

**KANSAS GEOLOGICAL SURVEY  
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**THE ORIGIN OF SURFACE LINEAMENTS  
IN NEMAHA COUNTY, KANSAS**

by

Susan M. DuBois

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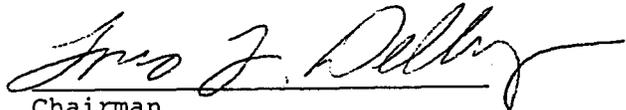
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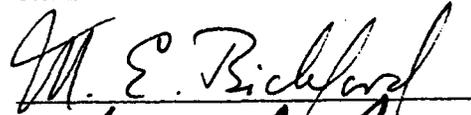
The Origin of Surface Lineaments  
in Nemaha County, Kansas

by

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## Abstract

Linear and curvilinear features detected on remote sensing imagery were correlated to drainage patterns in Nemaha County.

The influence of the Nemaha Ridge on present drainage networks appears significant. The Humboldt Fault was shown to breach the surface in the Fourmile Creek drainage basin near Bern, Kansas, offsetting Permian and Pennsylvanian beds by 54 to 74 m. Steep aeromagnetic and gravity gradients are superimposed over the trace of the Humboldt Fault zone and are likely related to it. The geophysical data suggest a complexly fractured basement surface. Several of the linear trends apparent on the aeromagnetic map coincide with present drainage trends.

Available subsurface well information was used to generate a modified interpretation of the Precambrian surface configuration compatible with geophysical and surface observations. Underlying structure, especially on the west side of the Humboldt Fault zone where basement rocks are relatively shallow, is believed to exert considerable control over present drainage patterns. A lineament formed by two streams near Baileyville, Kansas suggests recent movement in glacial deposits.

## Introduction

The Kansas Geological Survey is conducting a major re-evaluation of the geology and seismicity of Kansas in connection with design criteria for dams, nuclear power plants and other earthquake-sensitive structures. Northeastern Kansas was chosen as the first area of study because of the apparent concentration of seismic activity in this region. As part of the preliminary investigation, Dellwig and McCauley (in press) conducted a search for surface lineaments using LANDSAT-MSS and side-looking airborne radar imagery as well as conventional and satellite photography.

Many recent studies using LANDSAT imagery elsewhere have emphasized the relationships between lineaments and areas of high seismicity (O'Leary and Offield, 1977). However, as O'Leary and Offield (1977) stated:

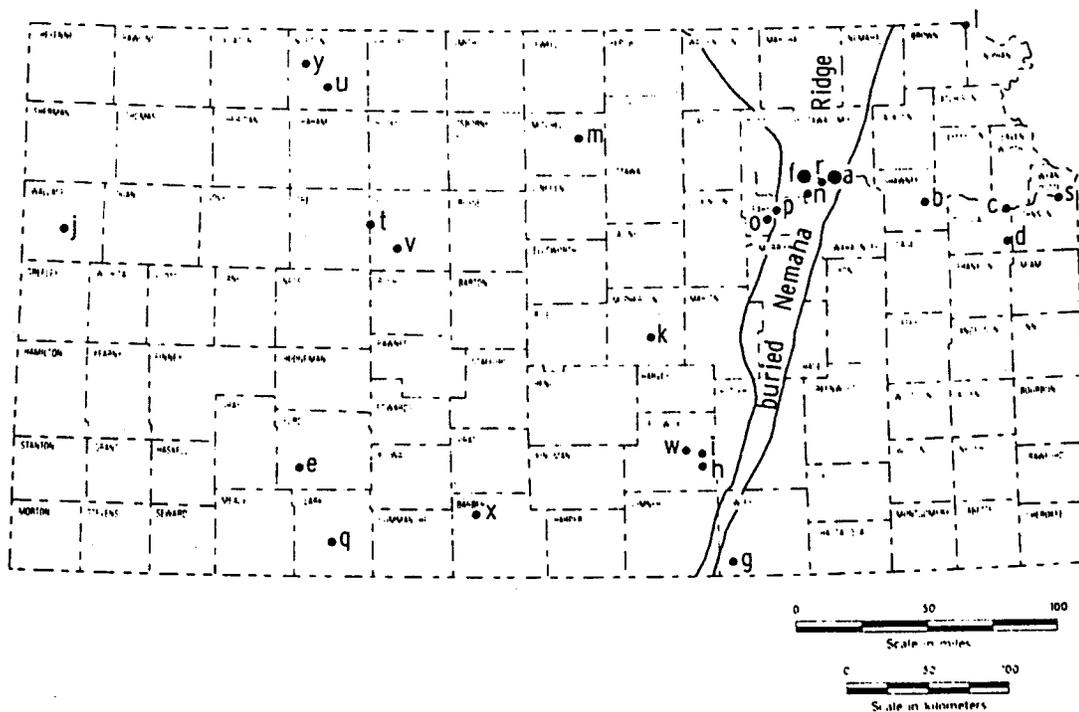
" . . . work is only beginning to establish the geological meaning and causes of lineaments. Far too often work stops with photoanalysis, statistics, and assumptions; detailed field examinations and comparisons with geophysical data are too rarely pursued."

The purpose of this study was to define and to determine the origin of the surface lineaments observed in Nemaha County and portions of the surrounding counties in Kansas and Nebraska. The study necessitated a surface investigation of the area, gathering of geophysical data, and a synthesis of existing information from water, oil and gas well records.

## Significance and Geologic Background

Kansas has long been identified with the Central Stable Region of the North American Continent (Snyder, 1968; Merriam, 1963). However, twenty-five earthquake epicenters in the state have been recorded since the mid-1800's (Fig. 1). The two most severe events, in 1867 and 1906,

# EARTHQUAKES IN KANSAS



## Explanation

a	1867	VIII	f	1906	VII	k	1927	V	p	1929	V	u	1933	V
b	1875	V	g	1907	IV	l	1927	VI	q	1929	V	v	1942	IV
c	1881	III	h	1919	IV	m	1928	IV	r	1929	V	w	1948	IV
d	1903	II	i	1919	IV	n	1929	V	s	1931	VI	x	1956	VI
e	1904	IV	j	1926	?	o	1929	V	t	1932	VI	y	1961	V

Location and dates of earthquakes in Kansas during the past 110 years. The number following the date is the earthquake intensity on the Modified Mercalli Scale.

Figure one

reached intensities VII-VII on the Modified Mercalli Scale, their epicenters being located in northeast Kansas near Manhattan (Merriam, 1966; Docekal, 1970; DuBois and Wilson, in press). Determination of the cause and mechanism for these events is as yet an unsolved problem.

Merriam (1963), Lee (1954), and other early investigators attributed much of the earthquake activity to movement along the Nemaha Ridge or the Humboldt Fault (Fig. 1) because of the proximity of several epicenters (MM VII-VIII) to these features in Kansas, Oklahoma, and Nebraska. The Ridge is composed of Precambrian granitic rocks. It forms the core of the Nemaha Anticline which consists of younger sedimentary rocks which have been folded and possibly faulted as a result of uplifts in the basement. The Humboldt Fault zone forms the eastern boundary of the Ridge.

More recently, the significance of the Mid-Continent Geophysical Anomaly (MGA) as a major structural feature has been recognized. The MGA (Fig. 2) represents a belt of mafic igneous rocks intruded along a late Precambrian rift zone (King and Zeitz, 1970; Coons et al., 1967). The structure is bounded by faults where it is exposed at the surface in the Lake Superior region, and geophysical data suggest that similar faults exist to the south where the feature is deeply buried beneath Paleozoic and younger strata (King and Zeitz, 1970). Surface structures associated with the MGA in northern Kansas include the Abilene Anticline and Irving Syncline (Jewett, 1941), both of which parallel its southeast flank; and the Riley County kimberlites (Brookins, 1970) which follow the same structural trend. These intrusives have been associated with right lateral strike-slip movement along a buried fault on the east flank of the Abilene Anticline (Chelikowsky, 1972).

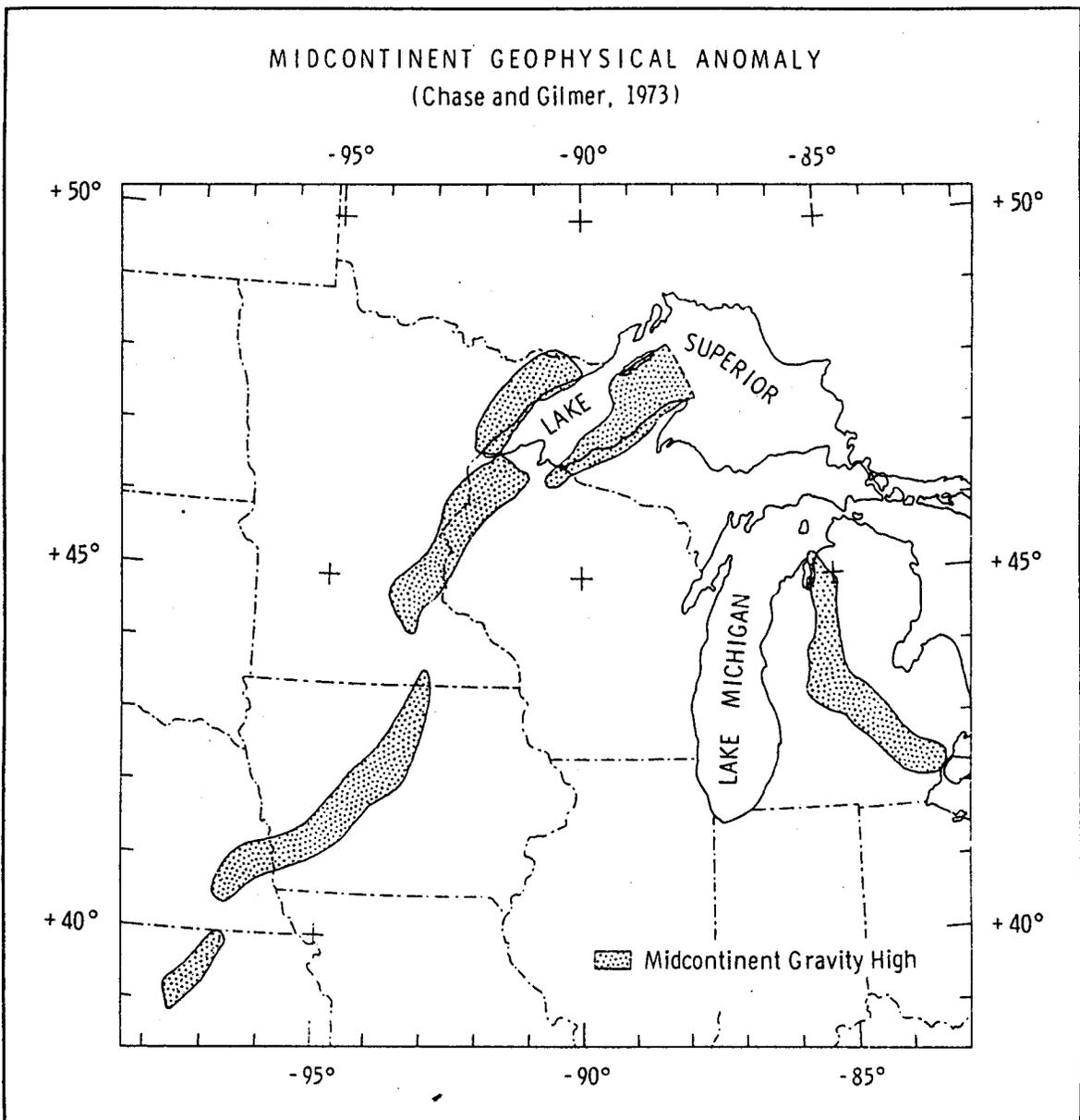


Figure two

Docekal (1970) studied the isoseismal patterns of intensity VII-VIII historical earthquakes in the midcontinent and showed a relationship to basement structure and lithology. He concluded that the stronger seismic events in the region were genetically related to the Arbuckle, Nemaha, or MGA structures or combinations of them.

Other possible causes for some of the minor earthquakes and lineaments include movement along previously undetected faults, and perhaps stress release associated with isostatic rebound after glaciation (Nansen, 1921; Daly, 1934; Wilson, personal communication). Neither of these mechanisms has been fully investigated in Kansas.

There is a need for a better understanding of seismic activity and structural history in Kansas from a practical standpoint as well. Proposed siting of nuclear power plants in eastern Kansas, southeastern Nebraska, and northeastern Oklahoma, along with locations of existing and proposed reservoirs near the trace of the Humboldt fault zone or within areas affected by past earthquakes illustrate the necessity for a scientific rationale in setting design and safety standards for engineered structures in this region.

#### Description of Study Area

The area (Fig. 3) centers in Nemaha County, in a glaciated region underlain by bedrock of Late Pennsylvanian and Early Permian age (Overlay\* 1). The general northwestward dip of the sedimentary strata in northeast Kansas is interrupted in Nemaha, Pottawatomie, and Jackson counties as a result of Late Permian and possibly post-Permian movements

\*Note: A base map of Nemaha County is included with the overlays in the back pocket.

