AN ABSTRACT OF THE THESIS OF

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Title: Drainage Development and Chert Gravels in Butler County, Kansas

Abstract Approved: [signature]

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Chert gravel in Butler County, Kansas can be divided into two distinctive types. Residual chert gravels have been weathered out in place on the dip slopes of the Flint Hills. These gravels are the source for the other type of chert gravels found in Butler County. The second type of chert gravel deposits found in this area are alluvial in nature. These alluvial chert gravels can be used to trace the past positions of streams in Butler County.

Alluvial chert gravels are found almost exclusively to the north of east-to-west flowing tributaries in southern Butler County. Apparently these streams are migrating laterally to the south as they cut downward. The simplest and most probable explanation for this southward migration and the resulting asymmetrical preservation of these alluvial chert

gravels is a subtle southward tilting of the underlying bedrock.

An apparent disparity exists between the pebble roundness value tests conducted in Butler County and those done along other streams east of the Flint Hills. East of the Flint Hills roundness values tend to show a high degree of angularity at the source and a steady increase in roundness values with downstream distance. In Butler County the opposite trend exists.

Chert east of the Flint Hills is weathered out on face slopes and is subject to initial mechanical breakup. West of the Flint Hills the chert weathers out on dip slopes by chemical means and is not subject to initial mechanical breakup. This helps to explain why the highest roundness values found in Butler county are associated with a residual deposit and the apparent trend to slight increases in angularity due to mechanical breakup with downstream distance.

Some quartzite pebbles have been found within the alluvial chert gravels in Butler County. These quartzite pebbles probably originated from a source to the west namely Ogallala-type arkosic gravels in western Kansas.

There are two distinct levels of deposits of alluvial chert gravels in Butler County. The upper level occupies a position at or near the top of hills forming the drainage divides between tributaries to the east of the Walnut River. The second level is located somewhat lower on the slopes and is referred to as a high-terrace gravel. Quartzite pebbles have been found only in the upper hill-top locations and it is assumed that the source for quartzite pebbles was not available at the time the younger high-terrace gravels were deposited.

DRAINAGE DEVELOPMENT AND CHERT GRAVEL DEPOSITS

IN BUTLER COUNTY, KANSAS

A THESIS

PRESENTED TO

THE PHYSICAL SCIENCES DIVISION

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STATEMENT OF GOALS

The goal of this research is to establish a comprehensive map of ancient alluvial chert gravels in Butler County. This will include distinction between different types, relative positions, and the sizes of given deposits. Such oddities as the presence of quartzite pebbles within the chert gravels, and the presence of these gravels only to the north of the Walnut River's east-to-west-flowing tributaries will receive special attention.

The significance of these deposits is that they provide information about the past and present stream morphology and drainage patterns in southern Butler County. They may also provide clues as to the structure and neotectonics of the underlying bedrock.

Chapter 1. INTRODUCTION

Butler County is located in south-central Kansas (Fig. 1). Butler County is the largest county in Kansas with a land area of 3750 sq. km (1443 sq. mi.). Butler County is almost entirely within the physiographic region known as the Flint Hills. The Osage Cuestas begin at the eastern edge of Butler County, and to the west are the Wellington-McPherson Lowlands and the Arkansas River Lowlands.

The climate of Butler County would be classified by Koeppen as "Cwa". This is winter dry, sub-tropical with a long hot summer. The hot month (July) in El Dorado averages 27 degrees C (80.3 F) (Brown in Penner et al. 1975). The cold month (January) averages 0 degrees C (32.2 F). Average precipitation for the year is 82 cm (32 inches), with 71% of this precipitation falling between April and September. The average number of frost free days is 190 extending from April 16 to October 23. Because of the seasonal and yearly variability these averages do not give a complete picture of the climate. Although on average Butler County would be classified as Cwa, a given year might classify as BSk, Dwa, or Cfa. For example the basic difference between Cwa and Dwa is that in a Dwa climate at least one winter month must average below 0 degrees C and in Cwa climates all months average above 0

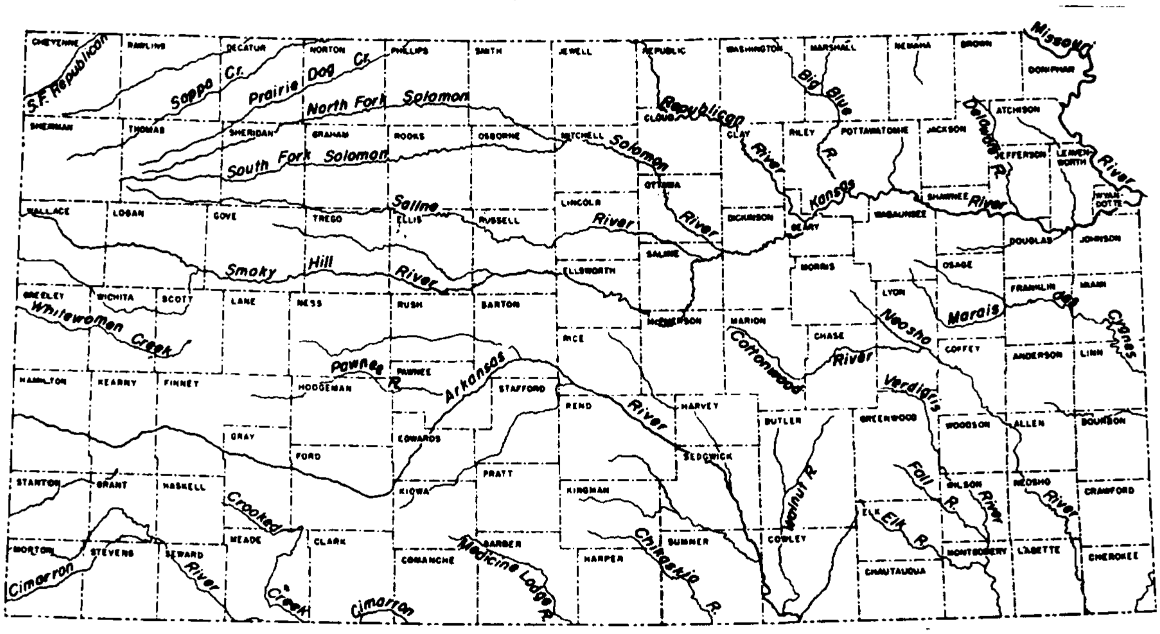

Figure 1. A map showing the positions of modern streams in Kansas and the locations of counties.

degrees C. Similar variations in precipitation could also change the classification.

The soils of Butler County are with one exception classified as Mollisols (Penner et al. 1975) in the 7th Approximation System used by the United States Department of Agriculture. Mollisols, as found in Butler County, are basically grassland soils. They are developed from limestone parent rock material, and characteristically display a thick, organic-rich surface layer. The one exception to this is the Goessel Series which is a Vertisol. Vertisols are soils with a high content of clay throughout. They usually show evidence of soil mixing caused by shrinking and swelling.

