GEOLOGY OF THE LAWRENCE AREA

by

Monta E. Wing

Submitted to the Department of Geology and the Faculty of the Graduate School of the University of Kansas in partial fulfillment of the requirements for the degree of Master of Arts.

Approved by:

_____

Department of Geology.

May 1921.

CONTENTS

Contents

Page

ILLUSTRATIONS

Illustrations

CHAPTER 1--INTRODUCTION

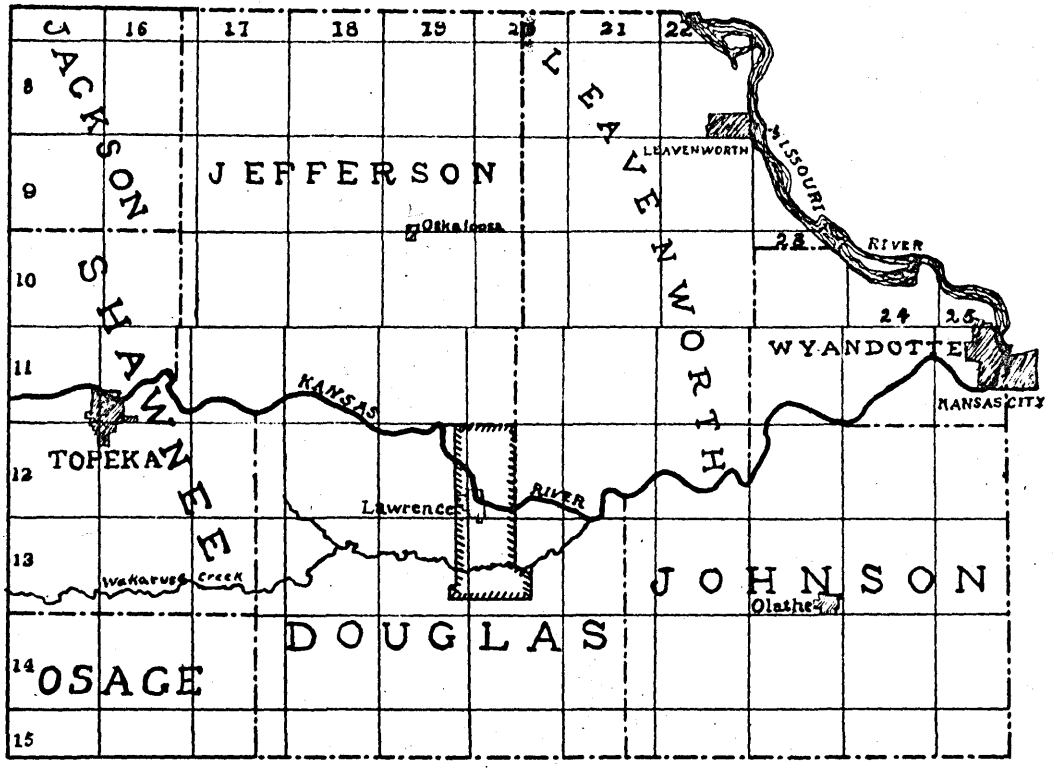
General Interest of Area

The area surrounding Lawrence is one of unusual interest. While it is one of the richest farming communities in the State of Kansas, it, also, has other industries drawing upon its large store of natural resources. Lawrence may boast of the largest water power project in the State, and of rock, brick, and sand in far greater quantities than sufficient to meet local needs.

With most of its wealth coming from natural resources, it may be expected that the region possesses geologic interest. This is further enhanced by the good exposures of sedimentary rocks and the presence of many glacial phenomena. Type sections of two divisions of the Pennsylvanian series occur in the area.

Further interest attaches to the region because of its early history and finally, because of the location of the University of Kansas at Lawrence. Greater scenic beauty is not found anywhere in the Plains Province than is seen from the top of Mount Oread upon which the University stands.

Plate 1



Section of eastern Kansas showing location of Lawrence and area included in report

Location

The area with which this report is concerned is a rectangular section four miles wide and extending north and south of Lawrence approximately five miles in each direction. This region was chosen because it includes parts of the valleys of Wakarusa creek and Kansas river, and the edge of the uplands on either side. It is representative of many similar sections in eastern Kansas and in the area of the Great Plains.

The area is bounded on the north by the Leavenworth County line, and on the east by the Jefferson County line. The range line between R19E and R20E runs through the area one mile from the western side. The township line between T12S and T13S runs through the center of Lawrence and across the projecting point of the hill upon which the University stands. The location, however, is more or less a matter of convenience, since the report with its descriptions and illustrations will apply in a general way to almost any part of eastern Kansas.

Lawrence, the only town included in the area is the County seat of Douglas County, Kansas. It lies approximately fifty miles west of Kansas City on the Atchison,

Topeka, and Santa Fe and Union Pacific railroads. Other railroad service is offered by a branch line of the Atchison, Topeka and Santa Fe which connects with Ottawa and points to the south, and a similar branch of the Union Pacific which runs to Leavenworth. Hourly passenger service to and from Kansas City is furnished by the Kaw Valley Interurban.

Acknowledgments

The main part of the material for the report was obtained from observation in the field. Everything that has been written, however, concerning the area has been reviewed, and drawn upon freely.

The accompanying map was compiled partly from section maps obtained from the Civil Engineering Department, and partly from field work with the plane-table and telescopic alidade by the author, assisted by students in the Department of Geology. Generous credit is due Professor W. C. McNown for his assistance with the map. Acknowledgment is made of the helpful criticism offered by Dr. Raymond C. Moore and other members of the faculty in the Department of Geology.

CHAPTER 2--HISTORY OF LAWRENCE

Settlement

Many things affect the location and growth of a city. Some are built and supported by the natural resources of the region surrounding. Others are affected by their location and points of vantage in our great economic systems. Still others have had their beginnings in history, and have been built to fill some historical need. Lawrence was founded when history was filled with the crimes of slavery and there was danger that it would engulf the new territory of Kansas. No more vivid history has been enacted in any town than occurred in Lawrence in the early part of her existence.

The first settlement was made at the present site of Lawrence in August, 1854.[1] The main purpose and cause of settlement was the desire of the northern people to secure Kansas as a free state after the passing of the Kansas-Nebraska Act in May 1854 which opened the terri-

---

1. Cordley, Richard W., History of Lawrence.

tory to slavery. Settlement was especially fostered by the New England Emigrant Aid Company of Massachusetts. Most of the settlers were from Massachusetts and the northern Atlantic States. The townsite was selected by Dr. Charles Robinson of Fitchburg and Mr. Charles H. Branscomb of Holyoke. That the beauty of the region played a large part in the selection of the townsite is conjectured from the fact that Dr. Robinson had traveled over, what was later to be called Mount Oread, in 1849 on his way to California with gold seekers, and had noted the "beauty of the spot and the magnificance of the view." Five years later, Dr. Robinson remembered this region in choosing a site for settlement.

The second party of emigrants arrived in September of the same year. Soon after, a town government was organized and the townsite was laid out. Disorders began immediately. Ruffians from Missouri claimed title to the townsite and many of the claims of the settlers. These disputes were settled only by determination and force. In 1855 Missouri voters invaded Lawrence and elected the Kansas legislature. This "bogus" legisla-

ture was repudiated with the result that murder and pillage followed. Several times militia from Missouri camped near Lawrence ready to attack the town at the slightest provocation. Sheriff Jones from Westport burned the Free-State Hotel, at the present site of the Eldridge House, and sacked Lawrence on May 21, 1856.

Civil War Period

Kansas took an active part in the Civil War sending 22,000 men out of a total population of 107,000. Many of these men were from Lawrence. An event around which the history of Lawrence is centered during this period is the raid by Quantrell on August 21, 1863.[2] With nearly four hundred men, Quantrell swoped down on Lawrence without the slightest warning, and murdered and burned in an extremely barbarious and cold blooded manner. Again the Free-State Hotel, now the Eldridge House, was burned. Nearly two hundred citizens of Lawrence were murdered and approximately two million dollars worth of property was burned or carried off in this raid. Only once following this during the Civil War period was

---

2. Cordley, Richard W., "History of Lawrence"

Lawrence threatened with invasion when Price made his memorable drive to the North. This was averted, however, by a narrow margin.

Permanent Development

While the first settlers came to Lawrence primarily to save Kansas as a free State, they were not unmindful of the fact that the town would be permanent and would play a large part in the development of the West. When the Lawrence townsite was laid out, certain blocks were reserved for school purposes and provisions were made for a college. These early beginnings resulted later in the State University being established at Lawrence, and undoubtedly added to her prosperity. Situated in the "Kaw Valley", the richest farming community in the State of Kansas, Lawrence is a thriving city to-day with a population of approximately thirteen thousand.

CHAPTER 3-TOPOGRAPHY AND DRAINAGE

General Statement

The topography of the Lawrence area consists of wide valleys, low rounded knolls and high, flat, uplands. The widest valley is that of the Kansas river flowing eastward through Lawrence. A few miles to the southward and separated from the Kansas by a low divide near Lawrence is Wakarusa creek flowing nearly parallel to the Kansas river and with a valley nearly as wide. Both to the south of the Wakarusa valley and to the north of the Kansas river valley are first gently rolling lowlands and in the background high, flat uplands capped with Oread limestone.

THE KANSAS RIVER SYSTEM

The principal drainage channel of this region as well as the largest stream in northern Kansas is Kansas river. Kansas or the "Kaw" as it is frequently called is formed by the junction of Smoky Hill and Republican rivers in Geary County, Kansas. The principal tributa-

ries of Smoky Hill river are Saline and Solomon rivers. The Kansas proper flows almost due east until it enters Missouri river at Kansas City. The largest tributary which enters Kansas river is Blue river which rises in southeastern Nebraska and flows south and east through Blue Rapids where it is joined by the Little Blue, and enters Kansas river at Manhattan.

The Kansas River Basin

The entire Kansas river basin drains an area estimated at 61,440 square miles or an area two-thirds as large as the entire state of Kansas.[3] Of this, 34,526 square miles are in Kansas, 17,405 square miles are in Nebraska, and 9,459 square miles are in Colorado. The catchment area is approximately 485 miles long and 200 miles in width at its widest point. The drainage area lies between Platte river on the north and Arkansas river on the south. These two streams encircle Kansas river in Colorado so that the latter is altogether a plains stream and is not affected by mountain storms or

---

3. Newell, F.H., "The Kansas River Basin" U.S.G.S., Bull.140, p.124, p.145.

melting snows from the highlands.

Rainfall and Floods

Both the Kansas and the Blue rivers have periods of high water each year.[4] Disastrous floods, however, are rare. The most notable flood occurred in May and June, 1903 when water covered all of the low bottom lands, causing considerable loss both in life and property.[5] All conditions of high water are caused by excessive rainfall within a short space of time and a rapid run-off due to the clayey soil and lack of restraining vegetation. The average rainfall near Kansas City where Kansas river enters the Missouri is forty inches per year. Near Lawrence the average rainfall is only thirty-six inches. The rainfall decreases gradually to the west until along the tributaries in Colorado it averages as low as ten inches per year.

The River Channel

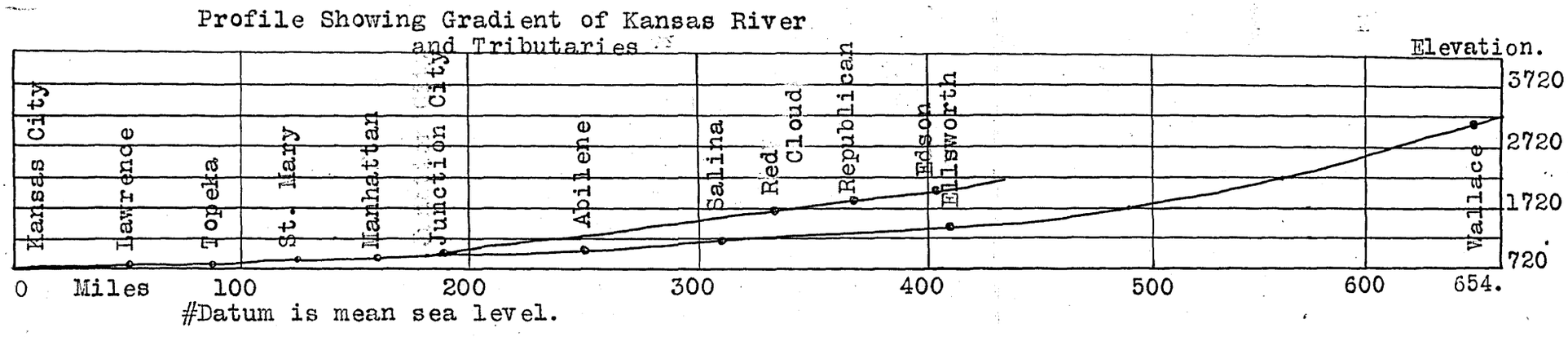
The average width of the channel near Lawrence is

---

4. Babb, C.C.,Hindler, M.C. and Hoyt, J.C. "Discharge Measurements" U.S.G.S. Water Supply Paper No.172, pp.259-261.

5. Haworth, Erasmus, "The Kansas River Flood of 1903" K.U.G.S.; Min.Res. for 1902, pp.63-81, 1903.

between 600 and 800 feet. The depth of the stream varies from place to place and changes frequently due to the shifting current, but ranges from a few feet to ten. The gradient decreases from ten feet per mile in the western tributaries to one and four tenths feet per mile below



Lawrence. Above Lawrence, the gradient is lessened by the dam which checks the flow and backs the water up stream for nearly six miles. The discharge which is computed from the flow times the cross-section ranges from between two and three thousand second feet (cubic feet per second) in an Ordinary year, to nearly fifty

---

6. Gannett, Henry, "Profiles of Rivers" U.S.G.S.; W.S.S. No.44, p.72, 1901.

thousand second feet during times of high water.

