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**Kansas Academy of Science
Multidisciplinary Guidebook 8**

Fall Field Trip in Chase and Butler Counties,
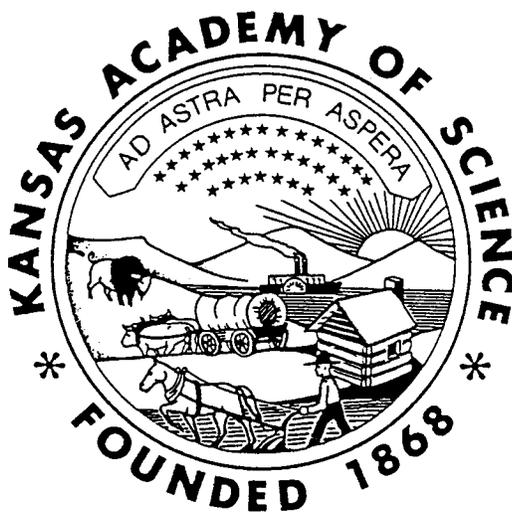Flint Hills Region, East-Central Kansas

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KANSAS ACADEMY OF SCIENCE MULTIDISCIPLINARY GUIDEBOOK 8

FALL FIELD TRIP IN CHASE AND BUTLER COUNTIES, FLINT HILLS REGION, EAST-CENTRAL KANSAS

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MULTIDISCIPLINARY GUIDEBOOK 8

FALL FIELD TRIP IN CHASE AND BUTLER COUNTIES,
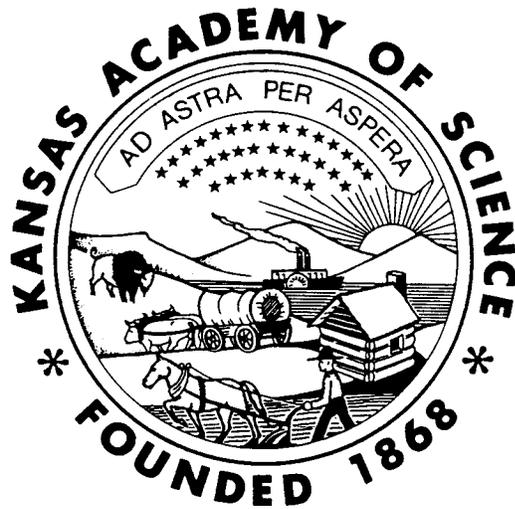FLINT HILLS REGION, EAST-CENTRAL KANSAS

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October 21, 1995

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RIW RIE   R5E   RIOE   RI5E   R2OE

1 2 3 4 5 6 7 8 9

JSA, 1995

km 0   20   40   60   80   100

miles 0   20   40   60

MISSOURI - ARKANSAS DIVIDE

LOCAL DRAINAGE DIVIDES

General location map for eastern Kansas. Major rivers, drainage basins, physiographic regions and counties are indicated. Field sites are located in southern Chase and Butler counties. Solid dot shows antelope restoration area. Numbered reservoirs: 1 - Clinton, 2 - Pomona, 3 - Melvern, 4 - Council Grove, 5 - Marion, 6 - John Redmond, 7 - El Dorado, 8 - Toronto, 9 - Fall.

*   *   *

GEOLOGY AND GEOMORPHOLOGY OF BUTLER AND CHASE COUNTIES

James S. Aber and Bryan A. Bain

INTRODUCTION

Butler and Chase counties are contained almost wholly within the Flint Hills physiographic province. Highest elevations exceed 500 m along the Flint Hills escarpment in eastern Butler and southeastern Chase counties; lowest elevations are <350 m in the Cottonwood and Walnut River valleys. Lower Permian strata outcrop at the surface and underlie relatively shallow soils throughout the field-trip region. Unconsolidated sediments are common, especially within river valleys and on uplands in the southwestern part of Butler County. Soils are developed in residual (weathered) bedrock material, alluvial deposits, and loess sediment.

Butler County became an important petroleum production and refining center early in this century following the initial discovery of gas near Augusta (1906) and later discovery of the giant El Dorado oil field in 1915. As a result of this economic development, detailed surface and subsurface geological mapping was carried out in the El Dorado vicinity by Fath (1921). Fath's maps demonstrate the remarkable structural complexity of surficial bedrock in the area. Later reconnaissance mapping of the regional geology was undertaken by Moore *et al.* (1951), Jewett (1964), Kellogg (1978), and O'Conner *et al.* (1982). Detailed mapping of surficial geology of Butler County was completed in the early 1990s (Aber 1991; Aber *et al.* 1994).

BEDROCK STRATIGRAPHY

The formal bedrock stratigraphy was defined and described by Zeller (1968) and Kellogg (1978), to which the reader is referred for detailed descriptions of lithology and thickness for individual units (Fig. 1). The Council Grove Group is found in easternmost Butler County and southeastern Chase County, where it crops out in the lower portion of the Flint Hills escarpment (Fig. 2). The Chase Group forms the crest of the Flint Hills escarpment in eastern Butler County. The outcrop patterns of bedrock units along the Flint Hills escarpment are extremely intricate, and many small erosional outliers of resistant bedrock units are present along the crest of the escarpment.

The Florence Limestone forms the resistant cap along much of the escarpment. However, in southeastern Chase County the Florence has been removed by erosion, and the Wreford Limestone forms the escarpment crest. Residual chert from the Florence and Wreford often drapes over underlying shale and limestone formations. The Chase Group is the surficial bedrock for most of Butler and southernmost Chase counties west of the Flint Hills
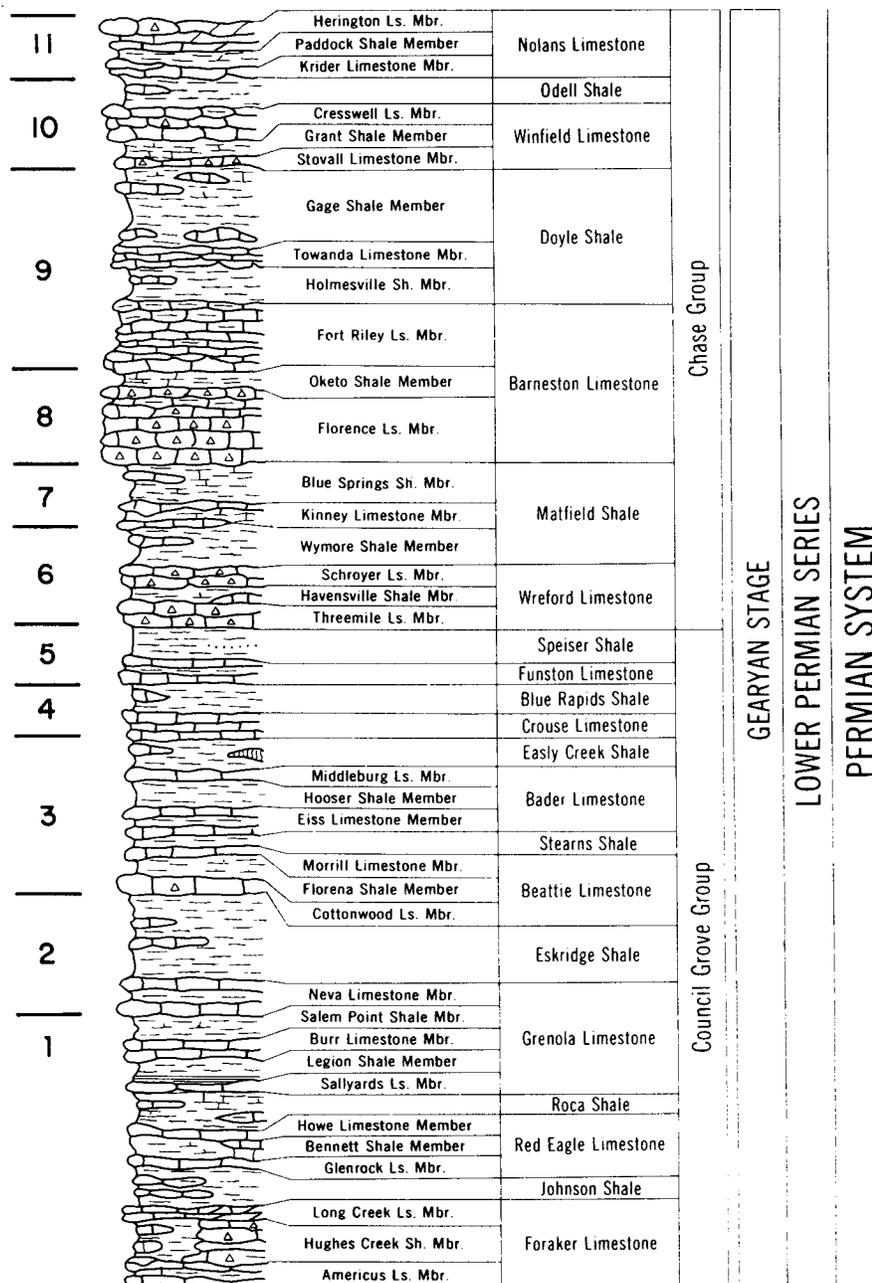
Figure 1. Standard stratigraphic column for Lower Permian units of the Council Grove and Chase Groups in southern Kansas. Map unit numbers as indicated on detailed maps (Figs. 2 & 3). The Neva Limestone is now considered to mark the base of the Permian in Kansas; map unit 1 is thus uppermost Pennsylvanian (Baars *et al.* 1994). Adapted from Lutz-Garihan and Cuffey (1979, fig. 3).
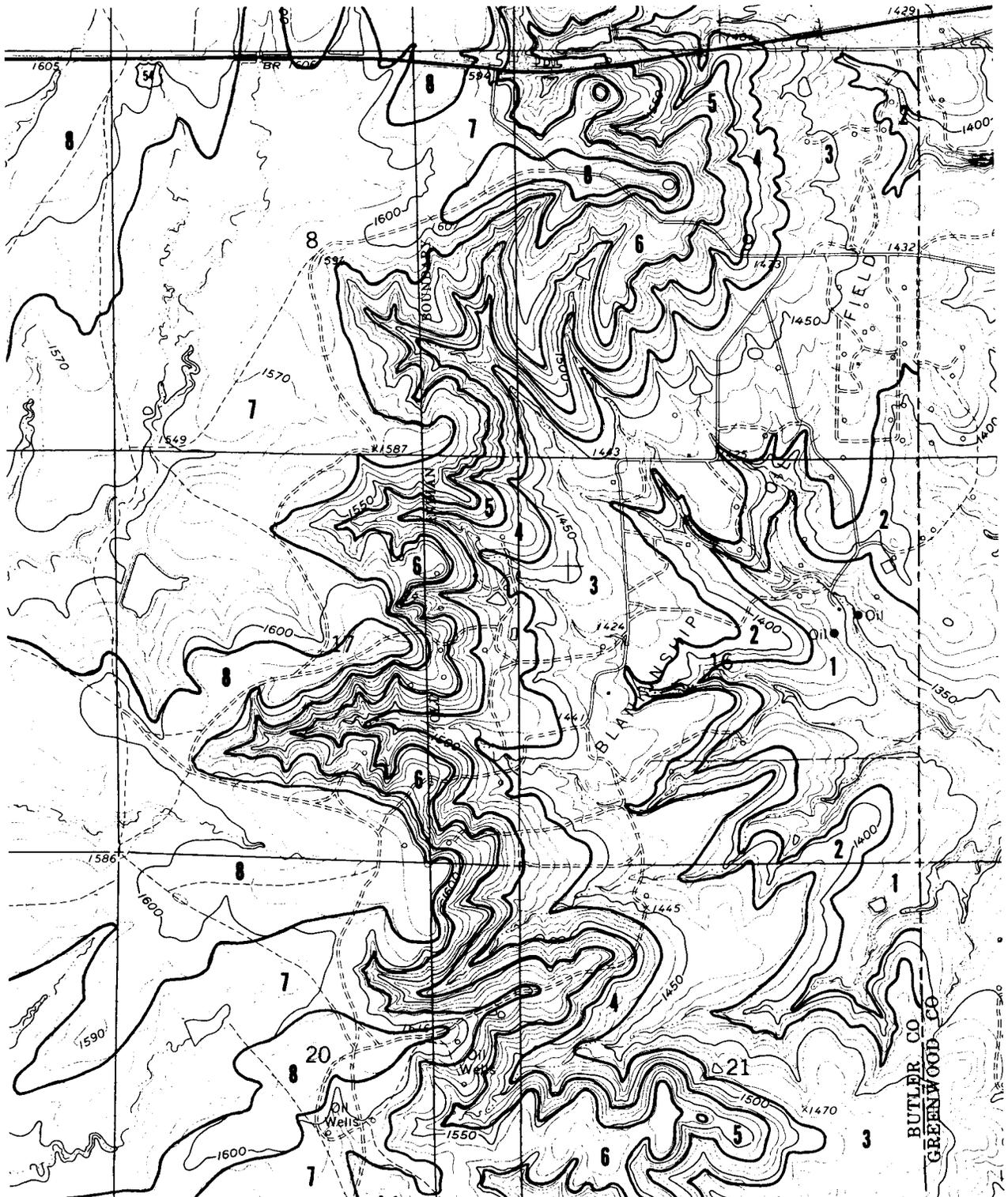
Figure 2. Portion of Rosalia topographic quadrangle showing map pattern of bedrock units 1-8 (see fig. 1). Crest of the Flint Hills escarpment exceeds 1600 feet elevation and forms the drainage divide between the Walnut basin (west) and Fall basin (east).