# NEMAHA COUNTY AND SURROUNDING AREA

(from GSA, 1959 Glacial map of the United States East of the Rocky Mountains)

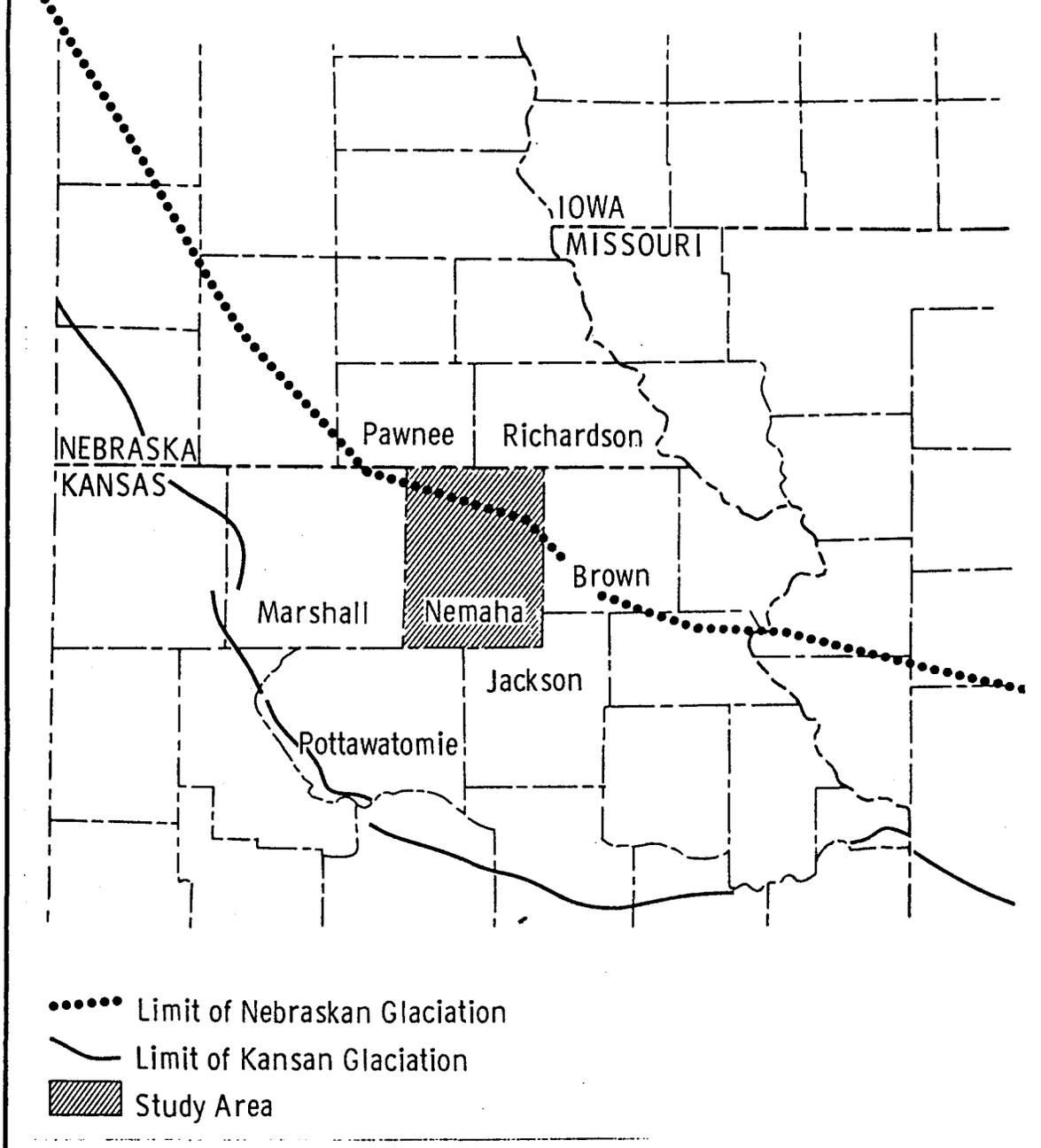


Figure three

(Ward, 1974) along the Nemaha Anticline, which lies near the center of the study area. Localized deformation of Permian beds occurs near Bern in Nemaha County where an eastward dip of up to 20° is recorded on the eastern flank of the anticline.

Movement along the Nemaha Ridge has greatly affected the thickness of the sedimentary rocks. Those on the west flank range in thickness from 175 meters (600 feet) near Seneca to 300 meters (1000 feet) at the western border of Nemaha County. On the steeper eastern flank the sedimentary sequence attains a thickness of 1200 meters (4000 feet) within a few kilometers of the axis (Ward, 1974).

The Precambrian Surface Map of Kansas (Cole, 1976) shows the Humboldt Fault at the eastern flank of the Nemaha Ridge extending through Nemaha County into Pottawatomie County. Another shorter fault is plotted on the same map a few miles east of the Humboldt with a trend approximately N 10° E (Overlay 2).

The nature of the surface expression of these subsurface displacements is debatable. Conclusive evidence concerning the presence and age of surface faulting was one of the main objectives of this study.

Bedrock exposures (Fig. 4) are scarce throughout northeastern Kansas because of the cover of Pleistocene glacial debris. Outcrops in Nemaha County are found only along stream valley walls, except in the northeastern corner of the county where erosion has removed some of the glacial deposits from the uplands (Ward, 1974). Both the Nebraskan and Kansan glaciers advanced into the study area (Fig. 3). The glacial deposits that remain vary in thickness from one to 115 meters (Ward, 1974; Frye and Walters, 1950; Mudge et al., 1959). Alluvial deposits



beneath the terraces and along present stream valleys are of Illinoian to Recent age (Ward, 1974). Scattered loess deposits can be found throughout the area.

Many of the present streams display prominent angular or rectangular drainage patterns (Overlay 3). Alignment of streams, such as Manley Creek, Negro Creek, and the North Fork of Vermillion Creek, along with apparent parallelism of many tributaries suggest the influence of underlying structure upon the drainage network. Several circular drainage patterns have developed: Turkey Creek, Wolf Pen and Deer Creeks, Harris Creek, Fourmile Creek, and Rock Creek exemplify this phenomenon in Nemaha County. Aeromagnetic and gravity surveys conducted by Yarger et al. (in preparation for open file) indicate that many of the geophysical anomalies in northeast Kansas are outlined by circular drainage features and lineaments found on the remote sensing imagery (Dellwig and McCauley, in press).

#### Previous Work

Numerous publications concerning the local and regional geology of northeastern Kansas (Merriam, 1963; Davis, 1951; Frye and Walters, 1950; Chelikowski, 1972) are available. In addition, specific reports on stratigraphy, structure, and groundwater conditions have been published for Nemaha (Mudge et al., 1959; Ward, 1974), Marshall (Walters, 1954), Jackson (Walters, 1953), Brown (Bayne and Schoewe, 1967) and Pottawatomie (Scott et al., 1959) counties. Materials inventory reports by the Kansas Highway Commission exist for Nemaha (Hargadine, 1970), Marshall (Hargadine, 1965) and Brown (Stallard and Fenity, 1966)

counties. Soil surveys have been completed by the Soil Conservation Service for Jackson (Campbell, in press), Brown (Eikleberry, 1960) and Marshall (Kutnink, in press) counties.

Other sources of information include water, oil and gas well records and measured sections kept on file at the Kansas Geological Survey. Yarger (in preparation for open file) has compiled aeromagnetic and gravity maps of northeast Kansas and Bickford et al. (in press) have produced a map of basement lithologies for the same region.

#### Method of Study

Initially an attempt was made to define the cause of expression of lineaments observed on the aerial and satellite imagery. Some of the more prominent features shown in Overlay 4 were field checked to determine their surface expressions. Where possible, bedrock type and attitude, joint orientation, and till fractures were noted. Black and white air photos (1:20,000) were used to locate bedrock outcrops and till exposures along linear or curvilinear stream valleys. Detailed mapping of geologic units was done in an area near Bern, Kansas. Geophysical investigations sponsored by the Kansas Geological Survey offered much data for interpretation. Aeromagnetic data collected and reduced by H. L. Yarger and R. R. Robertson were used to construct a computer-contoured map of Nemaha County (Overlay 5). Gravity data (Yarger, in preparation for open file) was reduced to Bouger values for the northern half of the county. Bouger readings for the southern half were available from a previous survey (Yarger, in preparation for open file). Two gravity profiles in the vicinity of the Kansas - Nebraska border were supplied by David Maroney and Raymond Burchett of the

Nebraska Geological Survey. The values from all sources were used to generate a Bouger gravity map (Overlay 6).

Six stations of the micro-earthquake detection network placed in operation in September, 1977 by the Kansas Geological Survey are located in the northeast section of the state. Data from these seismographs and six additional recorders yet to be installed will be of immense value in the continual updating of knowledge of seismic activity in the region. Information collected between December 1, 1977 and March 15, 1978 has been utilized in this study.

A preliminary search for existing well records in the oil, gas and groundwater files was fruitful. However, much of the water well data had to be discarded because it became apparent that the drillers' distinction between shale and clay was inconsistent at best. For this and other reasons it was not feasible to construct a reliable till thickness or bedrock surface map from the information. Ward's (1974) data proved useful in determining groundwater level anomalies in an area of suspected faulting.

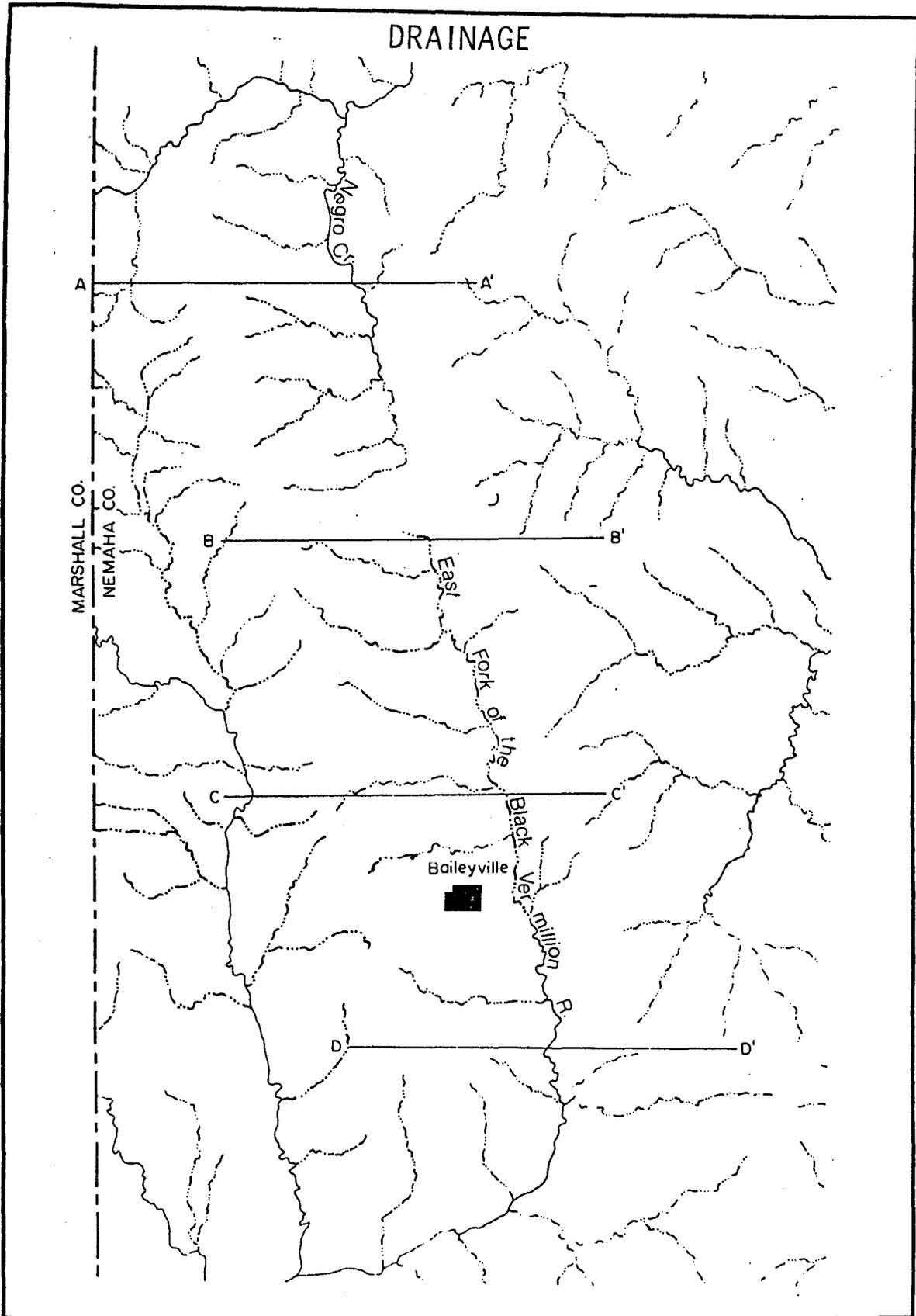
Recent oil and gas records were reviewed in an effort to verify Cole's interpretation of the Precambrian surface configuration (1976) in Nemaha County.

## Field Study

A field investigation of Nemaha County was conducted during the summer and fall of 1977. The original goal was to determine the surface expression of lineaments and curvilinears detected by Dellwig and McCauley (in press) on remote sensing imagery (Overlay 4). A strong correlation between most of these features and drainage channels soon became apparent (compare to Overlay 3). Three or four of the lineaments correspond to topographic divides, and one to a railroad. Information shown on Overlay 4 displays a rotational distortion when compared to Overlay 3 because it represents the fifth projection of the original features observed on the imagery.