Elevation and Gradient of the Kansas River[7]

Locality	Distance from Mouth in Miles	Heigth above Sea-Level in Feet	Fall per Mile
Kansas City	0	720	
Lawrence	50	796	1.52
Topeka	87	864	1.83
Manhattan	160	996	1.81
Salina	310	1,200	1.36
Wallace	654	3,280	6.05

The bed of Kansas river is composed of sand and silt. The only rocky place in the channel near Lawrence is just below the dam where the stone has been washed from a ledge, which outcrops in the bed of the stream, and partly from an old dam which was washed out years ago. Sand is deposited in the swifter current while silt is dropped as a black mud in quiet water. The bed of the stream is shifting as is shown by the sandbars and islands in figure 2. The channel is mark-

7. Gannett, Henry, "Profiles of Rivers" U.S.G.S.; W.S.S. No. 44, p.72, 1901.

ed by broad gentle curves as the current swings against one bank or the other.

Islands

Two types of islands are found in Kansas river near Lawrence. The one about a mile north of town was

Fig.2--View of Kansas river looking north from the foot of Ohio Street.

once part of the mainland and was formed when ice jammed the channel in 1910, causing water to back up and overflow to the south. A new channel was formed in this direction and the old channel to the north of the island was practically filled. Figure 3 shows the is-

land as it appears from across the new channel.

The other type of island is similar to the sand bar in origin and is characteristic of Kansas river. It is caused by the deposition of sand and silt, during periods of high water, in places out of the direct current of the stream or behind some obstruction. These are fre-

Fig. 3--View of island in Kansas river one mile north of Lawrence

quently swept away during succeeding periods of high water, when the current shifts, but are sometimes left undisturbed until a thick growth of timber, usually cottonwood, springs up and protects them. If the channel is clear such islands tend to creep down stream or to

one of the banks. The stream is continually wearing the upper side of the island away and depositing material on the protected side. Such an island existed a few years ago about a mile below the bridge, but has gradually moved down stream until at present it is found almost

Fig.4--Large curve and island in the Kansas river above the dam.

a mile below its original position. Figure 4 shows an island of this origin which has recently been formed just above the dam.

An island in such a position as that shown in the above figure on the outside of a curve is unusual under natural conditions. Here, however, the current and de-

position is affected by the dam and flume to the Bowersock Mill. The dam proper checks the water very little during flood times while the flume near the south bank is higher and a relatively greater check under such conditions. The flood waters headed for the dam create a line of friction with the slow moving water behind the flume along a line parallel to the shore and here the velocity of the stream is checked causing it to drop a portion of its load of sand and silt. Thus, the island has been built up from the point where the flume and dam meet, upstream, paralleling the shore for almost two hundred yards.

Sandbars

Very similar in origin to the islands of deposition are sand bars which form along the banks of the Kansas or on the protected sides of the islands. These are more numerous below the dam in this section where the water is not so deep. Considerable fine sand for construction work is obtained from them.

Banks and Flood Plains

The banks of Kansas river are sandy and caving and

very uneven as may be seen in figure 5. The south bank is higher in most places. Normally, good examples of lateral erosion are found on the outside of the curves where the stream swings against the bank and leaves a vertical cliff of variable height as in figure 6. In

Fig.5--The "Kaw" looking east from Massachusetts bridge.

this area, however, railroad tracks follow along both sides of the river and the banks have been jettied in most places to prevent such work. The jetties protecting the Missouri Pacific tracks one mile north of Lawrence are shown in figure 7.

The soil of the Kansas river valley is very sandy,

Fig.6--Lateral erosion on Kansas river one mile northwest of Lawrence.

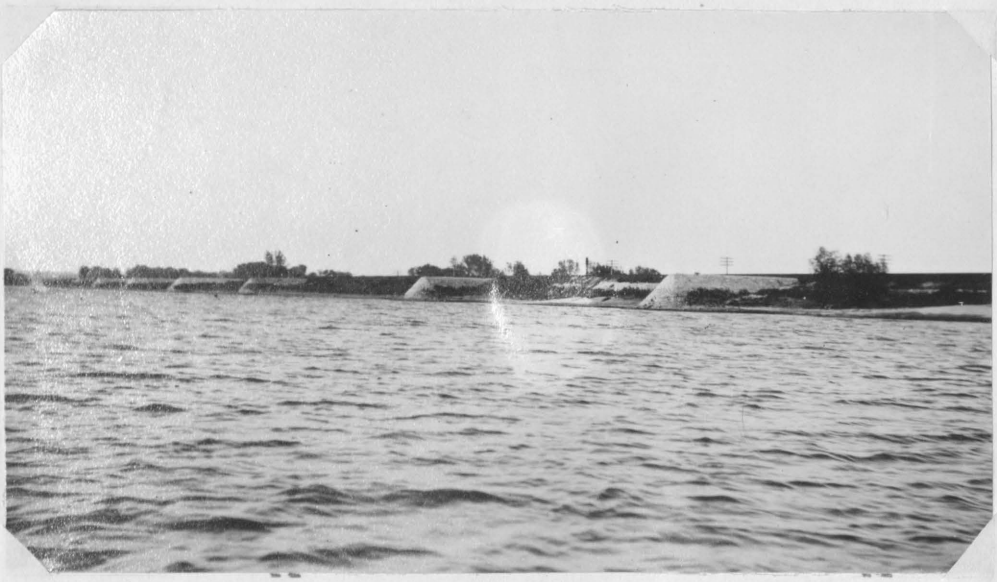


Fig.7--Jetties in the Kansas river along the Union Pacific tracks due north of Lawrence.

especially northwest of Lawrence a few miles, where the fine sand blows and drifts badly against the fences and shrubbery as may be seen in figure 8. Farther east and on the south side of the river the soil is blacker and more of the true alluvium type. Part of the sand north

Fig.8--Wind blown sand north of Kansas river which has lodged against a hedge fence.

of the river has been carried from the sand bars in the "Kaw" by the prevailing south-westerly winds, and part of it is the sand of old stream channels which cross the area.

Old River Channels

Probably the most notable feature of the Kansas

river valley in the area is this chain of old river channels which may be seen north of the present river. These are from ten to twenty feet in depth and from two hundred to four hundred yards wide. One bank, either the north or the west, is very steep, while the other is a more gentle slope. The north bank of one of these

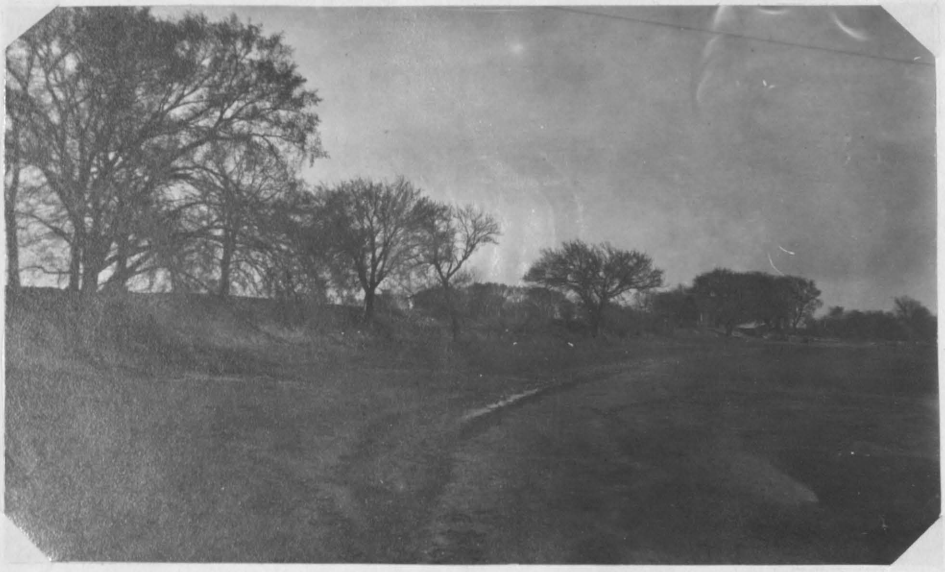


Fig.9--Old river channel northeast of Lawrence. The steep bank is on the north.

old river channels is shown in figure 9. Faint terraces exist at numerous places along the banks. The best defined channel and the deepest part is along the steeper bank. Several shallow lakes, one of which is shown in figure 10 are found in these. While these old

river beds are sometimes marshy during wet seasons, they are usually under cultivation and yield excellent crops.

Effect of Flood of 1903.

The flood of 1903 had a beneficial effect on the old river channels. Previous to that time, the soil in them was of the gumbo type, sour and too wet to cultivate.[8] The flood established better drainage in these old channels and left a deposit of from two to six feet

Fig.10--Shallow lake in old river channel two miles northeast of Lawrence.

of sand and silt which is very desirable for farming.

---

8. Personal communication from resident farmers.

Terraces

Another feature of the Kansas river is the terraces which exist at places along the present channel. Good examples of these may be seen about two miles below Lawrence where a well defined terrace exists on either side of the river. The best is the one on the north side of

Fig.11--River terrace on north side of Kansas river one mile east of Lawrence.

the river, shown in figure 11. These are composed of alluvium. Unlike those to the west which are approximately the same elevation, there is no fluvio-glacial material which can be seen on their surface. Since they are nearly the same elevation as the banks of the nearby

old river channels, they are probably remnants of the old flood plain and hence, erosional in origin. Their elevation above the first flood plain of the river is between five and ten feet.

Sloughs

At other places small sloughs are found on the flood plain near the present channel. These mark the courses of currents in the flood waters.

Mud Creek

The principal creek which enters the Kansas river and flows across the flood plains north of Lawrence is Mud creek. This creek flows from the northwest through a narrow meandering channel cut deeply into the Kansas river flood plains. Natural levees from five to six

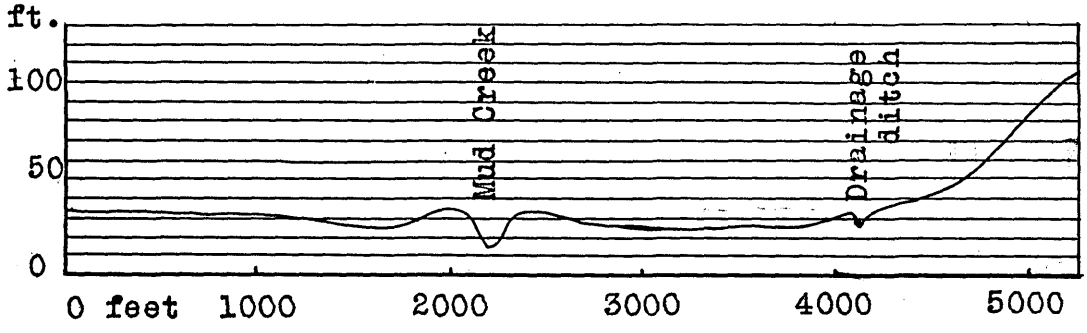


Fig.12--Profile showing natural dikes of Mud creek and the drainage ditch which protects the lowlands.

feet high have been thrown up on both sides of the stream.

Thus, there is a wide low place between the stream and the hills to the north which would become swampy were it not for a drainage ditch which encircles the foot of the hills and catches the water which flows from them.

Sluice gates have been built at the mouths of all drainage ditches on Mud creek. These permit water to enter the creek but check all back flow and thus, save the lowlands from excessive overflow.

WAKARUSA CREEK

Preliminary Statement

Rivalling the Kansas river in the size of its valley is Wakarusa creek which flows through the area. The Wakarusa rises in southwestern Shawnee county and flows due east past a point three miles south of Lawrence and enters Kansas river a few miles down stream.

The Basin

The basin of the Wakarusa is approximately fifty miles long and from ten to fifteen miles wide. Like the other streams in this region, its channel is near its southern bluff line. The south bank is much higher and often shows good exposures of shale and sandstone as in

figure 13. The north bank and valley floor are composed wholly of black alluvium and gumbo. Unlike Kansas river, there are no sand deposits in its valley or in the present stream bed exposed in this area. If any sand or gravel was ever deposited by the glaciers, it has been

Fig.13--South bank of Wakarusa west of Louisiana street bridge. Weston shales are exposed.

completely buried by alluvium as the stream moved to the south. No sand is being deposited at the present time because the Wakarusa throughout its course flows mainly through shale and limestone formations.

History of Wakarusa Creek

The development of Wakarusa creek is closely connected with the history of glaciation and the Kansas river.[9] Both are responsible for the large valley through which the Wakarusa flows to-day.

It is probable that the Wakarusa did not exist previous to the time of the Kansan ice sheet. In that case, this entire section of Kansas was drained by Kansas river and several tributaries which flowed along and across the present course of the Wakarusa. The ice sheet coming from the north crossed the divide into Kansas river basin sending torrents of water through its channel and enlarging its valley to an enormous extent. Soon, however, the glacier reached the Kansas between Lake View and Wamego

---

9. Todd, J.E., "History of Wakarusa Creek, Kansas" Kansas Acad.Sci. Vol.23-24, pp.211-218, 1911.

and blocked it. Water then backed up and overflowed the highlands to the south. At first numerous lakes dotted the front of the ice. Later, however, when the volume of water became great enough the lakes were joined and drainage was established to the eastward.
Hence, by using parts of valleys of tributary streams the Wakarusa was formed. The entire drainage of the ice sheet stretching from Montana to Kansas now flowed through the Wakarusa and the wide valley resulted. Then came the withdrawal of the ice and the Wakarusa was forced to depend upon rainfall for its existence.

