Topaz														
Tourmaline		1.2			2.6	2.3	1.8	0.4		0.4		1.6	1.8	0.4
Zircon	2.3	2.4	3.3	13.5	1.3		1.8	1.9		0.8	2.8	0.3	2.5	2.0
Hornblende	[illegible]	15.0	24.3	18.6	20.3	7.1	36.6	45.0	12.4	38.3	32.0	59.9	35.8	16.6
Leucoxene														
Limonite														
Hypersthene														
Enstatite	1.9		3.9		1.9	2.3	9.4	4.3	2.1	2.3	0.5		3.7	6.9
Tremolite												2.7		
							Light fraction							
Chalcedony	8.1	9.1	12.2	7.5	9.7	6.2	14.2	13.5	5.2	3.3	9.7	14.9	12.2	9.6
Clay mineral	5.8	29.6	3.1	2.7	7.3	12.2	5.8	16.9	31.9	21.5	3.9	3.5	3.4	5.0
Opal & glass	0.9	1.2		0.9			0.5							
Orthoclase	1.8	3.3	4.9	2.7	[illegible]	2.6	2.9	[illegible]		2.4	4.9	3.5	4.2	4.4
Plagioclase	4.0			1.6	3.3	2.2	1.4			1.5		2.2		2.8
Quartz	79.0	56.4	77.3	83.6	74.2	76.4	75.0	63.9	62.5	73.7	82.5	78.9	73.8	74.4

Table 3. Mineral analysis for the Pottawatomie county till deposit.

Minerals	1-A	2-A	3-A	4-A	5-A	6-A
			Heavy fraction			
Andalusite	9.40				0.3	0.41
Basaltic Hnbld.	0.47	0.86	1.90	1.30	2.1	3.30
Biotite	2.30	2.10	16.20	34.40	3.0	14.20
Chlorite	0.47	0.86	0.49	0.79	0.3	
Epidote	10.40	15.00	15.20	3.70	17.2	10.00
Garnet	5.60	3.00	0.98	2.10	4.0	1.20
Kyanite	0.94				0.9	0.83
Muscovite	7.10	10.30	14.20	25.10	3.3	15.40
Opaque	28.40	35.30	21.60	9.00	33.0	25.90
Sillimanite	1.40	0.43	0.49	0.53	0.3	1.60
Titanite						
Topaz						
Tourmaline	2.30	0.86	1.90	0.79	3.3	1.20
Zircon	0.94	1.70		0.53	0.9	0.41
Hornblende	24.30	25.80	23.60	20.10	27.4	62.70
Leucoxene						
Limonite						
Hypersthene						
Enstatite	4.70	3.40	1.90	1.30	2.1	4.10
Tremolite	0.47					
			Light fraction			
Chalcedony	5.40	7.90		1.00	17.3	10.0
Clay mineral	10.10	21.60	92.00	73.00	9.1	
Opal and glass				1.00	1.0	
Orthoclase	6.80	6.80		2.00	7.3	7.0
Plagioclase		0.75				3.3
Quartz	77.00	64.20	7.90	23.00	64.6	78.9

A comparison between the older till at the Pottawatomie county location and the apparently younger till which covers it show that (a) the zircon of the younger till is of the same species as that found in the terrace till of Marshall and Washington counties, and does not exhibit the color and pleochrism of the zircon found in the older till; (b) no plagioclase was found in the buried till, while a trace was found in the overlying till, and an abundance was found in the overlying sand, sample 6-A; (c) the rounding and weathering of the mineral particles in the older till was not readily apparent in the minerals of the overlying till. These are the only mineralogical differences between the two tills of the Pottawatomie county location that correspond to the differences between the till of the terrace sediments and the till of Pottawatomie county. It is believed, however, that the differences are adequate to give an indication of a difference in time of origin between the buried till and the overlying till in Pottawatomie county.

The minerals found in the overlying sand in Pottawatomie county, and those found in the sands of the terrace correspond fairly well, and showed no apparent differences in the degree of rounding and weathering.