Two areas were chosen for more detailed study: the linear drainage features trending northwest near Baileyville (T2S R11E) and an area northeast of Bern (T1S R13E) where the trace of the Humboldt Fault was believed to cross a curvilinear drainage system. The former area was selected because of the striking alignment of Negro Creek and the East Fork of the Black Vermillion River, which presently flow in opposite directions. Their orientation is parallel to that of a well developed joint set measured at several outcrops near Bern (Overlay 7). Interpretation of aerial photographs and 7 1/2 minute quadrangle maps confirmed a field observation that the drainage pattern of both streams is decidedly asymmetrical (Fig. 5). A linear, fairly flat-topped divide borders both sides of the drainageways for most of their length. However, the ridge on the west side is approximately 12 m. (40 ft.) higher than that on the east side (Fig. 5, profiles). Furthermore, both drainage patterns are barbed on the west side, with acute angles pointing to the south, suggesting that Negro Creek may have previously

# BAILEYVILLE VICINITY



# TOPOGRAPHIC PROFILE (Vertical exaggeration: 20x)

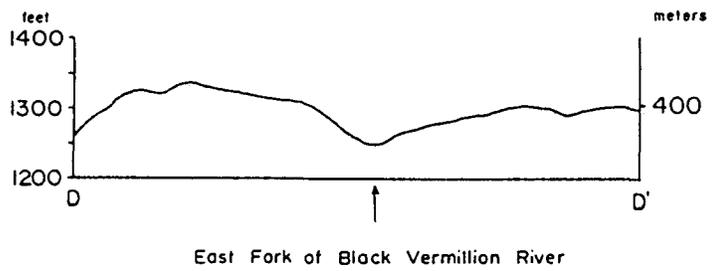
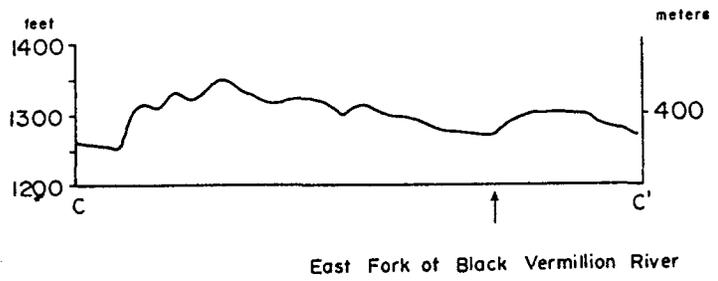
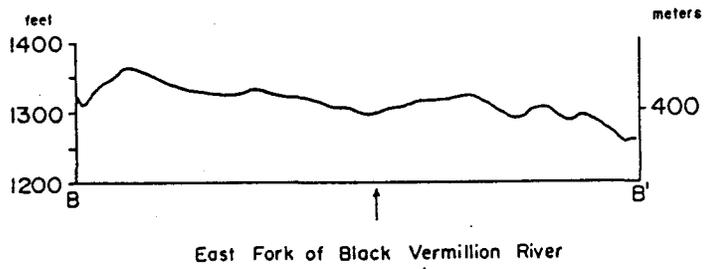
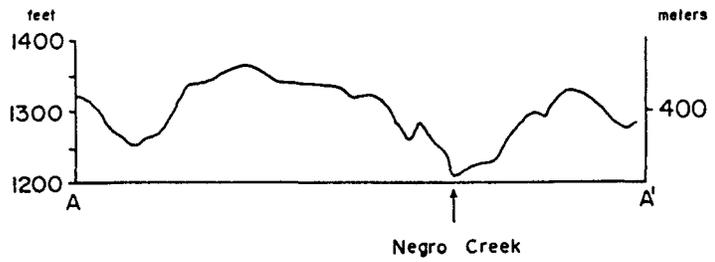


Figure five

flowed south. The area is overlain by till deposits which are estimated to range in thickness from 9 - 18 m. (30-60 ft.).

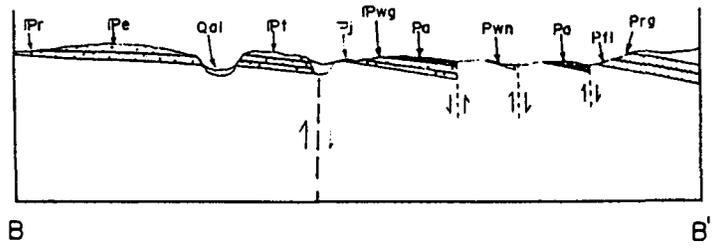
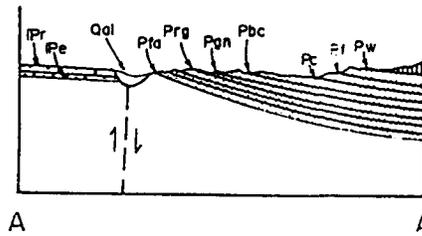
The absence of bedrock exposures and the nature of unstratified material make it difficult to establish faulting as the cause of the observations mentioned above. A drilling program could likely answer many questions. Until such a program is effected, it must suffice to conclude from the surface investigations that there has been recent uplift along the western side of these streams, lesser in extent to the north, causing stream piracy by Clear Creek. An alternate interpretation, variable thickness of deposition by Pleistocene glaciers on either side of the streams, encounters difficulties in explaining the nearly parallel trend of the adjacent stream and the nearly right angle junctions of both creeks as they flow into the major stream networks.

Fourmile Creek northeast of Bern occupies the southern portion of a curvilinear feature (Overlay 4) noted by Dellwig and McCauley (in press) on the state line. It spans the trace of the Humboldt Fault shown on the Precambrian surface (Overlay 2). Both Mudge (1959) and Ward (1974) implied the existence of a fault (west side upthrown) through this area, but neither discussed the details of this interpretation in their publications.

With the aim of uncovering positive evidence of faulting, six sections of T1S R13E were mapped in detail (Fig. 6). The main stream and all of its tributaries were followed and remnants of limestone ledges were traced across pastures and through wooded tracts in hope of verifying the previously mapped fault. Previously unmapped outcrops were discovered and some were created by trenching the road ditches. Contacts are at the base of the limestone units. Much of the lower



# SCHEMATIC CROSS SECTIONS



### LEGEND\*

Chase Group	Pw	Wreford ls.	} Permian
Council Grove Group	Pf	Funston ls.	
	Pc	Crouse ls.	
	Pbm	Bader ls.	
	Pbe		
Council Grove Group	Pbc	Cottonwood ls. Beattie ls.	
	Pc	Granola ls.	
	Prh	Howe ls.	
	Prg	Glenrock ls. } - - Red Eagle ls.	
	Pfl	Long Creek ls. } - - Foraker ls.	
Admire Group	Pfa	Americus ls.	
	Pa	poorly exposed, undifferentiated	
Kabaunsee Group	Pb	Brownville ls.	} Wood Siding Formation
	Pwg	Grayhorse ls.	
	Pwn	Nebraska City ls.	
	Pj	Jim Creek ls.	} Pennsylvanian
	missing		
	Pt	Tarkio ls.	
Pc	Elmont ls.		
Pr	Reading ls.		
Pw	Wakarusa ls.		

\*Shale units have not been included in legend.  
Refer to Fig. 4 for complete section and to Appendix for rock descriptions.

Figure six

Wabaunsee units exposed in the southwestern portion of Section 15 were omitted since the area of primary interest was the fault zone itself.

The evidence for faulting is very strong. Near the midpoint of the line separating sections 14 and 15 a road outcrop of Grayhorse limestone lies approximately 74 m. (250 ft.) east and 6 m. (20 ft.) higher than an exposure of Tarkio limestone in a creek bank. The dips of the units are approximately  $4^{\circ}\text{NE}$  and  $8^{\circ}\text{E}$ , respectively. Assuming the average thickness of the section missing or covered between these outcrops to be 37 m. (125 ft.), a dip eastward of about  $35^{\circ}$  would be necessary in order to attribute the proximity of these two units to folding rather than to faulting. This does not appear likely, based on the observed orientation of beds exposed in the immediate vicinity.

The highest dip observed in the area mapped is  $19^{\circ}\text{NE}$  in the south-central portion of Section 3, where Permian rocks of the Council Grove Group are exposed. Alluvial and glacial deposits cover the area west of these outcrops for several hundred meters, at which point gently dipping ( $2^{\circ}\text{E}$ ) ledges of Reading and Wakarusa limestone are found on the knob in the southwest corner of Section 3. A throw of 53-74 m. (180-250 ft.) is estimated, depending on the exact location of the fault. Similar observations can be made on the state line, 1.6 km. (one mile) north. Most of the joints measured fall into two sets. One set ( $\text{N}10\text{-}30^{\circ}\text{W}$ ) closely parallels the fault trend while the other ( $\text{N}80^{\circ}\text{E}$ ) is roughly perpendicular to it.

The estimated throw on the postulated faults shown in B-B' (Fig. 6) ranges from 3 m. to 15 m. (10-50 ft.). Changes in dip and strike in the intervening zone between the sparse outcrops in this area could produce the observed findings without faulting. However, the simplest

interpretation appears to be a series of small offsets, perhaps representing a splaying of the main fault as it dies out to the south, particularly in the light of knowledge of faulting in this area.

Generally speaking, beds dip southeasterly on the upthrown side of the fault zone, as opposed to northeasterly on the opposite side of the fault. Burchett (personal communication) has concluded that the bedding attitude varies considerably over short distances on both sides of the Humboldt Fault in Nebraska, indicating a complex structural pattern. Burchett could locate the fault only within a zone 0.4 km. to 0.8 km. wide that winds in a sinusoidal path northeastward to the town of Humboldt. The fault does not follow valleys exclusively, nor is its trace obvious on aerial photographs. Burchett has estimated a throw of 53-59 m. (180-200 ft.) in southeast Nebraska and has also found stratigraphic evidence for a second fault with an estimated throw of 12 m. (940 ft.) 3.2 km (2 mi.) west of the mapped trace of the Humboldt Fault on the state line. This fault has yet to be identified in Kansas.

Approximately six and a half kilometers (four miles) south of the area mapped in Figure 6, bedrock outcrops are completely absent near the fault trace. Along the southern edge of the county a few exposures occur in the stream valleys. Those nearest the fault trace, the Elmont limestone on the west and the Red Eagle limestone on the east, are separated by almost 5 km. (3 mi.) laterally and approximately 105 m. (350 ft.) stratigraphically. The geologic structure between outcrops is obscured by the overlying till.

Seyrafian (1977) studied the Humboldt Fault trace in Pottawatomie County, concluding that no surface faulting occurs there. Maximum

dips recorded by him are 4-5°SE on both sides of the fault trace. He found no evidence of missing or offset section at the surface. Two nearly parallel faults, both with upthrow to the west, were indicated by his subsurface correlations.

Thus expression in the bedrock of a southern extension of faulting has yet to be identified. However, it is clear that activity along the fault zone occurred at least as recently as Late Permian since rocks of this age have been tilted in Pottawatomie and Morris counties (MacFarlane, personal communication) and faulted in northern Nemaha County and southeast Nebraska.

Other more general observations at the surface include a denser drainage network in the southern half of the county than in the northern portion. Likewise, to the south the pattern is predominantly dendritic or pinnate. In contrast, circular, rectangular, and angular patterns are much more common in the northern section, with few drainage networks having a dendritic pattern.

#### Geophysical Data

The aeromagnetic data were collected in 1976 by H. L. Yarger and R. R. Robertson for the Kansas Geological Survey. From this information a map was generated by a computer-contouring program (Overlay 5). The grid-spacing has caused a slight east-west bias as the flight lines are separated by 3.24 km. (two miles) in the north-south direction, whereas readings were obtained approximately every 280 m. (250 yds.) along the line. However, none of the closed contours falls between grid lines, thus indicating good control in the contouring operation.

Compatibility of aeromagnetic and field data is significant. In the Fourmile Creek area, a steep gradient on the aeromagnetic map, with a relative high on the west side coincides with the fault mapped in Figure 6. In a like manner a north-south trend in aeromagnetic contours on the southern edge of the county, near America City, is superimposed on the Humboldt Fault zone (Overlay 2). Between these areas, it is difficult to detect a trend which follows the Humboldt Fault (compare Overlays 2 and 5).

In the vicinity of Baileyville positive aeromagnetic anomalies are found at the northern and southern extremes of the lineament formed by Negro Creek and the East Fork of the Black Vermillion River. Relative uniformity of magnetic intensity characterizes the southeast half of the county (Overlay 5) except for a distinct northwest-southeast trend between and parallel to Craig and Locklane Creeks (Overlay 3).

Further comparisons are somewhat more tenuous. The curvilinear pattern of the Turkey Creek drainage net appears to correspond to one observed on the aeromagnetic overlay. Some of the other curvilinear drainage patterns seem to correlate with curved aeromagnetic patterns.

Gravity surveys were conducted in 1972 for the southern half of the county by Yarger. Three traverses with readings every 1.6 km. were made along lines 28.8, 38.4 and 48 kilometers south of and parallel to the Nebraska-Kansas boundary. In 1977, a survey of the northern portion was completed with 6.4 km. (four-mile) spacings along lines 4.8, 11.2, 17.6, and 24 kilometers south of the state border. Two additional shorter profiles were provided by the Nebraska Geological Survey, one along the state line and the other one section south, in the vicinity of Fourmile Creek. The Bouger values were hand-contoured to produce

## Overlay 6.

Comparison of the gravity data with the aeromagnetic and drainage maps shows many of the trends already noted. In the Fourmile Creek area and also in the southern portion of the county a north-south trend predominates along the trace of the Humboldt Fault zone. A gravity high appears near Baileyville. The southeast half of the county is without significant anomalies.

Other observations include two east-west trends in the northwest and west-central regions that appear on both the gravity and aeromagnetic maps. The northwest aeromagnetic trend near Craig and Lock-lane Creeks is absent on the gravity map. It should be noted, however, that the grid-spacings are wider on the gravity map in that area than elsewhere. Local features might not be expressed in the large gaps between data lines in the south.

Evaluation of regional geophysical data is shown in Figure 7. The profiles are all roughly 180 km. (112 mi.) long and include the MGA. A regional decrease eastward in both gravity potential and magnetic susceptibility can be observed. However, a sharpening of the gradients near the trace of the Humboldt Fault zone (Fig. 7, Overlay) is most likely a local effect of uplift along the Nemaha Ridge rather than a direct result of the MGA. The latter feature is a full width of the large anomaly further west and thus likely not the cause of the local step on the profiles (Steeple, personal communication).

Qualitative interpretation of the gravity and aeromagnetic map overlays strongly suggests basement faulting along the linear trends formed by very steep gradients in the northern and southern extremities of the county near the Humboldt Fault trace. A lithologic contrast



could produce the same effect, but the fact that faulting at the surface has been observed in one of these locations lends support to the former interpretation.

In the central portion of the area there is more geophysical evidence to support an east-west offset along the fault zone than to justify Cole's interpretation of a continuous south-southwest trending fault. The relative difference in contour density (Overlay 5 and 6) between the northwest and southeast halves of the county can perhaps be attributed to the effects of elevation differences in the basement on either side of the Humboldt Fault. On the west side, the Precambrian surface lies at a depth of 180-300 m. (600-1000 ft.). In contrast, basement rocks lie 600-1200 m. (2000-4000 ft.) beneath the surface on the down-thrown side. The "blanketing" effect of the sedimentary section would smooth magnetic and, to some extent, gravity anomalies associated with basement topography.

If a homogeneous upper basement lithology is assumed for the small area covered by Nemaha County, the aeromagnetic variations can be attributed mainly to variations in the elevation of the Precambrian surface. Sedimentary rocks generally have negligible magnetic susceptibilities (Dobrin, 1976) and thus little effect on the configuration of the aeromagnetic map (Overlay 5). According to M. E. Bickford (personal communication), many of the well-samples from the Precambrian rocks exhibit cataclasis, indicating that faulting has occurred in the basement rocks. It is conceivable that some of the positive anomalies on Overlay 5 may result from shallower igneous or metamorphic rock which has been faulted upwards as blocks.