The retreating ice filled the Kansas river with flood waters and cut its valley much deeper. The result on the Wakarusa was that it tended to become a small intrenched stream. Thus, it is to-day, a small stream varying from 20-50 feet wide, and intrenched from twenty to thirty feet below its flood plain as may be seen in figure 14. Its current is much swifter than that of Kansas river.

While the stream itself is very small, averaging not over twenty or thirty feet in width, it is quickly affected by rains and soon fills its entire channel. It is sub-

ject to overflow during rainy seasons. The relatively large size and depth of its channel is explained by the large amount of water which flows through it during flood times. The Wakarusa seems not to have moved to any great extent over its flood plains, and yet several

Fig.14--Wakarusa creek south on Louisiana street road.

large meanders are shown in its course. One exists due south of Haskell Institute campus and another just east of the road on Haskell Avenue. Lateral erosion is active on the outside of the meanders. A good example of this may be seen in figure 15.

Natural Levees

Like Mud creek, the Wakarusa has built up natural levees along its banks. These were formed during flood times. As the flood water spread over the banks, its velocity and carrying power were lessened by the diminishing depth of the water and by friction with the slow moving back water. Consequently, its load was dropped and formed the low marginal ridges which are called, "natural levees."

Fig.15--Lateral erosion on the Wakarusa east of Louisiana street bridge.

Due to the fact that the Wakarusa follows its southern bluff line along most of its course, the levee on the

south bank where it occurs is of little concern. To the north, however, the wide Wakarusa valley lies below the level of the levee. The levee prevents flood waters from returning quickly to the channel, and leaves a low stretch of land between the stream and the bluffs into which the hill water seeps causing many marshes. The

Fig.16--Drainage ditch north of the Wakarusa one mile south of Lawrence.

above condition has been bettered somewhat by the construction of a drainage ditch,as shown in figure 16, at the foot of the highlands to catch and divert the water which flows from them. Sluice gates have, also, been

constructed where all drainage ditches cross the levee preventing any back-flow from the main stream into the lowlands.

Tributaries to the Wakarusa

The largest creek which enters Wakarusa is Coal creek which flows from the south past the western edge of Blue Mound and joins the Wakarusa on the north. Like the Wakarusa, it has a very wide flood plain and is similar in other respects. It flows against its eastern bluff line leaving its entire flood plain to the west.

A very singular drainage feature occurs to the south of the Wakarusa and near the western edge of the area under discussion. Two small creeks may be seen flowing through the same valley for over a mile before they enter the Wakarusa. One follows the eastern bluff while the other one is near the western edge of the valley. Throughout this distance the two channels run almost parallel and make similar turns. Such a condition is favorable for stream piracy. If one would send a small tributary back and tap the other channel, such would occur and subsequent drainage would follow the one channel.

Numerous other small creeks drain into the Wakarusa All have interesting features but are very similar. Most of them head a few miles back in the high escarpment caused by the Oread limestone. Here their beds are very steep and narrow with V-shaped valleys. This portion of the valley is youthful. Farther down stream all of these valleys reach a point where the gradient is greatly reduced; the valley begins to widen out and there is the beginning of a flood plain. Here the valley has reached maturity. Before reaching the mother channel the flood plains of these creeks are relatively wide. The larger streams flow through meandering channels and may be classed as "old."

The area as a whole is well drained. Only in small portions of the valleys are there places which are marshy and too wet to be farmed profitably.

UPLANDS TOPOGRAPHY

General View

Three sections of the area remain to be described. One consists of the uplands and mounds south of the Wakarusa; another the divide between the Kansas and the Waka-

rusa; and lastly the low bluff line and the escarpment north of Kansas river.

The Area South of the Wakarusa

That part of the area lying south of the Wakarusa is quite varied in its topography. Four miles southeast of Lawrence is a prominent eliptical shaped mound shown

Fig.17--Distant view of Blue Mound four miles southeast of Lawrence.

Fig.18--View of Blue Mound across the flood plain of Rock Creek.

in figures 17 and 18, which is called Blue Mound, and to the southwest of town another flat topped mound with three prominent domes called the Three Sisters (figure 18). The former reaches an elevation of 1,050 feet, while the latter is only 1,000 feet above sea level. Both are steep sided and slope down rapidly from their high points to an elevation one hundred and twenty to one hundred and fifty feet below. This is the general

Fig.19--Distant view of the Three Sisters.
Four miles south of Lawrence.

elevation of the uplands in this section and exists as a prominent bench around each of the mounds. This bench is shown clearly around the base of the Three Sisters in figure 19.

The uplands and benches are underlain by a heavy bed of sandstone. This sandstone causes a moderate escarpment along the valley of the Wakarusa and along the creeks which cross the area. The uplands are as a rule gently rolling and lie at an elevation from forty to eighty feet above the flood plain of Wakarusa creek. The second uplands are found immediately south of the area under discussion and are represented by the two mounds in the area.

The Divide Between the Wakarusa and the Kansas River

The divide between Wakarusa creek and Kansas river is very similar in topography to the area south of the Wakarusa. The second uplands are represented by Mount Oread upon which the University stands. To the north, south, and east and approximately one hundred and fifty feet below the Oread escarpment are the first uplands which are underlain by sandstone. The divide as a whole is pointed towards the east where the flood plains come together about four miles east of Lawrence. Since the formations dip to the west in this region, the gen-

eral level of the uplands becomes gradually lower in that direction. Small creeks cut into the edges of the divide on all sides.

Uplands North of Kansas River

In the eastern part of the area, north of Kansas river, the same general conditions exist as between the

Fig.20--The flood plain and Oread escarpment north of Kansas river. Northwest of Lawrence.

Wakarusa and the "Kaw" and south of the Wakarusa. To the west, however, the flood plains reach to the foot of the second uplands or to the Oread limestone escarpment, as may be seen in figure 20. The topography of

all of the area north of Lawrence has been modified by the action of glaciers. All of the creeks are wider. The hills are more rounded and are covered with a thin mantle of fluvio-glacial drift. In some places the first uplands have been covered with wind blown sand and silt which has been carried from the river valley.

Summarizing, the principal features in the topography of the Lawrence area are:

1. The Drainage System including
   (a) The Kansas river with its wide flood plains and old river channels.
   (b) Wakarusa creek with a valley nearly equaling that of Kansas river and its natural levees.
   (c) The creeks ranging in age from young to old which drain the uplands and flow into the Wakarusa and Kansas river.
2. The uplands (a) south of Wakarusa creek (b) between the Wakarusa and Kansas river, and (c) north of Kansas river, all with the exception of one area to the northwest having a "first uplands" rolling in nature caused by a heavy bed of sandstone and a "second up-

land" flat topped and capped with Oread limestone.

The interesting details in regard to the topography are:

(a) Special features such as the high mounds; the natural levees, old river channels, sand dunes etc.

(b) The modifications of the preëxisting topography due to glaciers, wind blown sand etc.

CHAPTER 4--STRATIGRAPHY OF THE LAWRENCE AREA

Structural Relations

Kansas lies in the area of the Great Plains country. The formations which are seen at the surface are relatively flat lying and undisturbed within the state. To the east, however, the Ozark uplift has tilted the rocks up so that in eastern Kansas they dip slightly to the west. To the west, the Rocky Mountains have likewise tilted the strata so that in western Kansas the formations dip to the east. Structurally, then, Kansas lies in a great syncline with the lowest part near the center of the state.

Effect on Topography

The surface is further affected by these two great uplifts. The Ozark uplift occurred much earlier than that of the Rocky Mountain, hence, erosion has been active longer and wider stretches of the older formations are exposed. As one goes westward from the main uplift, one passes successively from older to younger formations.

Since the surface in Kansas rises towards the Rocky Mountains, and the formations dip gently to the westward, each formation capped by a hard strata forms a table-land with a rugged eastward facing escarpment. The best example of such in the Lawrence area as well as in eastern Kansas is the Oread limestone which caps the Lawrence shales and makes the prominent escarpment west of the town of Lawrence.

Age and Classes of Rocks

The stratified rocks in this area are Pennsylvanian in age. They are composed of alternating limestone and shales with the shales largely predominating. Several large beds of sandstone, also, are found in the section. The other rocks, much younger in age, are the river alluvium and sand deposits, and glacial drift, including till, erratics and fluvio-glacial deposits.

The Pennsylvanian Series

The Pennsylvanian rocks in Kansas are divided as follows:[10]

---

10. Moore, Raymond C., "Geology of Kansas" State Geological Survey of Kansas, Bull.6,Part 2, p.18,1920.

Divisions of the Pennsylvanian Rocks of Kansas

	Wabaunsee formation
	Shawnee "
Missouri Group	Douglas "
	Lansing "
	Kansas City "
	Marmaton formation
Des Moines Group	Cherokee shale

The Douglas Formation

The Douglas formation, the principal division which is exposed in this area is further subdivided into the following alternating shales and limestones:

Oread	limestone
Lawrence	shale
Iatan	limestone
Weston	shale

The Kanwaka shale, the lowest member of the Shawnee formation is exposed in small patches above the Oread limestone escarpment..

The Weston Shale

The Weston shale, the lowest member of the Douglas formation, outcrops in the first uplands and the low rounded knolls in the area. To the north of Kansas river, however, it is covered with sand and silt so that its presence is determined only from the relief of the region and the sandy nature of the soil. To the east, the Weston shale rises higher above the flood plains and may be seen in numerous cuts.

Between the Wakarusa and Kansas river the Weston shale is exposed below the limestone which outcrops in eastern Lawrence and near the southeastern corner of Woodland cemetery. South of the Wakarusa, the Weston shale outcrops around the base of Blue Mound and to the east.

This member is approximately one hundred feet thick and is composed of clayey and sandy shale with several rather extensive beds of pure sandstone. One bed of sandstone occurs near the base of the member and forms a prominent outcrop along the banks of the Wakarusa three miles east and two miles south of Lawrence. This

bed, shown in figure 21, is approximately fifteen feet thick and is composed of fine grained, buff colored sandstone. It is massively bedded near the base and gradually becomes thinner bedded near the top. Ripple marks, cross-bedding and other shore-line characteristics are prominent in some localities. Like most sandstone members , this bed changes rapidly in its characteristics within

Fig. 21 Basal sandstone in Weston shales along the Wakarusa six miles southeast of Lawrence

a short distance. The central part of the Weston shale member is composed of buff colored and bluish grey shale.

Another prominent sandstone bed occurs near the top of the member. It may be studied at numerous places

south of the Wakarusa in exposures similar to that in figure 22, and also east of Lawrence, as shown in figure 23 of the outcrop in the road southeast of Haskell Institute. Like the lower sandstone, this one is massively bedded in part. It is usually light buff in color but

Fig.22. Exposure of sandstone in upper part of Weston shales. West of Blue Mound.

occassionally contains bluish-grey layers and sometimes

dark red beds. In some places thin layers of sandstone have been cemented with silica and are very hard and blue with a characteristic conchoidal fracture. In other places the sandstone contains local deposits of

Fig. 23. Exposure of sandstone in the upper part of the Weston shales east of Haskell Institute.

carbonate of lime. The sandstone in these places contains numerous invertebrate fossils. One such locality occurs five miles due south of the University near the southeastern corner of section 24.

To the southeast around Blue Mound, and east and northeast of Lawrence, this upper sandstone contains

numerous ferns and other plant fossils.

Several carbonaceous layers occur in the Weston shales as shown in figure 24. A bed of coal from fifteen to eighteen inches thick was mined near Blue Mound years ago.[11] This vein occurs approximately forty feet below the top of the Weston shales.

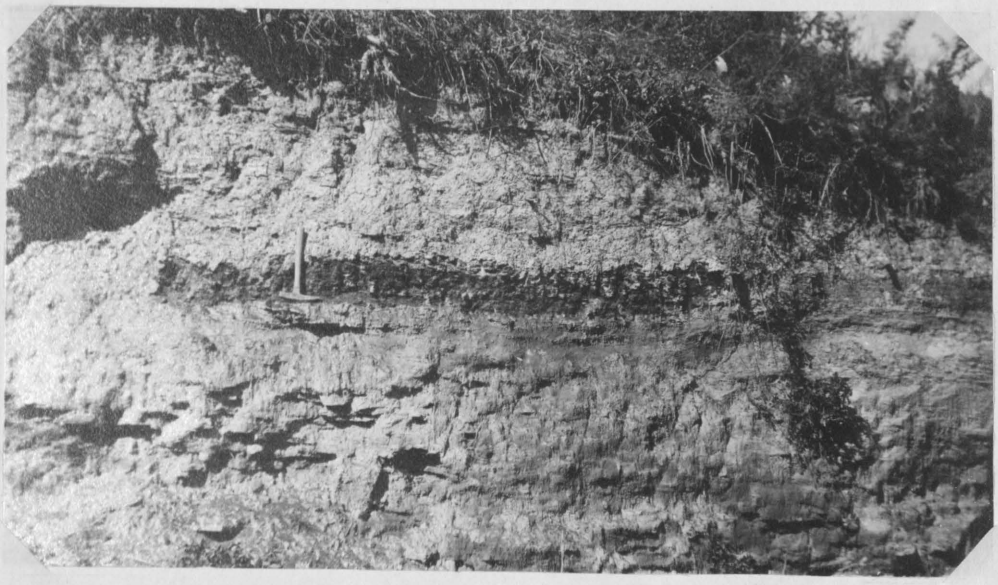


Fig.24--Exposure of carbonaceous layer in the Weston shales near cemetery. East of Lawrence.