Although the Kansas Geological Survey includes most of Butler County in the Flint Hills, the topography varies significantly from the eastern edge of the county to the west. The Department of Agriculture divides the county into two distinct resource areas (Penner et al. 1975). The eastern part of the county is referred to as the Bluestem Hills. This region is strongly sloping and hilly. The western part of the county is referred to as the Central Loess Plains. In general the topography of this region is more subdued, and is said to be gently sloping or undulating.

The drainage of Butler County is related for the most part to the Walnut River and its tributaries (Fig. 1). This includes: the Whitewater River, the Little Walnut River, Rock Creek, Muddy Creek, and many other small named and unnamed streams. The headwaters of two other major drainage systems are also found in Butler County. The Cottonwood River and the Verdigris River both have tributaries which begin in the northeastern and eastern parts of Butler County respectively. All three of these river systems share a common destination, as they all drain into the Arkansas River.

The surface geology of Butler County is composed mainly of well-consolidated sedimentary rocks of Permian age. These rock layers tend to slope gently downward to the west. Several important buried structures are found in Butler County, the most obvious of which is Nemaha Arch. This structure is a buried fault zone. In addition several folded structures are present in the area which have been exploited for petroleum production.

The focus of this research, however, is on relatively young (Neogene age) chert gravel deposits. Alluvial chert gravels provide effective markers of the past positions of present-day streams. These gravels are erosion resistant, which allows them to be remarkably well preserved. The chert gravels in Butler County have been quarried extensively to be used as a road surfacing material. These open-pit quarries, some of which are still in use, are in general easily accessible and offer excellent opportunities for collection of samples.

Chapter 2. PREVIOUS RESEARCH AND PUBLICATIONS

Chert gravels in eastern Kansas have been recognized since the late 1800s (Parker 1884). The origin of these deposits has been a source of much conjecture over the years. O'Connor (1953) established that these gravels are in fact the remnants of stream terraces. Recently, Aber (1985, 1988) has concluded that the source of most of the chert in these deposits is the Flint Hills. He contends however that certain exotic quartzite, black chert, and granite pebbles, which have been found in these gravels, must have come from a source farther to the west. Aber (1985, 1988) has proposed that these exotics could have been transported into the area by a now extinct river system he referred to as the "Old Osage River" (Fig. 2).

Aber (1988) listed three possible sources for quartzite exotics: (1) basal Cretaceous conglomerates of central Kansas, (2) Ogallala-type arkosic gravels west of the Flint Hills, and (3) glacial erratics derived from northeastern Kansas. He concluded that Ogallala-type gravels and Cretaceous conglomerates were major and minor sources for quartzite exotics in east-central Kansas, but that no glacial erratics were transported into the region.

Law (1986) demonstrated that chert gravels in eastern Kansas could be mapped quite easily by referring to available soil survey maps. The Olpe-Kenoma soil complex

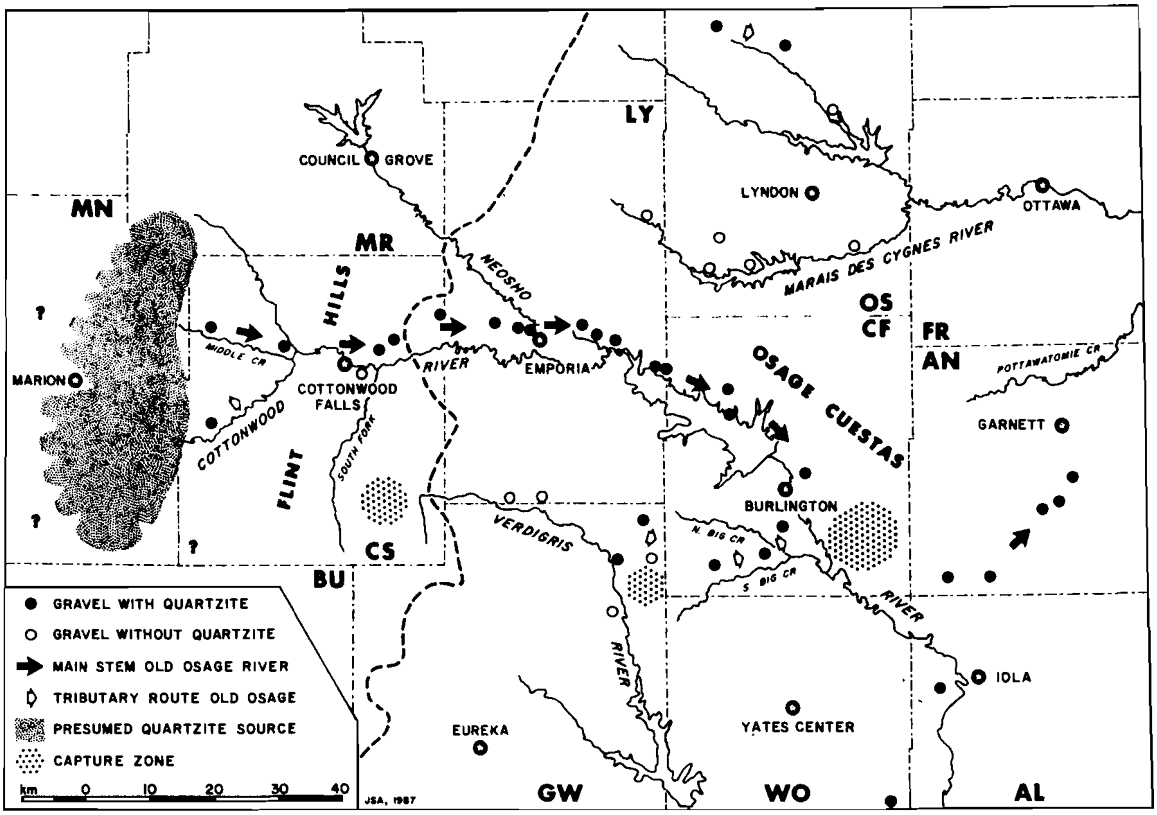

Figure 2. A map of the now extinct river system referred to by Aber (1988) as the "Old Osage River."

and the Olpe series soils closely correspond with alluvial chert gravel deposits in Chase, Lyon, Coffey, and Anderson Counties. This simplifies the mapping process especially in Butler County, because its soil survey maps and available topographic quadrangles are at the same scale (1:24,000).