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Figure 3. Portion of Gordon topographic quadrangle showing outcrop pattern of the Winfield Limestone (unit 10, see fig. 1). Note general dip of strata to west and buttelike erosional outliers of Winfield Limestone.

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escarpment. Although the landscape is generally less rugged, intricate outcrop patterns have resulted from stream dissection, and small outliers of resistant bedrock units form buttelike hills (Fig. 3).

LOWER PERMIAN CYCLOTHEMS

Cyclothems are systematic repetitions of bedrock lithology and fossils in the stratigraphic column. The upper Pennsylvanian cyclothems of eastern Kansas 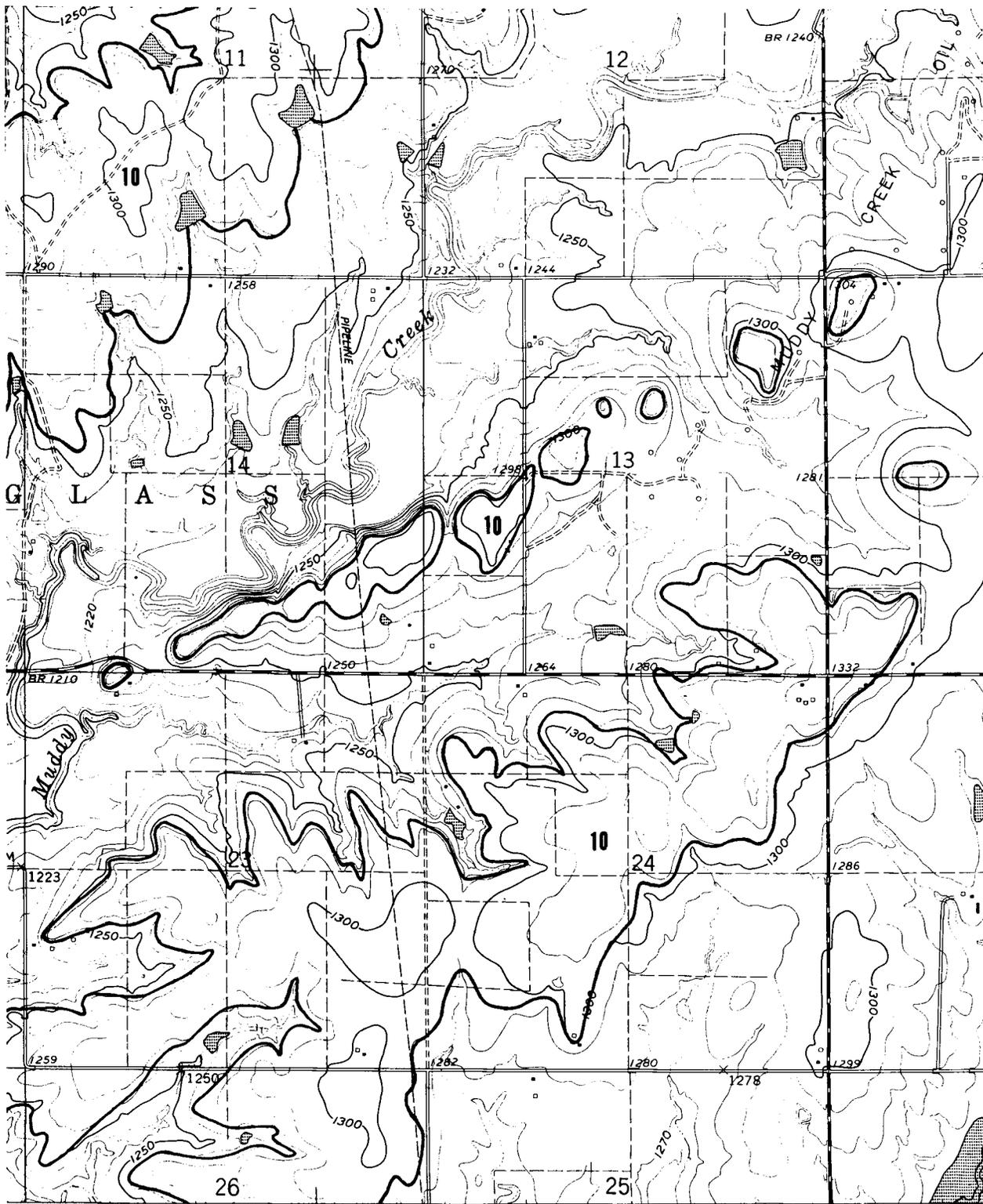have been world famous since the work by Moore (1964). No less impressive are lower Permian cyclothems of the Flint Hills region (Fig. 4). The cyclothem model includes six units, from the top down:

6.   Limestone: tan to gray, platy to massive, fossiliferous limestone, chalky limestone, or dolomitic limestone; cross bedding, oolites, and ripple marks common; locally cherty toward base with algal bed toward top; diverse fossils. Examples: Morrill, Funston, Schroyer, Fort Riley, Cresswell, Herington. Environment: offshore regressive sea to shallow, high-salinity, lagoon.

5.   Shale: gray or green, fissile to platy, calcareous, fossiliferous shale or shaly limestone; diverse fossils including trilobites. Examples: Florena, Havensville. Environment: farthest offshore sea of maximum transgression.

4.   Cherty limestone: tan or light gray, platy to massive, fossiliferous limestone or chalky limestone; scarce to abundant nodules or beds of chert; locally may display algal banding or cross bedding; diverse fossils including many echinoids and fusulinids. Examples: Neva, Cottonwood, Crouse, Threemile, Florence, Stovall. Environment: far offshore, shallow sea of near-maximum transgression.

3.   Shale: gray, tan or green, platy, fossiliferous, calcareous shale and shaly limestone; abundant brachiopod and mollusk fossils. Examples: upper Eskridge, upper Easly Creek, upper Speiser, upper Wymore, upper Gage. Environment: shallow, normal salinity, transgressive sea.

2.   Limestone: one or more, thin, gray or tan, chalky or coquina, fossiliferous limestones; abundant brachiopods and mollusks. Examples: middle Eskridge, middle Speiser. Environment: shallow to estuarine, low-salinity sea.

1.   Shale: platy, somewhat calcareous, maroon or red shale above green and black shale; generally few fossils, black shale has inarticulate brachiopods, maroon shale lacks marine fossils. Examples: lower Eskridge, lower Speiser, lower Wymore, lower Gage. Environment: lagoon or estuarine (green or black) to emergent (maroon) tidal flat or sabhka.
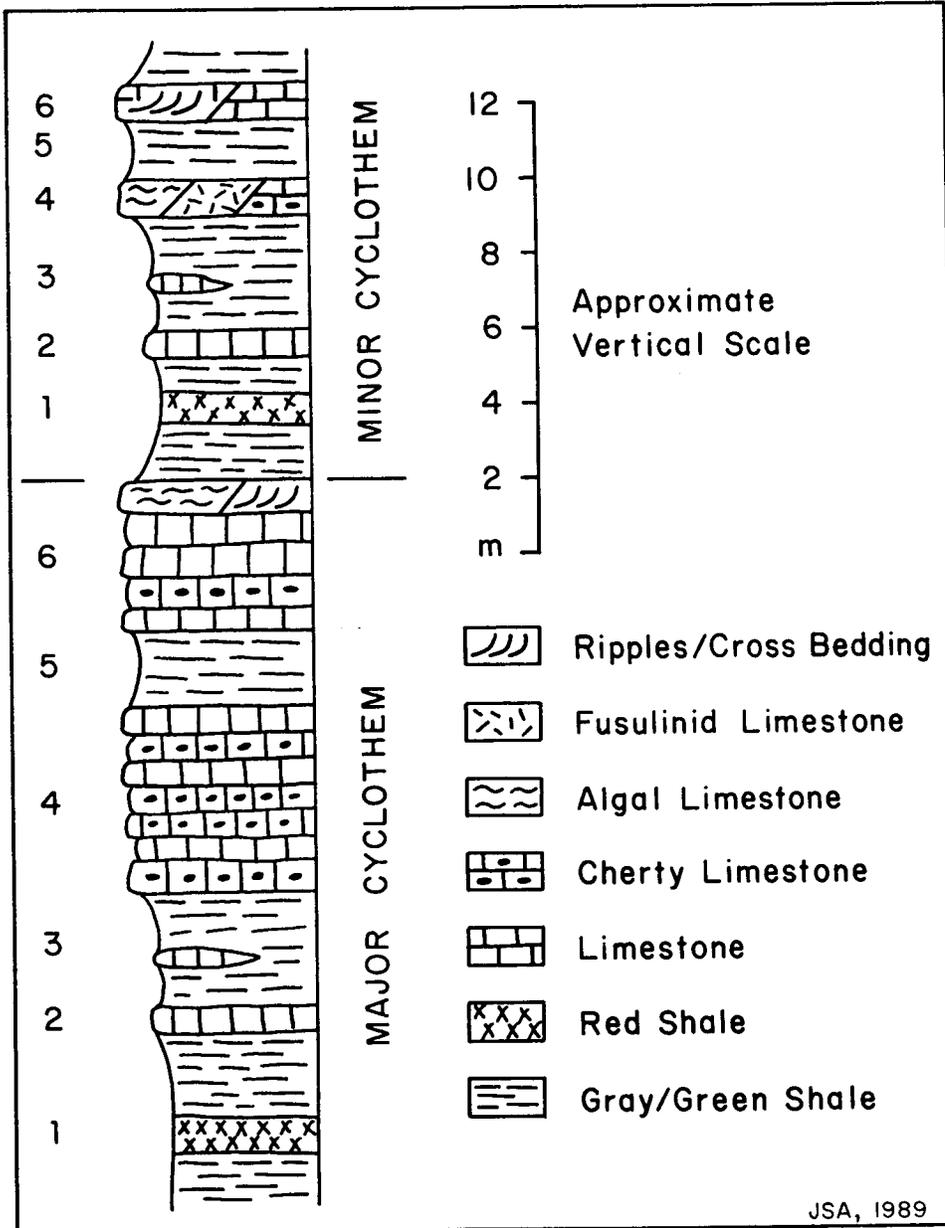
Figure 4. Ideal major and minor cyclothems for Council Grove and Chase Groups, Lower Permian, southern Kansas. Taken from Aber (1991, fig. 6).