The mineral analysis of the younger till presented in Table 3 compares favorably, in some instances, with the average mineral analysis of glacial sediments taken from Harned. The differences existing between the two analyses may be attributed to variations in sampling, the number of samples taken, and the fact that the data taken from Harned is an average while that presented in Table 3 is not.

The foregoing seems to indicate that there is some difference in age between some of the till, or glacial drift, that borders on the Kansas River, and those which lie farther to the north along the Big and Little Blue Rivers. If the compared deposit to the south is older, probably Nebraskan, there is no alternative but to refer the younger glacial deposits to the north to the Kansan glacial stage.

MECHANICAL ANALYSIS OF THE TERRACE

A mechanical analysis of the "spot" samples taken from the terrace was undertaken in order to show as conveniently as possible the size distribution of the sands and gravels which form the major portion of the terrace.

In order to present this data in its most easily assimulated form, the histogram has been resorted to as offering the greatest universal appeal and clarity (22).

Figures 10 and 16 represent the frequency distribution of the various sizes of material found in the till which lies at the surface of the terrace. Figure 10 represents the till found at the gravel pits just to the west of Blue Rapids, and Fig. 16 the till located a few miles west of Waterville.

The histograms show a decided tendency in both instances toward two modal classes (1/32 mm. and 1/4 mm. sizes). In the till represented by Fig. 16 it is evident that there is reater variation in size of the material than there is in the till represented by Fig. 10, but that there is less variation in the frequency distribution of the various sizes represented. Both histograms, however, are typical of glacial till.

One other histogram of glacial till was selected for purposes of comparison, Fig. 23. This represents the till of the terrace remnant located south of Cleburne in Riley county along highway K-13. The histogram shows two definite modal classes, one varying on either side of the 1/64 mm. size, and the other in the clay fraction of the material. Here again the histogram shows the typical poor sorting found in glacial tills.

Of the three tills considered, the one at Waterville, and the one at Blue Rapids present a very great similarity, while the one found farther to the south shows a difference in that the greatest frequency distribution tends to be toward the finer size of materials. An explanation for this may be found in the suggestion that the ice probably had deposited the largest portion of its coarse material while it was stagnated to the north of the Little Blue.

Figure 11 shows the frequency distribution of the coarse sand presented in the section, Fig. 8. Approximately all of the sand is concentrated between the 1 mm. and the 1/8 mm. sizes with a fairly definite modal class in the 1 mm. size.

EXPLANATION OF PLATE IX

Fig. 10. Histogram of Sample Number 1.

Fig. 11. Histogram of Sample Number 2.

PLATE IX

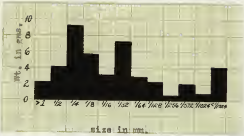


Fig. 10

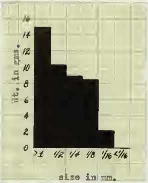


Fig. 11

It is interesting to compare this with the histogram of Fig. 13 which represents similar coarse sand taken from a terrace remnant lying approximately 18 miles to the north near Marysville along the eastern side of the Big Blue valley. Figure 13 shows an even greater concentration of material between the 1 mm. and the 1/4 mm. sizes indicating that the material farther to the north is somewhat coarser.

Of the histograms so far discussed there seems to be shown a definite trend of coarser to finer material proceeding from north to south through the area affected by the glacial ice.

Figure 15 represents the gray, silt-clay of Fig. 8. As indicated, this material should rather be termed a slightly clayey silt, but there was just enough of the clay fraction present in the bed to make exact field classification difficult. As shown, the major portion of the sediment in this particular bed is concentrated in the 1/32 mm. size making only one modal class and rendering the classification of the bed as a clayey-silt correct.

Figure 12 represents the gray clay lens indicated in the cross section of Fig. 8. Enough of the clay size material is present to make the classification of the material as a clay correct, but there is a decided amount of larger sized particles present causing the clay to be quite silty in texture.

Figure 26 represents the finely cross-bedded sand shown in Fig. 8. There is but one modal class depicted with nearly all of the material being concentrated in the 1/8 mm. and the 1/16 mm. sizes.