One must regard the above assumption with caution. Small variations in magnetic susceptibility can cause large (hundreds of gammas) aeromagnetic anomalies (Dobrin, 1976). Even if the upper kilometer or so of the basement is of uniform lithology, a deeply buried contact would affect the total field magnetic intensity. Also, the possibility of small mafic dikes or plugs existing within an extensive mass of granitic composition and producing magnetic anomalies should be considered. As of this writing, all of the Precambrian core samples from Nemaha County have been classified as granite (Colc and Ebanks, 1974).

A microearthquake was recorded near Seneca on January 27, 1978 (Overlay 7). The coordinates of the epicenter are within two kilometers of 39°48.99'N latitude and 95°57.99'W longitude (Don Steeples, personal communication). The estimated Richter magnitude is 2.3. All seven of the local events recorded by the Kansas Geological Survey network since December 1, 1977 are shown in Figure 8. The four earthquakes which occurred in the eastern section of Kansas appear to be associated with the Humboldt Fault system. It is interesting to note that the Seneca event corresponds to the east-west trends on the gravity and aeromagnetic overlays. It also lies near the trace of the buried Humboldt Fault (Overlay 2).

#### Subsurface Well Control

After a review of water well records on file in the Groundwater Section of the Kansas Geological Survey it was determined that it was not practicable to construct a reliable till thickness map for Nemaha County. The data are largely concentrated in present alluvial valleys, thus leaving large areas with sparse information. Also most of the

# MICROEARTHQUAKES RECORDED SINCE DECEMBER 1, 1977

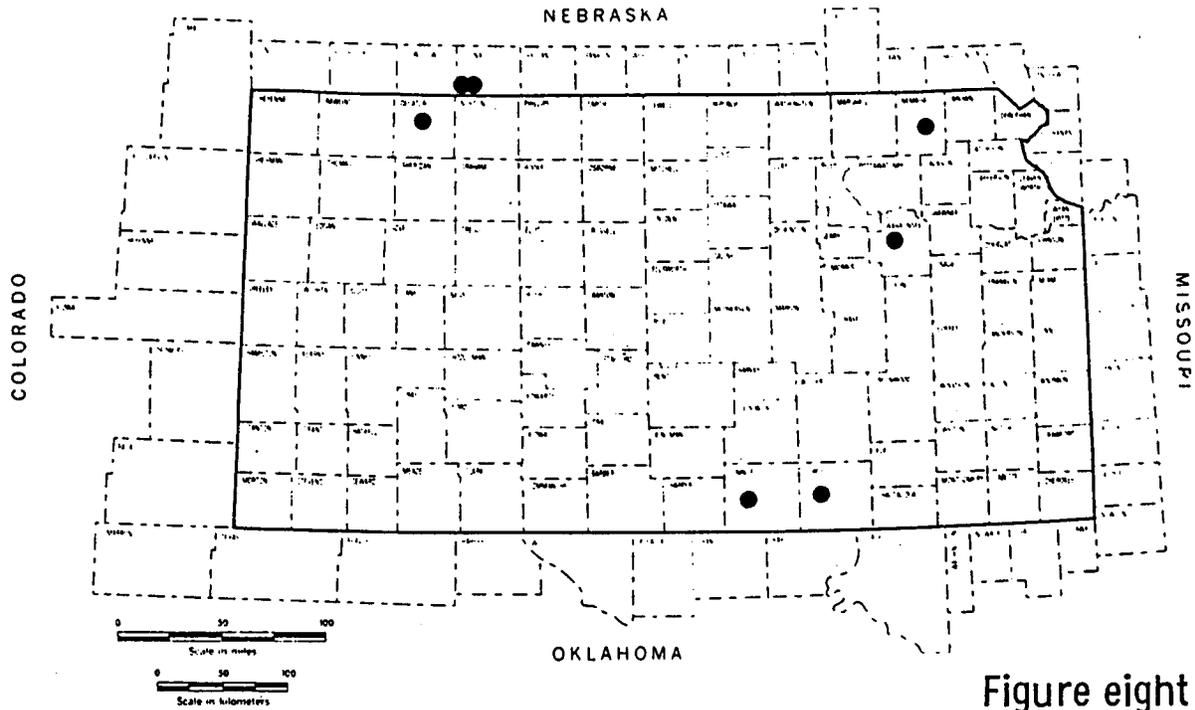


Figure eight

wells do not extend to bedrock in areas with thick till cover. As mentioned previously, the driller's logs often contained records of "blue shale" or "blue clay" with recorded depths followed by question marks.

One observation that may be relevant to this study is a difference in the depth to water table on either side of the Baileyville lineament (Fig. 5, Overlays 1, 3, 4). At Baileyville (elevation 388 m. or 1300 ft.) the water table exists at a depth of 7.5 m. (25 ft.). Less than one mile east, at the same elevation, the water table is 18 m. (60 ft.) beneath the surface. The lineament passes between these two locations. A difference of 6 m. (20 ft.) in water table depth exists 4.9 km. (3 mi.) north, near the divide between Negro Creek and the East Fork of the Black

Vermillion River. A few kilometers further north, on either side of Negro Creek, the depth to water is 1.5 m. (5 ft.). The aquifer in all of the above wells is glacial drift. Variation in water-bearing characteristics throughout the till could account for the differences in water table depth. However, another possible cause might be an offset in a water-bearing horizon due to faulting. A drilling program or seismic reflection survey would be required in order to define the cause of the peculiar drainage feature in this vicinity.

A map of buried valleys inferred from a drilling program was constructed by Ward (1974) for Nemaha County (Overlay 8). The axes of the major valleys appear well-documented by test hole information. However, the width of the valleys along with the trend and the density of tributaries in this pre-glacial system are less well known. It has been suggested (Ward, personal communication) that the topographic inversion caused by deposition in the previous drainageways may account for some of the curvilinear drainage patterns established by present streams. They may have previously been tributaries to the now-buried valleys, and consequently had to change flow directions. Comparison of Overlays 3 and 8 indicates that some present streams follow old channel trends (see the Nemaha River; Turkey, Wolf Pen, Deer, and Wolfley Creeks). Ward's hypothesis may have some merit in the northwest section of the county where curved tributaries cross the buried valley axes. However, a correlation cannot be established without a more accurate and detailed delineation of the old channel networks.

The portion of the Precambrian Surface Map which covers Nemaha County was compiled by Cole (1976) on the basis of 17 deep wells drilled

into the basement rock. Data from surrounding counties influenced the contouring process near the borders. Geophysical information was not available.

Since then, two additional wells have penetrated the Precambrian rocks: one located in Sec. 20 T1S R13E and another in Sec. 13 T5S R12E. The former penetrated the basement surface at an elevation of 175 m. (585 ft.), the latter at -438 m. (-1430 ft.). A search of the oil and gas records on file at the Kansas Geological Survey provided information used to project the elevation of the Precambrian surface at several other locations, based on the elevation at which lower Paleozoic units were found. There is, however, a large area (roughly 378 sq. km. or 144 sq. mi.) in the southwest region for which no subsurface well control is available.

#### Modified Precambrian Surface Configuration

On the basis of all of the information gathered for this project, a modified interpretation of the Precambrian surface configuration was generated (Overlay 9). The two north-south trending faults correlate well with the two subsurface faults mapped by Seyrafian (1977) immediately southwest in Pottawatomie County. They represent the main vertical displacements along the Humboldt Fault zone. An apparent right-lateral offset along the western fault is suggested by the areomagnetic data. However, with a lack of subsurface well control along this trend, it is preferable to postulate an en echelon pattern of faulting rather than a strike slip fault offsetting a previously continuous Humboldt Fault.

The faults inferred primarily from subsurface well information on the downthrown side of the main fault zone appear to coincide with the southeast trending aeromagnetic contours in this region. Aeromagnetic data strongly suggests a more complex system of faults and fractures on the Precambrian surface. However, the absence of subsurface well control in many areas made it impossible to depict the extent and type of movement as well as the relative ages of faulting activity throughout the region.

### Conclusions

The initial goal of determining the surface expression of lineaments and curvilinear features (Overlay 4) was accomplished by analysis of current drainage patterns, topographic divides and cultural features in Nemaha County. The origins of various drainage patterns throughout the county then became the central focus of the study.

Thick till deposits overlie the buried valleys (Overlay 8) which occupy primarily the southern half of the county. Present drainage networks (Overlay 3) in this area are predominantly dendritic as one would expect to develop in a flat-lying, relatively homogeneous medium.

Underlying structure appears to have much control over drainage patterns in areas where present streams have encountered the bedrock surface, particularly along the Humboldt Fault zone and west of it where basement rocks lie at a depth of only 180 m. Several linear and curvilinear drainage features coincide with geophysical anomalies which are similar in appearance. A complexly-fractured basement surface is

strongly suggested by aeromagnetic data. Many of the present stream valleys likely follow directional weaknesses induced by structural activity.

Although relative ages of basement faulting in Nemaha County cannot be determined from available information, the distinct lineament formed by two streams near Baileyville suggests that there has been recent movement in glacial till. Post-Pleistocene activity is also strongly indicated by the microearthquake recorded January 27, 1978 and by several other events which have occurred near the trace of the Humboldt Fault zone during the period of historical record.

### Acknowledgements

In addition to my three advisors, several staff members of the Kansas Geological Survey gave me much encouragement and many helpful suggestions during this project. Special thanks are extended to Richard Young and Carla Kuhn Fisher who drafted all of the illustrations used in this thesis. Kaye Long and Esther Price typed the final copy of the manuscript.

I wish to express much gratitude to Joyce Budai and my husband, Jim DuBois, who were faithful field assistants during the summer and fall of 1977.

QUATERNARY

Pleistocene

Recent and Wisconsinian Stages:

Alluvium - Thickness: 0-9 m. (0-30 ft.) Deposits of brown to bluish-gray sandy, gravelly clay. Thin beds of sand or gravel may occur at the base or within the deposit. Gravel is composed of limestone, chert, igneous, and metamorphic fragments.

Wisconsinian and Illinoisan Stages:

Terrace and Valley-fill Deposits - Thickness: 0-15 m. (0-50 ft.) Discontinuous deposits of brown sandy clay on stream-valley walls or deposits of grayish-brown to gray sandy clay, fine to coarse sand and gravel beneath the flood-plain. Gravel is composed of limestone, chert, igneous, and metamorphic fragments.

Loess - Thickness: 0-4 m. (0-15 ft.) Wind-deposited brown to reddish-brown slightly sandy silt, generally in upland position.

Kansas Stage:

Cedar Bluffs Till - Thickness: 0-30 m. (0-100 ft.) Heterogeneous mixture of brown, reddish-brown, yellowish-brown, or light-gray clay, silt, sand, and gravel. Erratics are common. Locally contains lenses of sand and gravel.

Glaciofluvial Deposits - Thickness: 0-15 m. (0-50 ft.) Outwash composed of fine or coarse quartz sand, silt, gravel, and boulders. Locally occurs between the Cedar Bluffs and Nickerson Till.

Nickerson Till - Thickness: 0-70 m. (0-240 ft.) Heterogeneous mixture of dark-gray to bluish-gray with some reddish-brown clay, silt, and sand, and gravel. Contains less erratics than Cedar Bluffs Till. Locally contains lenses of sand and gravel.

Atchison Formation - Thickness: 0-30 m. (0-100 ft.) Well-graded, finally cross bedded, fine to very fine silty sand. Locally becomes gray sandy silt or clay. Very thin layers of clay and gravel scattered throughout. Gravel is common at the base. Generally confined to buried valleys.

Nebraskan (?) Stage:

Fluvial Deposits - Thickness: 0-4 m. (0-15 ft.) Limestone and chert gravel derived locally from older rocks. Contains igneous material. Confined to lower part of deep buried valleys.

## PERMIAN

### Lower Permian

#### Chase Group:

Wreford Limestone - Thickness: 0-12 m. (30-40 ft.) Upper limestone is tannish gray, medium hard, and massive with many lenses and nodules of gray chert. Intervening shale is not exposed in Nemaha County. Lower limestone is light-gray and fossiliferous with bands of chert throughout. The limestones decompose leaving only chert at weathered exposures.

#### Council Grove Group:

Speiser Shale - Thickness: 4-6 m. (15-20 ft.) Varicolored, clayey, calcareous shale. Contains a thin persistent bed of gray, hard, fossiliferous limestone in upper part.

Funston Limestone - Thickness: 1-2 m. (5-7 ft.) Three or more layers of gray, hard, massive, dense limestone separated by beds of gray, silty, calcareous shale.

Blue Rapids Shale - Thickness: 5-6 m. (18-22 ft.) Grayish-green and maroon, clayey, calcareous shale. Contains thin beds of soft, tannish-gray limestone in lower part.

Crouse Limestone - Thickness: 3-5 m. (10-16 ft.) Upper limestone is tan, medium hard, and blocky to platy. Intervening shale is tannish gray, clayey, blocky, and calcareous. Lower limestone is gray, hard, massive, and fossiliferous.

Easley Creek Shale - Thickness: 4-5 m. (15-18 ft.) Grayish-green and maroon, silty, calcareous shale. Contains thin calcareous beds in middle and lower parts.

Bader Limestone - Thickness: 7-8 m. (23-27 ft.) Upper limestone is light gray, medium hard, massive, fossiliferous, and porous where weathered. Intervening shale is varicolored, silty, and calcareous with thin beds of gray, hard, clayey limestone. Lower limestone consists of two beds of gray, soft to hard, fossiliferous limestone separated by a tannish-gray, silty, clayey, calcareous shale.

Stearns Shale - Thickness: 4-5 m. (15-18 ft.) Tannish-gray, grayish-green to purple, silty, calcareous shale. Contains thin bed of limestone near top.

Beattie Limestone - Thickness: 3-4 m. (10-15 ft.) Upper limestone is gray to tannish brown, porous, and fossiliferous. Intervening shale is tannish gray, silty, thin bedded, fossiliferous, and very calcareous. Lower limestone is light gray, massive with solution channels, soft, cherty, and fossiliferous.