Aber (1985, 1988) and Law (1986) have both observed an asymmetrical pattern of preservation of alluvial chert gravels in eastern Kansas. These gravels tend to be located almost exclusively on the northern valley sides of west-to-east-flowing streams. They also observed that present-day west-to-east-flowing streams tend to be cutting into their southern valley sides. Three possible explanations have been proposed to explain this phenomenon: 1) unequal sediment input, 2) the Coriolis effect, which in the northern hemisphere tends to deflect movements to the right, and 3) subtle crustal tilting to the south, which would explain the southward migration of these streams and the apparent headward expansion of the Arkansas River's southward flowing tributaries.

Chapter 3. METHODS AND PROCEDURES

Methods and procedures are best divided into three phases. The first phase involved developing an accurate method for mapping the alluvial chert gravels in Butler County. The second phase entailed collection, field observation, and analysis of the gravel itself. The third phase involved drafting a 1:100,000 scale map of Butler County with an appropriate set of symbols to represent the alluvial chert gravels.

Phase I:

The Olpe-Norge Soil complex as defined in the Butler County Soil Survey (Penner et al. 1975) is 50% Olpe Series soils, 30% Norge Series soils, and 20% Irwin Series soils. Olpe soils tend to be at or near the crests of hills and Norge soils are between the slopes.

A representative profile of an Olpe soil appears as follows (Penner et al. 1975):

A1-- 0 to 10 inches, dark-brown (7.5 YR 3/2) silty clay loam, very dark brown (7.5 YR 2/2) when moist; strong, fine, granular structure; slightly hard when dry; pebbles about one half inch in diameter make up 5 percent of this horizon; medium acid; gradual, smooth boundary.

B1-- 10 to 14 inches, dark reddish-gray (5 YR 4/2) heavy silty clay loam, dark reddish (5 YR 3/2) when moist; strong, fine and very fine, subangular blocky structure; hard when dry; firm when moist; thin and patchy clay films; about 10 percent of this horizon is chert pebbles one half inch in diameter; slightly acid; gradual, smooth boundary.

B21-- 14 to 30 inches, dark-red (2.5 YR 3/6) gravelly clay, has the same color when moist; moderate and strong, fine, blocky structure; extremely hard when dry, very firm when moist; continuous clay films that clog some pores and cover the surface of some pebbles; about 85 percent of this horizon is rounded chert pebbles; slightly acid; clear, wavy boundary.

B22t-- 30 to 42 inches, red (2.5 YR 4/6) clay, dark red (2.5 YR 3/6) when moist; moderate, medium, blocky structure; extremely hard when dry, very firm when moist; distinct, thick and continuous clay films; these impart a dark-brown (7.5 YR 4/2) dry color to ped surfaces; about 10 percent of horizon is rounded chert gravel; few, hard, black iron-manganese concretions; neutral; clear, wavy boundary.

The boundaries of alluvial chert gravel deposits in Butler County correspond closely with the boundaries of the Olpe-Norge soil complex as mapped by the Soil Conservation Service (Penner et al. 1975). These Soil Survey maps are published at a scale of 1:24,000, which is the same scale as the 7.5-minute topographic quadrangles provided by the Kansas Geological Survey. This allows the data from the Soil Survey maps to be transferred directly to the topographic maps by tracing the boundaries using a light table (Fig. 3).

Phase II:

After the alluvial chert gravels were located using the soil survey maps, it was necessary to field check the data to make sure that the Olpe-Norge soil complex included all of the alluvial chert gravels in Butler County. These chert gravels have been quarried extensively, so it was a rather simple matter to examine one quarry after another while checking the locations on the topographic maps.

Samples of chert gravels in Butler County were taken along the Little Walnut River. The first sample (site 1) was taken from the source of the chert. This deposit was residual chert which had weathered out of the Florence Limestone, but had not been transported. At this site and at the others a random sample of pebbles was collected. These samples contained enough material so that about 50 pebbles of the desired size could be extracted from them. In addition any unusually large cobbles, quartzite pebbles, or pieces of the fossilized wood were also collected.