Thin local limestones are also found interbedded in the shales at some places.

---

11. Haworth, Erasmus, "The Coal Fields of Kansas", Kansas University Geological Survey, Vol.1; pp.218-220;p.225.

A detailed section of the upper part of the Weston measured east of Woodland cemetery is as follows:

No.	Ft.	Total	Description
9.	2.4	2.4	Iatan ls. hard,compact,blue limestone. Very hard,fossiliferous. Fossil forms filled with calcite.
8.	3.2	5.6	Sandy shale near bottom grading into thin bedded flinty limestone near top.
7.	6.3	11.9	Bluish grey shale near bottom. Sandy shale bluish grey with buff colored streaks in upper part. Near top are found septaria which are cracked and the cracks filled with calcite.
6.	0.8	12.7	Black carbonaceous shale. Resembles mass of black decomposed leaves and roots.
5.	0;3	13.	Argillaceous shale. Yellowish grey.
4.	5.3	18.3	Sandstone. Very thin bedded, fine grained.
3.	4.4	22.7	Heavy massive sandstone bed. Very

No.	Ft.	Total	Description
			fine grained. Light greyish and buff in color.
2.	5.	27.7	Grey and yellow shale. Slightly sandy.
1.	21.5	49.2	Arenaceous shale. More arenaceous in upper part. Thin bedded. Streaked with brown sandstone layers. Bluish grey to buff concretion of red and yellow ochre near top.

Another section which includes beds (1) and (2) of the foregoing and some beds below was measured on the Wakarusa just west of the bridge on the Louisiana street road. It is as follows:

No.	Ft.	Total	Description
10.	8.	8.	Massive, buff colored, fine grained sandstone.
9.	10.	18.	Soft, buff colored sandstone, very shaly.
8.	7.5	23.5	Bluish grey and buff colored arenaceous shale.

No.	Ft.	Total	Description
7.	2.4	25.9	Light buff arenaceous shale.
6.	2.	27.9	Greyish buff sandstone.
5.	0.5	28.4	Reddish sandstone layer.
4.	1.8	30.2	Thin bedded, greyish yellow sandstone.
3.	0.5	30.7	Black shale.
2.	3.2	33.9	Buff colored thin bedded sandstone.
1.	4.	37.9	Fine grained light buff colored sandstone. Thin bedded.

The sandstone in the Weston shales are important for their abundance of excellent water.

The Iatan Limestone

The Iatan limestone which caps the Weston shale member is often confused with thin local limestones both above and below. In the area around Lawrence the Iatan may be studied in the eastern edge of town, near the southeastern edge of Woodland cemetery and at many places south of the Wakarusa. The best exposures occur around the base of Blue Mound. The Iatan limestone is usually found capping the first uplands in this area.

The type exposure of the Iatan limestone is found near Iatan, Platte County, Missouri, from which place it gets its name. In Leavenworth County and to the north it is reported as attaining a thickness of fifteen feet or more. In Douglas County and south to the southern edge of the state, its maximum thickness is only a mat-

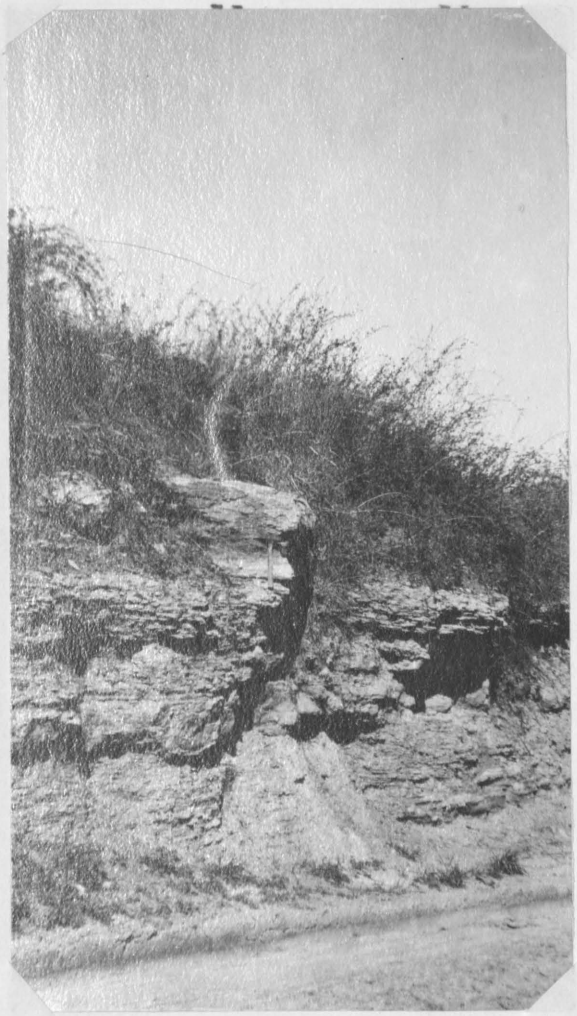


Fig.25--Exposure of the Iatan limestone near cemetery east of Lawrence.

ter of a few feet.[12] Near Lawrence it ranges from eighteen inches to two feet and six inches where it was measured near Woodland cemetery. This exposure is shown in figure 25.

The Iatan is an extremely hard bluish grey limestone, containing in places numerous Fusulina. It sometimes weathers into large blocks and sometimes into two or three layers. One of its chief characteristics is that its fossil shells have been replaced with crystalline calcite. These often stand out on the weathered surface of the limestone.

The Lawrence Shales

The Lawrence shales are approximately one hundred and fifty feet thick in their type locality near Lawrence. They occupy the face of the escarpment caused by the overlying Oread limestone. This member is composed of clayey and sandy shale with occasionally a thin limestone of only local extent. Near the base, the member is quite sandy and sometimes contains a massive bed of sandstone from ten to twenty feet thick. In their un-

---

12. Moore, Raymond C. and Haynes, Winthrop P., "Oil and Gas Resources of Kansas", St. Geol. Sur. of Kans. Bull, 3; p. 101, 1917.

weathered condition the shales are bluish in color but weather to a deep buff. The sandstone near the base of the member is water bearing. A thin bed of coal has been mined from the Lawrence shales in Douglas County (?)

The Oread Limestone

The Oread limestone occupies the top of the high

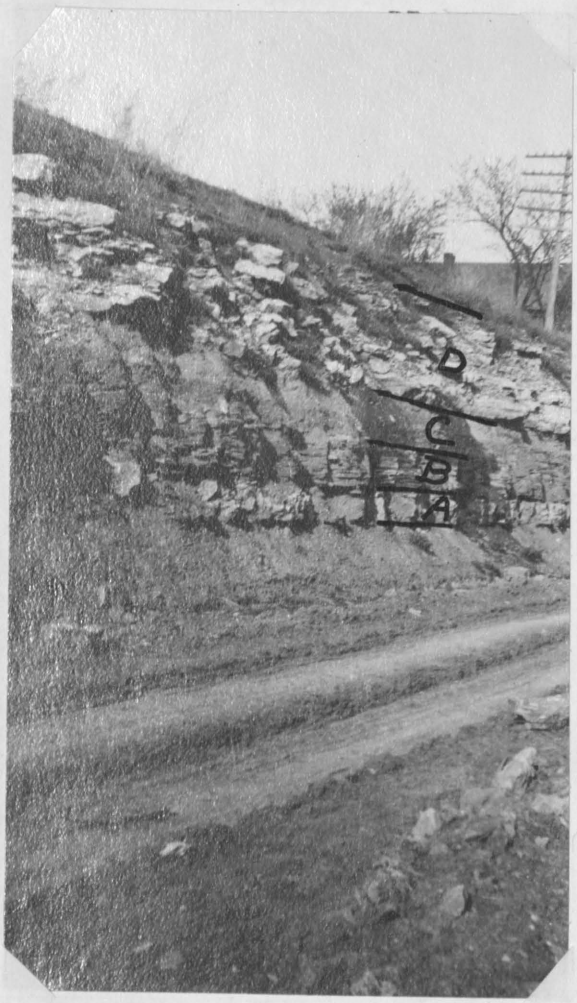


Fig.26--Exposure of Oread limestone in cut on Fort to Fort Highway in West Lawrence.
(a) Middle Oread
(b) Carbonaceous shale
(c) Buff colored shale
(d) Upper Oread.

escarpment north, south and west of Lawrence. The member is composed of three limestones separated by shale, the upper and lower ones being much thicker than the middle member. The lower bed of limestone lies on the top of Blue Mound, causing that prominent feature of the topography. It is believed, however, that there is no Oread limestone on the Three Sisters, in place, with the exception of broken remnants. The Oread limestone is named from Mount Oread which it caps and upon which the University stands.

A typical section of the Oread limestone is as follows:

Section of Oread Limestone on Fort to Fort Highway (cut in road west of Lawrence-figure 26).

No.	Ft.	Total	Name	Description
6.	10.	10.	Upper Oread	Grey to yellow. Badly weathered and broken.
5.	3.	13.	Shale	Yellow-clayey.
4.	3.	16.	Shale	Black carbonaceous. Laminated cleavage resembling slate. Numerous small black mud concre-

No.	Ft.	Total	Name	Description
				tions.
3.	1.7	17.6	Middle Oread	Massive,blue,grey. Very hard. Conchoidal fracture.
2.	11.8	29.4	Shale	Grey-buff.
1.	10.5	39.9	Lower Oread	Upper half buff,massive limestone. Many Fusulina. Cherty in upper part. Lower 5' chalky white in unweathered condition; weathers to light buff.

All members of the Oread limestone are suitable for construction work and are quarried to a considerable extent. Quarries in the lower member are shown in figures 27 and 28, while figure 29 shows an exposure of the upper member in quarry six miles northeast of town.

Shawnee Formation

Kanwaka Shales

Only small patches of the Kanwaka shales, the lowest member of the Shawnee formation, are exposed in the

Fig.27--Exposure of the Lower Oread in West Lawrence. Note the white color of the lower 5' and the dark buff color of the upper half.

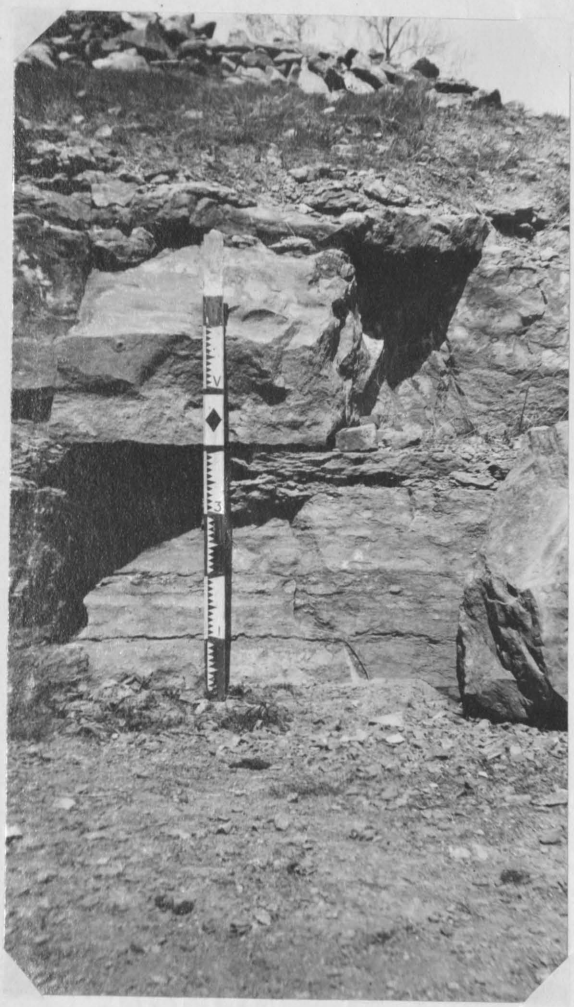


Figure 28--Exposure of Lower Oread in West Lawrence.

Fig.29--Exposure of Upper Oread on limestone escarpment northeast of Lawrence near the rock crusher.

boundaries of this report. These occur above the Oread limestone escarpment. West of Lawrence, this shale member is exposed quite extensively and attains a thickness of approximately 100 feet. The shales are very clayey and a light buff in color.

Quaternary Deposits

The quaternary deposits in this area include the glacial drift which is found extensively, and the river alluvium and sand deposits of relatively recent origin.

The glacial deposits consist of till, fluvio-glacial drift, and boulder erratics deposited beneath or along the front of the ice. These are discussed more fully in the following chapter on the "Pleistocene in the Lawrence Area."

The river deposits are very important in the vicinity of Lawrence because such a large proportion of the area lies in the river and creek valleys. The wealth of the area is due to the rich farm lands found in Kansas river valley and in Wakarusa valley. Minor deposits of alluvium are found in all of the creeks. The deposits in the main consist of sandy alluvium, sand and gravel, and gumbo. These are described in detail in the dis-

cussion on the Kansas river and Wakarusa creek and under the heading "Soils".