Major cyclothems are 50-100 feet (15-30 m) thick and include thick, cherty limestone units (Fig. 4). The Speiser/Wreford and Blue Springs/Barneston cyclothems are typical examples. Minor cyclothems are usually only 25-40 feet (8-12 m) thick, and thin limestones of variable lithology are typical. Good examples include the Eskridge/Beattie, Easly Creek/Crouse, Blue Rapids/ Funston, Wymore/Kinney, Gage/Winfield, and Odell/Nolands cyclothems.

Water depth probably did not much exceed wave base during deposition of minor cyclothems. The absence of black shale from the core position (unit 5) of major cyclothems also suggests that deep water conditions were not achieved during major marine transgressions. The total range of relative sea-level change between exposed sabhka stage (unit 1) and maximum transgression (unit 5) was probably 100 feet (30 m) or less (McCrone 1964).

The bedrock stratigraphy has remarkable lateral consistency; unit thicknesses vary little and only a few noticeable facies changes are present. Slight thinning of bedrock strata occurs in the central and southwestern portion of Butler County over the crest of the Nemaha Uplift. Many limestone units show evidence of deposition in very shallow water across this area. Typical sedimentary structures include cross bedding, ripple marks, oolites, and algal laminations. Such features are present in limestone units from the Cottonwood up through the Fort Riley. This region is part of what Imbrie *et al.* (1964) named the *Greenwood Shoal* of the early Permian sea.

Lower Permian cyclothems are similar to Upper Pennsylvanian cyclothems of eastern Kansas (Klein and Willard 1989); each cyclothem includes a triad of limestone-shale-limestone (units 4, 5 and 6) and represents mainly marine sedimentation. Lithologies of individual units within Lower Permian cyclothems differ considerably, however, from Upper Pennsylvanian cyclothems. Red beds, cherty limestone, and evaporites (subsurface) are common in Lower Permian strata; whereas coal, sandstone, and black shale are scarce to absent. The lithologic differences between Upper Pennsylvanian and Lower Permian cyclothems are thought to reflect a combination of factors: (1) increasing aridity of the climate, (2) decreasing supply of clastic sediment, and (3) decreasing amplitude of transgressive/regressive cycles during early Permian time (Aber 1991).

Many explanations for Pennsylvanian and Permian cyclothems of the midcontinent have been proposed. These explanations generally fall into three categories: crustal movements, glacio-eustatic sea-level changes, and delta-lobe shifting. The Lower Permian cyclothems of Butler County do not contain features associated with deltaic sedimentation, and the remarkable lateral consistency of units argues against significant local crustal movements during the early Permian (Moore 1964). The most reasonable explanation for repeated marine transgressions and regressions is glacioeustasy related to glaciation in Gondwana (Aber 1991).

STRUCTURAL FEATURES

Bedrock dip is normally westward or northwestward at 20 to 40 feet per mile (4-8 m/km), but this varies in many areas. Northward, southward, and eastward dips as steep as 60 to 80 feet per mile (11-15 m/km) are commonly developed in association with

folds. Dip angle may locally be as great as 10° in these situations.

Fold structures--anticlines and synclines--are present in surficial bedrock in many parts of Butler and Chase counties. In most cases, anticlines and synclines occur in closely matched pairs, but this is not true in all situations (Fig. 5; Table 1). Basement control of structures in surficial bedrock of the midcontinent was recognized long ago by Fath (1921, p. 149), who stated that these structures are "in large part the surface expression of deep-seated readjustments along ancient faults or lines of weakness present in the pre-Cambrian basement rocks of the region."

The crest and trough of an anticline/syncline pair are generally parallel to each other, with the syncline located from $\frac{1}{2}$ to 2 miles east of the anticline. Between the anticline and syncline, bedrock dips toward the east. The fold pair may extend for several miles in northerly to northeasterly trends. The two longest folds in Butler County are both synclines: Walnut Syncline (10) and Gordon Syncline (19). Syncline troughs coincide in many places with stream valleys (Fig. 6).

Table 1.   Surficial anticlines and synclines of Butler County,
           Kansas. See Figure 5 for locations.

Structure	Associated Oil Field or River
1. Blankinship Anticline	Blankinship, Young
2. Beaumont Anticline	Ferrel, Ferrel South, Shinn, Shinn NE, Wehrman
3. Grouse Syncline	Grouse Creek
4. Latham Syncline	none
5. Brant Anticline	Brant-Sensenbaugh
6. Eagle Syncline	Eagle Creek
7. Cole Syncline	Cole Creek
8. Burns Dome	oil field
9. DeGraff Anticline	none
10. Walnut Syncline	Walnut River and West Branch Walnut River
11. Dunkle Syncline	unnamed stream
12. El Dorado Anticline	El Dorado
13. Hammond-Fowler Syncline	none
14. Pierce Anticline	Pierce
15. Shumway Anticline	El Dorado
16. Augusta North Anticline	Augusta North
17. Augusta Syncline	Walnut River
18. Augusta South Anticline	Augusta
19. Gordon Syncline	none
20. Douglass Anticline	oil field
21. Salter Syncline	none
22. Rose Hill Anticline	oil field
23. Seltzer Syncline	Seltzer Spring
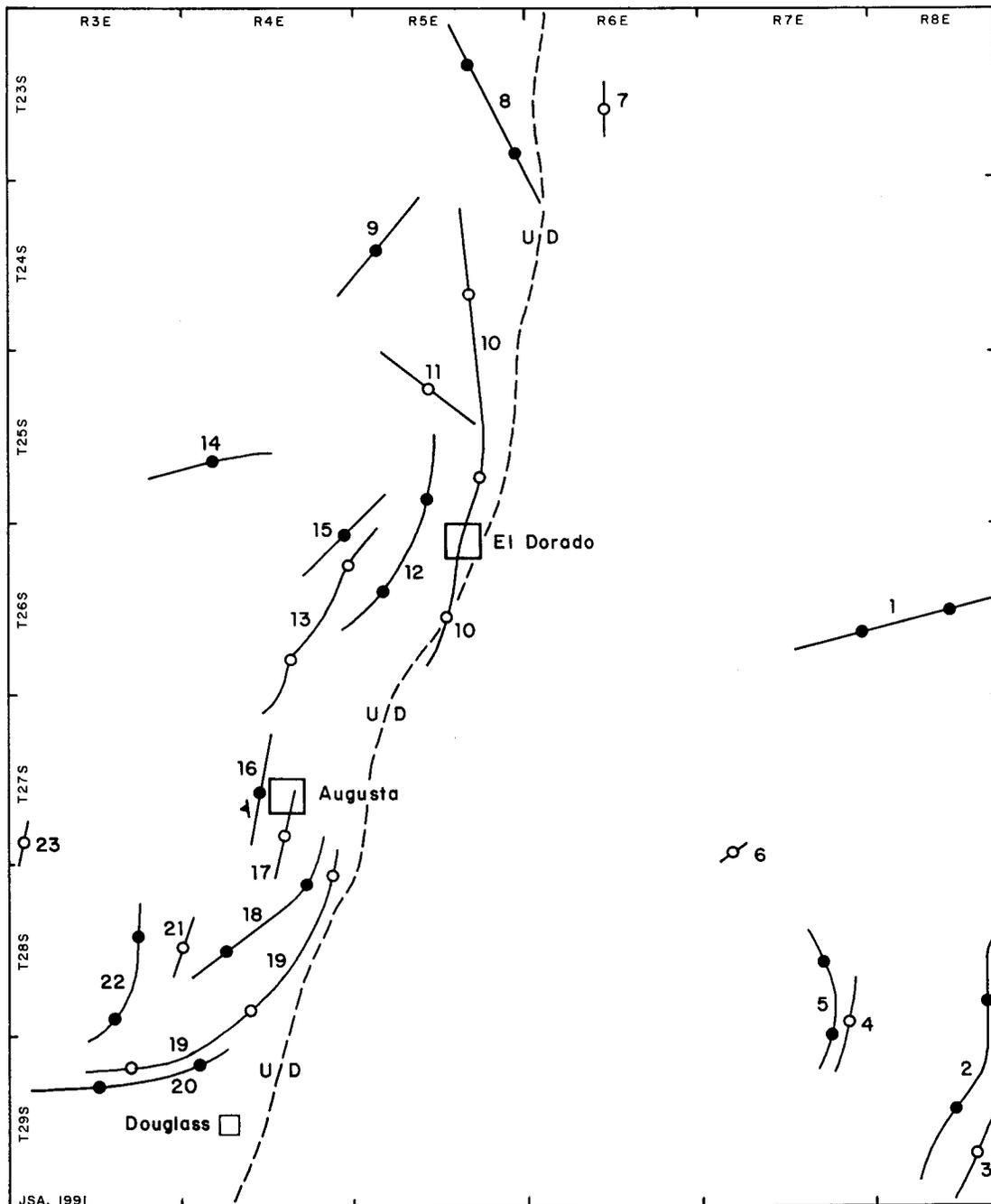
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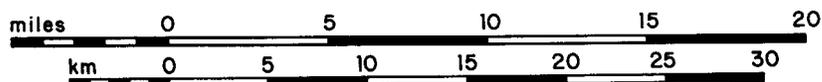
Figure 5. Anticlines, synclines, and faults in surficial bedrock of Butler County, Kansas. Many anticlines and synclines are arrayed in curved, *en echelon* patterns over the crest of the Nemaha Uplift immediately west of the buried Humboldt Fault zone. Taken from Aber (1991).

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Figure 6. Portion of the Latham SE topographic quadrangle. Grouse Creek follows a syncline trough, and the crest of Beaumont Anticline to the west is breached in several places by small tributary streams. Map slightly reduced from original 1:24,000 scale.