The samples were wet sieved to separate the small-

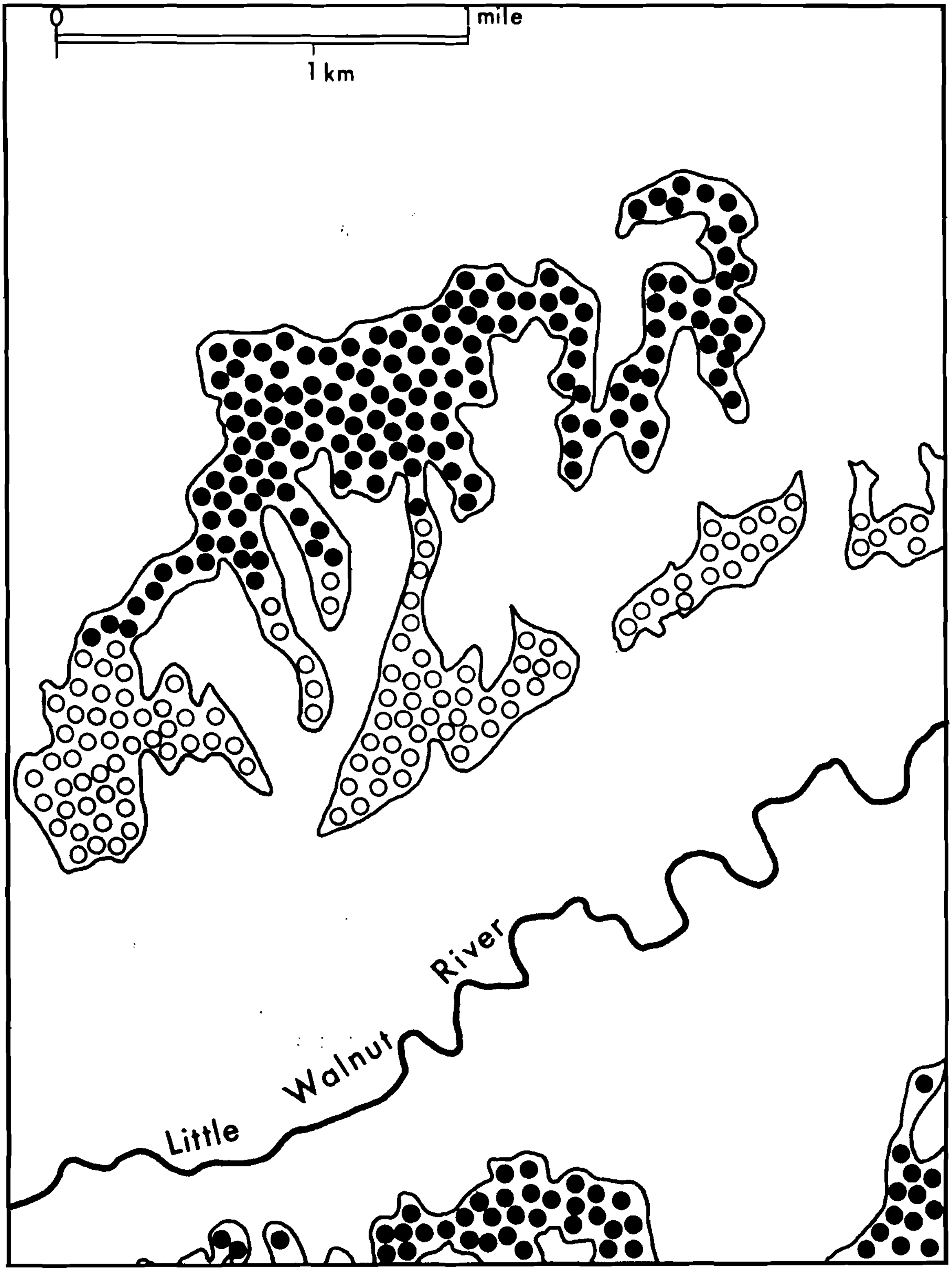

Figure 3. A portion of a representative 7.5 minute quadrangle (Leon) with alluvial chert gravel deposits. Solid circles represent hill-top gravels and open circles represent high-terrace gravels.

pebble size (16-25 mm). About fifty of these pebbles from each site was subjected to a roundness test. Pebble roundness was calculated using the Cailleux method: $C = d/l \times 1000$, where (d) represents the diameter of the sharpest corner, (l) is the length of the pebble at its long axis, and (C) is the roundness. This process is repeated for each pebble in the sample, and an average of 50 pebbles from each sample was recorded and graphed.

Phase III:

The topographic maps with the chert gravel deposits marked on them are useful in that they show nearly exact locations and sizes for alluvial chert gravel deposits in Butler County. They are, however, difficult to work with, as a large flat area is required to view all the necessary quadrangles. A smaller scale, representative map which included the entire county was a more desireable solution for analysis of patterns.

A 1:100,000 scale topographic map of Butler County was available from the United States Geological Survey, and this was selected as a base map. The map borders, township corners, major streams, water bodies, and the locations of the two largest cities were transferred to the base map. Roads and highways were left off the map since they were not necessary for reference points and might tend to detract from the purpose of the map.

Alluvial chert gravel deposits in Butler County are not all of the same nature or size. This map is intended to be a representative tool; thus, a set of symbols was established to delineate between different sizes and types of deposits. Circles of three different sizes were selected to represent the location and size of given deposits.

The smallest circles are used to denote deposits that are smaller than 40 acres. Medium-sized circles are used to show deposits larger than 40 acres but smaller than 160 acres. The largest circles represent deposits greater than 160 acres. Most of these deposits tend to be continuous and parallel to the present streams or upwards from them, so these circles are chained together to give a more realistic appearance on the map (map in pocket on back cover).

Chapter 4. RESULTS

Gravel distribution:

In viewing the topographic quadrangles, it is apparent that the alluvial chert gravels in Butler County tend to be located at two separate and usually distinct levels (Fig. 3). The first level is 10 to 15 meters above the modern flood plain and these deposits will be referred to as "high-terrace gravels." The second level is located more than 20 meters above the modern flood plain and these deposits will be referred to as "hill-top gravels."

High-terrace gravels tend to form chains of arcuate-shaped deposits. These chains may be continuous or broken intermittently by small streams. These deposits also vary widely in areal extent and lateral continuity. In some locations, the high-terrace gravels and hill-top gravels may form relatively continuous deposits from the top of the hills downward to a level some 10 meters above the modern flood plain.

Hill-top gravels are, as the name implies, located at or near the top of the hills which form the drainage divides between modern streams. The hills on which these deposits rest range in elevation from 20 to 30 meters above the modern flood plains.

All of the alluvial chert gravels in Butler County are located on the northern banks of east-to-west-flowing streams. These streams display a strong tendency to flow along the southern edge of their valleys.

Hill-top gravels are usually 1.5 to 3 km north of modern streams, and high-terrace gravels are typically 0.5 to 1.5 km north of modern streams. It would seem that the distance between modern streams and related chert gravels is largely dependent on the direction of flow of the stream. Streams such as Hickory Creek, which flow nearly straight west, tend to be farther from their associated chert gravels. Streams such as Muddy Creek which flow in a more southerly direction are closer to their related chert gravel deposits.

Pebble and cobble analysis:

Twelve individual pebble samples were collected and analyzed. Sample 1 was collected from a residual deposit, and it displayed the highest average roundness value of 118 and the highest standard deviation of 64. Samples 2, 3, 4, 5, 7, and 8 were collected from high-terrace gravel deposits along the Little Walnut River (Table 1). Samples 6a, 6b, 9a, and 9b were collected from two separate hill-top gravel deposits (Table 2). Sample 10 was collected from an isolated deposit in the southeastern corner of Butler County.

The average roundness values of the high-terrace gravel samples along the Little Walnut River vary from 104, (sample 4) to 83, (sample 5). Sample 4 has the highest roundness value of any high-terrace sample (104) and second-highest standard deviation for all samples tested (56). Sample 7 has the lowest standard deviation (32).

The average roundness values of the hill-top gravels vary from 92 (sample 6a) to 61 (sample 9b). Sample 6a has the highest standard deviation (51), while sample 9a has the lowest standard deviation (27).

In general roundness values are highest at or near the source of the chert and become progressively lower with increased distance from the source (Tables 1 & 2). This would seem to be true for both high-terrace gravels and hill-top gravels. The lowest standard-deviation values are not found with the highest roundness values, as one might expect. The lowest standard deviation values are found farther from the source areas, except at the one isolated sample site in the southeast corner of the county. A graph of the pebble roundness values versus downstream distance along the Little Walnut River displays trends for both high-terrace gravels and hill-top gravels (Fig. 4).

Maximum cobble size decreases in a downstream direction. In or near residual chert gravels, irregularly shaped cobbles greater than 20 cm in length can be found. To the west, however, cobbles are rare and for the most part only large pebbles are present in alluvial chert gravels near the Walnut River.

SAMPLE	SITE 1	SITE 2	SITE 3	SITE 4	SITE 5	SITE 7	SITE 8
1	91	143	40	57	56	27	80
2	133	107	91	88	115	63	58
3	100	111	97	150	42	125	73
4	94	33	129	118	23	98	71
5	143	29	71	77	143	100	83
6	97	56	65	61	115	156	95
7	129	34	40	119	226	56	22
8	71	200	59	77	61	50	89
9	97	73	56	125	91	67	70
10	57	65	71	75	167	98	87
11	61	37	80	65	44	125	61
12	143	100	75	77	22	37	83
13	100	83	154	32	63	86	73
14	91	212	150	171	61	91	22
15	67	27	24	36	56	152	152
16	147	128	115	65	107	125	97
17	184	71	100	148	47	100	30
18	79	194	143	91	172	50	118
19	65	103	53	129	74	67	69
20	119	34	86	94	37	114	148
21	71	192	91	71	54	78	63
22	167	74	61	28	57	91	108
23	143	143	80	125	54	57	61
24	105	100	56	225	160	77	89
25	167	175	80	44	100	121	59

Table 1. A table of the individual roundness values of pebbles in samples taken from high-terrace locations.