Eskridge Shale - Thickness: 10-12 m. (35-40 ft.) Clayey, calcareous shale, tan and grayish green in upper part and maroon, purple, and grayish green in lower part. A persistent thin bed of hard, massive fossiliferous limestone is in upper part.

Grenola Limestone - Thickness: 7-9 m. (25-30 ft.) Upper limestone composed of alternating beds of limestone and shale. Top bed is grayish brown, soft, porous limestone. Other beds are tannish-gray limestone and dark-gray shale. Shale below upper limestone is tan to gray, silty, and calcareous. Middle limestone consists of two or more beds of gray, medium-hard, massive limestone separated by tan, silty, calcareous shale. Lower shale is gray, silty, and calcareous. Lower limestone is gray to tannish gray, hard, and fossiliferous.

Roca Shale - Thickness: 3-6 m. (10-20 ft.) Gray, tan, and grayish-green, clayey, blocky, calcareous shale.

Red Eagle Limestone - Thickness: 2-4 m. (8-12 ft.) Upper limestone is tannish brown, soft, clayey, and porous. Intervening shale is clayey, calcareous, blocky, and gray in upper part, but very thin bedded, dark gray, and fossiliferous in lower part. Lower limestone is gray, medium hard, massive, and fossiliferous.

Johnson Shale - Thickness: 4-6 m. (15-20 ft.) Tannish-gray to grayish-orange, silty, platy, thin-bedded, calcareous shale.

Foraker Limestone - Thickness: 10-13 m. (35-45 ft.) Upper limestone is soft, massive, dolomitic, impure, and gray to tannish gray. Intervening shale is gray, silty, fossiliferous, calcareous and contains several thin limestone beds in upper and middle parts. Lower limestone composed of an upper gray, hard, fossiliferous bed and lower gray, medium-hard, massive to shaly bed.

#### Admire Group:

Janesville Shale - Thickness: 21-24 m. (70-80 ft.) Upper shale is variegated, clayey in upper part, sandy in lower part with sandstone lenses. Intervening limestone is tannish gray, medium hard, and very fossiliferous. Lower shale is tannish gray to olive drab, silty, and contains thin lenses of clayey limestone or sandy, micaceous shale.

Falls City Limestone - Thickness: 1-2 m. (6-8 ft.) Upper limestone is tan, medium hard, massive and is a coquina of fossil fragments. Intervening shale is tannish gray to dark gray, and clayey. Lower limestone is gray, very calcareous shale to gray, soft, fossiliferous, shaly limestone.

Onaga Shale - Thickness: 7-10 m. (25-35 ft.) Tannish-gray, grayish-green, and maroon, clayey shale at top of formation separated from tannish-gray, grayish-green, and maroon, silty, calcareous shale by a thin light-gray, medium-hard, massive, fossiliferous limestone.

PENNSYLVANIAN

Upper Pennsylvanian

Wabaunsee Group:

Wood Siding Formation - Thickness: 6-9 m. (20-30 ft.) Three gray to grayish-brown, hard, fossiliferous limestones separated by gray to grayish-brown and maroon, silty to sandy, micaceous, calcareous shales. Upper shale contains thin, cross-bedded sandstone beds locally.

Root Shale - Thickness: 12-15 m. (40-50 ft.) Greenish-gray to tannish-gray, clayey, sandy shale at top of formation separated from tannish-gray to bluish-gray, sandy, clayey, fossiliferous, calcareous shale by a thin gray to greenish-gray, medium-hard, fossiliferous limestone. Thin coal beds occur in upper part of both shales, and sandstone occurs locally in the lower shale.

Dover Limestone - Thickness: 4-6 m. (15-20 ft.) Upper limestone is tannish brown, sandy, conglomeratic, fossiliferous, and massive. Intervening shale is gray and maroon, sandy, clayey, fossiliferous, and calcareous. Lower limestone is tannish gray, medium hard, massive, and fossiliferous.

Pillsbury Shale - Thickness: 6-9 m. (20-30 ft.) Greenish-gray and maroon clayey shale. May contain thin beds of sandy, micaceous shale or sandstone.

Zeandale Limestone - Thickness: 6-9 m. (20-30 ft.) Upper limestone is tannish gray, medium hard, and fossiliferous. Intervening shale is grayish brown and silty in upper part, grayish green and maroon, blocky, fossiliferous, and calcareous in lower part. Lower limestone is grayish brown, fossiliferous, hard, massive, somewhat dense in the upper part and shaly near the base.

Willard Shale - Thickness: 9-12 m. (30-40 ft.) Gray to brownish-gray, silty, sandy, micaceous shale. Upper part contains micaceous cross-bedded sandstone.

Emporia Limestone - Thickness: 3-4 m. (10-15 ft.) Upper limestone is bluish gray to brown, hard, and fossiliferous with thin beds of gray, clayey, calcareous shale. Intervening shale is gray to greenish gray, calcareous, and blocky. Lower limestone is three or four beds of bluish-gray to brown, slightly fossiliferous, hard, dense limestone.

Auburn Shale - Thickness: 4-9 m. (15-30 ft.) Tan to gray in upper part, tan to yellow in middle part, and greenish-gray in lower part, silty and clayey, fossiliferous shale. Contains thin limestone beds.

Bern Limestone - Thickness: 4-7 m. (15-25 ft.) Consists of an upper tannish-brown, bedded, soft-to-medium-hard, fossiliferous limestone separated by thin beds of shale; a middle gray to greenish-gray, silty to clayey, calcareous shale; and a lower gray to brown, bedded, soft-to-medium-hard, fossiliferous, porous limestone.

Scranton Shale - Thickness: 34-40 m. (115-135 ft.) Consists of thick upper and lower tan, bluish-gray, greenish-gray and maroon, sandy to silty, micaceous, clayey shales separated by a 1-foot thick gray, medium-hard, fossiliferous, lenticular limestone. The shales include lime-cemented, cross-bedded, ripple-marked sandstones. The thin Elmo coal bed separates the shales where the limestone is absent.

Howard Limestone - Thickness: 2-3 m. (5-10 ft.) Alternating beds of bluish-gray, fossiliferous, hard, dense limestones that weather to brown, and dark-gray to tannish-gray, calcareous, silty shale. Contains coal bed at base of formation.

Shawnee Group:

Topeka Limestone - Thickness: 6-9 m. (20-30 ft.) Nine alternating beds of bluish-gray to gray, fossiliferous, hard to medium-hard limestone that weather to brown, and bluish-gray to black, somewhat fossiliferous, calcareous, silty shale. Locally, thin coal beds occur in the shale.

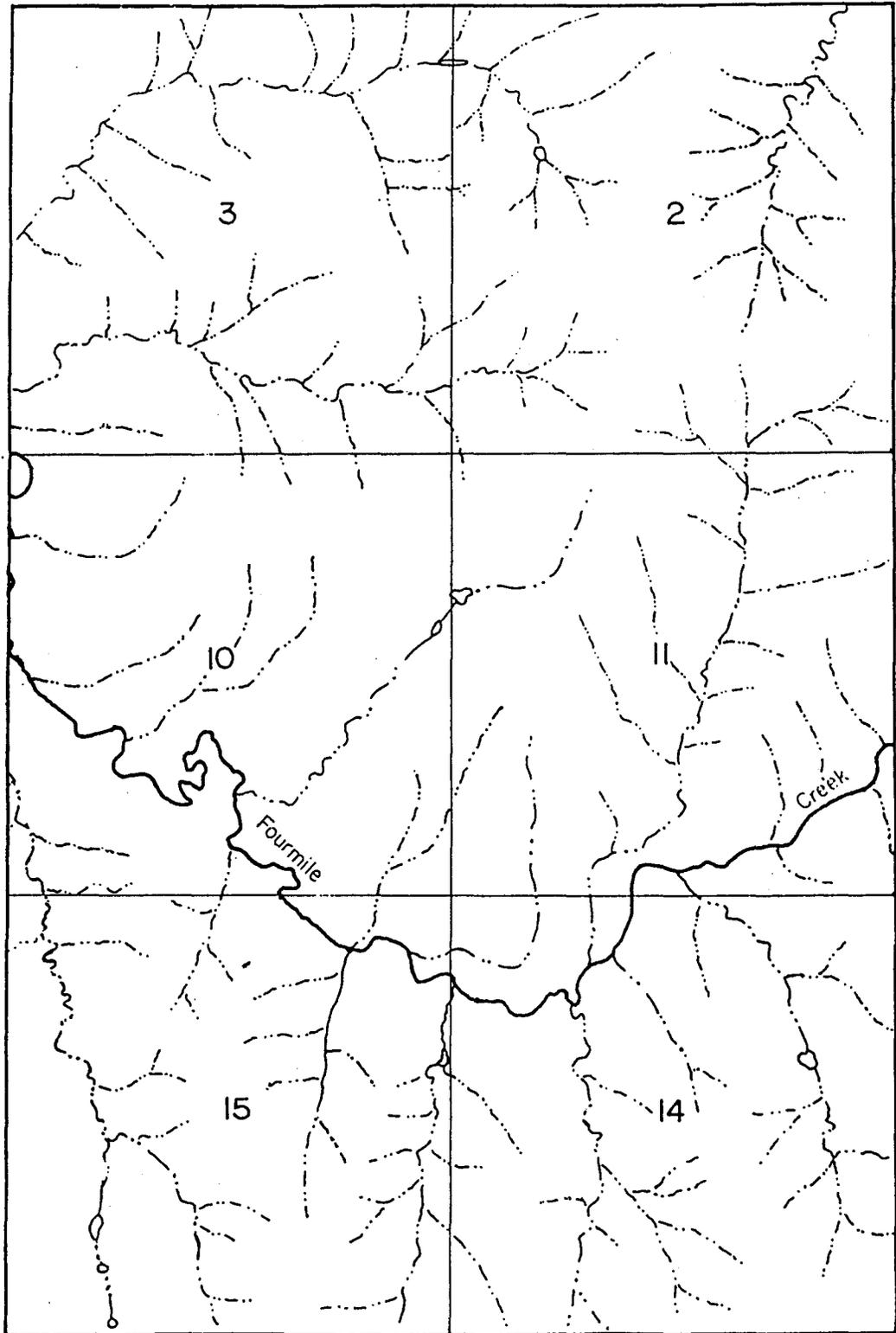
## REFERENCES

- Bayne, C.K. and W.H. Schoewe (1967) Geology and Groundwater Resources of Brown County, Kansas: Kansas Geological Survey Bull. 186.
- Bickford, M.E., et al., (in press) Geologic Map of Precambrian Basement Rocks of Kansas.
- Bickford, M.E., Department of Geology, University of Kansas, personal communication.
- Brookins, D.G. (1970) Kimberlites of Riley County: Kansas Geological Survey Bull. 200.
- Burchett, Raymond, Nebraska Geology and Conservation Survey, personal communication.
- Campbell, H. (in press) Soil Survey of Jackson County, Kansas: Dept. of Agriculture Series.
- Chase, C.G. and T.H. Gilmer (1973) Precambrian Plate Tectonics: The Mid-continent Gravity High: Earth and Planetary Sci. Let., Vol. 21, pp. 70-78.
- Chelikowsky, J.R. (1973) Structural Geology of the Manhattan, Kansas Area: Kansas Geological Survey Bull. 204, Pt. 4.
- Cole, Virgil (1976) Precambrian Surface Map of Kansas.
- Cole, Virgil and W.J. Ebanks (1974) List of Kansas Wells Drilled into Precambrian Rocks: Subsurface Geology Series 1, Kansas Geological Survey.
- Coons, R.L., G.P. Woolard, and G. Hershey (1967) The Structural Significance and Analysis of the Midcontinent Gravity High: AAPG Bull. V. 51, n. 12, pp. 2381-2399.
- Daly, R.A. (1934) Selections from "The Changing World of the Ice Age," Paper #7 in Glacial Isostasy, John T. Andrews, ed. (Stroudsburg, PA: Dowden, Hutchinson and Ross, Inc., 1974) p. 111.
- Davis, S.N. (1951) Studies of Pleistocene Gravel Lithologies in Northeast Kansas: Kansas Geological Survey Bull. 90, Pt. 7.
- Dellwig, L.F. and J.R. McCauley (in press) Lineaments of Northeast Kansas.
- Dobrin, M.B. (1976) Introduction to Geophysical Prospecting (York, PA: McGraw-Hill Book Co., Inc.)
- Docekal, Jerry (1970) Earthquakes of the Stable Interior with emphasis on the Midcontinent: Ph.D. Thesis, University of Nebraska.