It is indicated from the histograms and discussion presented above that the glacial ice must have been stagnated in the vicinity of Blue Rapids for a considerable period of time while the sediments represented by Fig. 8 were deposited. After this temporary stagnation a lobe of the ice apparently moved down the valley of the Big Blue depositing on its margin another terrace, a remnant of which is still to be seen at Cleburne.

Figures 17 and 18 represent samples taken from top to bottom at exposures of insufficient thickness to allow selective sampling of the different beds. The two samples include the till at the top and extend on down into the stratified gravel beneath.

In this instance Fig. 17 shows a concentration in the 2 mm. to 1/4 mm., the 1/32 mm. to 1/64 mm., and in the clay fraction sizes, while Fig. 18 shows a concentration in the 1/4 mm. to 1/8 mm., the 1/64 mm. to 1/128 mm., and in the clay fraction sizes.

In these two cases, Fig. 18 represents a sample taken approximately three miles to the north and west of that shown in Fig. 17. Some difference in coarseness of material is presented, with the sample taken to the north being slightly the coarser even though the two samples bear approximately the same relation in distance from the ice front which evidently trended to the north and west between the two sampling locations.

EXPLANATION OF PLATE X

Fig. 12. Histogram of Sample Number 3.

Fig. 13. Histogram of Sample Number 4.

PLATE X

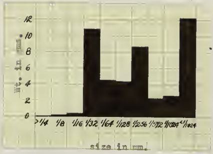


Fig. 12

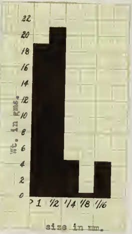


Fig. 13

EXPLANATION OF PLATE XI

Fig. 14. Histogram of Sample Number 5.

Fig. 15. Histogram of Sample Number 6.

PLATE XI

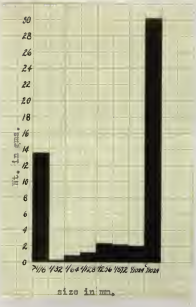


Fig. 14

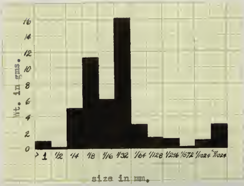


Fig. 15

EXPLANATION OF PLATE XII

Fig. 16. Histogram of Sample Number 7.

Fig. 17. Histogram of Sample Number 8.

PLATE XII

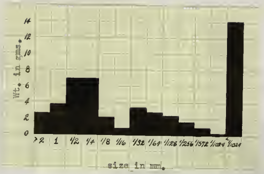


Fig. 16

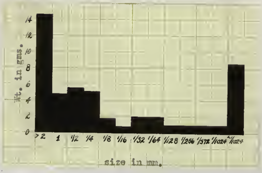


Fig. 17

EXPLANATION OF PLATE XIII

Fig. 18. Histogram of Sample Number 9.

Fig. 19. Histogram of Sample Number 10.

PLATE XIII

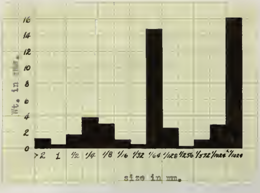


Fig. 18

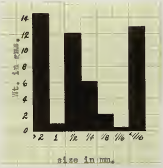


Fig. 19

EXPLANATION OF PLATE XIV

Fig. 20. Histogram of Sample Number 11.

Fig. 21. Histogram of Sample Number 12.

PLATE XIV

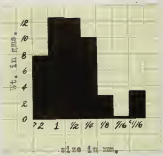


Fig. 20

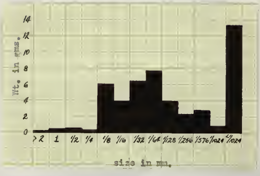


Fig. 21

EXPLANATION OF PLATE XV

Fig. 22. Histogram of Sample Number 12A.

Fig. 23. Histogram of Sample Number 13.