Surficial folds of Butler County are located above major
uplifts in the basement surface. Folds in the western portion of
the county are associated with the Nemaha Uplift, which is
bounded on its eastern side by the buried Humboldt Fault. The
basement surface is offset by several 100 feet to more than 1000
feet (300 m) along the fault zone (Bickford et al. 1979). Local
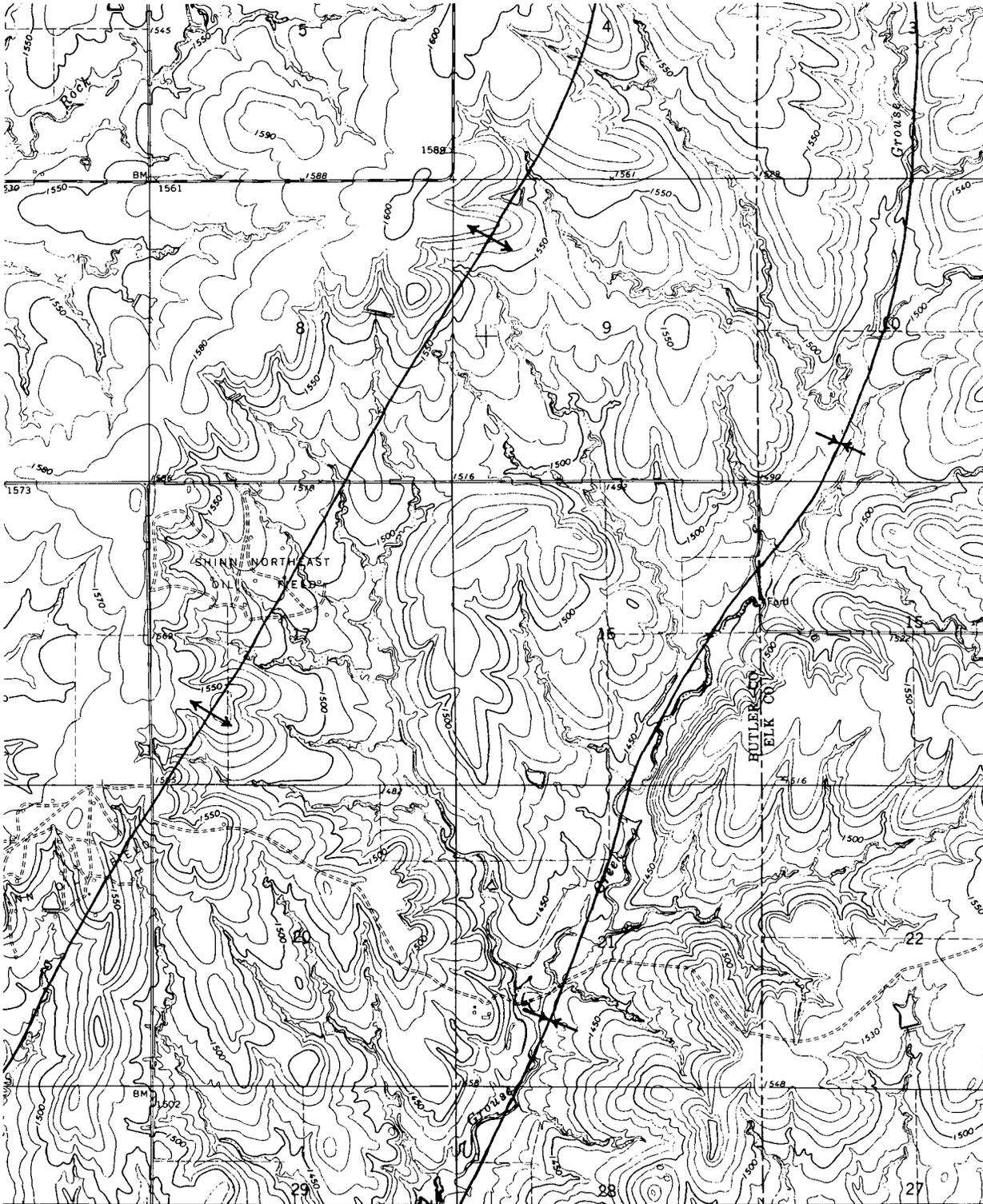culminations on the Nemaha Uplift correspond to the Burns, El
Dorado, and Augusta-Douglass regions of surficial folding.
Surficial folds in the southeastern portion of Butler County are
located above a more subtle uplift in the basement surface.

JOINTS

     Joints are ubiquitous in bedrock of the Flint Hills. Joint
measurements in Butler County show that at most sites two sets of
joints are present (Fig. 7). Some sites have three joint sets, a
few sites have only one set of visible joints. The two dominant
joint sets (1 and 2) are complementary (around 90° angle) and are
present at most sites. Three minor joint sets (3-5) are each
found at less than one-quarter of sites.

     Joints sets 2 and 3 are related to well-known basement
structures. Joint set 2 (310-335°) is parallel to numerous
northwest-trending basement faults found throughout eastern
Kansas--the Fall River trend. Joint set 3 (15-35°) corresponds
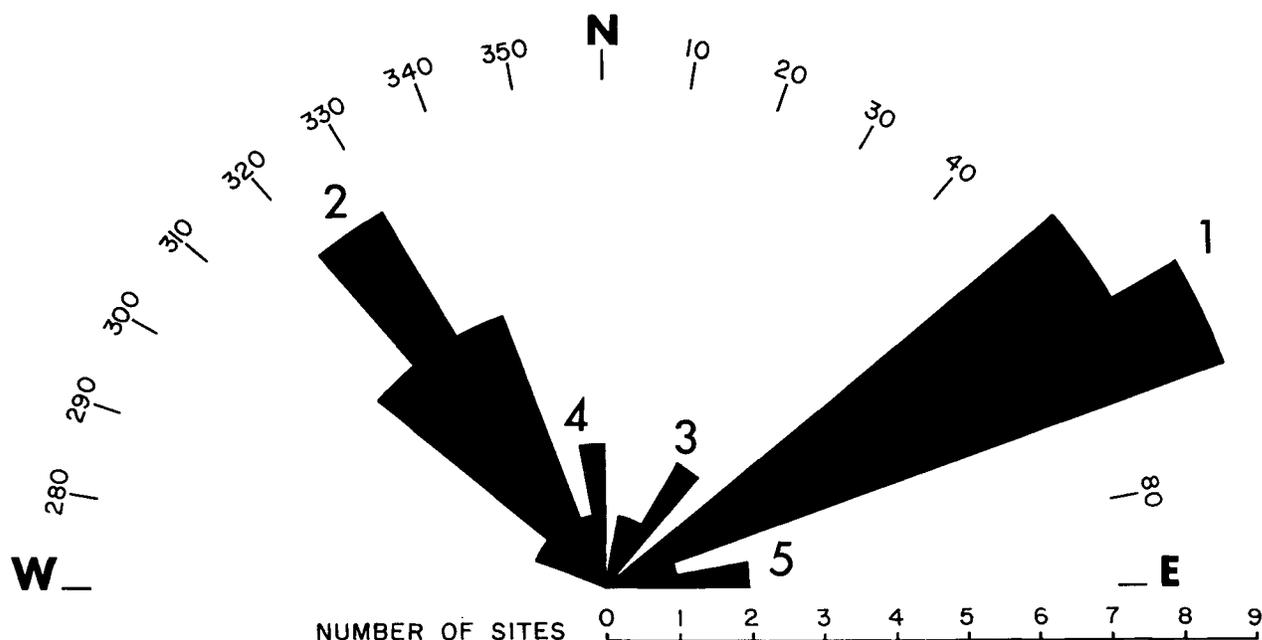to the north-northeast trend of the Humboldt Fault zone on the

Figure 7. Rose diagram of joint strike orientation for
Butler County, Kansas. Joints are grouped by 10° intervals;
numbers (1-5) indicate joint sets; scale shows number of sites
with joints in each interval. Taken from Aber (1991).

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eastern side of the Nemaha Uplift. Joint set 1 (50-65°) is widely present throughout eastern Kansas, but it is not obviously related to any known basement structures.

SOILS AND UNCONSOLIDATED SEDIMENTS

Soils series are useful as indicators for unconsolidated sediment of various types. Selected soils and corresponding unconsolidated sediments are summarized below, based mainly on Penner *et al.* (1975):

Olpe Series: Parent material consists of alluvial chert gravel, 3-8 feet (1-2½ m) thick, with locally interbedded sand and clay of the Norge Series. Located along high terraces and hill tops (Fig. 8). Hill-top gravels display strong oxidation and clay enrichment in B horizons, whereas high-terrace gravels are less strongly oxidized in B horizons. Parent gravel of the Olpe series is thought to be Neogene (Miocene or Pliocene) in age.
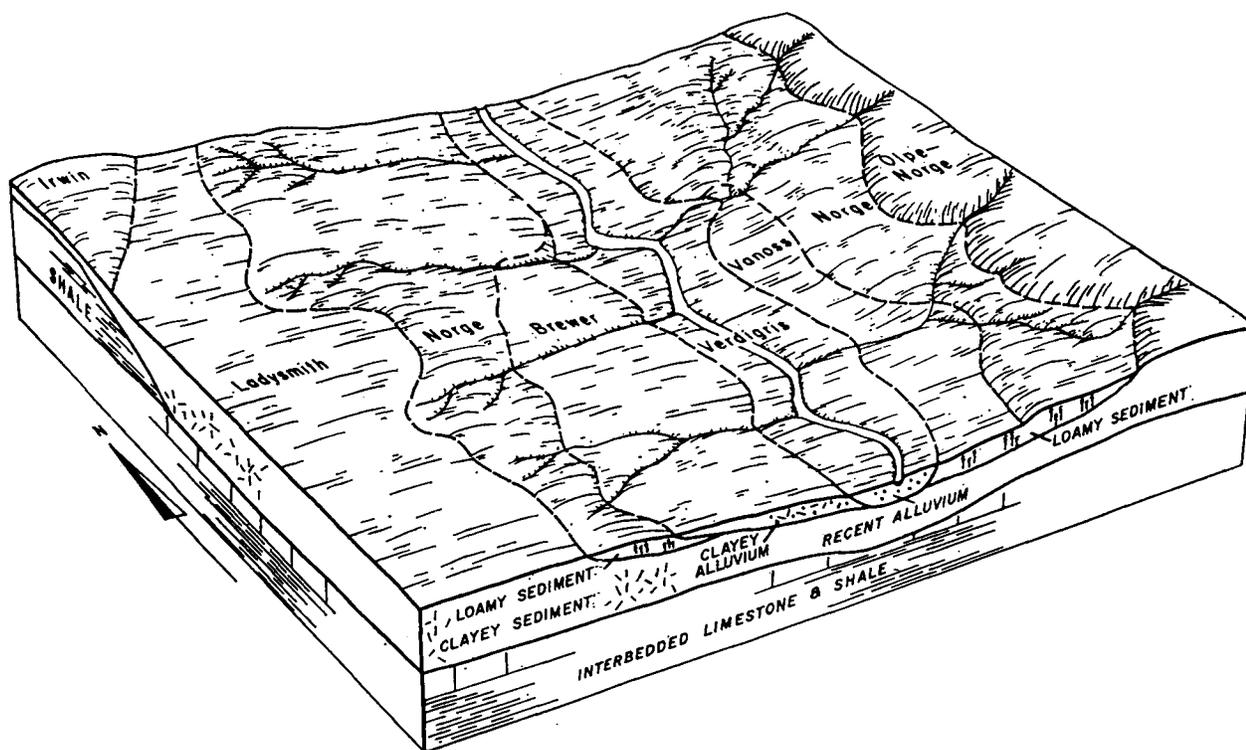

Figure 8. Typical soils associated with alluvial deposits in Butler County, Kansas. Note Olpe-Norge soil on high terrace; Norge, Ladysmith and Irwin soils on low terrace; and Verdigris, Brewer and Vanoss soils on valley bottom. Taken from Penner *et al.* (1975, fig. 3).

Note: Florence soil represents residual chert accumulations, not alluvial deposits. It is a good indicator for the Florence and Wreford bedrock units, where not covered by loess soils.

Verdigris Series: Parent material consists of silt and clay alluvium greater than 5 feet (1½ m) thick in modern valleys. Covers level bottom lands and floodplains (Fig. 8), and associated with Brewer, Osage, and Vanoss soils. These soils are assumed to be Quaternary, probably late Pleistocene and/or Holocene in age.

Note: Low terraces, 10-20 feet (3-6 m) above floodplain, are covered by Irwin, Ladysmith, or Norge soils. These terrace surfaces are thus at least as old as the loess soil cover and may be late or middle Pleistocene in age.

Goessel Series: Parent material consists of sandy, silty, clay >5 feet (>1½ m) deep on nearly level to gently sloping uplands in western portions of Butler County. May include small pockets of Rosehill soil. Goessel soil represents wind-blown loess, which is assumed to be Quaternary, probably late Pleistocene and/or Holocene in age.

Note: many other upland soils have a significant loess component, including Rosehill, Dwight, Irwin, Ladysmith, and Labette soils. However, these soils are underlain by shallow weathered bedrock in the 3-5 foot (1-1½ m) range.

LEON GRAVEL

Upland chert gravel deposits are widespread in southern Butler and northern Cowley counties (Fig. 9). These gravels are formally designated as the *Leon Gravel* after the city of Leon (Aber 1992). A stratotype was designated in NE¼ sec. 35, T27S, R5E (Fig. 10). As defined, the Leon Gravel is equivalent to the Olpe or Olpe-Norge soil map units within the Walnut drainage basin of Butler and Cowley counties. The Leon Gravel is usually 1-2 m thick and rests on bedrock. It can be informally separated in some places into upper and lower members on the basis of topographic position in relation to adjacent modern valleys:

1. Upper member: hill-top or drainage-divide positions, about 18-30 m (60-100 feet) above modern floodplains. Olpe soil B2 unit color is typically moderate to dark reddish brown (10 R 4/6 to 3/4).