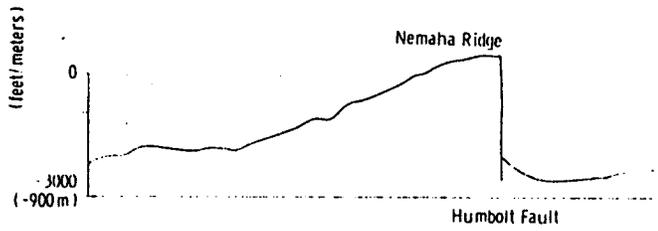
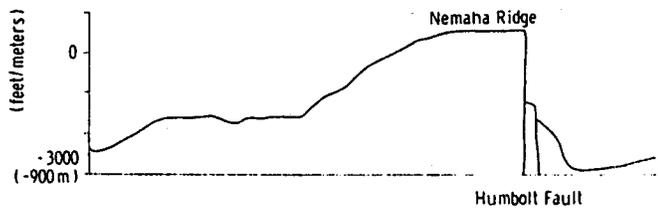
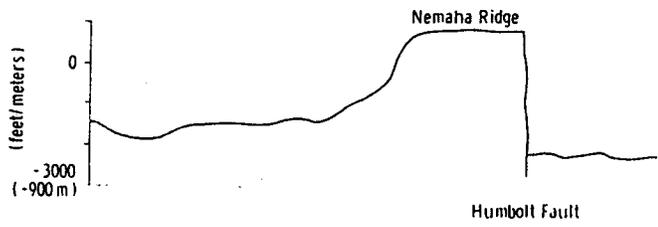
- DuBois, S.M. and F.W. Wilson (in press) A Revised and Augmented List of Earthquake Intensities of Kansas, 1867-1977.
- Eikleberry, R.W. (1960) Soil Survey of Brown County, Kansas: United States Department of Agriculture Series No. 7.
- Frye, John C. and K.L. Walters (1950) Subsurface Reconnaissance of Glacial Deposits in Northeast Kansas: Kansas Geological Survey Bull. 86, Pt. 6.
- Hargadine, G.D. (1965) Materials Inventory of Marshall County, Kansas: State Highway Commission of Kansas Materials Inventory Report No. 7.
- Hargadine, G.D. (1970) Materials Inventory of Nemaha County, Kansas: State Highway Commission of Kansas Materials Inventory Report No.19.
- Jewett, J.M. (1941) The Geology of Riley and Geary Counties, Kansas: Kansas Geological Survey Bull. 39.
- King, E.R. and I. Zietz (1971) Aeromagnetic Study of the Midcontinent Gravity High of the Central United States: GSA Bull., v.82, pp. 2187-2208.
- Kutnink, P. (in press) Soil Survey of Marshall County, Kansas: United States Department of Agriculture Series.
- Lee, W. (1954) Earthquakes and the Nemaha Anticline: AAPG Bull., v.51, n. 12, pp. 2381-2399.
- MacFarlane, P.A. Environmental Protection Agency, Kansas City, Missouri, personal communication.
- Merriam, D.F. (1956) History of Earthquakes in Kansas: Bull. Seism. Soc. Am., v.46, pp. 87-96.
- \_\_\_\_\_ (1963) The Geologic History of Kansas: Kansas Geological Survey Bull. 162.
- Mudge, M.R., C.P. Walters, and R.E. Skoog (1959) Geology and Construction Material Resources of Nemaha County, Kansas: Kansas Geological Survey Bull. 1060-D.
- Nansen, F. (1921) "Selections from the Strandflat and Isostasy," Paper #6 in Glacial Isostasy, John T. Andrews, ed. (Stroudsburg, PA: Dowden, Hutchinson and Ross, Inc., 1974) p. 99.
- O'Leary, D.W. and T.W. Offield (1977) "New Basement Tectonics," Geotimes, Feb. issue, p. 21.
- Scott, Glenn R. et al. (1959) Geology and Construction-Material Resources of Pottawatomie County, Kansas: Kansas Geological Survey Bull. 1060-C.

- Seyrafian, Ali (1977) The Humboldt Fault - Pottawatomie County, Kansas, Precambrian in Present: M.S. Thesis, University of Kansas.
- Snyder, F.G. (1968) Tectonic History of the Midcontinental United States: University of Missouri at Rolla Journal, No. 1, pp. 65-77.
- Stallard, A.H. and D.P. Fenity (1966) Materials Inventory of Brown County, Kansas: State Highway Commission of Kansas Materials Inventory Report No. 8.
- Steeple, D.W., Kansas Geological Survey, personal communication.
- Walters, Kenneth L. (1953) Geology and Groundwater Resources of Jackson County, Kansas: Kansas Geological Survey Bull. 101.
- \_\_\_\_\_, (1954) Geology and Groundwater Resources of Marshall County, Kansas: Kansas Geological Survey Bull. 106.
- Ward, John R. (1974) Geohydrology of Nemaha County, Northeast Kansas: University of Kansas Publication, Groundwater Series No. 2.
- Wilson, Frank W., Kansas Geological Survey, personal communication.
- Yarger, Harold L., et al. (in preparation for open file at Kansas Geological Survey) Aeromagnetic and Gravity Maps of Northeast Kansas, data sets from aeromagnetic and gravity surveys of Northeast Kansas.

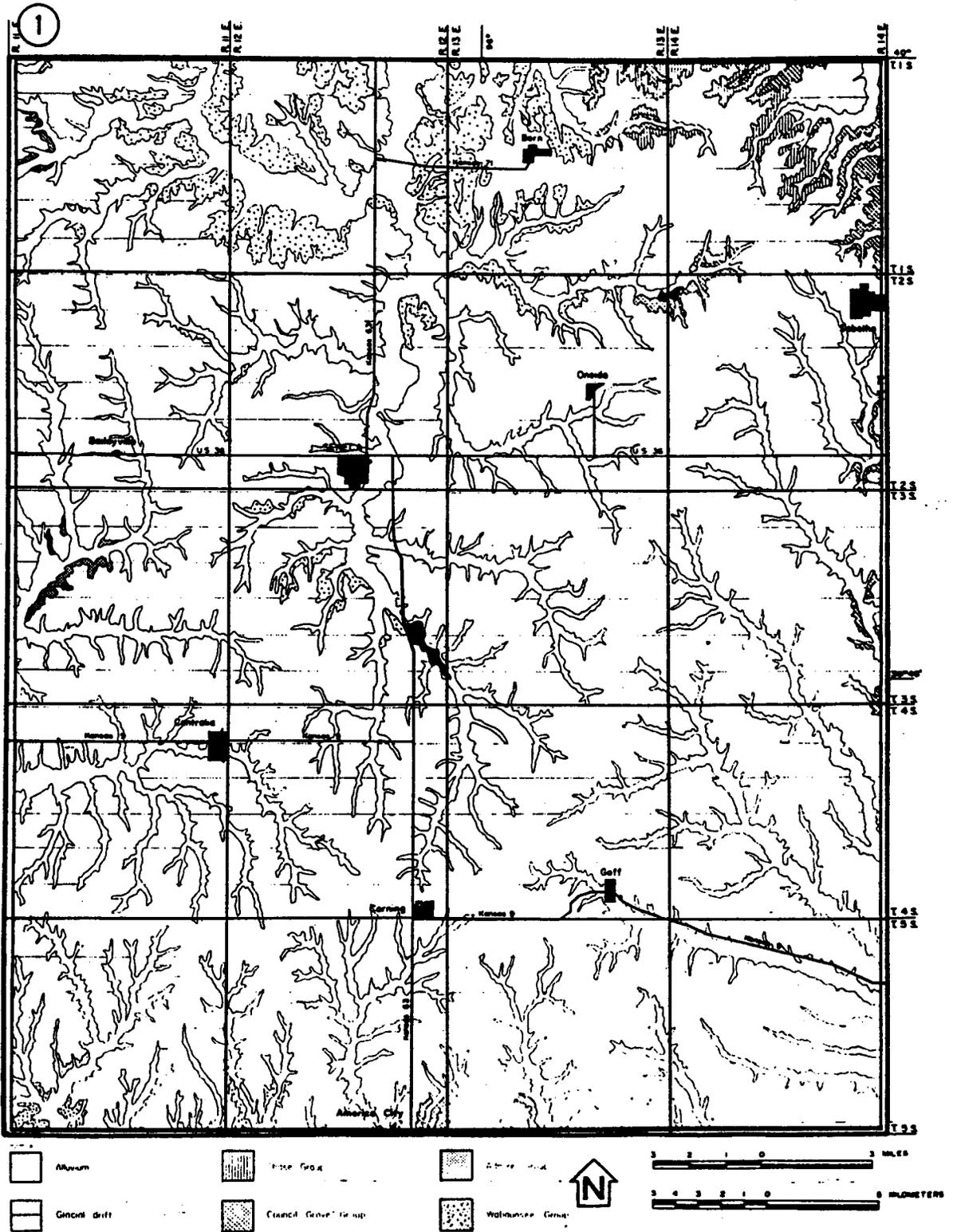
# DRAINAGE



PRECAMBRIAN SURFACE

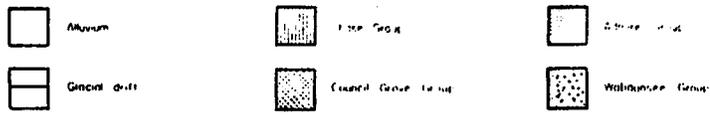
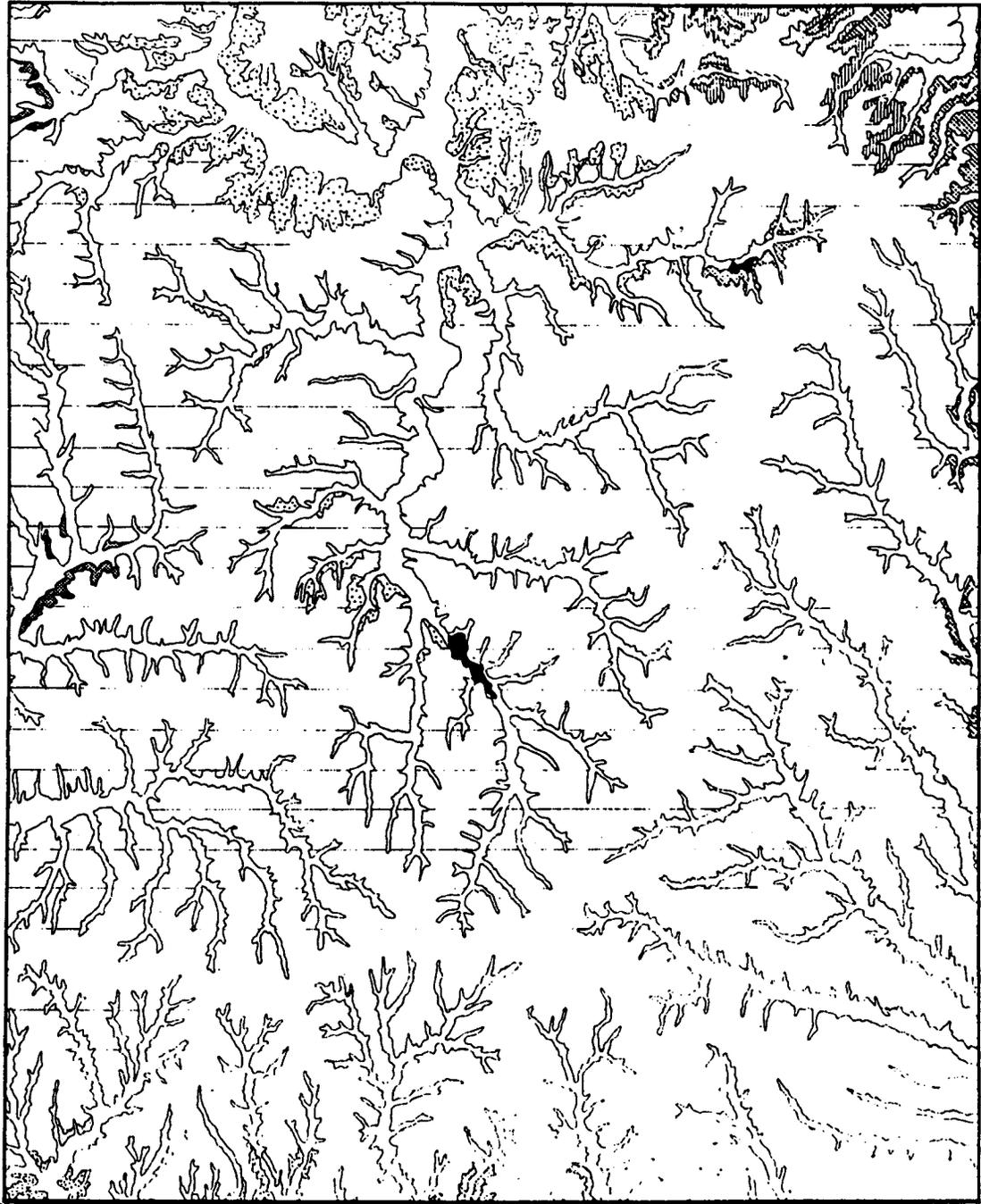


# BASE MAP OF NEMAHA COUNTY, KANSAS



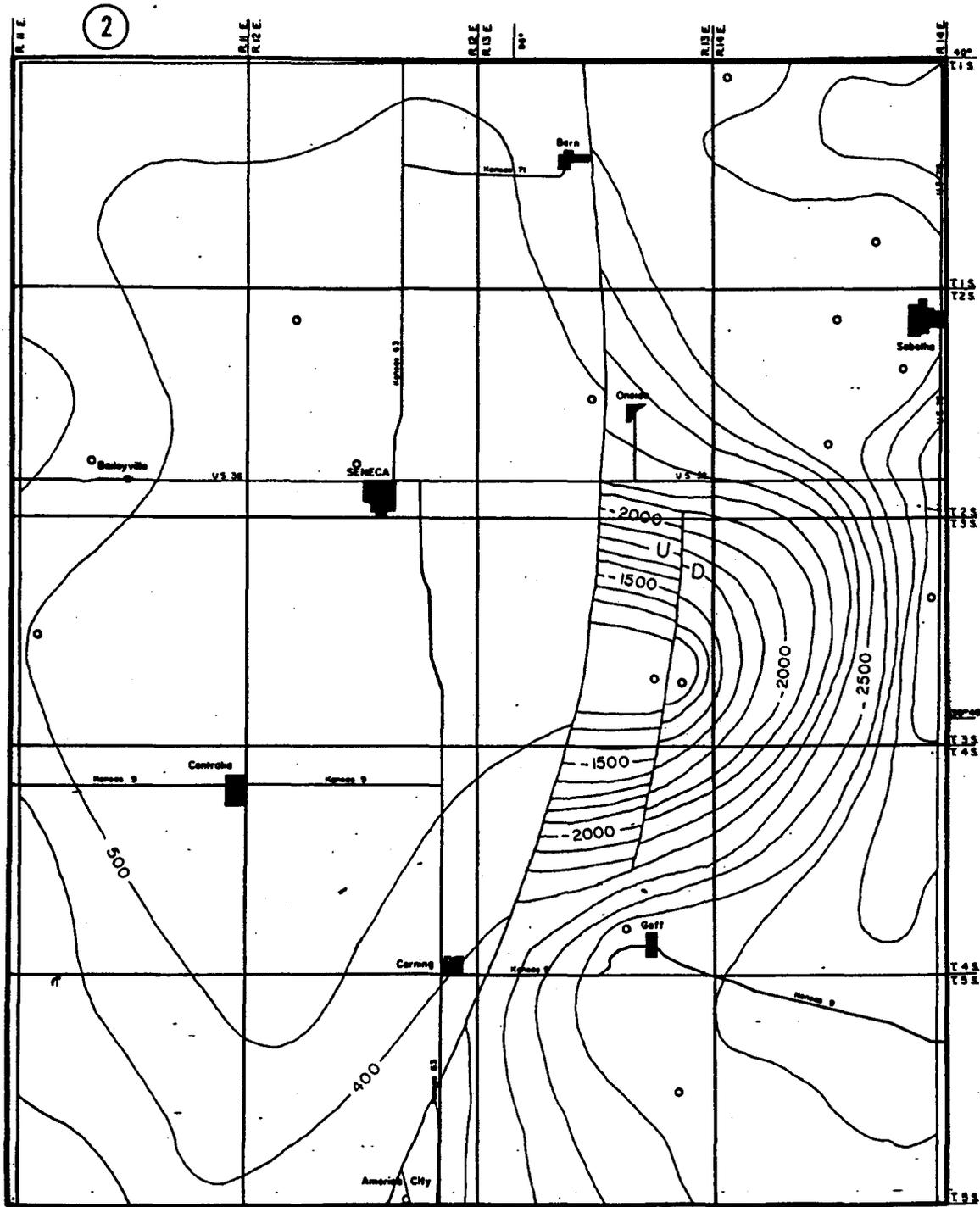
Generalized Geology (Ward, 1974)