PLATE XV

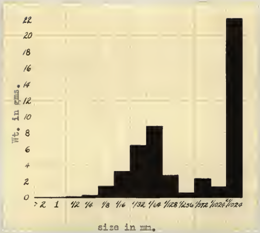


Fig. 22

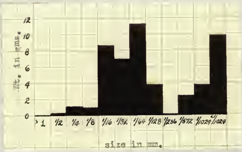


Fig. 23

EXPLANATION OF PLATE XVI

Fig. 24. Histogram of Sample Number 14.

Fig. 25. Histogram of Sample Number 15.

PLATE XVI

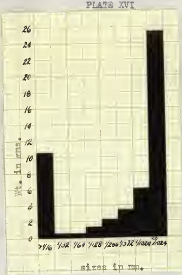


Fig. 24

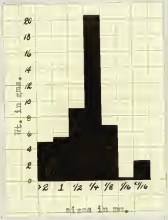


Fig. 25

EXPLANATION OF PLATE XVII

Fig. 26. Histogram of Sample Number 16.

Fig. 27. Histogram of Sample Number 17.

PLATE XVII

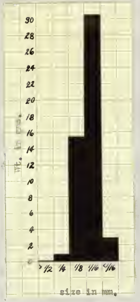


Fig. 26

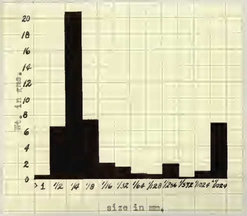


Fig. 27

Figures 19 and 20 represent the outwash sands taken at the locations shown in Table 1 in Washington county. There is not much difference in frequency distribution between these two samples except in the 1 mm. sizes where Fig. 20 shows the greatest concentration. The histogram shown as Fig. 25 may be compared favorably with the preceding two. Here a sand, bearing the same stratigraphic relationship, that is, lying directly under the till, was collected. This was taken at the location shown in Table 1 near Cleburne. The histogram shows a distinct modal class in the 1/4 mm. size with fairly even distribution in the larger and smaller sizes to either side. Again the sediments to the south of the glaciated area present a slight tendency toward greater fineness of material.

Figure 27, taken on the same terrace remnant as the sample shown by Fig. 25, presents the same modal class in the 1/4 mm. size.

A discussion of the histograms, Figs. 14, 21, 22, and 24, which represent clay materials, is given under the following section on clay mineral analysis.

CLAY MINERAL ANALYSIS OF THE TERRACE

In order to complete the mineral analysis of the deposit, and to investigate the possibility that the type of clay mineral present in the terrace might have some relationship to the age of the deposit, the clays present were identified and compared with those found in the older till represented in this report by Plate VIII-A.

As explained in the discussion under "Methods" of this report, there were three different means applied in the identification of the clay minerals of the terrace. These were thermal dehydration, thermal analysis, and determination of the optical properties of the clays concerned.

In Figs. 28, 29, and 30, the thermal dehydration curves presented were made from samples number 5 and 4-A respectively with the typical Illite curve of Nutting (23) inserted as Fig. 30 for means of comparison. The two curves of Figs. 28 and 29 correspond almost exactly with that of Fig. 30. Using this method of identification alone leaves but little doubt that the two clays are illites.

The above is further corroborated by the thermal analysis curves of Figs. 31 and 32. These are compared in turn with the thermal analysis curve for Illite of Berkelhamer (24). The endothermic peaks at 140 to 155 degrees correspond favorably as do the peaks at 600 degrees. The endothermic peak at 900 degrees shown by Berkelhamer was not obtained, but a trace of the exothermic peak which he obtained at approximately 950 degrees was obtained at the lower temperature of 900 degrees. The reason for not obtaining the exothermic peak at 900 degrees is not known, but may be attributed to a lack of sensitivity in the galvanometer circuit of the recorder.

As seen by comparing Figs. 28 and 29, as well as Figs. 31

EXPLANATION OF PLATE XVIII

Fig. 28. Thermal dehydration graph of Sample Number 5.

Fig. 29. Thermal dehydration graph of Sample Number 4A.

Fig. 30. Thermal dehydration graph for Illite (Nutting).

Fig. 31. Thermal analysis graph for Sample Number 5.

Fig. 32. Thermal analysis graph for Sample Number 4A.

Fig. 33. Thermal analysis graph for Illite (Berkelhamer).