SAMPLE	SITE 1	SITE 2	SITE 3	SITE 4	SITE 5	SITE 7	SITE 8
26	38	54	133	65	94	78	88
27	40	80	67	118	148	91	94
28	78	156	303	71	114	111	95
29	241	153	87	40	94	61	103
30	143	212	115	152	32	167	114
31	184	74	26	147	94	67	140
32	77	77	140	132	75	111	67
33	171	114	32	219	67	34	69
34	139	160	77	100	97	138	133
35	65	129	103	33	61	54	57
36	71	51	115	136	138	69	125
37	111	56	86	63	63	114	87
38	122	36	120	172	143	49	79
39	212	69	172	50	29	100	91
40	23	97	97	91	65	100	86
41	130	59	74	107	80	79	69
42	103	200	30	67	105	75	217
43	74	103	100	75	24	83	120
44	143	94	64	114	103	65	100
45	222	77	80	125	32	71	108
46	103	63	179	100	48	148	32
47	167	115	154	313	95	111	182
48	400		87	28	74	93	49
49	40		114	188	57	118	115
50	57		87	148	77	100	67
MEAN	118	101	94	104	83	90	89
STANDARD DEVIATION	64	53	48	56	44	32	37

Table 1 continued. The remainder of the roundness values for high-terrace samples with average values and standard deviations.

SAMPLE	SITE 6A	SITE 6B	SITE 9A	SITE 9B	SITE 10
1	94	133	77	34	29
2	190	43	65	56	77
3	33	83	65	28	83
4	61	89	88	77	63
5	188	91	94	118	100
6	172	65	111	143	74
7	107	67	133	28	55
8	23	161	80	29	48
9	70	83	108	63	63
10	49	161	67	89	53
11	206	45	78	63	61
12	200	56	91	97	38
13	120	94	48	26	111
14	106	238	115	152	38
15	69	143	61	54	65
16	71	34	67	30	74
17	31	28	94	77	65
18	130	115	97	30	71
19	115	74	140	94	63
20	68	57	130	48	69
21	121	29	40	100	167
22	28	57	70	25	63
23	67	167	106	61	77
24	30	162	91	51	24
25	120	20	119	29	88

Table 2. A table of individual pebble roundness values for samples taken from hill-top sites. Also included in this table are roundness values for site 10.

SAMPLE	SITE 6A	SITE 6B	SITE 9A	SITE 9B	SITE 10
26	73	57	97	25	29
27	43	107	57	65	100
28	33	83	86	91	190
29	71	42	129	26	115
30	63	73	83	37	74
31	29	24	118	34	50
32	115	47	54	103	49
33	88	94	77	80	61
34	75	161	103	83	83
35	69	32	61	24	29
36	50	98	63	185	57
37	94	47	100	34	57
38	67	67	34	33	63
39	95	97	54	69	69
40	38	98	89	29	74
41	94	95	74	23	61
42	133	86	87	67	154
43	143	81	129	68	
44	125	125	81	42	
45	174	56	88	26	
46	37	23	81	53	
47	184	75	135	125	
48	67	114	154	49	
49	148		67	26	
50	20		79	61	
MEAN	92	85	88	61	72
STANDARD DEVIATION	51	46	27	37	34

Table 2 continued. The remainder of the roundness values for hill-top sites and site 10 with average values and standard deviations.

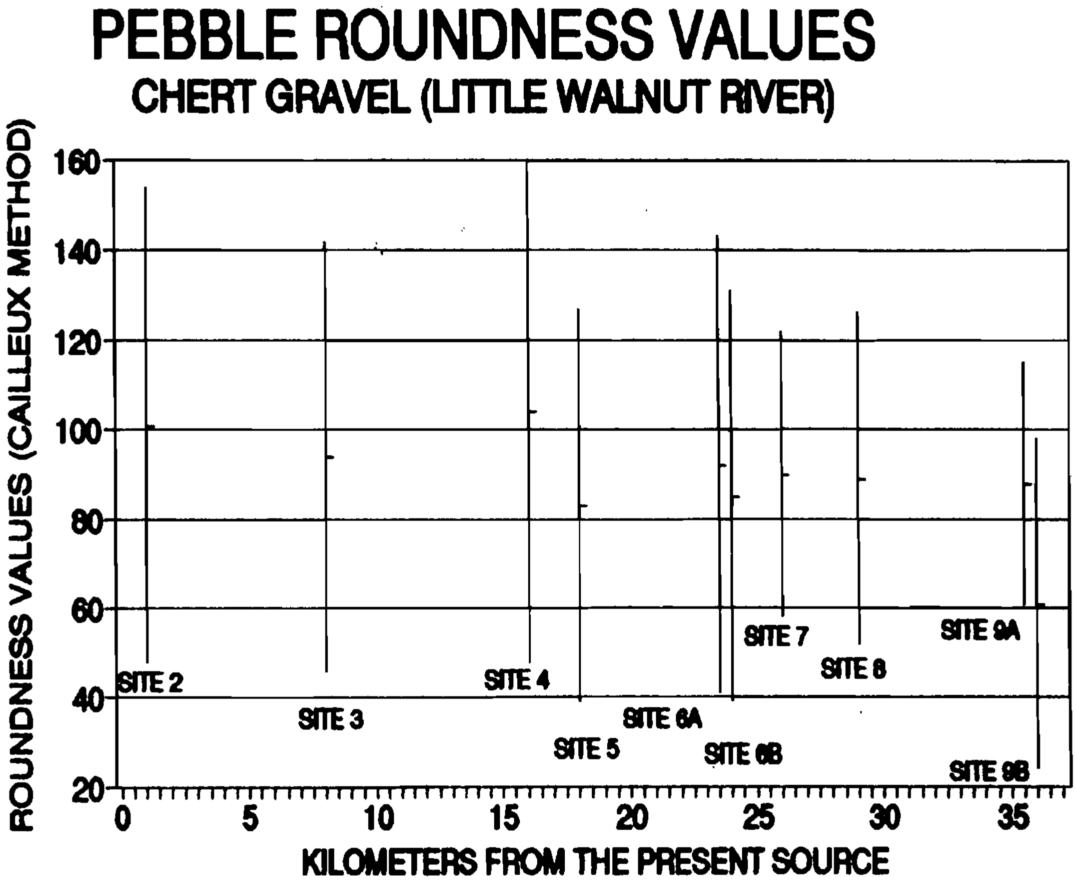

Figure 4. A graph of the average roundness values for all samples taken from sites along the Little Walnut River. Sites 6a, 6b, 9a, and 9b are hill-top locations, others are high-terrace locations. Average values are represented by short horizontal lines and vertical lines represent one standard deviation up and down.