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Generalized Geology (Ward, 1974)

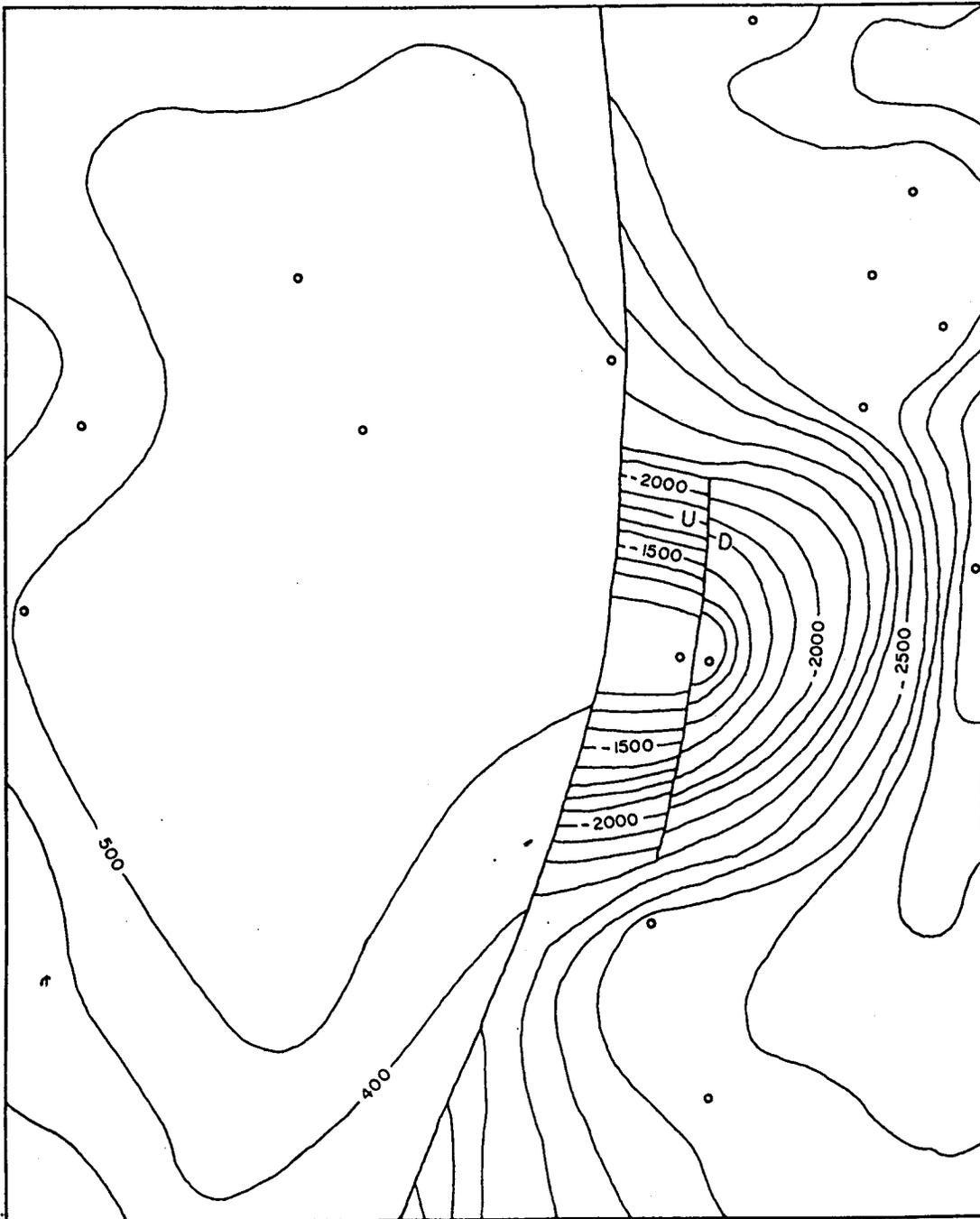
# BASE MAP OF NEMAHA COUNTY, KANSAS



○ Well to the Precambrian  
Precambrian Surface (Cole, 1975)-

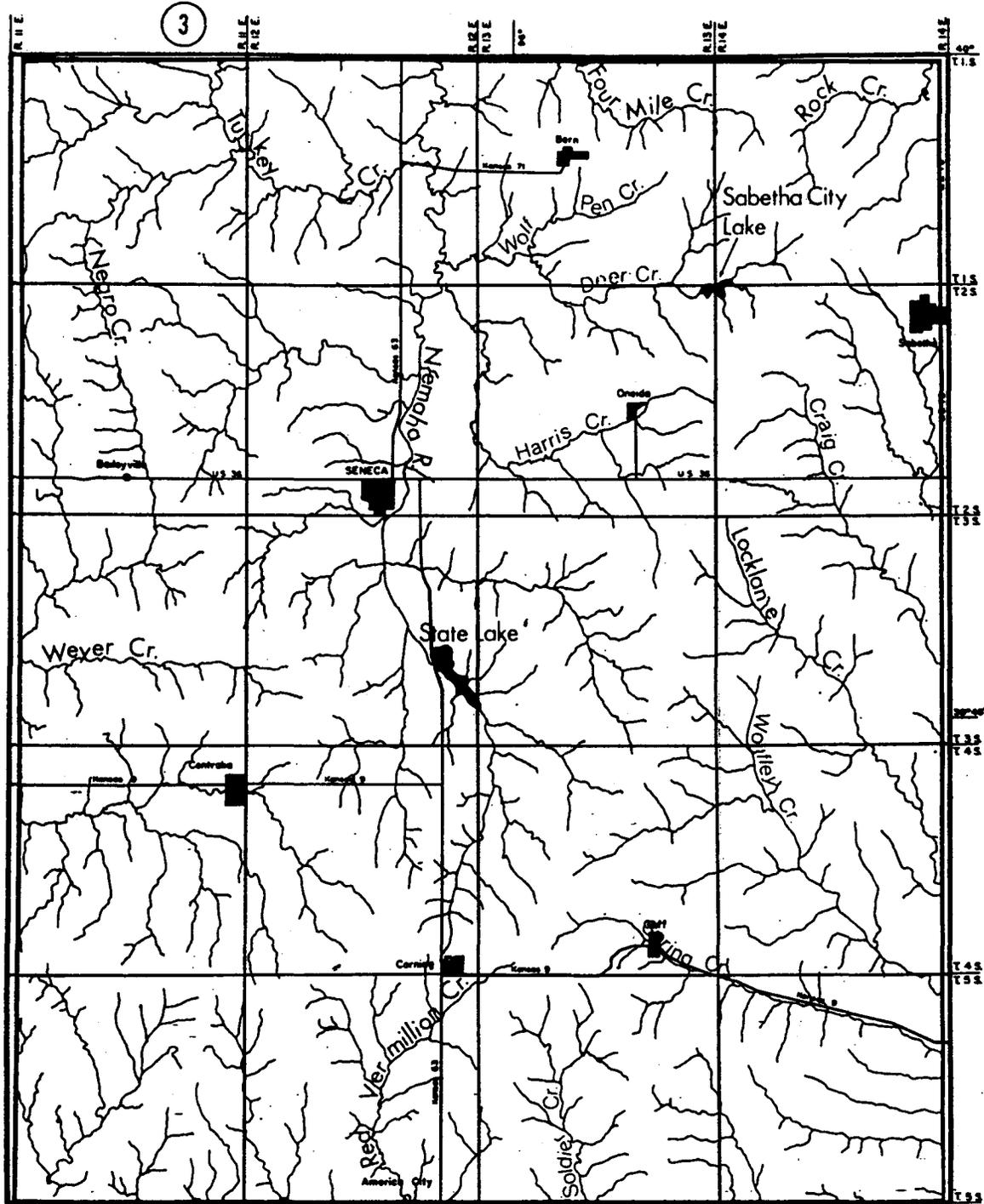


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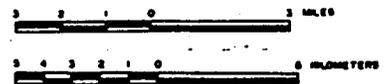


• Well to the Precambrian  
Precambrian Surface (Cole, 1975)

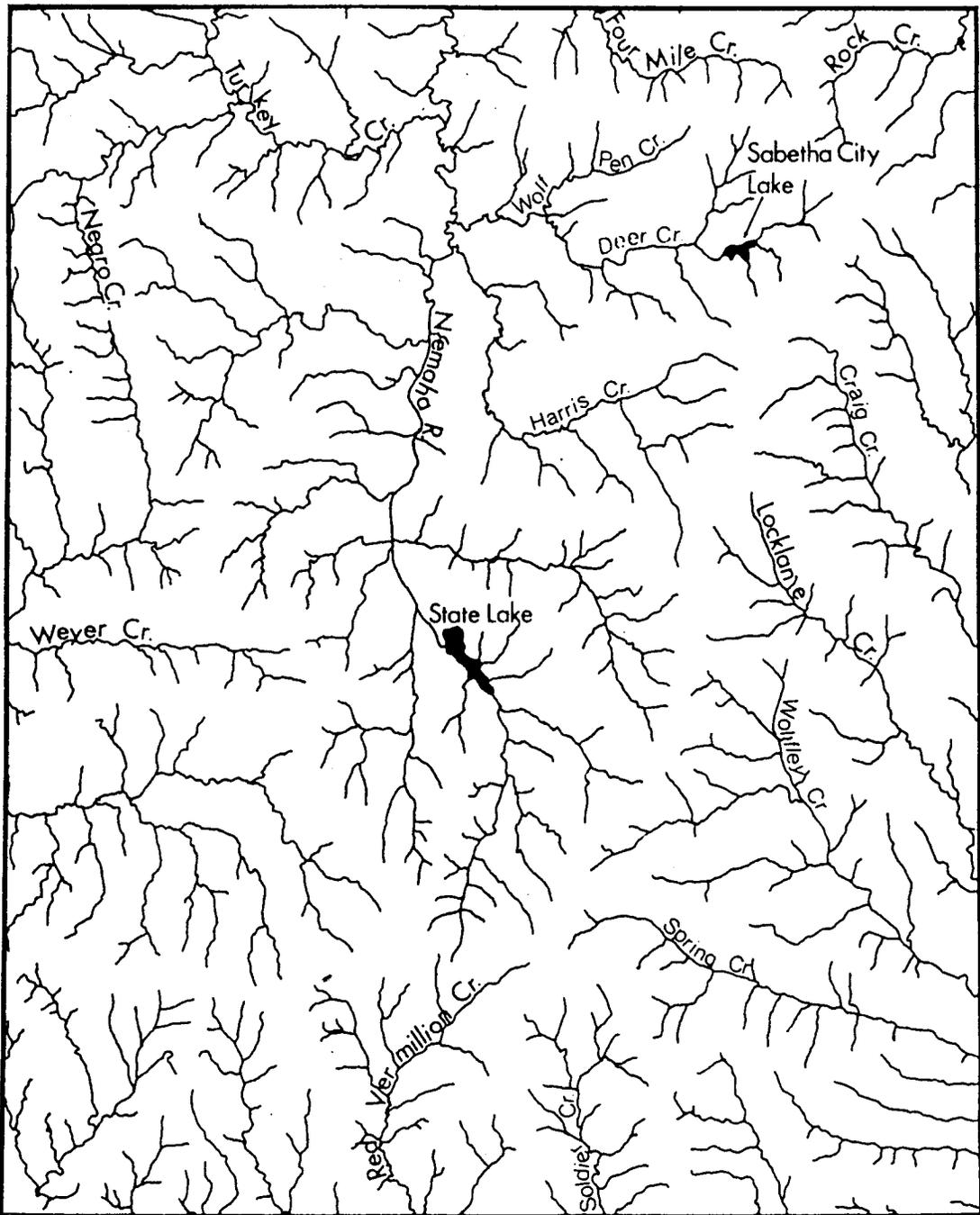
# BASE MAP OF NEMAHA COUNTY, KANSAS



Drainage (Streams are third order or higher)