PLATE XVIII

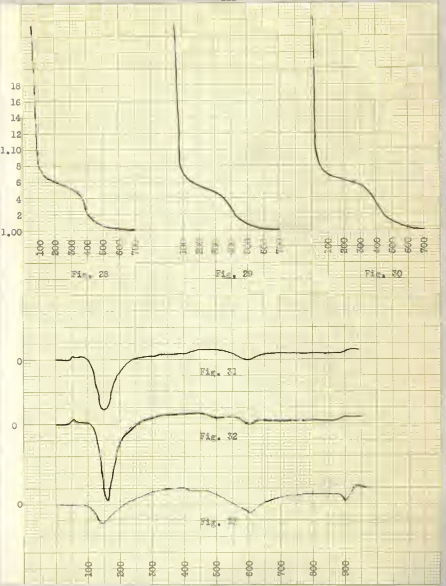


Fig. 28

Fig. 29

Fig. 30

Fig. 31

Fig. 32

Fig. 33

and 32, the clays of the older till of Pottawatomie county and those of the terrace are identical. All clays encountered were tested in a similar manner, and all gave almost identical results.

The optical properties of the clays may be summed up as follows:

Biaxial	(-)
2V	small
n	1.56 to 1.57

While the optical properties of a clay are not of themselves conclusive for purposes of identification, the above refractive index appears to check fairly well with that given by Ross (25) for Bravaisite, which is synonomous with Illite. In this case, Ross lists the mean index for Bravaisite as 1.55. The slight variance between the two may be attributed to a slightly different content of iron, or water. It was noted while taking the refractive indices of the various clay samples, that those clays with an apparent higher iron content also had a slightly higher refractive index.

In many of the clay samples studied under the petrographic microscope, there appeared small inclusions. These may have been minute particles of quartz, or sodium silicate carried over from the dispersion process. Time did not permit further investigation of these particles, but if they were quartz, or any other mineral an explanation of their presence in material that had been sedimented for approximately 48 hours would be interesting.

Clay Geodes and Vein Fillings. Plates XIX and XX illustrate one manner of occurrence for the clay samples taken from the kame terrace at Blue Rapids. Concentrations of the Illite occurred in cavities and veins in the horizon indicated in Plate VIII-A. It was also noted that the clay had migrated to form around rootlets in the layer as well.

Allen (26) has shown that this is not an unusual occurrence for the clay minerals montmorillonite, nontronite, kaolinite, halloysite, dickite, gibbsite, and diaspore. He has stated in part that:

> Migration of these minerals takes place rarely by transfer of their constituents as true solutions but generally as colloidal suspensions whose formation and movement are favored by conditions of good drainage and the presence of dispersing agents.

In accordance with the discussion presented in the preceding paragraphs, the mineral "Illite", or Bravaisite, may then be added to the clays which form secondary clay deposits as geodes and vein fillings by means of migration as colloids after deposition.

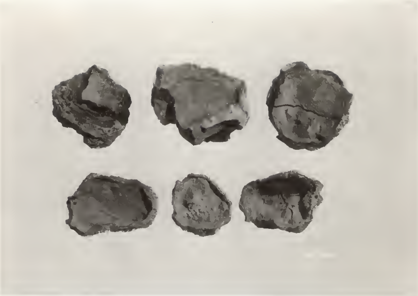
It will be noted that the geodes shown on Plate XIX are not complete. Only the bottom part of the geodes could be collected since the clay lining around the sides and upper portions of the cavities from which the samples were taken was too fragile to be removed intact.

Histograms of the Clay Mineral, Illite. Figures 14, 21, 22, and 24 represent the size frequency distribution of the clay samples taken. Figure 14 is the clay pictured in the form

EXPLANATION OF PLATE XIX

Clay Geodes (Illite) from the Blue Rapids gravel pit, Marshall county. SE 1/4, NW 1/4, S30, T4S, R7E.

PLATE XIX



EXPLANATION OF PLATE XX

Clay vein filling (Illite) from the Blue Rapids gravel pit, Marshall county. SE 1/4, NW 1/4, S30, T4S, R7E.