Representative map:

The presence of two distinctive positions of alluvial chert gravel has been established, therefore, it was necessary to have a different symbol for high-terrace gravels and hill-top gravels. The simplest method to accomplish this is to fill in those circles which represent hill-top gravels and leave those circles which represent high-terrace gravels open. It is necessary therefore to delineate between the two relative positions of deposits in a numerical method.

The distinction between the two is a matter of relative location with respect to the modern associated streams. The lowest hill tops which are occupied by hill-top gravels have an elevation which is approximately 20 meters above the modern flood plain of the related stream. This figure was adopted as the dividing line between those gravels which are represented as hill-top gravels and those which are considered high-terrace gravels. In other words, any gravel deposit which is located more than 20 meters above the modern flood plain has been considered to be a hill-top gravel. Gravel deposits found lower than 20 meters and more than 10 meters above the modern flood plain are shown as high-terrace gravels.

Chapter 5. INTERPRETATION

Soils:

The Butler County Soil Survey (Penner et al. 1975) stated that Olpe soils formed in gravelly clayey sediment. The Olpe soil seems to consist of two components. 1) The uppermost component may include a thin layer of loess at the surface. This layer is usually less than 25 cm in thickness, and may be missing in some profiles. This corresponds roughly to the top of the A1 horizon. 2) The second component consists of alluvial material (clay and chert) which was deposited by streams. This component is stained dark red or red brown in most cases and is approximately 1.5 to 3 m in thickness. This component corresponds to the B1, B21, B22t, and B3 horizons. The chert content varies from 10% to 85% in these horizons.

The B horizons of the Olpe soil are a paleosol that began to develop in chert gravel alluvium prior to the deposition of the loess cover in which the surface soil is formed. Hill-top gravels display strong oxidation in the B horizon, but B horizons are less strongly oxidized within high-terrace gravels. This suggests that hill-top gravels were subjected to longer or more intense weathering prior to loess coverage than were high-terrace gravels.

The soil survey (Penner et al. 1975) pointed out the similarity between the Olpe soil profile and the Florence soil profile. The Florence soil is a true soil. A true soil is one which has formed directly from the underlying bedrock. Its profile is remarkably similar to the Olpe profile with two notable exceptions. In the Florence soil, chert fragments were described as angular in nature. In the Olpe soils, the chert was referred to as "rounded chert pebbles." The Olpe profile description mentions that these chert pebbles become stratified in the lower part of the B2t horizon. The chert fragments in the Florence soil do not display any stratification. The fact that these pebbles are rounded and stratified within the soil profile are evidence that the chert pebbles in the Olpe soils are alluvial deposits.

The Florence soil is related to the Olpe soil in that the Florence is the source of sediment (especially chert) in the Olpe soils and the Olpe-Norge soil complex. The two soils are even found in close proximity to each other and may even be somewhat mixed in some locations. The simplest method two distinguish the two soils from each other is by observation of the color of the chert and clay matrix. The chert and clay matrix in the Florence (residual gravels) tends to be orange or orange red in color. The Olpe and Olpe-Norge complex contains chert and clay matrix which tends to be red-brown, brown, or even gray-brown in color.

Chert gravels:

Pebble analysis of chert gravels in Butler County shows several trends in pebble roundness: 1) the highest roundness values recorded are in residual deposits, 2) roundness values tend to decrease with downstream distance in both high-terrace and hill-top gravels, 3) roundness values at site 10 seem to contradict roundness values along the Little Walnut River, and 4) there seems to be a wide variance in roundness values of samples taken from the same site (Fig. 4).

Higher roundness values than would be expected at site 1 could be explained by the situation in which the chert gravels are weathering out of the Florence Limestone. Previous roundness studies of high-terrace and hill-top gravels on west-to-east-flowing streams east of the Flint Hills (Law 1986) showed the opposite trend in roundness. The source of this chert is cherty limestones exposed on the face slopes of the Flint Hills escarpment. These chert deposits are angular shards of chert nodules which have weathered out of the limestone and broken up as they were transported downslope by gravity and erosion.

Residual chert gravels in Butler County tend to be weathered out on fairly flat dip slopes and are not subject to initial mechanical breakup. The chert nodules are therefore weathered chemically and are largely intact with relatively few sharp edges. This would seem to explain the relatively high roundness values found at site 1.

If the residual chert gravels did weather out intact, it would seem logical that initially they would tend to suffer mechanical breakup while they were being transported downstream, as shown by the decrease in maximum cobble size. This could explain the trend of slightly lower roundness values with downstream distance in both high-terrace and hill-top gravels.

The single sample taken at site 10 seems to have an average roundness value contradictory to the above explanation. The chert at site 10 comes from a different source. This chert was derived from the Wreford Formation and its source area is on the face slope rather than on the dip slope of the Flint Hills. Instead of being a contradiction, site 10 might in fact provide further evidence in favor of the above theory.

These explanations are, however, somewhat speculative because of the variance in roundness values within sample sites and the samples themselves. It would seem that much additional analysis of pebble roundness values in this area would be necessary to achieve conclusive results.

Gravel distribution:

The pattern of distribution of alluvial chert gravels in Butler County can be used to make several interpretations about stream patterns, stream morphology past and present, and possibly the structure of underlying bedrock. The asymmetrical nature of the deposits, the two distinct levels of preservation, and the presence of the gravels along the lower reaches of Muddy Creek all give clues as to past and present conditions. It is also interesting to note that these alluvial chert gravels are preserved almost exclusively in the southern half of Butler County, east of the Walnut River.

The location of these chert gravels in southern Butler County east of the Walnut River can be explained quite easily. These alluvial chert deposits can only form along streams which flow through source areas. The streams west of the Walnut River do not flow through areas in which chert is weathering out of underlying limestone strata, therefore significant deposits of alluvial chert gravels are not found west of the Walnut River.

The Walnut River is expanding headward, and this explains the lack of alluvial chert gravels in northern Butler County. The streams in northeastern Butler County have reached areas with significant residual deposits of chert in relatively recent times. At the time that the streams in southeastern Butler County were depositing chert in hill-top and high-terrace locations, the streams in northeastern Butler County were not yet flowing through areas with significant residual chert deposits.

Muddy Creek in southern Butler County has significant alluvial chert gravel deposits even though its headwaters do not reach into the source areas for chert gravels. This does not, however, contradict the above hypothesis about streams in northern Butler County. It seems likely that the chert gravel along Muddy Creek was transported into the area by either Hickory Creek or the Little Walnut River.