2. Lower member: high-terrace positions, roughly 6-12 m (20-40 feet) above modern floodplains. Olpe soil B2 unit color is typically moderate brown (5 YR 4/4).
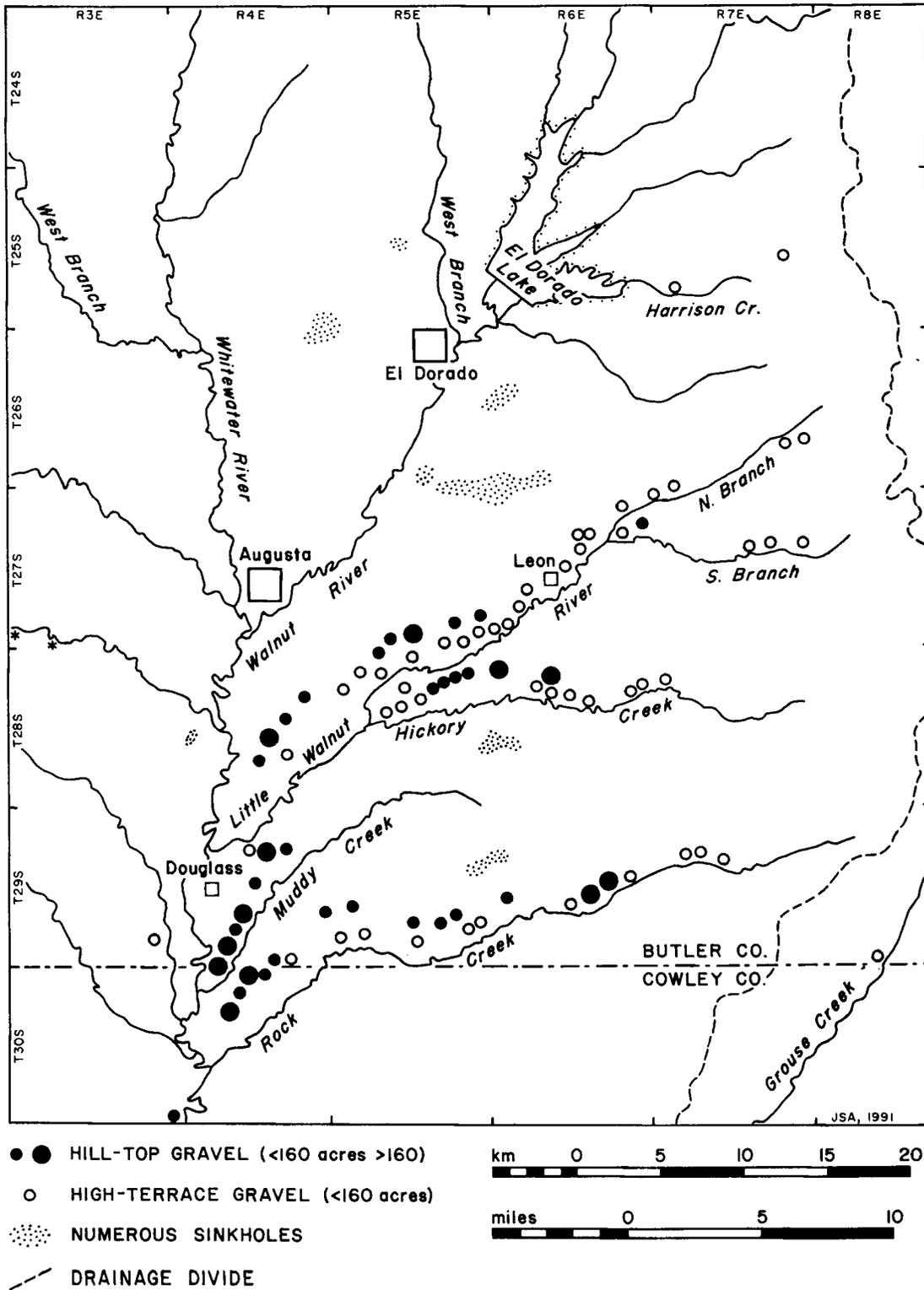
Figure 9. Map of Butler County (except T23S) and northern Cowley County showing upland chert gravel deposits (Olpe soil), sinkhole zones, and principal streams. High-terrace gravels are <50 feet (<15 m) and hill-top gravels are >50 feet (>15 m) above modern valley flood plains. Taken from Aber (1991).

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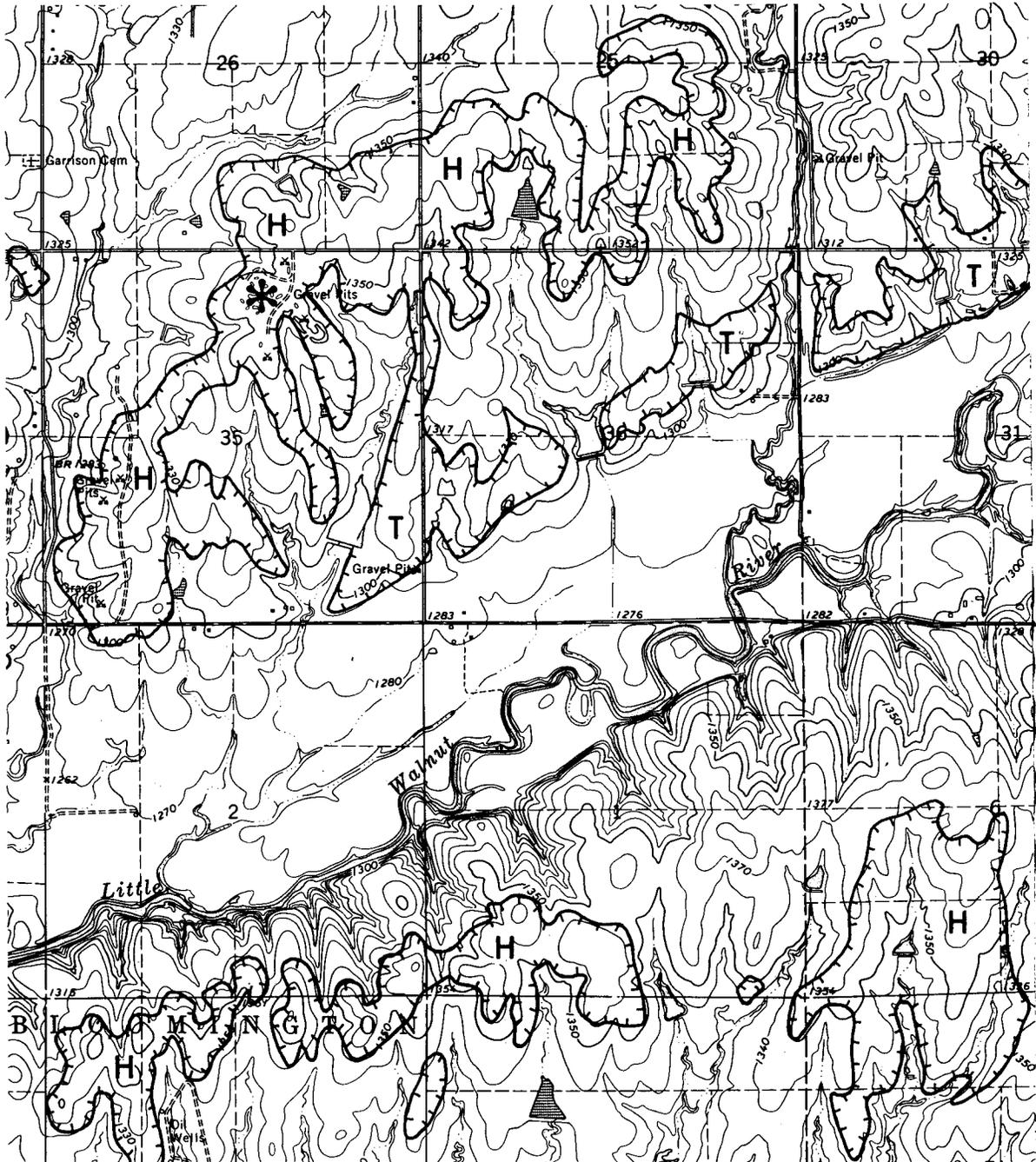
Figure 10. Portion of Leon topographic quadrangle showing
distribution of Leon Gravel and location of the Leon Gravel
stratotype (asterisk) in NE¼ sec. 35, T27S, R5E. H = hill-top
gravel; T = high-terrace gravel. Map reduced from original
1:24,000 scale; elevations in feet; contour interval = 10 feet.
Gravel limits based on Penner *et al*. (1975); adapted from Aber
(1992, fig. 4).

The stratotype vicinity demonstrates typical geomorphic conditions for the Leon Gravel (Fig. 10). High-terrace and hill-top deposits are preserved north of the Little Walnut valley at 6-12 m and 18-25 m respectively above the valley floor. In places, gravel is continuous between the high-terrace and hill-top positions. Hill-top gravels preserved south of the Little Walnut valley are situated on the local divide between Little Walnut and Hickory basins. Hill-top gravels gradually rise in the downstream direction relative to the modern Little Walnut valley. In the stratotype vicinity, highest gravels are 25 m above the nearby valley floor. Downstream on the divide between the Little Walnut and Walnut basins, hill-top gravels are up to 30 m above the valley floor.

The Leon Gravel is thought to be more-or-less equivalent to Neogene chert gravels that are common in the Neosho, Verdigris, Fall, and Marais des Cygnes basins east of the Flint Hills (Aber 1988). However, the true age of the Leon Gravel is uncertain. Exotic pebbles of quartz and quartzite are present, but extremely rare, in both high-terrace and hill-top gravels associated with tributary streams east of the Walnut River. These quartzite erratics presumably were reworked from Ogallala-type gravel of High Plains provenance.

Leon Gravel in hill-top positions beside the Walnut River valley south of Douglass is noticeably different from upstream gravel deposits. Gravel south of Douglass is thick (10 feet), has a high content of coarse quartz sand, and has a high content of milky quartz pebbles derived from the Nolands Limestone. Erratic quartzite pebbles are relatively abundant in this vicinity. All these features indicate a major influx of sediment coming into the ancestral Walnut basin from the west.

It is likely that the Arkansas River once flowed eastward from the Wichita vicinity into southern Butler County; it may have flowed across the Flint Hills escarpment into southeastern Kansas. This would explain the presence of quartzite erratics in Leon Gravel throughout southern Butler County. Drainage in eastern Butler County was reversed when the Arkansas River was diverted southward along the path of the Walnut River. Another later diversion rerouted the Arkansas River southward in its modern location and left the Walnut River in its present drainage basin. The timing of these drainage shifts is unknown.

STRUCTURAL CONTROL OF DRAINAGE

It is clear that bedrock structural features have exerted a strong influence on stream erosion patterns in Butler and Chase counties. Streams follow the troughs of synclines in several places; the most noteable examples are West Branch Walnut River and Grouse Creek (Figs. 5 and 9). Joint sets have likewise influenced drainage development. Most eastern tributaries of the Walnut River flow downdip, parallel to joint set 1 (50-65°);

examples include the Little Walnut River and its North Branch and portions of Rock Creek. Hickory Creek and parts of Rock Creek valleys are parallel to joint set 5 (70-80°).

The western tributaries of Walnut River follow valleys that are mostly parallel to joint set 2 (310-335°), including the West Branch Whitewater River. Joint set 3 (15-35°) relates to the main stem of the Walnut River northeast of Augusta, including the west arm of El Dorado Lake. These two trends correspond to major lineaments found across eastern Kansas (Burchett et al. 1983).