PLATE XX

of geodes, and vein fillings. This material is nearly all concentrated in the less than 1/1024 mm. size. The apparent abnormal concentration in the greater than 1/16 mm. size is due almost entirely to the presence of clay crystals which could not be dispersed, and which were caught upon the 250 mesh screen as the sample was being sized.

Figures 21 and 22 represent two clay boulders, or clay balls, taken at the locations shown in Table 1. In both instances two modal classes are shown, one culminating in the 1/64 mm. size and the other in the clay fraction. This, coupled with the mineral analysis of the two clay balls indicates that they represent merely clay concentrations in the outwash gravels and were not boulders that became weathered to clay after deposition in the sands and gravels of the terrace.

Figure 24 shows the size distribution of an Illite sample taken from the terrace remnant at Cleburne. Here again the concentration in the greater than 1/16 mm. size was due to difficulties met with in obtaining a complete dispersion of clay crystals, the remainder of the material being concentrated in the clay fraction.

ECONOMIC ASPECTS OF THE TERRACE

Figure 6 shows one of the larger of the gravel pits of the terrace being mined. This shows the most elaborate sand quarrying equipment in operation on the terrace at any place along its entire length. In this instance, the sand is washed and graded making it suitable for use in concrete, plaster, mortar and road aggregate.

At the time the research was being conducted for this report, there were four sand pits being quarried in order to obtain aggregate for the above purposes. The pit to the north side of US highway 77 was not being operated even though its supply of aggregate was by no means exhausted, see Plate III.

In addition to the pits being operated for commercial purposes many small pits were being intermittently quarried by the local farmers for domestic purposes. These being of current economic importance only to the farmers upon whose land the pits exist.

As a future source of aggregate of high quality, the deposits of the terrace are to all practical purposes inexhaustible. Sand and gravel is present under the thin till capping, along the entire length of the terrace. In places the sands are as thick as 55 feet, while at other locations an apparent thickness of 20 feet only is attained.

The clay found in the terrace is of no economic importance since it is not of the type required for commercial purposes, and does not exist in deposits extensive enough to warrant mining in case any commercial use were discovered.

ADDITIONS OF THIS REPORT TO PREVIOUS KNOWLEDGE

As nearly as could be ascertained from a close perusal of the literature on the subject of Kansas glaciation, this is the first attempt to describe one of the glacio-fluvial terraces known to exist in the northeastern part of the State.

So far as is known by the author, none of the glacial deposits that have been described in this region have been defined as kame terraces, while there has been some hint given in a few articles on the subject, that outwash deposits, some of which are in the form of terraces, are known to be in existence along some of the streams of the area.

There was no reference in the literature consulted to the occurrence of the clay mineral Illite in the form of geodes and vein fillings. The description of the occurrence of Illite in the glacial sediments of Kansas is believed to be new.

The classification and description of the buried moraine in Pottawatomie county has not been previously done, and should add to the knowledge pertaining to the occurrence of possible "Nebraskan" glacial sediments in Kansas.

SUMMARY

There is a glacio-fluvial terrace along the southern and western margins of the Little Blue River valley. A part of this terrace, along the western side of the river where it flows to the south in Washington county, has been classified as a glacial outwash terrace, while the remainder of the deposit, between the towns of Waterville and Blue Rapids from west to east, and between the Little Blue to the north and the hills to the south, has been referred to as a kame terrace.

The mineral content, mechanical analysis, and geologic relationship of the deposit to the surrounding area have been presented and discussed, and have been used to show that there is some reason to believe the sediments of the terrace were deposited during the Kansan stage of glaciation, while some of the glacial deposits farther to the south along the Kansas River are older, and should probably be referred to the Nebraskan glacial stage.

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LIST OF REFERENCES

(1) Bouyoucos, George John
Comparison of the hydrometer method and the pipette method for making mechanical analysis of soils, with new directions. Am. Soc. Agron., Jour. 22: 747-51. 1930.

(2) Nutting, P. G.
Some standard thermal dehydration curves of minerals. U. S. G. S. Prof. Paper 197-E, 1943.