In either case Muddy Creek would originally have been a part of another stream. The Little Walnut River could have flowed southward roughly parallel to the Walnut River into what is now Muddy Creek. It would have remained in this position until it was captured upstream by the Walnut River at some time after the alluvial chert gravels along Muddy Creek were deposited.

The other possibility is that Hickory Creek and Muddy Creek were connected at the time of deposition of the chert gravels along Muddy Creek. In this case Hickory Creek would have been captured by the Little Walnut River at some time after the chert gravels along Muddy Creek were deposited.

Alluvial chert gravels in Butler County are preserved almost exclusively on the northern sides of the modern east-to-west-flowing stream valleys. The streams occupying these same stream valleys also tend to be at or close to their southern bluffs. The Coriolis effect would, presumably, influence these streams to cut into their northern (right) banks. As this obviously is not the case, it seems unlikely that the asymmetrical pattern of gravel preservation was caused by the Coriolis effect.

Another proposed cause of asymmetrical preservation of alluvial chert gravels is an unequal input of sediment. This would imply that the source areas for the chert were north of the deposits and that a preponderance of the tributaries drained into the main streams from the north. The source areas for the chert are in fact to the east of their present location in Butler County. In addition, there does not appear to be a significant difference in the number of tributaries entering streams from either side.

It is seemingly clear that some force other than the Coriolis effect or uneven input of sediment is causing the asymmetrical pattern of preservation of alluvial chert gravels. The simplest explanation for a southward migration of streams in Butler County would be subtle tilting of the underlying bedrock. The existence of crustal tilting has been inferred from the asymmetrical nature of alluvial chert and the current position of streams in their valleys.

Subtle crustal tilting has been proposed as a possible cause for the asymmetrical pattern of preservation of chert gravels in eastern Kansas (Aber and Sleezer 1990). A neotectonic structural arch, which is believed to be uplifting along a west-to-east axis roughly parallel to the Kansas/Nebraska border, has been proposed as a possible cause for the aforementioned subtle tilting of the underlying strata in Kansas. This proposal is further strengthened by similar asymmetrical patterns of valley development in western Nebraska which trend in the opposite direction as those in Kansas.

Crustal tilting would explain the pattern of southward migration of east- or west-flowing streams in eastern Kansas. In addition, this would also explain the apparent headward expansion of south-flowing streams such as the Walnut and Whitewater Rivers, at the expense of drainage basins with other flow orientations.

The problem with this explanation is that no tilting of this sort has ever actually been measured by surveying or geodetic techniques. In addition, this tilting is probably so subtle that it would be difficult, if not impossible, to measure in the field. It is possible, however, to measure the effect this subtle tilting has had on the streams in Butler County in terms of lateral distance of migration and amount of downcutting. Based on the positions of hill-top and high-terrace gravels in relation to the current position of modern streams, the east-to-west flowing tributaries of the Walnut River have downcut approximately 10 m per km of southward lateral migration.

The positions of alluvial chert gravels on the tops of drainage divides between streams in Butler County suggests a regional inversion of topography. The hill-top gravels represent one past position of present-day streams which now occupy positions in valley floors. It would seem that hill-top and high-terrace gravels are the result of times when these streams remained at a given elevation long enough to deposit significant amounts of chert. These deposits were thick enough and erosion resistant, so that they were preserved as they are seen today.

Quartzite erratic pebbles:

Several small quartzite pebbles were found within the alluvial chert gravels in Butler County. These pebbles are yellowish brown in color. These quartzite pebbles were only found in the hill-top gravels. It would seem that at the time the hill-top gravels were deposited quartzite pebbles were fairly common. None of these quartzite pebbles, however, have yet been found in the high-terrace gravels.

The quartzite pebbles must have been transported into the area at some time during or before the time that the hill-top gravels were deposited. Quartzite pebbles that are found in the hill-top gravels could have been derived from Ogallala-type deposits, which may have extended into the area at this time (Aber 1988). Ogallala-type deposits containing quartzite pebbles may have formed a fairly continuous cover in the area. These deposits were apparently completely stripped away before the high-terrace gravels were deposited.

Ogallala-type gravel was probably present in central Kansas during late Tertiary (Miocene-Pliocene) time.

However, the presence of quartzite in hill-top gravel of Butler County does not fix the age of Butler County chert gravel. The age of hill-top and high-terrace gravels may span a time range from late Tertiary through early Pleistocene.

Chapter 6. CONCLUSIONS

Alluvial chert gravel deposits can be used to trace the past positions of certain streams in Butler County. These chert gravels show a distinct trend of stream migration toward the south. The most probable cause for this tendency of stream migration in Butler County is subtle crustal tilting to the south. This subtle tilting of the underlying strata would also explain the apparent headward expansion of the Walnut and Whitewater Rivers at the expense of other drainage basins.

The apparent disparity in pebble roundness values between studies done along streams east of the Flint Hills and those conducted in Butler County can be explained by a difference in the method by which the chert is weathered out of the source limestone. Chert nodules in source areas in Butler County are predominately weathered out on dip slopes and are not subjected to initial mechanical breakup. This explains the existence of apparently higher pebble roundness values in residual chert gravels in Butler County as opposed to alluvial chert deposits downstream.

Quartzite pebbles have been found only in hill-top deposits in Butler County. The probable source for these quartzite pebbles are Ogallala-type gravels found currently in western Kansas (Aber 1988). As none of these quartzite pebbles have been found in high-terrace deposits in Butler

County, it is assumed that these quartzite-bearing gravels had been completely eroded away from the region before the high-terrace gravels were deposited.