CONDITIONS OF SEDIMENTATION

Sedimentary rocks are those composed of transported fragments or particles of older rocks which have undergone disintegration. The principal agents of transportation are wind, water and glaciers. Water is the most important since it is active as rain, in streams, and in the oceans. Sedimentary rocks may be either marine or non-marine in origin.

All of the general classes of sedimentary rocks are represented in the Lawrence area. These comprise the muds, clays, shales, limestones and sandstone. Of these the muds, clays and shales may be classed together since they are so closely related. Mud is the finer products of erosion, often earthy in character, which has been deposited in water and may be either continental or marine. Clay is composed of the same material which has been compacted. Shale is clay which has become more compact and more or less fissile or laminated. When subjected to intense pressure shale becomes slate, its

metamorphic equivalent.

Limestone, the second class of sedimentary rocks is usually of organic origin. When formed organically, it is composed of tests and shells of marine invertebrates. Its deposition occurs in the seas when conditions are favorable for the growth of marine animals and when the seas are relatively clear. Muddy water results in impure limestone or clay partings within the limestone.

Sandstone is sand which has been cemented and compacted into a firm rock. The sand grains are the result of the decomposition and the breaking up of the igneous rocks and are composed principally of quartz. Sand differs from gravel in the size of the grains and in being composed mostly of quartz. The principal cements in sandstone are iron oxide, calcium carbonate, and silica. When metamorphosed by heat and pressure, sandstone becomes quartzite.

The rocks exposed in the Douglas formation represent widely different conditions of sedimentation. Quick changes in deposition are shown by the succession of

strata which are exposed in the area. Limestones of marine origin and sandstones and shales of both marine and non-marine origin alternate with one another in the geologic column.

Immediately below the Weston shales occurs the Stanton limestone. This limestone is approximately sixty feet thick and represents a long period of submergence when conditions were favorable for the growth of marine animal life, the tests and shells of which go to make-up limestone.

Immediately following this, the Weston shales were deposited under entirely different conditions. The basal sandstone of this member is cross bedded, ripple marked, and has other shore line characteristics. It is fine grained and indicates that the neighboring land was not of great relief and that the streams which deposited this sand were sluggish and meandering.

Following this, a long period ensued when mud was deposited and shale formed. During this time, intermittent submergences brought the land below the sea and initiated the deposition of limestone. Thus, the formations laid down in this period consist of blue and

yellow shales with several thin local limestones. Near the top of the shales are found several carbonaceous layers, among them an eighteen inch vein of coal, which indicates, swampy or other similar conditions favorable for the growth of coal forming vegetation existed at the time of deposition.

Finally, in a recurrence of earlier conditions, fine grained sandstone was deposited towards the close of the Weston shale period. Evidence of near shore conditions of deposition at this time is shown in the numerous plant and marine fossils found closely associated in the upper sandstone.

The Iatan limestone just above the Weston shales represents an incursion of the sea when conditions over a wide spread area were favorable for the deposition of limestone.[13]

The Lawrence shales indicate the possible driving back of marine waters and the deposition of mud under non-marine conditions. The shales, however, in the lower few inches are not without indications of the struggle

---

13. Twenhofel, W.H., and Dunbar, Carl O., "Nodules with Fishes from the Coal Measures of Kansas", Am.Jour.Sci., Vol.38, p.163, Aug.1914.

between marine and non-marine deposition. Vertebrate fossils are found in these lower shales.[14]

Like the Weston shales a prominent sandstone bed is found in the basal part of the member. The main part of the shales are sandy and contain characteristics indicating near-shore deposition. A thin vein of coal fifty feet below the top of the member represents swampy conditions, while maroon colored streaks in the shales show that the opposite or arid conditions existed for short periods. Thin, local limestones indicate temporary submergences of the land. As a whole, the Lawrence shale member indicates a wide variety of conditions of deposition.

A long period of submergence caused the deposition of the Oread limestone. During this time conditions were favorable for the growth of marine invertebrates as is showm by the numerous fossils in the limestone. Twice the deposition of the limestone was interrupted causing the Oread to be divided by shale into three members.

---

14. Twenhofel, W.H. and Dunbar, Carl.O, "Nodules with Fishes from the Coal Measures of Kansas", Am.Jour.Sci., Vol.38,pp.159-160,Aug.1914.

The lower shale parting is buff colored while the upper one is black and carbonaceous in part.

Buff colored Kanwaka shale overlies the Oread limestone. Streams were again depositing mud and silt in the area. Thus, it may be seen that conditions of sedimentation were not only changing for each member of the formations exposed in the area, but were continually being interrupted and changed during the deposition of each member.

PALEONTOLOGY

The fossils of the Douglas formation are not unlike those of the underlying Lansing formation.[15] At the base of the latter, however, many new species of invertebrate fossils are introduced, which are not found earlier and are found throughout both of these divisions of the Pennsylvanian. In both the Lansing and the Douglas, many of the older species were becoming extinct while in the Shawnee formation which followed there was an apparent lull in the extinction of any species.

---

15. Moore, Raymond C., "Geology of Kansas", State Geological Survey of Kansas, Bull.6,Part 2, p.40,1920.

Both the Iatan and the Oread limestones are rich in invertebrate fossils, while the Weston, Lawrence, and Kanwaka shales are relatively barren.

The Iatan Limestone

Two new species appear for the first time in the Iatan limestone.[16] These are:

. Limopteria marian White

Fenestella shumardi Prout?

Ten species, all Pelecypods but one, are peculiar to the Iatan. The most important species are:

Limopteria longispina Cox

Pteria longa Gein.

Pteria sulcata Gein

Schizodus compressus Rogers

Some seven or eight species appear for the last time:

The most abundant species is Productus pertenuis.

The moderately abundant species are as follows:[17]

Anthozoa

Aulopora? prosseri

Lophophyllum profundum

---

16. Beede,J.W. and Rogers,A.F., "Coal Measures Faunal Studies",Kans.Uni.Geol.Sur. Vol.9,pp.344-345;1908.

Brachiopods

Chonetes granulifer

Derbya Bennetti

Derbya Keokuk

Meekella striaticostata

Orbiculoidea missourensis

Productus cora

Productus nebraskensis

Seminula argentea

Bryozoa

Polypora elliptica

Polypora triangularis

Pelecypods

Edmondia nebraskensis

Limopteria longispina

Limopteria marian

Myalina subquadrata

Myalina swallowi

Pseudomonotis hawni

Pteria longa and P. sulcata

Schizodus compressus

---

17. Beede, J.W. and Rogers, A.F., Loc.cit.p.328.

The Oread Limestone

Seven species of invertebrate fossils are peculiar to the Oread limestone.[18] These are as follows:

Orthonema salteri (M and W)

Pinnatopora ptilaporoidea Rogers

Polypora missouriensis Rogers ?

Polypora spinulifera Ulr?

Chaenocardia ovata (M and W)

Derbya broadheadi (H and C)

Twenty species disappear.[19] The principal ones being:

Cypridella americana Rogers

Rhombocladia delicata Rogers

Proboscidella sp.

Amblysiphonella sp.

Limopteria longispina Cox

Aulopora prosseri Beede

Euconospira missouriensis Swallow

Ephippoceras ferratus Cox

Domatoceras lasallense (M and W)

Fenestella perelegans Rogers

---

18 and 19. Beede, J.W. and Rogers, A.F. loc.cit. pp.344-345.

Ceriocrinus missouriensis (M and G)

Thamniscus tenuiramus Rogers

Fenestella kansasensis Rogers

The most abundant species in the Oread limestone is Productus cora. Other fossils moderately abundant are as follows:[20]

Anthozoa

Aulopora prosseri

Lophophyllum profundum

Brachiopods

Ambocoelia planoconvexa

Chonetes granulifer

Derbya bennetti

Derbya keokuk

Enteletes hemiplicata

Hustidia mormoni

Marginifera longispina

Meekella striaticostata

Orbiculoidea missouriensis

Productus pertenuis

Productus semireticulatus

---

20. Beede,J.W. and Rogers,A.F. loc.cit.p.328.

Pugnax utah

Rhipodomella pecosi

Seminula argentia

Spirifera cameratus

Spiriferina kentuckyensis

Squamularia perplexa

Bryozoa

Polypora triangularis

Rhombopora lepodendroidea

Stenopora carbonaria

Gastropod

Bellorophon crassus

Weston Shales

The Weston shales contain fossils of both marine invertebrates and non-marine plants. Both are found in the sandstone near the top of the member.

The imvertebrates are not found generally throughout the area where the sandstone is exposed, but occur only in small areas. One such place occurs five miles due south of the university near the southeastern corner of section 24. Here the fossils are exceedingly numerous

and well preserved. The principal species are those found in the nearby Iatan limestone.

Plant fossils are found in the sandstone where it is exposed around the edge of Blue Mound and northward across the Wakarusa along the low bluff-line. The principal species are ferns. A fossil seed? was picked up by the writer near the center of the south line of section (9) three miles southeast of Lawrence. This specimen resembles a nut-meg, but is much larger.

Lawrence Shales

In general, the Lawrence shales are barren of fossils. Near Oak Hill cemetery, however, east of Lawrence is an area where the lower few inches of shales contain numerous nodules with fossil fishes in their centers.[21] This fossiliferous strata is a yellowish-grey shale approximately two inches thick lying just above the Iatan limestone.

The nodules are greyish in color, are composed of silica and lime and have granular surfaces. They are usually oblong, some two inches in length, with the di-

---

21. Twenhofel,W.H. and Dunbar, Carl O.,"Nodules with Fishes from the Coal Measures of Kansas",Am.Jour.Sci., Vol.38, pp.157-163;Aug.1914.

ameter varying from three quarter inches to one and one-quarter inches. As many as one dozen of these nodules are found in one square foot of the shale.

The fossils in the nodules are chiefly vertebrates and are composed of skulls, bones and spines of fishes. Several well preserved brains were also found in the nodules.

CHAPTER 5-THE PLEISTOCENE IN THE LAWRENCE AREA

Introduction

As previously indicated, all of the topography of the area surrounding Lawrence cannot be accounted for by those agents of erosion active in the region to-day. The Wakarusa valley is much broader than seems reasonable from the present size of the stream. Even the Kansas valley seems to be slightly overgrown. The hills to the north of Kansas river are rounded and are covered by a material part of which is foreign to the native rocks of the region. At other places in the area are boulders unlike the underlying rocks. The conclusion is that such rocks have been brought in from some distant source, and that the same agents which transported them modified the preexisting topography. Such has been the work of the glaciers.

The Glacial History of North America

The glacial history of North America is one of alternate advances and withdrawals of the ice sheets. The advances are represented by glacial deposits which were

carried out by the ice and deposited as till or drift.' The withdrawal of the ice or the inter-glacial epochs are marked by deposits of peat, soil etc. Further evidence of the inter-glacial epochs is (1) the unconformity between the drift of one epoch and that of the following, and (2) evidence that one drift was leached and weathered before the deposition of the next.

Six advances of the ice are recognized in the interior of North America.[22] These together with the inter-glacial intervals and two sub-stages, numbered in the order of their age, are as follows:

13. The Champlain Sub-stage (Marine)
12. The Glacio-lacustrine Sub-stage.
11. The Later Wisconsin, the sixth advance.
10. The Fifth interval of deglaciation (unnamed)
9. The Earlier Wisconsin, the fifth invasion.
8. The Peorian, the fourth inter-glacial interval.
7. The Iowan,the fourth invasion.
6. The Sangamon, the third inter-glacial interval.
5. The Illinoian, the third invasion.
4. The Yarmouth or Buchanan,second inter-glacial

---

22. Chamberlin and Salisbury,"Earth History"Vol.3,p.383.

interval.

3. The Kansas or second invasion of the ice.

2. The Aftonian, the first known inter-glacial interval.

1. The Sub-Aftonian or Jerseyan, the earliest known invasion of the ice.

It is believed that the later stages in general were much shorter than the earlier ones.[23] Thus, the above list of invasions and withdrawals of the ice are numbered with the longer stages at the bottom. Of these, the Kansan or second invasion of the ice is probably the only one which reached Kansas.

The principal ice sheets moved in all directions from three great centers in Canada namely, (1) Labrador, east of Hudson Bay; (2) Keewatin, west of Hudson Bay; and (3) the Cordilleran region of British Columbia. As near as can be ascertained, the ice which affected northeastern Kansas and the area around Lawrence came from the central ice zone. This has been determined by tracing the drift back to its source towards this center

---

23. Chamberlin and Salisbury, loc.cit.p.383.

and by noting the direction of movement of the ice as shown in the striae on the underlying rocks.

The cause of the ice sheets is more or less a matter of conjecture. Because of their tremendous size, however, it is certain that they were not the result of coalescing of mountain glaciers alone, but resulted, also, from thick accumulations of snow over a long period of time which did not melt, due to the cold climate. It is estimated that ice accumulated in the three great centers to a depth of several miles.

The Kansan Ice Sheet

The greatest distance which any of the ice sheets moved from their sources was fiften hundred miles when the ice moved from the Keewatin center to Kansas during the Kansan advance.[24] Roughly, the western limit of the Kansan ice sheet is as follows:[25] Through the eastern edge of the Dakotas, and southwestward across Nebraska into Kansas slightly west of the Big Blue river. From thence, the limit of the drift may roughly be bounded by the Blue river on the west, and the Kansas river on the south.