(3) Speil, Sidney, Berkelhamer, Louis H., Pask, Joseph H. and Davies, Ben. Differential thermal analysis, its application to clays and other aluminous minerals. Bu. Min. Tech. Paper 664, 1945.

(4) Thwaites, F. T.
Outline of glacial geology, rev. ed. 119 p. 1941.

(5) Hay, Robert.
Some characteristics of the glaciated area of Northeastern Kansas. Kans. Acad. Sci., Trans. 13: 104-06, 1891-92.

(6) Todd, J. E.
The moraines of Kansas. Sci. n.s. 37: 457. no. 951.

(7) Schoewe, W. H.
Evidences for the relocation of the west drift borders in Eastern Kansas. Kans. Acad. Sci., Trans. 42: 367, 1939.

(8) Schoewe, W. H.
Drift in Kansas, (Abstracts). G. S. A. Bul. 40: 125-6, no. 1, 1929.

(9) Schoewe, W. H.
Additional evidences of an ice invasion south of the Kansas River in Eastern Kansas. Kans. Acad. Sci., Trans. 31: 109-11, 1930.

(10) Smyth, B. B.
The buried moraine of the Shunganunga. Kans. Acad. Sci., Trans. 15: 95-104, 1895-96.

(11) Schoewe, W. H.
Glacial striae and grooves in Kansas. Kans. Acad. Sci., Trans. 34: 145-47, 1931.

(12) Todd, J. E.
Kansas during the ice age. Kans. Acad. Sci., Trans. 28: 33-48, 1917.

(13) Flint, Richard Foster.
Glacial map of North America. G. S. A. Spec. Paper no. 60, pts. 1 and 2, 1945.

(14) Schoewe, W. H.
Glacial geology of Kansas. Pan. Am. Geol., 40: 102-10, no. 2, 1923.

(15) Chamberlin, T. C.
Preliminary paper on the terminal moraine of the second glacial epoch. Extract of the 3rd annual report of the director U. S. G. S. 1881-82, 291-402, 1883.

(16) Brown, T. C.
Kames and kame terraces of Central Massachusetts. G. S. A. Bul. 42: 467-79, 1931.

(17) Chamberlin, T. C.
Ibid.

(18) Hay, Robert.
Ibid.

(19) Brown, T. C.
Late Wisconsin ice movements in Massachusetts. Am. Jour. Sci. 23: 462-68, 5th ser., 1932.

(20) Schoewe, W. H.
Drift in Kansas. (Abstracts) G. S. A. Bul. 40: 12[illegible]-6, no. 1, 1929.

(21) Harned, C. H.
The mineralogy and mechanical analysis of the mantle rock in the Manhattan area. Unpublished thesis. Kans. State Col. of Agr. and Appl. Sci. 119 p. 1940.

(22) Krumbein, W. C. and Pettijohn, F. J.
Manual of sedimentary petrography. 549 p. 1938.

(23) Nutting, P. G.
Ibid.

(24) Berkelhamer, Louis H.
An apparatus for differential thermal analysis.
Bu. Min. Tech. Paper 664, 38-55, 1945.

(25) Ross, Clarence S.
Minerals and mineral relationships of the clay minerals. Jour. Am. Cer. Soc., 28: 173-83, (7), July 1945.

(26) Allen. Victor T.
Effect of migration of clay minerals and hydrous aluminum oxides on the complexity of clays.
Jour. Am. Cer. Soc., 28(10): 265-75, Oct. 1945.

(23) Nutting, P. G.
Ibid.

(24) Berkelhamer, Louis H.
An apparatus for differential thermal analysis.
Bu. Min. Tech. Paper 664, 38-55, 1945.

(25) Ross, Clarence S.
Minerals and mineral relationships of the clay minerals. Jour. Am. Cer. Soc., 28: 173-83, (7), July 1945.

(26) Allen. Victor T.
Effect of migration of clay minerals and hydrous aluminum oxides on the complexity of clays.
Jour. Am. Cer. Soc., 28(10): 265-75, Oct. 1945.