The upper North Branch Verdigris River flows toward the NNW as does the South Fork Cottonwood, and headwater streams of the Fall drainage flow opposite to the SSE. These parallel and aligned trends relate to joint set 4 (340-350°). The upper North Branch Verdigris turns abruptly toward the east in southeastern Chase County. This is one of the most prominent drainage anomalies in Kansas. At one time, the North Branch Verdigris River may have extended farther west, but the western portion was captured by headward erosion of the South Fork Cottonwood.

Upland chert gravels in the Walnut drainage basin are preserved almost exclusively on the northern sides of eastern tributaries--Little Walnut, Hickory and Rock valleys, and on the eastern side of the lower Walnut valley (Fig. 9). The same patterns hold true for lower (= younger) terraces within these valleys, and modern rivers are cutting bedrock bluffs in many places on opposite valley sides. Valley asymmetry is the result of systematic river migration during downcutting, which may reflect long-term crustal warping downward to the south across much of eastern Kansas (Aber et al. 1995).

KARST FEATURES

Karst geomorphology is well developed in many parts of the Flint Hills, as a result of ground-water solution of thick limestone units. Common karst features in the Flint Hills include sinkholes, caves, and springs. Sinkholes are abundant in the Fort Riley Limestone in several portions of Butler County (Fig. 9). Where present, sinkholes are quite numerous and conspicuous; a density of 10 or more sinkholes per quarter section is typical. Elsewhere sinkholes are generally lacking in the Fort Riley outcrop region.

Zones of dense sinkhole development are associated with several structural and topographic conditions:

1. structural crests of anticlines (oil fields).
2. upland drainage divides.
3. nearly level to gently sloping land surface.
4. entrenched river valleys nearby.
5. lack of thick surficial cover (chert gravel or loess).

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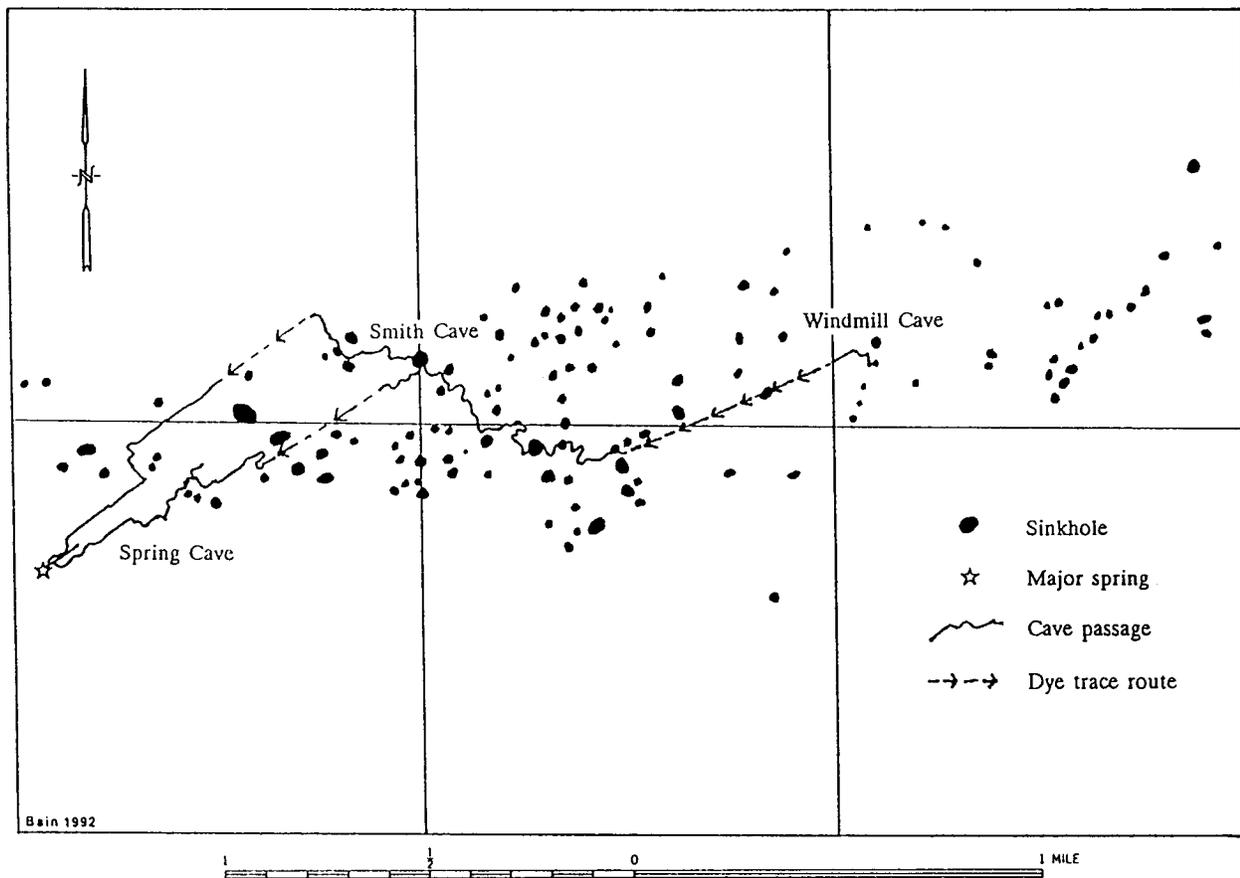
Figure 11. Numerous sinkholes and caves developed in Fort Riley Limestone, in the region between El Dorado and Leon, central Butler County. Taken from Bain (1992).

These factors in combination are thought to enhance the possibility for vertical drainage of water into highly fractured, soluble bedrock with resulting sinkhole solution. Springs and caves are also known in association with sinkhole zones, especially in the region between El Dorado and Leon (Fig. 11).

CAVES

Caves are fairly common within the Fort Riley Limestone of the Flint Hills, especially in central Butler County. Three caves and numerous sinkholes have been mapped in the karst terrain between El Dorado and Leon (Fig. 11). Spring Cave has a surveyed length of >8500 feet (>2500 m); Smith Cave is >7200 feet (>2200 m) long, and Windmill Cave has >670 feet (>200 m) of mapped passages. The combined surveyed length of these caves is, thus, more than 3 miles (5 km).

The three enterable caves are connected by water-filled passages. Dye tracing has confirmed the hydrologic connections, which suggest an integrated ground-water flow system. Water

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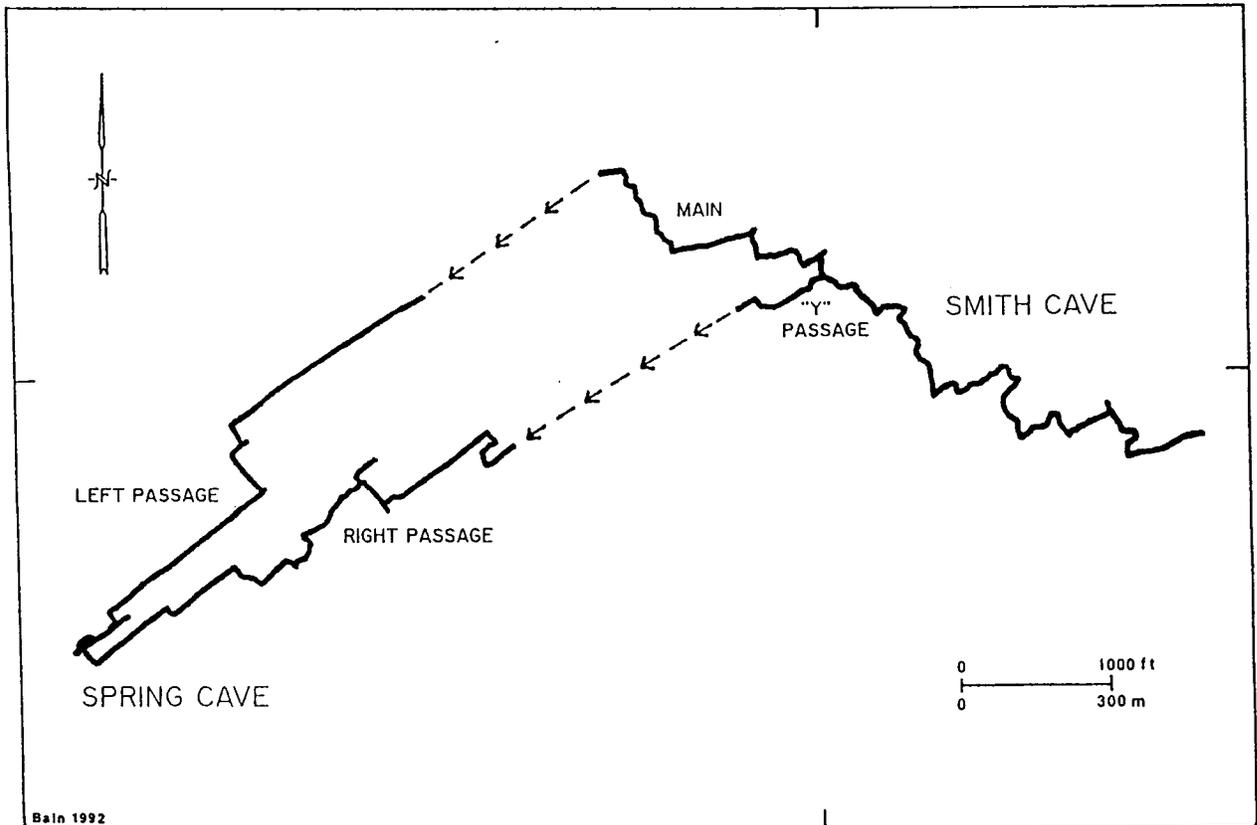Figure 12. Detailed map of surveyed passages in Spring Cave and Smith Cave. Dashed lines indicate hydrologic connections demonstrated by dye tracing. Taken from Bain (1992).

input is via sinkholes and soil percolation, and the entire system drains westward to a perennial spring (Fig. 11). Normal (low flow) discharge of the spring is approximately 200 gal/min (12½ l/s). As with many karst springs, Spring Cave is extremely flashy (flood prone) following heavy rainfall, when the spring may become a raging torrent several times the normal discharge. At such times, sediment transport and mechanical erosion are greatly increased within the cave system.

Spring Cave passages are strongly controlled by fractures (Fig. 12). Passages are tall, narrow, solutionally enlarged joints that have sharp, angular bends at joint intersections. Passages follow the two main joint trends of the region at 50-70° and 300-320°. Two parallel passages--right and left--emerge at the spring entrance and are connected upstream to passages of Smith Cave. Smith Cave and Windmill Cave exhibit some joint control of their passage trends, but not so much as Spring Cave.

Smith Cave displays passages that are often controlled by bedding planes, especially in its eastern and central sections (Fig. 12). The passages are sinuous and have elliptical shapes at the tops with relatively flat ceilings. The lower parts of

passages are characterized by vadose canyons in which streams are actively downcutting. Most ground water in Smith Cave flows along the Main (northern) passage into the left passage of Spring Cave. However, the Y passage diverts about 25-30% of flow from Smith Cave into the right passage of Spring Cave. The Y passage once may have been a tributary of Smith Cave, but through underground stream piracy its direction of drainage is reversed now into Spring Cave (Bain 1992).