---

24 and 25. Todd, J.E., "Drainage of the Kansan Ice Sheet", Kansas Acad.Sci., Vol.22, pp.107-112, 1909.

Effect on Kansas

Due to the fact that probably the Kansan ice sheet is the only one which reached Kansas and that such a long period of time has elapsed since then, Kansas shows few of the effects of glaciation. If the ice left a surface dotted with lakes and swamps and poorly drained, normal erosion has had time to repair the damage. If a thick coating of drift covered the area, erosion has almost completely laid bare the native rocks with the exception of small areas.

The topography of northeastern Kansas, in general, is not typical of a glaciated region, but is the result of normal erosion on alternate layers of hard and soft rocks. Only faint evidences of glaciation may be seen in the rounded hills and widened valleys. The clearest proof that glaciers covered the northeastern corner of Kansas is shown in drift, till, and boulders which were carried from the north and dropped as far south as the limits of the ice, roughly outlined above.

Effect on the Lawrence Area

The effects of the ice sheet on the area surrounding Lawrence are definite but with the exception of the

uplands topography are not due so much to the ice itself as to the water which flowed from it.

The first uplands north of Kansas river exhibit a topography somewhat characteristic of a glaciated area. The hills are rounded and the valleys wide and aggraded to a great extent. Many of the valleys and such erosional features seem not to have any place in the present system of drainage. Some of the ridges are characteristically oblong in shape. The most characteristic one exists in section 10, Twp.12, south,R 20 east, three miles east of the university and four and one-half miles north. The longest axis of this ridge runs north and south and is nearly a quarter of a mile long, while it is only approximately one hundred yards wide. The ridge is covered with many different kinds of boulders. Many other ridges and hills shaped by the ice exist both to the east and west of the one in section 10.

The effect of the ice on the valleys of Kansas river and Wakarusa creek has already been mentioned. The Wakarusa valley particularly is unusually wide considering the present size of the stream. The stream originated dur-

ing glacial times from the channel cut by the flood waters around the front of the ice. The size of its valley is due directly to the vast amount of water which flowed through it during this period.

Not all of the work of the Kansan ice sheet consisted in cutting wide river valleys and in otherwise eroding the surface. Many deposits were laid down during the period. Those in the vicinity of Lawrence consist of till, fluvio-glacial drift, and many glacial boulders.

Glacial Deposits

While glacial deposits are found scattered generally throughout the area, most of them seem to be arranged in definite terraces or patches according to elevation.

The highest of these occurs at an elevation between one thousand feet and one thousand and fifty feet. South of the Wakarusa, it is represented by boulders on the top of the hill called, Three Sisters, and a line of boulders around the edge of Blue Mound. Between the Wakarusa and the "Kaw" numerous boulders are found on Mount Oread and the escarpment to the west. North of the Kansas river, gravel, boulders and clay of glacial origin cover the hills in the Oread escarpment to an elevation of one thous-

and and fifty feet. The deposits here resemble till somewhat, but are weathered to such an extent as to make identification uncertain.

Another bouldery veneer at a lower elevation covers the top of a long mound, trending east and west, one mile northeast of the Three Sisters.

This mound resembles a moraine so much in appearance that it has been referred to as such.[26] However, there is no till underneath the boulders and it probably represents deposits in the channel of the glacial stream. Its elevation is between nine hundred and thirty and nine hundred and fifty feet above sea level.

The boulders found on the mound in section ten northeast of Lawrence occur at about the same elevation as the above. While no till is recognized in either deposit, it might easily have existed at one time and been washed away.

Beneath the boulders, south of the Wakarusa from twenty to forty feet is found gravel, sand and clay resembling till. The best occurrences may be seen on the hills near the center of the south lines of sections nineteen

---

26. Hay,Robert, "Characteristics of the Glaciated Area of Northern Kansas", Kans.Acad.Sci.,Vol.13,pp.104-106.

and twenty, Twp. thirteen south, R 20 east, and in hills farther to the south at about the same elevation. It is believed that these deposits represent till in a badly weathered condition.[27]

The lowest boulder terrace, as well as the lowest deposit of till in the area, may be seen on the low es-

Fig.30-Bouldery terrace southeast of Haskell Institute.

carpment southeast of Haskell Institute. As shown in the accompanying picture, figure 30, the boulders are exceedingly numerous and some are very large. The largest lies on the side of what is called Violet Hill one-half mile east of Haskell Institute. It is composed of reddish granite and is approximately seven feet in diameter.

---

27. Personal communication from Dr. W.H. Schoewe.

The general elevation of this line of boulders is between eight hundred and fifty and eight hundred and sixty feet.

Associated with the boulders are deposits of till composed of sand, gravel and clay. These may be seen at many places where the boulders are in evidence. No deposits are found in the Wakarusa valley or to the south at this low elevation because the Wakarusa has worked over and covered up all deposits as it has moved its channel in this direction.

A similar line of drift occurs along the edge of the first uplands north of the Kansas river. The best exposure may be seen in the road just below the school house near the southeastern corner of section eight, Twp.12, south, R. 20 east. This deposit is composed of sand, gravel and a small percentage of clay. Faint stratification is shown in some places, but in most places the deposit is so badly weathered and covered that it is studied with difficulty. Its elevation is between eight hundred and fifty and eight hundred and seventy feet above sea level or at about the same elevation as the lowest bouldery terrace and till southeast of Haskell Institute. In its

weathered condition the deposit resembles till but because of its stratification in freshly exposed cuts, the deposit must have been laid down, in part, either in a glacial lake or in a stream which flowed from the ice.

The best example of a fluvio-glacial deposit occurs at the Lawrence brick plant where the excavation as shown

Fig.31.--Excavation at Lawrence Brick Plant.
(a) Fluvio-glacial deposit;(b) bluish shale.

in figure 31 has exposed between six and eight feet of gravel, sand and clay. The gravel is composed of quartzite, granite, feldspar, and green stone. All carbonate of lime or native limestone has been leached from the bed.

A few large boulders, some two feet in diameter are found in this deposit. This drift lies fifty feet above the Kansas river or about the same elevation as the lower boulders to the south. From its stratified condition, it appears to have been deposited by a glacial stream.

Summary

In summary, the glacial deposits in the Lawrence area are as follows:

1. The highest line of boulders and drift on Three Sister, Blue Mound and on the Oread escarpment to the west and north at an elevation between 1000 and 1050 feet.

2. Boulder covered mounds, one northeast of Three Sisters and another northeast of Lawrence in section 10. Elevation 930-960 feet.

3. Deposits of till at an elevation between 900-920 south of the Wakarusa along the centers of the south lines of sections nineteen and twenty.

4. Till and drift at an elevation between 850-870 feet as follows:

1. Boulders and till on low escarpment

southeast of Haskell Institute.

2. Drift at foot of first uplands north of the Kansas river.

3. Fluvio-glacial drift at Lawrence brick plant.

Erosional History

The topography of parts of the area and the deposits of drift and till are strongly suggestive of the erosional history of the glaciers. From the highest bouldery patches it is certain that pre-glacial drainage was approximately one hundred and seventy feet higher than at present and that the Oread escarpment extended several miles farther to the east. The Kansas river existed previous to the time of the glaciers, but Wakarusa creek did not originate until during this time. The drainage south of the Kansas river consisted of creeks which flowed along and across the present site of Wakarusa creek and entered Kansas river.[28]

As the ice approached from the north, it crossed and blocked the Kansas above Lawrence. The overflow

---

28. Todd, J.E., "History of Wakarusa Creek", Kans. Acad. Sci., Vol. 23-24, pp. 211-218; 1911.

to the south first caused lakes which later developed into Wakarusa creek which flowed around the head of the ice and entered the Kansas river to the east.[29] This earliest channel of the Wakarusa is represented by the boulders on the top of Three Sisters and around the edges of Blue Mound. The later history of the ice consists of long periods when torrents of water from melting ice rushed through the Wakarusa cutting the formations down rapidly, alternating, with periods when the ice would not melt so rapidly and would advance and bring thick deposits of boulders, till, and drift. These later periods account for the lower boulder terraces. The deposits of till represent times when the ice advanced even across the Wakarusa because, deposits of till, as stated above, are found south of that creek. Glacial streams, also, left their deposits of sand and gravel such as the one at the Lawrence brick plant.

Kinds of Boulders

The boulders scattered throughout the area are composed mainly of quartzite, granites and green stones

---

29. Todd, J.E., "Drainage of the Kansas Ice Sheet", Kans. Acad. Sci., Vol. 22, pp. 107-112; 1909.

named in the order of their abundance.

Quartzite

The quartzite boulders are by far the most numerous. Most of them are tinted with red depending upon the amount of iron oxide which they contain. Some of them are dark red in color while others are finely streaked with white and red. These boulders were brought by the ice from southwestern Minnesota and northwestern Iowa. Most of them are very hard and show little effects of weathering. They were characteristically rounded and smoothed by the ice in transportation.

Granite

Granite boulders are, also, found in the area. Most of them are reddish or pinkish in color. Some are subangular like the quartzite boulders,while others are found as irregularly shaped blocks. Not all of them are weathered to the same extent. Some crumble at the slightest touch while others are almost as hard as the quartzite boulders.

Green Stone

A few boulders of green stones including diorites, diabeses, and gabbros are found. These boulders are us-

ually very small and are weathered only slightly.

Native Rock

Limestone and flint native to the region are frequently found in the bouldery patches associated with the northern boulders.

A complete list of the boulders found in the mound in section ten, four miles northeast of Lawrence, is as follows:

Granite
Quartzites
Diorites and gabbros
Hornblende and mica schists
Granite gneiss
Conglomerate
Limestone and flint
Limestone conglomerate

CHAPTER 6--ECONOMIC GEOLOGY

Introduction

The mineral resources of the Lawrence area comprise bituminous coal, brick clay, and shale, building limestone, crushed limestone, building sand, and water including the water which is used for domestic purposes and the water which the Kansas river affords as a source of power. While no oil or gas has been found in the area as outlined, several gas wells have been drilled just to the east, and there is a possibility that this may be one of the valuable resources of the region in the future.

Coal

The last coal was mined in Douglas County in 1893.[30] At that time cheaper coal was being shipped in from Leavenworth County and the mines here were abandoned. The mines were located around Sibleyville and near Blue Mound. Some coal was also reported to have been mined

---

30. Crane,W.R., "Stratigraphy of Kansas Coals",Kans. Univ.Geol.Sur.,Vol.3,pp.186-189;1908.

near the hill in East Lawrence.[31] All that remains today of the coal fields of Douglas County are vague reports and sink holes which mark the sites of the old shafts.

The coal was mined from a vein ten to fifteen inches thick approximately one hundred and fifty feet below the bottom of the Oread limestone or about thirty feet below the Iatan limestone. Early reports placed this vein of coal in the Lawrence shales, and since no coal has been mined in recent years, no effort has been made to change this statement to conform with the present division of the shales nomenclature. The coal occurs below the Iatan limestone and, therefore, in the Weston shales. Coal does occur in the Lawrence shales, however, appearing in a thin vein on the south side of the hill on which the University stands. Coal has also been mined in southwestern Franklin County and in Atchison County, about fifty feet below the Oread limestone.[32]

---

31. Hawroth,Erasmus, "The Coal Fields of Kansas", Kans. Univ.Quart.,Vol.3,p.297, 1895.

32. Crane,W.R., "Stratigraphy of Kansas Coals", Kans. Univ.Geol.Sur. Vol.3,p.186;1898.

The quality of the coal has been described as moderately good. It was the fact, however, that the vein was very thin that caused it to be mined on only a small scale and finally prevented its being mined in competition with the Leavenworth coal. Both the stripping method and the shaft method with horse hoisters were employed.

Brick Clay and Shale

Various products are manufactured by the Lawrence Vitrified Brick and Tile Company in its plant near the

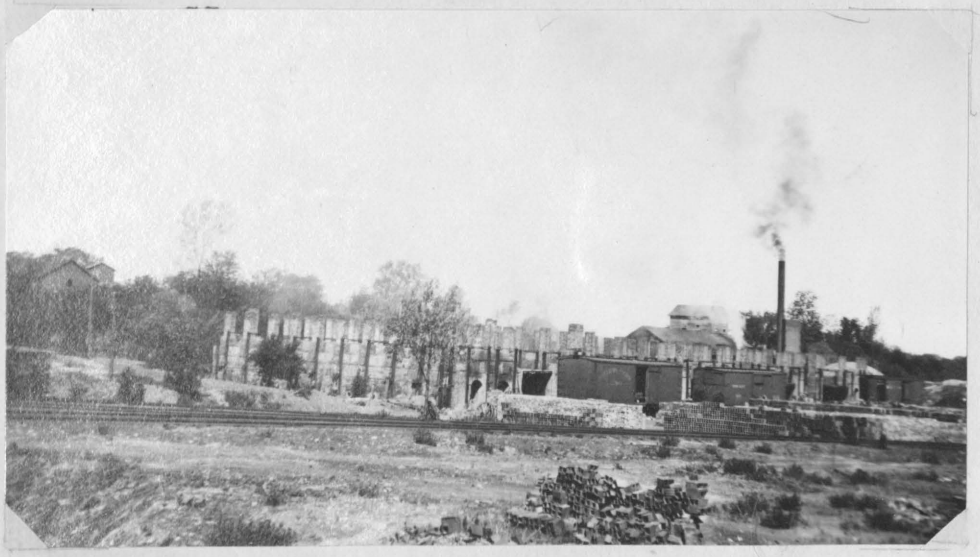


Fig.32--Lawrence Vitrified Brick and Tile Plant.

north end of Mississippi Street (figure 32). These include building tile of various sizes, silo blocks, face

brick, paving brick and common brick.