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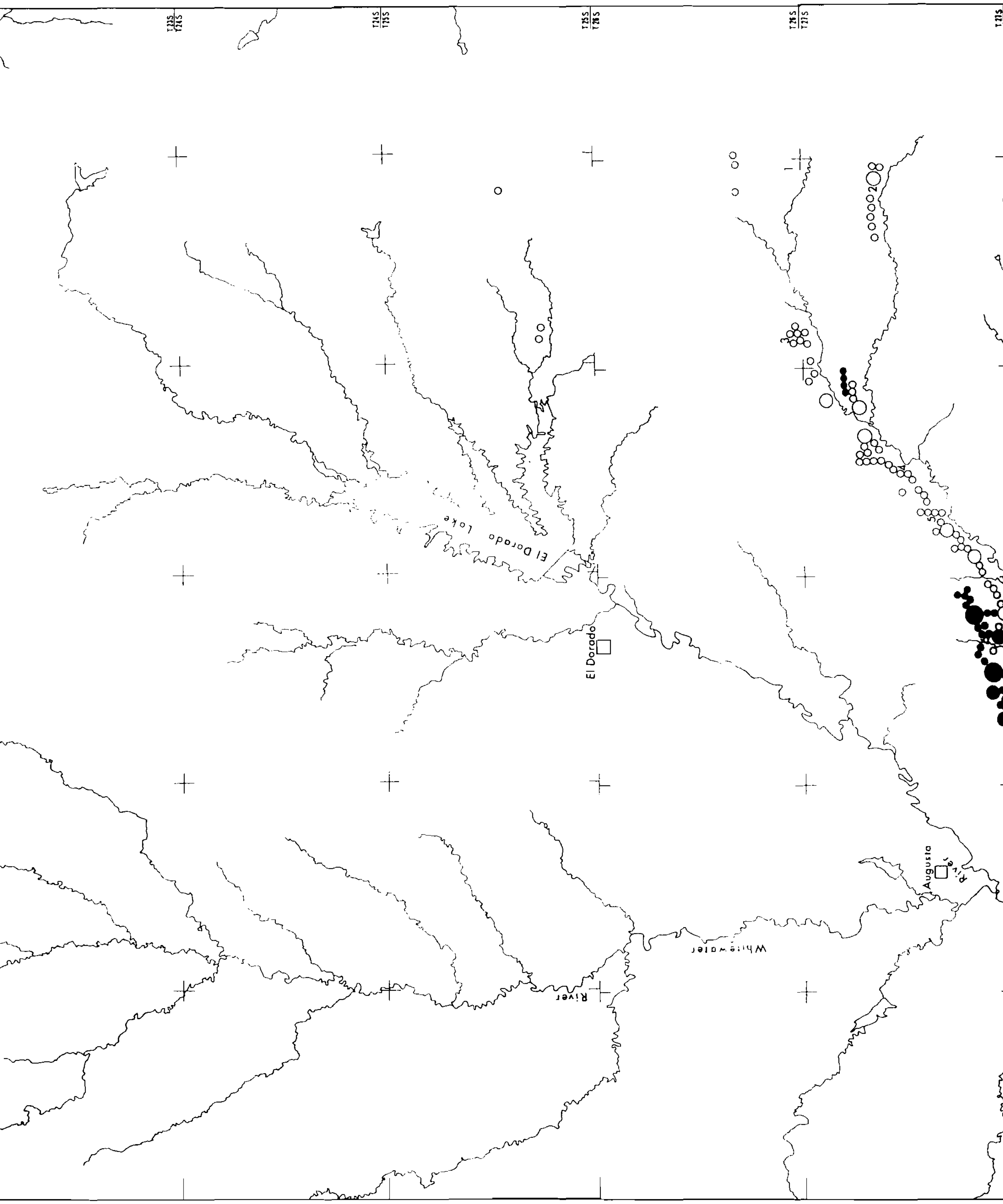

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El Dorado Lake
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Augusta
Whitewater
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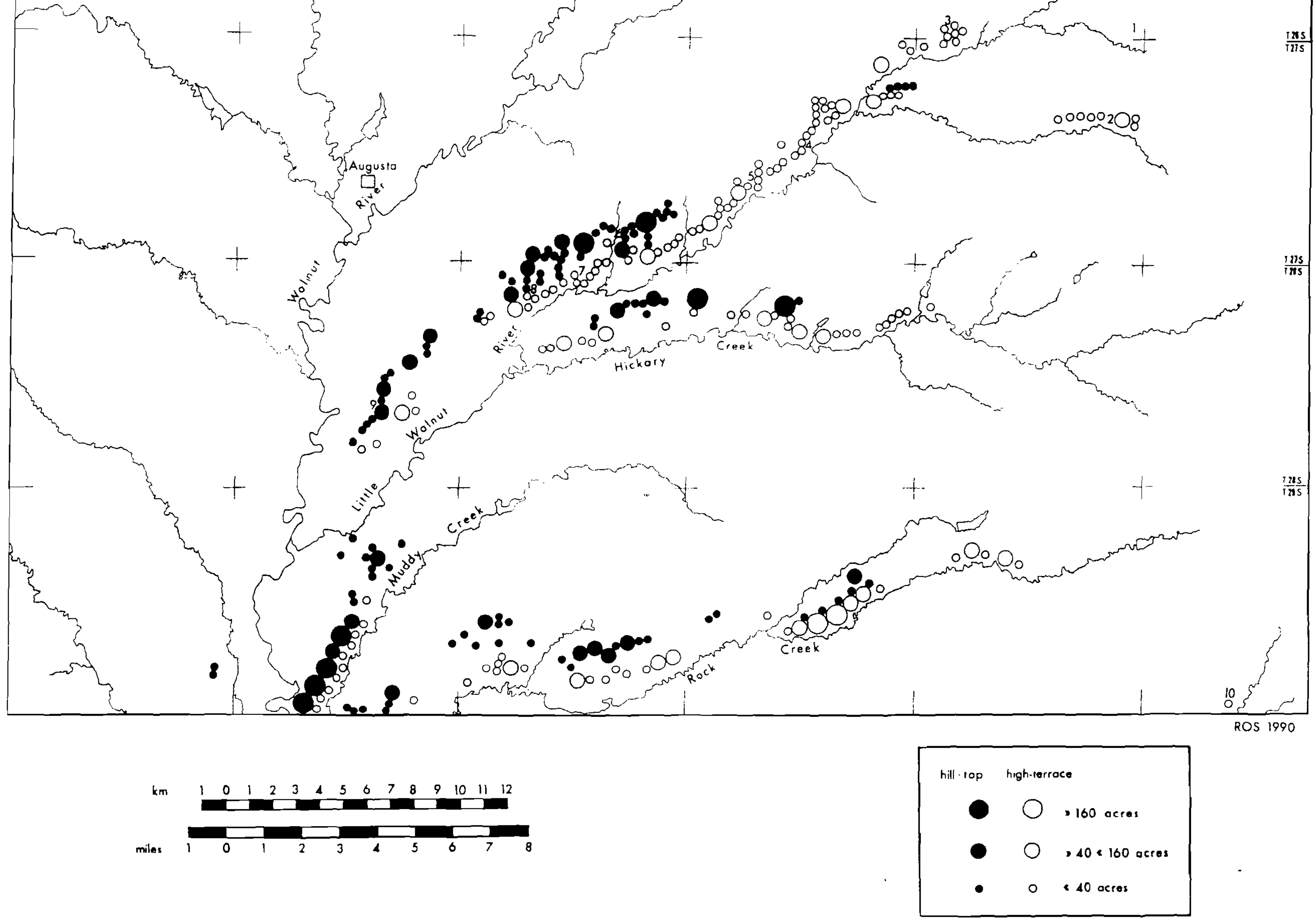

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