CAVE ORGANISMS

The Spring/Smith cave stream is inhabited by fairly abundant populations of albino isopods, amphipods, crayfish, and catfish. This diverse faunal assemblage suggests stability in water quality and also that these species probably have thrived for many generations in the cave environment (Bain 1992). In Smith Cave, catfish were identified as black bullheads (*Ictalurus melas*), and the predominant amphipod species appears to be Clanton's cave amphipod (*Stygobromus clantoni*).

| | 250 to 500 mg/L | | 751 to 1000 mg/L |
| | 501 to 750 mg/L | | > 1000 mg/L |

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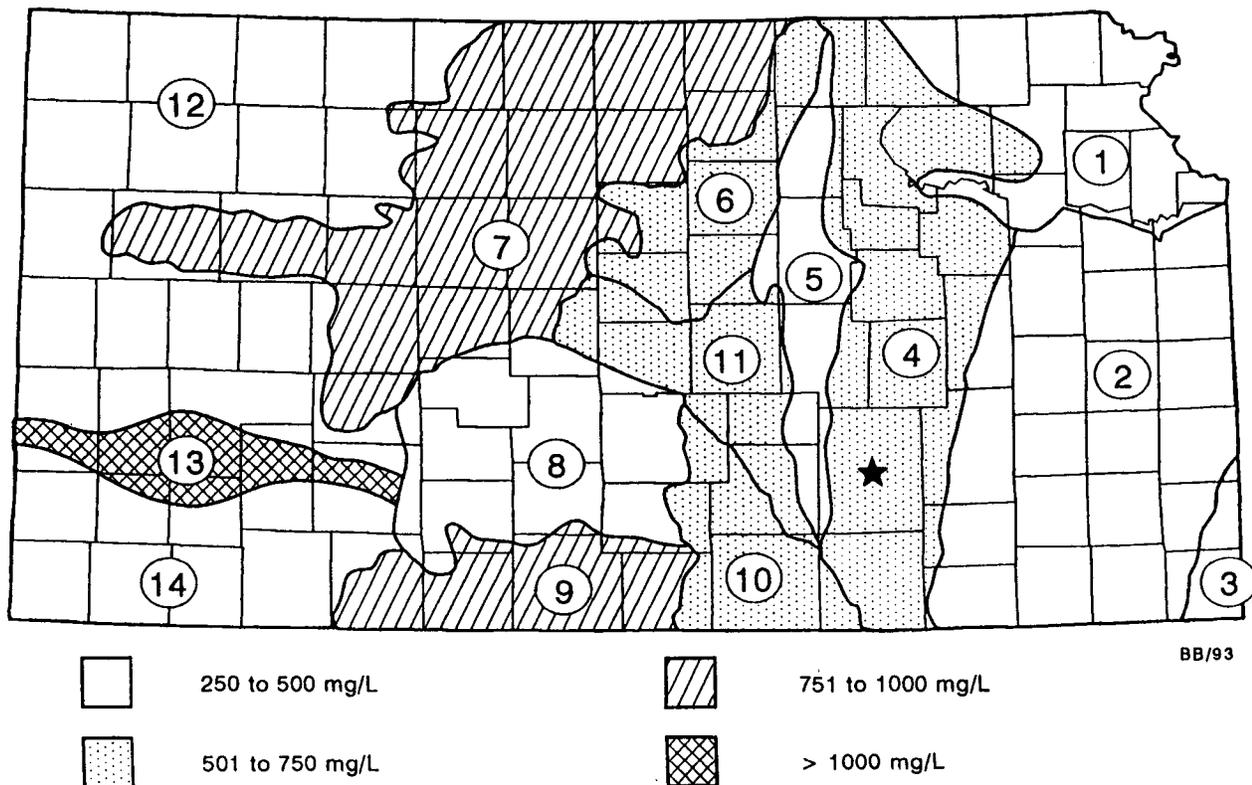
Figure 13. Mean total dissolved solids concentrations for Kansas ground-water regions, 1991-92. Region 4 is the Flint Hills; star indicates location of Spring/Smith/Windmill cave system in Butler County. Taken from Bain (1994).

20

| | 200 to 300 mg/L | | 401 to 500 mg/L |
| | 301 to 400 mg/L | | > 500 mg/L |

BB/93
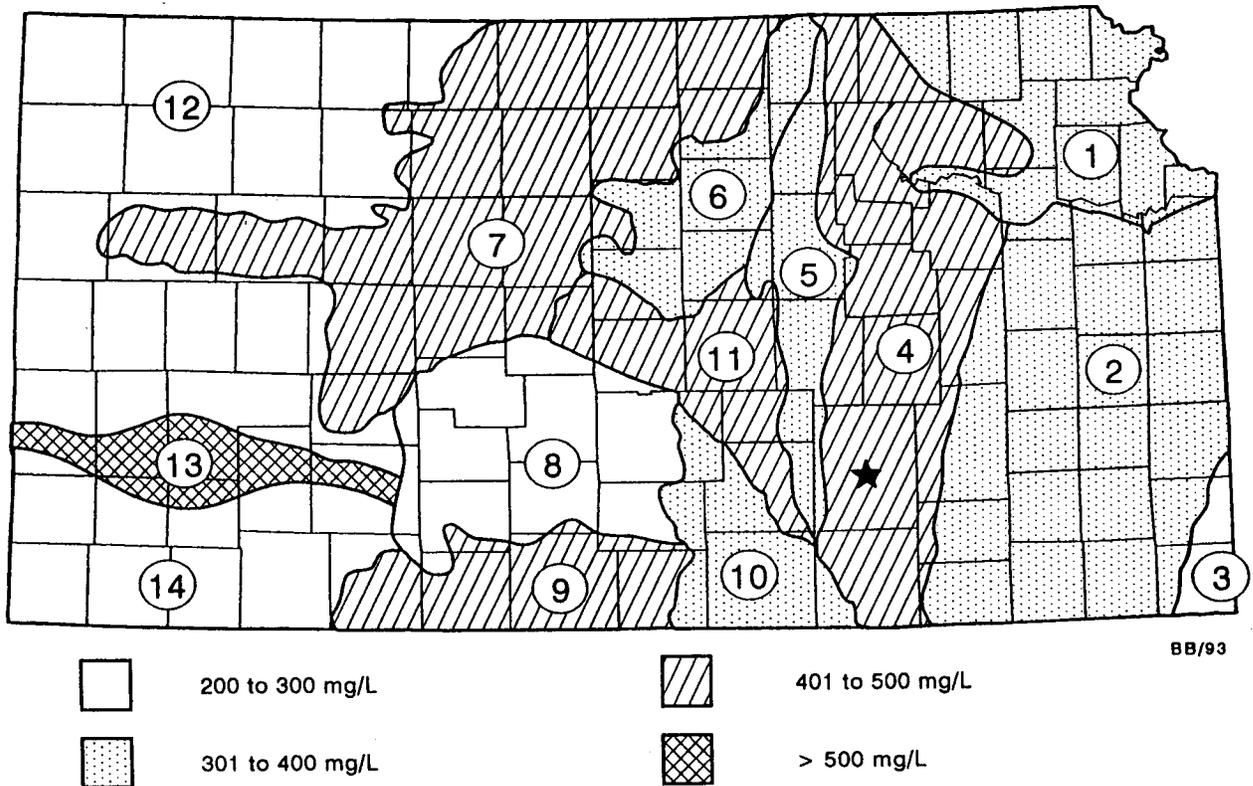
Figure 14. Mean total hardness concentrations for Kansas ground-water regions, 1991-92. Region 4 is the Flint Hills; star indicates location of Spring/Smith/Windmill cave system in Butler County. Taken from Bain (1994).

GROUND-WATER CHEMISTRY

Ground water from Smith Cave is sampled regularly as part of the *Groundwater Quality Monitoring Network* (site I.D. 00017602) of the Kansas Department of Health and Environment. Ground water of the Flint Hills region generally has high total dissolved solids and high total hardness concentrations (Figs. 13 and 14).

*   *   *

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BIOTA OF THE SOUTHERN FLINT HILLS AND REINTRODUCTION
OF PRONGHORN INTO THE REGION

Elmer J. Finck and Brad D. Simpson

INTRODUCTION

The biology of the southern Flint Hills has not been extensively studied. The area, including parts of Chase, Greenwood, and Butler counties, is dominated by the land management practices associated with season-long grazing by cattle (*Bos tarus*). The biodiversity of the region remains high and is often the area within the state where populations of species that have had major reductions in numbers elsewhere are still doing well.

Generally speaking, the Flint Hills is a major biological region in Kansas that has flora and fauna, which are mixed components of regions to the east and west. Many species reach their state distributional limits in the Flint Hills. Typically not much has been said about differences in the biota between the northern and southern regions of the Flint Hills. Many more studies associated with Konza Prairie Research Natural Area in the northern Flint Hills have been published. Thus, one can use the checklists for Konza Prairie as an approximation of the flora and fauna of the southern region. See the following papers for the respective taxa: flowering plants (Freeman and Hulbert 1985; Freeman and Gibson 1987), bryophytes (Merrill 1991), mammals (Finck *et al.* 1986), birds (Zimmerman 1985) and herpetofauna (Heinrich and Kaufman 1985)

Of course, one can expect that there are shifts in numbers of organisms within any particular species and some species that would be more abundant in one region as compared to the other. Some notable vertebrate examples include the following. Black-tailed jack rabbit (*Lepus californicus*) is absent on Konza Prairie, but is abundant in Lyon, Chase, and Greenwood counties. Scissor-tailed flycatcher (*Muscivora forficata*) is more abundant in the southern than northern region of the Flint Hills, as is the massasauga (*Sistrurus catenatus*). Southern bog lemming (*Synaptomys cooperi*) is more abundant on Konza Prairie than in the southern Flint Hills. One species of special interest, the pronghorn (*Antilocapra americana*), has been reintroduced into Lyon and Chase counties.

At one time pronghorn roamed in huge herds throughout the western half of the United States, extending into the western edge of the tallgrass prairie ecosystem (Nelson 1925; Einarsen 1948; Yoakum 1978). With European settlement came the destruction of native grasslands and the massive slaughter of North American ungulates. Pronghorn populations were historically estimated to be equal to or greater than bison (*Bos bison*), the population fell to 13,000 by 1920 (Nelson 1925). In

Kansas, for example, as few as 10 pronghorn remained in the extreme southwestern portion of the state in 1923 (Nelson 1925; Yoakum 1978, 1986).

PRONGHORN TRANSLOCATION

Beginning in 1922, the first extensive census of pronghorn recorded 26,700 individuals in the United States (Nelson 1925). During the next decade, pronghorn populations increased to 130,000, and by 1976 the population reached 404,400 individuals. Today the population stands at more than half a million, primarily because of translocating pronghorn back into previously occupied areas with suitable habitat. In Kansas, 1,100 individuals inhabited the western most counties in 1976, (Yoakum 1978, 1986) with the present population estimated to be 1,600 (K. Sexson, KS Dept. Wild. and Parks, pers. commun.). Eighty percent of all pronghorn inhabit shortgrass prairie or a grassland/ shrubland mixture (Yoakum 1978).

Translocating pronghorn to areas where they once occurred is a management technique in effect since 1924 (Nelson 1925). Although the success of a translocation is attributed to the establishment of a population into formerly occupied areas, not every translocation is successful (Hlavachick 1970; Sexson and Choate 1981; Delmonte and Kothmann 1984; Goldsmith 1987).

Kansas Department of Wildlife and Parks (KDWP) began a restoration program for pronghorn in 1964, releasing 75 individuals in Wallace County (Hlavachick 1970). Other translocations followed (1966-1967) in Barber, McPherson, Ellsworth, and Edwards counties but were unsuccessful (Sexson and Choate 1981). By 1969, the only successful translocation was in Wallace County, which had an annual population increase of 17% (Hlavachick 1970).

In an attempt to establish a population in the easternmost part of their former range, KDWP released 37 pronghorn in 1978 and another 98 individuals in 1979, to Chase County, Kansas (Funk 1978, 1979; Sexson and Choate 1981). Additional releases of 127 and 24 animals followed in 1982 and 1983, respectively. Bi-annual surveys since 1986 have estimated the population to be approximately 46 individuals.

No other translocations into the tallgrass prairie are being attempted at the present time. However, future translocations are anticipated on Konza Prairie of Riley County, Kansas (T. Barkley, Kansas State Univ., pers. commun.) and the Prairie Preserve in Osage County, Oklahoma (B. Hamilton, pers. commun.). Both sites are property of The Nature Conservancy.