The materials for the tile and brick are excavated by a steam shovel from the side of a nearby hill. A section exposed in this cut is as follows:

3. Sand, gravel, and boulders (fluvio-glacial) 5'

2. Shale, dark blue at base and grading into yellow above. 20'

1. Limestone shows only in the floor of the excavation. Thickness reported 15'

Various proportions of the two upper divisions are used depending upon the product required. The iron content of the upper division is high and gives a deep red colored brick when burnt. The gravel and sand were deposited by an old river during glacial times and contain many of the characteristic quartzite boulders brought by the ice from the north.

It is not certain whether the shale of the second division is part of the Weston shales or belongs to the Lawrence shales. It is believed that the former classification is correct.

The limestone exposed in the base of the excavation is reported to be fifteen feet in thickness. This is

much thicker than the outcrop of the Iatan elsewhere in this area, but the measurements are uncertain. On the other hand, however, it is not certain that it is the Iatan but it occupies a similar position below the Oread. The bed dips noticeably to the southwest.

Building Limestone

The limestone of the region, particularly the Oread, has been quarried extensively for building purposes. A majority of the University buildings are constructed from this limestone. Of these might be mentioned Haworth Hall, Marvin Hall, Robinson Gymnasium, Dyche Museum, and the Chemistry building. The Oread limestone contains considerable iron and changes to a deep buff color when weathered. All members of the Oread limestone are quarried.

Crushed Limestone

Oread limestone has been quarried and crushed at numerous places for construction work in this area. The demand for crushed rock has not been large nor consistent, however, hence none of the quarries have been worked any considerable length of time. Small quarries are opened at the most convenient points when crushed rock

is needed. Oread limestone tests high in hardness, toughness, cementing values and in wearing qualities, and is suitable for most types of construction work. Its French coefficient of wear is between seven and eight, while Joplin flint is eleven and granite ranges between thirteen and twenty-four. The toughness of Oread limestone is between six and seven which is also high for the limestones in eastern Kansas.

At the present time, crushers are located west of

Fig.33--Rock crusher on the Oread escarpment. Six miles northeast of Lawrence.

town. One which crushed limestone for the Fort to Fort Highway is located northeast of Lawrence six miles

on the Oread limestone escarpment and is shown in figure 33.

The Iatan limestone is quarried for only local needs in this area.

Building Sand

Good building sand is obtained in this area from the Kansas river. Part of it is hauled directly from the sand bars along the banks, while the rest is obtained by dredging in the swifter currents of the stream. The sand from the sand bars is very fine but is used to a considerable extent. A much coarser and better graded sand is obtained by dredging. All of the sand is composed of quartz with very few impurities and is moderately sharp.

The sand which outcrops in the ledges near Lawrence is not used since it is harder to obtain than the river sand and is too fine to be of any value.

Water

Lawrence and the surrounding area are fortunate in having an abundant supply of water. Since so much of the area lies in the major valleys, water from the underflows is an important factor in the supply. Good, pure,

soft water in unlimited quantities is obtained from this source. The first uplands are supplied by water equally as good from sandstones in the Weston shales. Water is obtained on the high, flat uplands by drilling to the sandstone near the base of the Lawrence shales.[33]

Several springs are found on the hillsides where the water bearing sandstones outcrop. Doubtless, other springs could be opened up by digging away the mantle soil where prominent seeps occur.

The water in the Kansas river might, also, be mentioned as one of the chief water resources of the region. Part of the Lawrence city water comes from this source. Its greatest asset, however, lies in the fact that it is the most important source of water power in the state of Kansas. The Bowersock Mill and dam (figure 34) is the largest water power project in the State and is the only place where water power is utilized on Kansas river. The mill is capable of generating from 2500-3000 horse power. Its power, however, is lessened by ice in the winter and by high water during wet seasons.

---

33. Young, C.C., "Notes on the Waters from the Sandstone in the Lawrence Shales", Kans.Acad.Sci. Vol.23-24,pp.199-200;1909.

The mill and dam are located on the south side of the river on Massachusetts Street. Here the bank is about fifty feet above the river making the location particularly favorable. The bank is also moderately high on the north side. The channel between the two points is rocky with slight rapids just to the east.

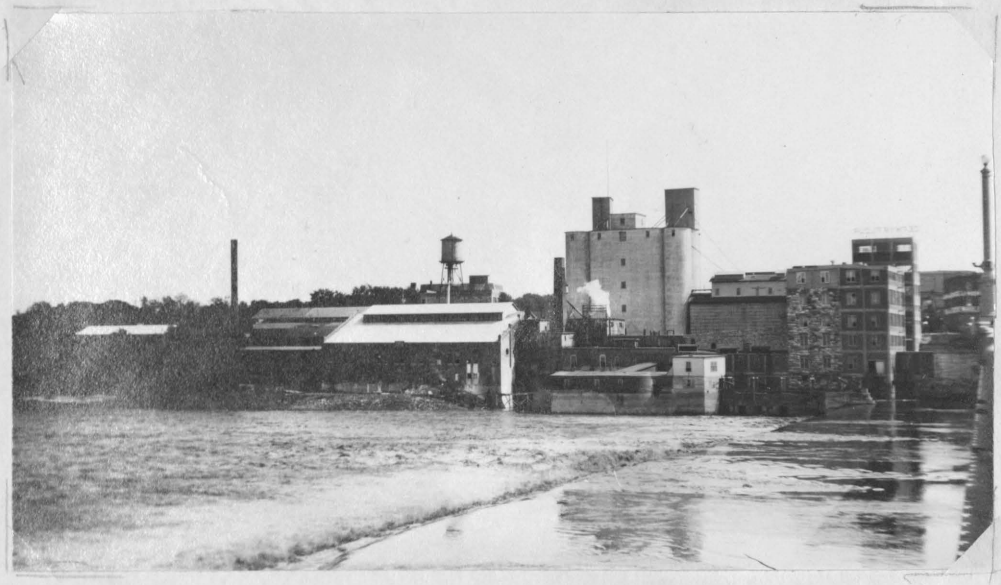


Fig.34--Bowersock mill and dam. Height of water slightly above normal.

These conditions so favorable for the location of a dam and water power mill were early recognized and the first dam was built in 1872.[34] It consisted of brush

---

34. Newell,F.H.,"The Kansas River",U.S.G.S. Water Supply Bull. No. Series No.140,p.145.

and logs. During the high water of 1874 part of the dam was washed away and in 1877 the remaining part disappeared. As each section "went out", however, the present dam was built. Since then, the dam has been reenforced and improved so that to-day it is almost all concrete.

The north half of the present dam rests on hard pan and is composed of a timber crib filled with stone which has recently been built up with concrete. The south half rests on a limestone ledge between two and three feet thick and is composed of cement masonry and concrete.

Soil

Six general types of soils are found in the vicinity of Lawrence. These are sandy alluvium, gumbo, sandy loam, black loam, and residual and glacial soil on the uplands.

The sandy alluvium is the most productive soil. It is found over all of the Kansas river flood plains with the exception of a few places on the south side, but not to any great extent in the Wakarusa valley. It owes its origin to the river. Due to its large percentage of sand, it drains readily. On the other hand, however, it blows easily in places. Alfalfa, corn, wheat, potatoes and legumes grow well on this soil.

Gumbo soil is found, also, in the valleys. Small patches occur on the flood plains south of Kansas river. The greater part of the gumbo soil, however, is found on the flood plains of Wakarusa creek. It is characterized by poor drainage. Only by innoculating the soil and preparing it with sweet clover can alfalfa be grown. The principal crops raised are corn, wheat, oats, and grasses.

The sandy and black loams are residual soils formed by the decomposition of sandstones and shales. They are found on both the first and second uplands. The black loam is moderately good for farming, but the sandy loam where it is composed mostly of sand is sometimes rather lean. Corn, wheat, and oats are the principal crops.

Glacial soil covers the uplands north of Kansas river. Unlike the glacial soils farther north, they are not very productive. They are composed mainly of clays with a small amount of gravel. Because of their clay content, they are rather impervious and drain poorly. Iron oxide colors them a characteristic red. Small grains and corn are raised on them.

A slightly different soil from the foregoing originates from the decomposition of the limestones which

underly the uplands. When not too rocky this soil is very rich.

Only a small percentage of the land in the vicinity of Lawrence is unsuitable for cultivation. The faces of the escarpments are too rocky and too steep to be farmed, while small portions of the valleys are too wet. Outside of these, the soil near Lawrence is the best in Kansas.

Oil and Gas

Oil and gas have not been found in the immediate vicinity of Lawrence. To the northeast, however, several gas wells have been drilled which make the outlook for the production of oil and gas in this portion of the state much brighter.

Six wells have been drilled to date while two others will be begun in the near future. Only one well of the entire number was dry, while another was drilled too deep and ruined by water. The total production of the remaining four wells is estimated at 3,850,000 cubic feet. The production of the largest well was measured at 2,200,000 cubic feet. This well, which was the first drilled, ran open for sixty days due to bad caves and the loss of the tools in the hole. After it was confined for one hour,

its rock pressure measured 260 pounds. The gas sand is reached at a depth between 720 to 800 feet.

BIBLIOGRAPHY

1. Adams, George I. Stratigraphy of the Upper Carboniferous of Kansas. U.S.Geol.Survey, Bull.211, pp. 43-45, 1903.
2. Babb, Cyrus C., Hindler, M.C., and Hoyt, J.C. Discharge Measurements of the Kansas River. U.S. Geol.Survey, Water Supply Paper, No.172, pp. 259-261.
3. ---- The Kansas River. Ibid, pp. 258-259.
4. Bailey, E.H.S. Mineral Waters of Kansas. Kan.Univ. Geol.Survey, vol.7, pp.290-291, 1902.
5. Beede, J.W. and Rogers, A.F. Coal Measure Faunal Studies. Kan.Univ.Geol.Survey, vol.9, pp. 345-346, 1908.
6. Bennett, John. Section from Kansas City to McFarland. Kan.Univ.Geol.Survey, vol.1, pp.113-115, 1896.
7. -----Synopsis of the Invertebrate Fauna of Douglas County. Kan.Univ.Geol.Survey, vol.1, pp.291-292, 1896.
8. Broadhead, G.C. Carboniferous Rocks of Eastern Kansas. St.Louis Acad.Sci., Trans.,vol.4, pp.481-493, 1884.
9. Chamberlin, and Salisbury. Earth History, vol.3, pp. 382-383.
10. Cordley, Richard W. History of Lawrence.
11. Crane, W.R. Chemical Properties of Kansas Coals. Kan. Univ.Geol.Survey, vol.3, p.280, 1898.
12. -----Detailed Stratigraphy of the Kansas Coals. Ibid pp.186-189.
13. Davis, A.P. Report of Stream Measurements for 1896. U.S.Geol.Survey, 18th Ann.Rept., pt.4, pp.218-223.
14. -----Height of Kansas River for 1896. U.S.Geol.Survey, Water Supply Paper, No.11, p.60.
15. Davis, W.M. Current Notes on Physiography. Science, new ser., vol.17, pp.193-195, 1903.
16. Eckel, E.C. Analysis of Pennsylvanian Limestones. U.S.Geol.Survey, Bull.522, p.182.
17. -----Analysis of Coal Measure Limestones. U.S.Geol. Survey, Bull.243, p.168.
18. Gannett, Henry. Profiles of Rivers. U.S.Geol.Survey Water Supply Paper, No.44, p.72, 1901.
19. Grover, N.C. The Kansas River Measurements for 1917. U.S.Geol.Survey, Water Supply Paper, No.456, pp. 233-237, 1918.

20. Hall, John. Section from Boycourt to Alma. Kan.Univ. Geol.Survey, vol.1, pp.102-103, 1896.
21. Haworth, Erasmus. The Coal Measures Soils. Kan.Univ. Geol.Survey, vol.1, p.259, 1896.
22. -----A Section from Coffeyville to Lawrence. Ibid, pp. 136-138.
23. -----Stratigraphy of the Carboniferous. Ibid, pp.160-161.
24. -----The Coal Fields of Kansas. Ibid, pp.218-226.
25. -----Stratigraphy of the Kansas Coal Measures. Kan. Univ.Quart. vol.3, p.278, 1895.
26. -----The Coal Fields of Kansas. Ibid, pp.297-309.
27. -----Topography of Eastern Kansas. Kan.Univ.Quart. vol. 2, pp.129-136.
28. -----A Section from Cherryvale to Lawrence. Ibid, pp. 118-124.
29. -----Stratigraphy of the Kansas Coal Measures. Kan. Univ.Geol.Survey, vol.3, pp.93-94, 1898.
30. -----The Kansas River Flood of 1903. Kan.Univ.Geol. Survey, Mineral Res. for 1902, pp.63-81, 1903.
31. -----Lead and Zinc in Douglas County. Kan.Univ.Geol. Survey, vol.8, 1904.
32. -----Useful Minerals of Kansas. U.S.Geol.Survey,Bull. 585, pp.78-80.
33. -----Useful Minerals of Kansas. U.S.Geol.Survey,Bull. 624, pp.135-138.
34. Haworth, Erasmus, and Bennett, John. General Stratigraphy of Kansas. Kan.Univ.Geol.Survey, vol.9, p. 106, 1908.
35. Haworth, Erasmus, and Kirk, M.Z. The Neosho River Section. Kan.Univ.Quart., vol.2, p.110, 1894.
36. Hay, Robert. Geology and Mineral Resources of Kansas. Kan.St.Board of Agri., 8th Bien.Rept., 1891-1892, pp.99-162.
37. -----Characteristics of the Glaciated Area of Northern Kansas. Kan.Acad.Sci., vol.13, pp.104-106.
38. -----The River Counties of Kansas. Kan.Acad.Sci.,vol. 14, pp.230-260, 1896.
39. Hindler, M.C. and Hoyt, J.C. Discharge Measurements of the Kansas River at Lecompton for 1904. Water Supply Paper No. 131, pp.92-94.

40. Hinds, Henry and Green, F.C. The Leavenworth, Smithville Quadrangle, U.S.Geol.Survey, Atlas Folio No. 206, 1917.
41. Keyes, Charles R. Stratigraphy of the Kansas Coal Measures. Am.Jour.Sci.,3rd. ser., vol.1, pp. 239-243, 1895.
42. -----The Missourian Series of the Carboniferous. Am. Geol., vol.23, p.306.
43. Kirk, M.Z. A Section Along the Neosho River. Kan. Univ.Geol.Survey, vol.1, p.79.
44. Knox, M.V.B. Drift in Kansas. Am.Jour.Sci.,3rd.ser. vol.8, pp.466-467, 1874.
45. Moore, Raymond C. Geology of Kansas. Kan.St.Geol. Survey, Bull.6, pt.2, pp.40-42, 1920.
46. Moore, Raymond C. and Haynes, W.P. General Stratigraphy of Kansas. Kan.St.Geol.Survey, Bull.3, pp.78-102, 1917.
47. Morscher, L.N. Corrading Action of River Water During High Floods. Kan.Univ.Geol.Survey, Min.Res. for 1902, pp.82-97, 1903.
48. Mudge, B.F. Geology of Kansas. Kan.St.Bd. of Agri. 4th Ann.Rept. for yr. ending Nov.30,1875, pp.107-127, 1875.
49. Murphy, V.E. Notes on the Discharge of the Kansas River at Lawrence since 1881. Kan.Univ.Quart., vol.4, p.163.
50. Newell, F.H. The Kansas River. U.S.Geol.Survey, 19th Ann,Rept., pp.337-338.
51. -----Kansas River Drainage for 1898. U.S.Geol.Survey, 20th Ann.Rept. pp.304-305.
52. -----Kansas River Drainage for 1899. U.S. Geol.Survey, 21st Ann.Rept. pt.4, p.228.
53. -----Kansas River Drainage for 1900. U.S. Geol.Survey, 22nd.Ann.Rept. pt.4, p.331.
54. -----The Kansas River Basin. U.S.Geol.Survey. Bull. 140, p.124, p.145.
55. -----The Kansas River. U.S.Geol.Survey, Water Supply Paper, No.140, p.145.
56. Parker, H.N. Quality of the Water Supplies. Water Supply Paper, No.273, pp.80-81.

57. Rogers, Austin F. Pottawatomie and Douglas Formations Along the Kansas River. K.U.Quart., vol.9, p.254 and p.334.
58. Swallow, G.C. Section of the Rocks in Eastern Kansas. Am.Ass.Adv.Sci.,Proc.,vol.15, pp.57-82, 1867.
59. Swallow, G.C. and Hawn, F. The Rocks of Kansas. St. Louis Acad. of Sci.,Trans., vol.1, pp 173-175.
60. Swen, E.G. A Preliminary Report on the Glaciated Area of Kansas. Kans.Univ.Quart., vol.4, pp.153-159, 1896.
61. Todd, J.E. Drainage of the Kansan Ice Sheet. Kan. Acad.Sci., vol.22, pp.107-112, 1909.
62. -----History of Wakarusa Creek,Kansas. Kans.Acad. Sci., vol.23-24, pp.211-218, 1911.
63. -----Pleistocene Crustal Movement in the Mississippi Valley. K.U.Sci.Bull.,vol.6, No.4, pp.375-379, 1912.
64. -----The Pleistocene of Kansas. Unpub.Rept.
65. Twenhofel, W.H. and Dunbar, Carl.O. Nodules with Fishes from the Coal Measures of Kansas. Am. Jour.Sci., vol.38, pp.157-163, Aug.1914.
66. Upham, Warner. Erosion, Transportation and Deposition of Drift by the Ice Sheets. Geol.Soc. of Am., vol.6, pp.343-351, 1895.
67. White, Charles A. The Origin of Red Quartzite Boulders. Am.Ass.Adv.Sci.,Proc., vol.17, pp.340-342.
68. White, David. Fossil Plants of the Upper Carboniferous and Permian of Kansas. U.S.Geol.Survey, Bull. 211, p.87 and p.113.
69. Wooster, L.C. The Limit of Drift.(Kansas) Sci., vol. 12, p.132, 1888.
70. Yates, J.A. Certain Features of the Lawrence Shale. Kan.Acad.Sci., vol.22, pp.117-121.
71. Young, C.C. Notes on the Waters from the Sandstone in the Lawrence Shales. Kan.Acad.Sci. vol.23-24,pp. 199-200, 1909.

INDEX

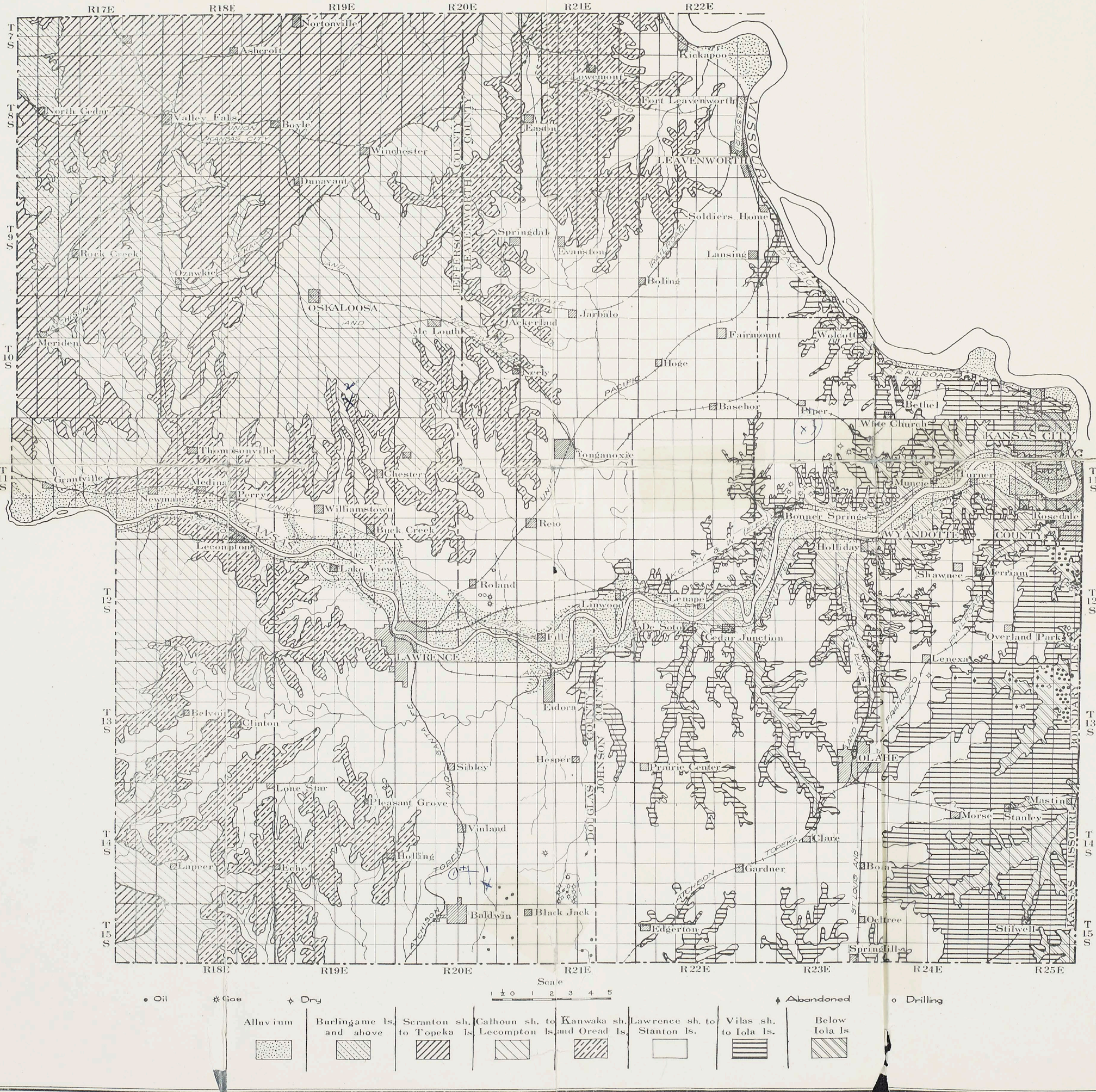
Index

Index

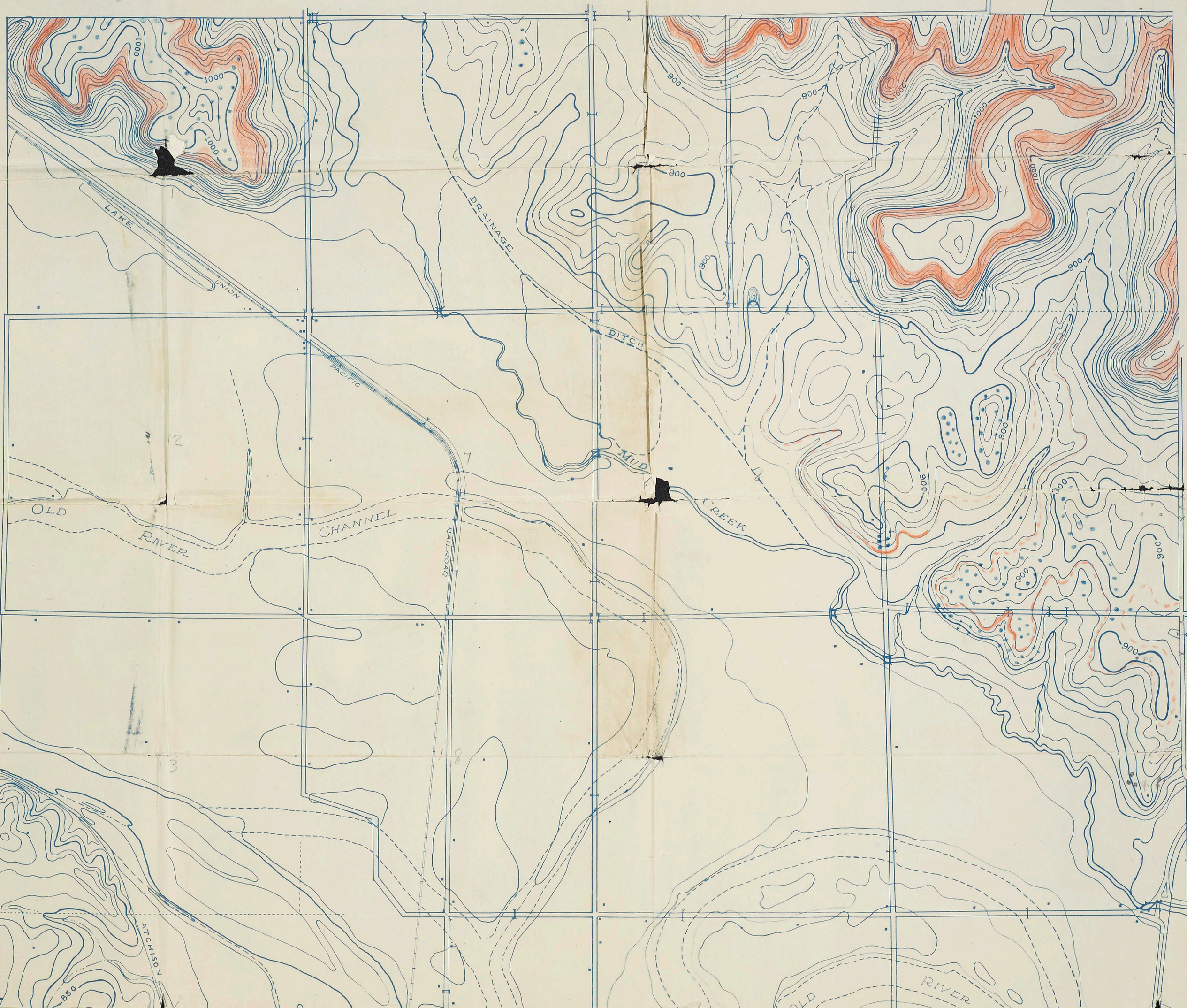
STATE GEOLOGICAL SURVEY OF KANSAS

GEOLOGICAL AND PRODUCTION MAP OF JEFFERSON, LEAVENWORTH, WYANDOTTE, DOUGLAS, AND, JOHNSON COUNTIES, KANSAS

RAYMOND C. MOORE STATE GEOLOGIST



Geologic and Topographic Map
of
Lawrence Area



TOPEKA AND SANTA FE RAILROAD

CHANNEL

UNION PACIFIC RAILROAD

KAW VALLEY INTERURBAN

KANSAS RIVER

SANTA FE RAILROAD

OAK HILL CEMETERY

850

1000