Renewed interest was expressed by KDWP for restoring pronghorn to once-occupied areas in Kansas that have potential for population growth, like the tallgrass prairie. The KDWP

pronghorn strategic plan states a need "to restore animals to areas determined to be suitable for their expansion and to determine limiting factors acting on the population" (KDWP 1987). This creates an opportunity to study pronghorn ecology and behavior in an ecosystem that had been depleted of pronghorn until 1978. In addition, it will provide information for future translocation attempts in other areas of the tallgrass prairie.

Because only 46 pronghorn, from the 286 animals previously released, occur in the Flint Hills, KDWP wanted to identify limiting factors that may be involved in establishing a viable population in this region. By releasing pronghorn into their former range in the Flint Hills region, it would be possible to complete a post-release survey and to monitor their behavior following release. Thus, an additional 50 animals in 1991 and 49 in 1992 were released in the same area as previous releases.

A post-release survey is essential to determine success or failure of the translocation and to evaluate the translocated population's future potential and viability (McCarthy and Yoakum 1984; Nielsen 1988; O'Gara and Yoakum 1990). As information is lacking on tallgrass prairie pronghorn, other than bi-annual aerial surveys to estimate population size, we determined post-release dispersal, home range establishment, habitat use, and behavior of translocated pronghorn (Simpson 1992), fawn mortality and home range (Rothchild 1993), and use of key areas in the winter and spring by pronghorn (Eccles 1995).

PRONGHORN STUDY AREA

The pronghorn study area is located in Chase and Lyon counties, Kansas, in the 10,000 km² Flint Hills region, the largest continuous tract of tallgrass prairie remaining in North America. The study area is semi-confined by the Kansas Turnpike (I-35) on the south and east, the Cottonwood River on the north, and the South Fork of the Cottonwood River on the west (Fig. 15). Along the turnpike there is a net-woven wire fence, flush at ground level, to deter pronghorn from getting onto the turnpike. The rivers are deeply channeled and are bordered by riparian habitat that could deter pronghorn from crossing. The study area within the semi-confined prairie is 335 km².

The study area is privately owned by several landowners and is grazed by cattle from 15 April through 15 October, with some cattle being removed by 15 August (Horak 1985). The entire area normally is burned in late March and is usually burned annually. Less than 2% of the study area is cultivated, mainly in the river valleys. Human access is limited; two county roads run north/south on each end of the study area and a road maintained for Williams Pipeline Company (Tulsa, OK) runs east/west in the southern part of the study area.

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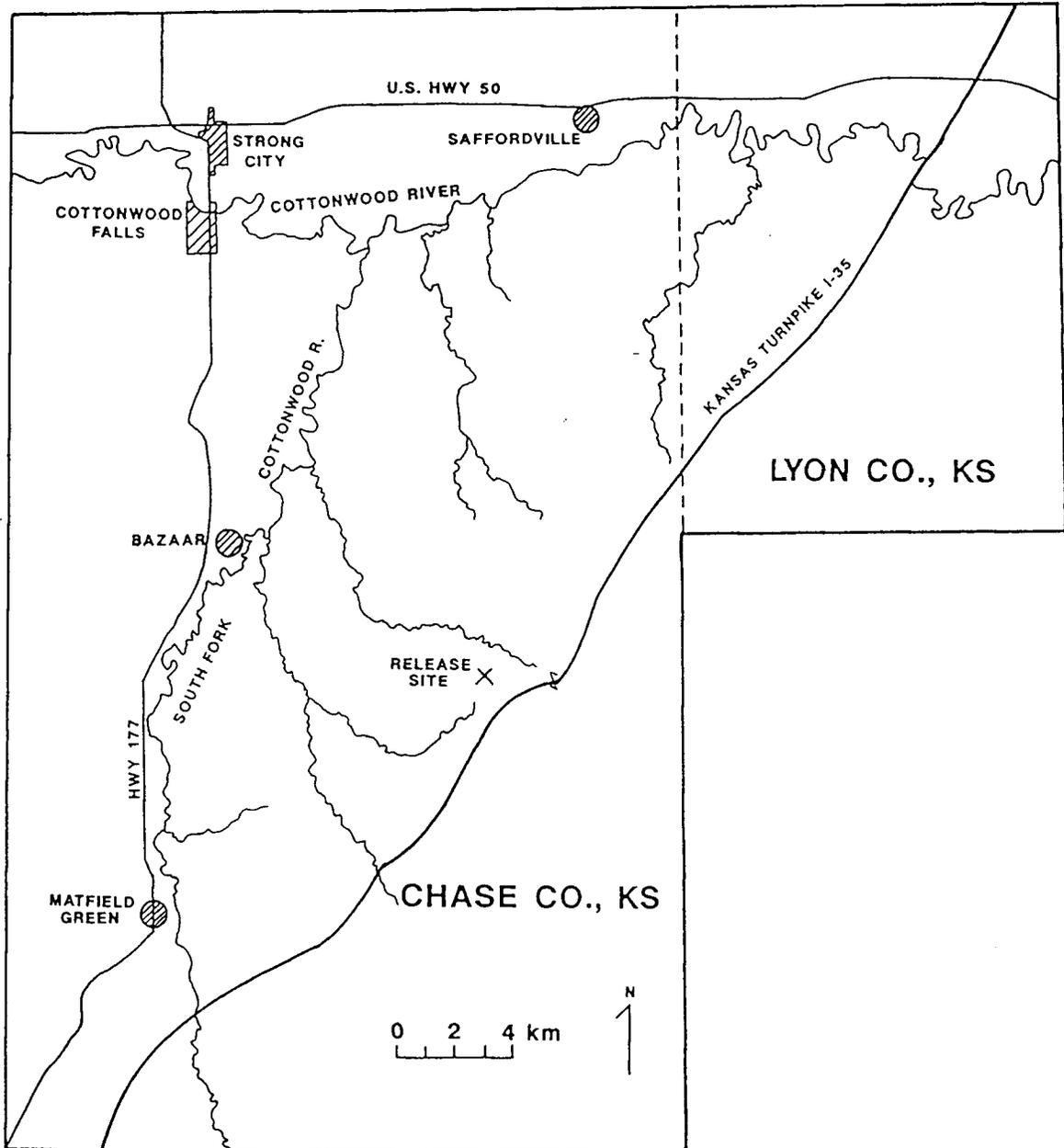
Figure 15. Overview of the Flint Hills study area for the pronghorn reintroduction project in Chase and Lyon counties, Kansas.

The topography of this region of the study area consists of gently to steeply sloping hills (1% to 50%), with moderately deep soils that have a subsoil of silty clay and shallow clay loam (Neill 1974). Elevation ranges from 335 to 460 m.

Warm season grasses, little bluestem (*Andropogon scoparius*), big bluestem (*A. gerardii*), indian grass (*Sorghastrum nutans*) and switchgrass (*Panicum virgatum*), and cool season grasses, Kentucky bluegrass (*Poa pratensis*), Scribner's panicum (*Panicum*

scribnerianum) and Canada wild rye (*Elymus canadensis*) are the dominant vegetation of the study area. Black sampson (*Echinacea angustifolia*), western ironweed (*Vernonia baldwinii*), broomweed (*Xanthocephalum dracunculoides*), common ragweed (*Ambrosia artemisiifolia*), sunflower (*Helianthus spp.*), and goldenrod (*Solidago spp.*) are common forbs. Lead plant (*Amorpha canescens*) is the most abundant shrub.

The water supply on the site is generally dependable and of good quality. Ponds are constructed on intermittent springs and watersheds to provide a reliable source of water for livestock. Fifty-five year average annual rainfall is 80.4 cm, with 71% falling between April and September (Neill 1974). During 1991, annual rainfall was 62.0 cm, with 62% falling between April and July.

Summers are characterized as hot and dry, winters as cold and dry. The mean annual maximum temperature during 1991 and the 55-year average are 20.2°C. Mean annual minimum temperature during 1991 and the 55-year average are 7.2°C and 6.5°C, respectively. Snowfalls are light, averaging 42.5 cm per year, often melting within a week (Neill 1974).

RESULTS AND DISCUSSION

Our assumption that the two rivers in the study area would prevent pronghorn from dispersing a long distance may not be valid. After an ice storm in late October 1991, four radioed individuals moved back and forth across the South Fork of the Cottonwood River and were often found in an alfalfa field (pers. obs.). Ranchers and the general public also reported unmarked pronghorn west of the river. Goldsmith (1987) reported pronghorn traversed through areas predetermined as unsuitable habitat that were assumed to be barriers to movement. Einarsen (1948) also reported pronghorn crossing large rivers. We speculate that the presence of existing animals may have minimized the distance moved from the release site.

Autenrieth (1978) reported that key range areas for pronghorn are variable in relation to land use, geographic location, climate, soils, and habitat types. Most of these key areas have been identified in western habitats, however not in the Flint Hills before Eccles (1995) demonstrated that heavily grazed areas in and around salt licks were more heavily used in the winter and spring then expected by random. Key areas may influence home range size, movements, and carrying capacity of pronghorn.

Annual burns may also increase habitat quality and affect habitat use (Courtney 1989). Fire not only improves nutritional quality of forage and recycles nutrients in ungrazed tallgrass prairie, but also decreases forb and woody plants (Abrams *et al.* 1986), some of which are desirable forage for pronghorn. However,

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Table 2. Comparison of abiotic and biotic factors in the Flint Hills study area in Chase and Lyon counties, Kansas, 1991, versus recommended values for grassland/sagebrush community (Yoakum 1980).

Variable	Flint Hills	Yoakum (1980)
Area (km^2)	335	>260
Precipitation (cm)	80.4+	25 – 38
Water every km^2	1	1.6 – 7
Vegetative c (%)	81+	50
Grass composition (%)	67+	15 – 20
Forb composition (%)	11	5 – 15
Shrub composition (%)	2	2.5 – 15
Grass species (#)	>21+	5 – 10
Forb species (#)	50	10 – 50
Shrub species (#)	5	5 – 10
Veg. height (cm)	13 – 38	25 – 38
Fence height (cm)	10 – 46	41

+ = value exceeds recommendation by Yoakum (1980).

cattle grazing also influences the vegetation community by favoring forbs.

We examined the release site relative to the variables that Yoakum (1980) recommended as suitable for pronghorn (Table 2). Over 2-3 times more precipitation falls than is recommended, but it did not affect fawn survival (Rothchild 1993). According to Yoakum (1978) and O'Gara and Yoakum (1990) too much or too little of any biotic or abiotic factor may become the component that limits productivity and/or survival of pronghorn. Therefore, the combination of rainfall and vegetative c may become factors that determine the viability of pronghorn in tallgrass prairie.

Water sources are plentiful, 1 per km^2, and easily accessible in the Flint Hills, therefore, water should not be a limiting factor. In addition, the plentiful water supply should allow complete distribution of pronghorn throughout the Flint Hills study area. Sundstrom (1968) found pronghorn distribution was related to water sources in Wyoming.

Height of the bottom wire of fence ranged from 10 - 46 cm, with an average of 35.5 cm. It is recommended by Yoakum (1980) that the bottom wire be at least 41 cm from ground level. The low of 10 cm was uncommon and occurred in only a short stretch. Average fence height in the Flint Hills is just below the recommended height and could be a problem. However, pronghorn were observed going under fences with variable heights and appeared to have little difficulty. Some areas along the fenceline showed extensive use. Therefore, we suggest that fence height in the Flint Hills is not a factor that limits pronghorn movements.

While it is too early to tell, the pronghorn reintroduction
seems to be a success. The home range of these pronghorn is
similar to other populations (Simpson, 1992), as is the fawn
mortality (Rothchild 1993). We suspect that populations were
never really very high in tallgrass prairie, unless large areas
were intensively grazed by bison. If cattle management practices
change in the Flint Hills, we would expect changes in the
viability of the pronghorn population in Chase and Lyon counties.

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