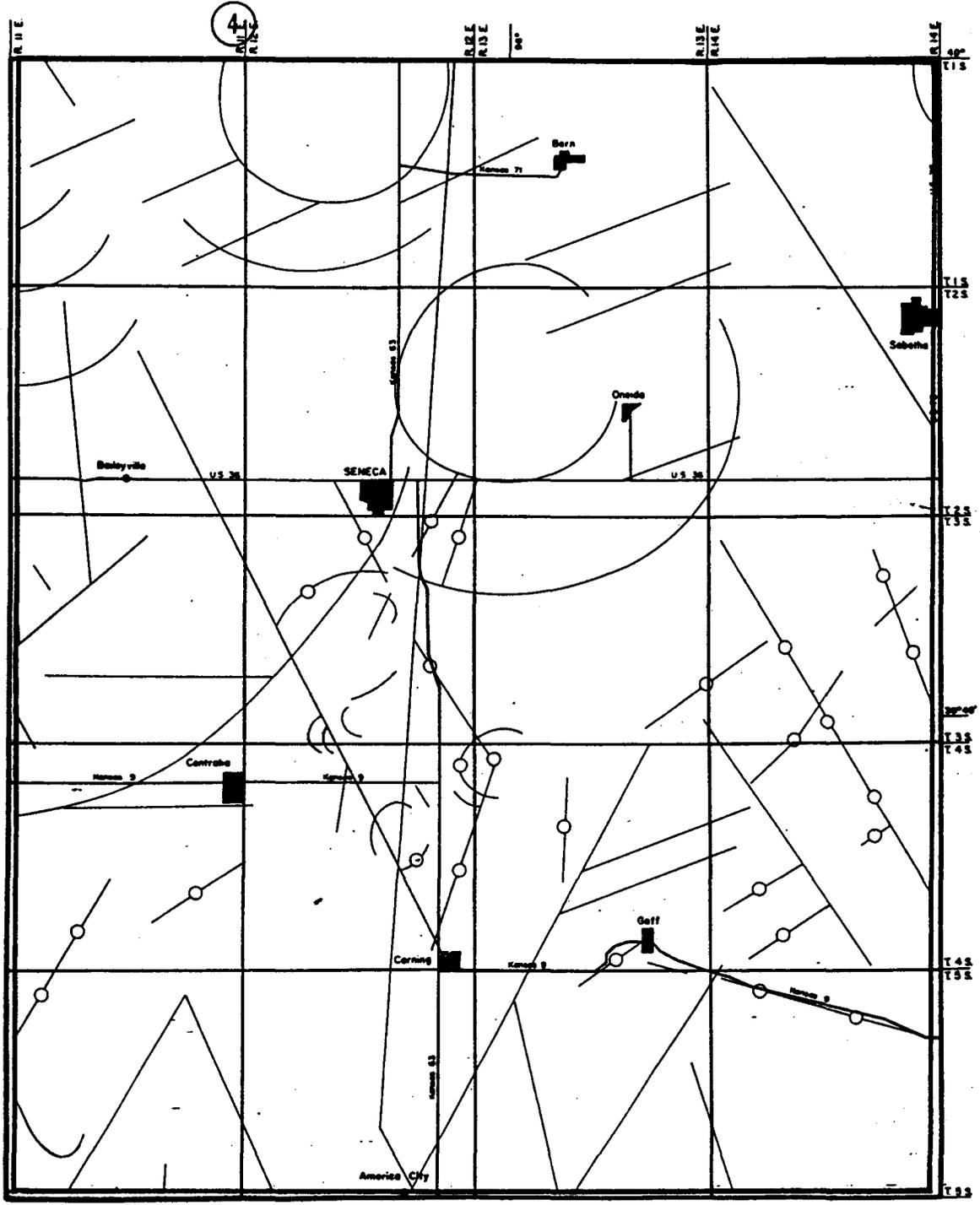


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Drainage (Streams are third order or higher)

# BASE MAP OF NEMAHA COUNTY, KANSAS

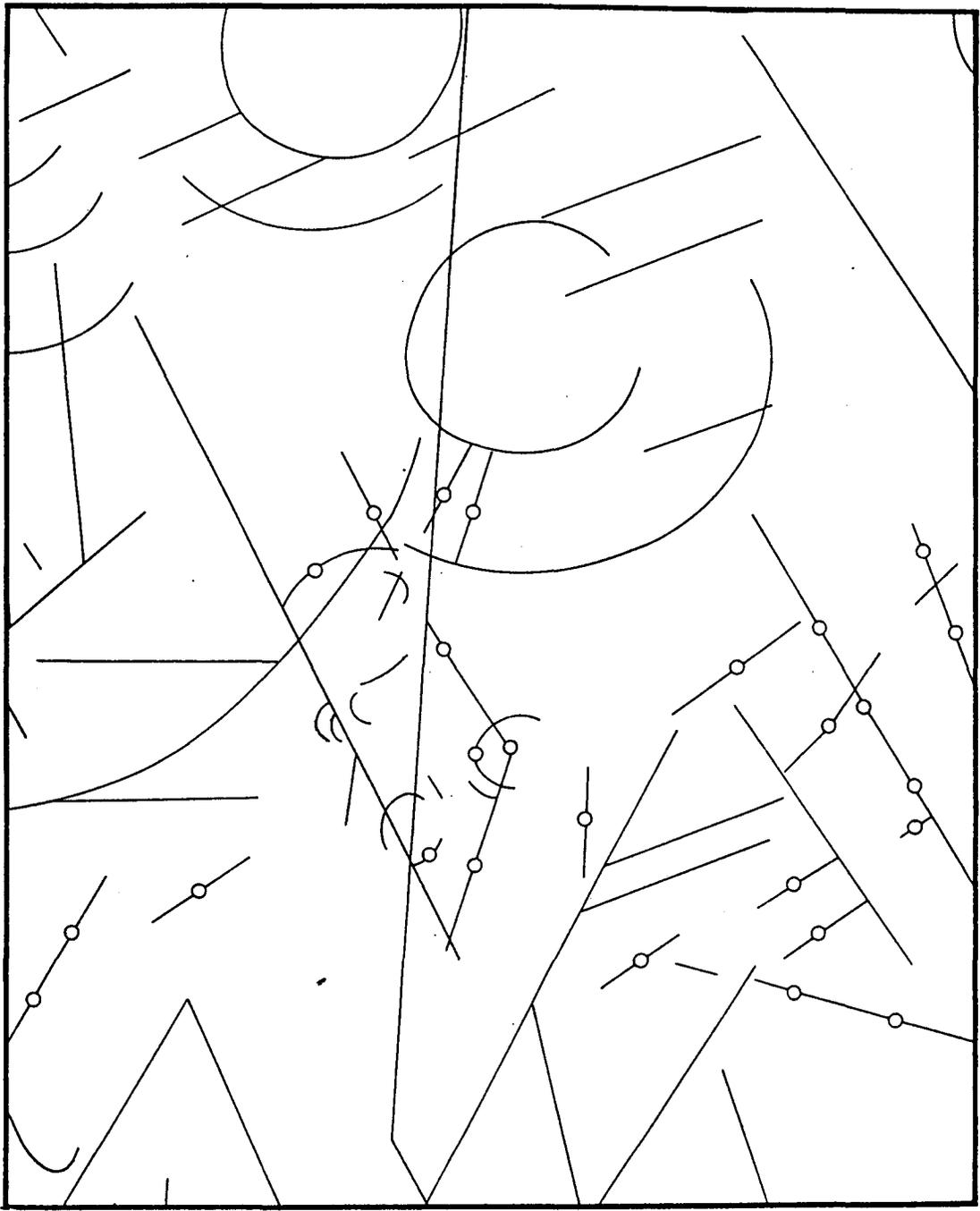


- Landsat Imagery
- High Altitude Photography

Lineaments & Curvilinear Features  
(Dellwig & McCauley, in press)



4

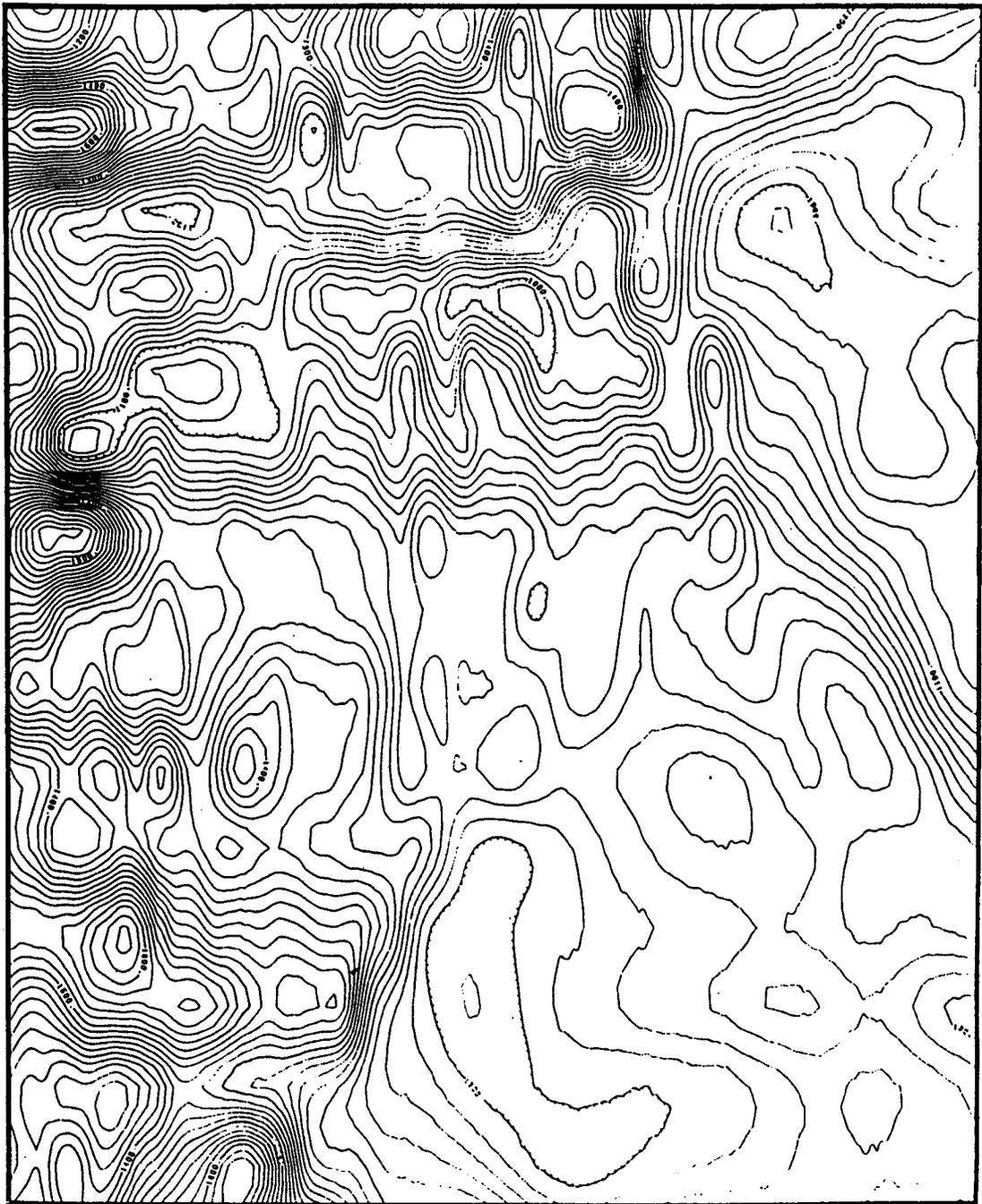


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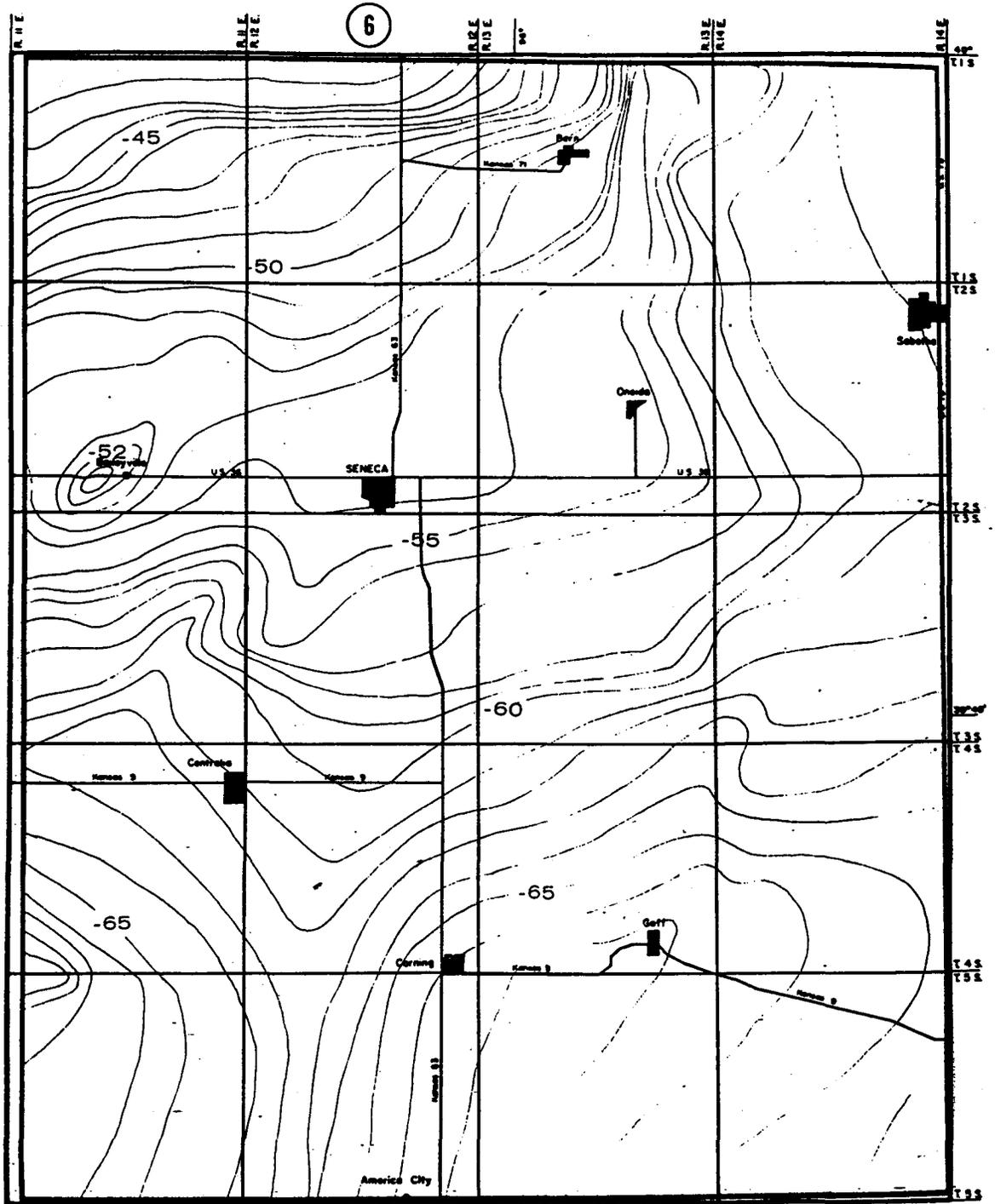


5



Aeromagnetic Map (Compiled by Randy Robertson)  
Contour Interval = 20 gammas

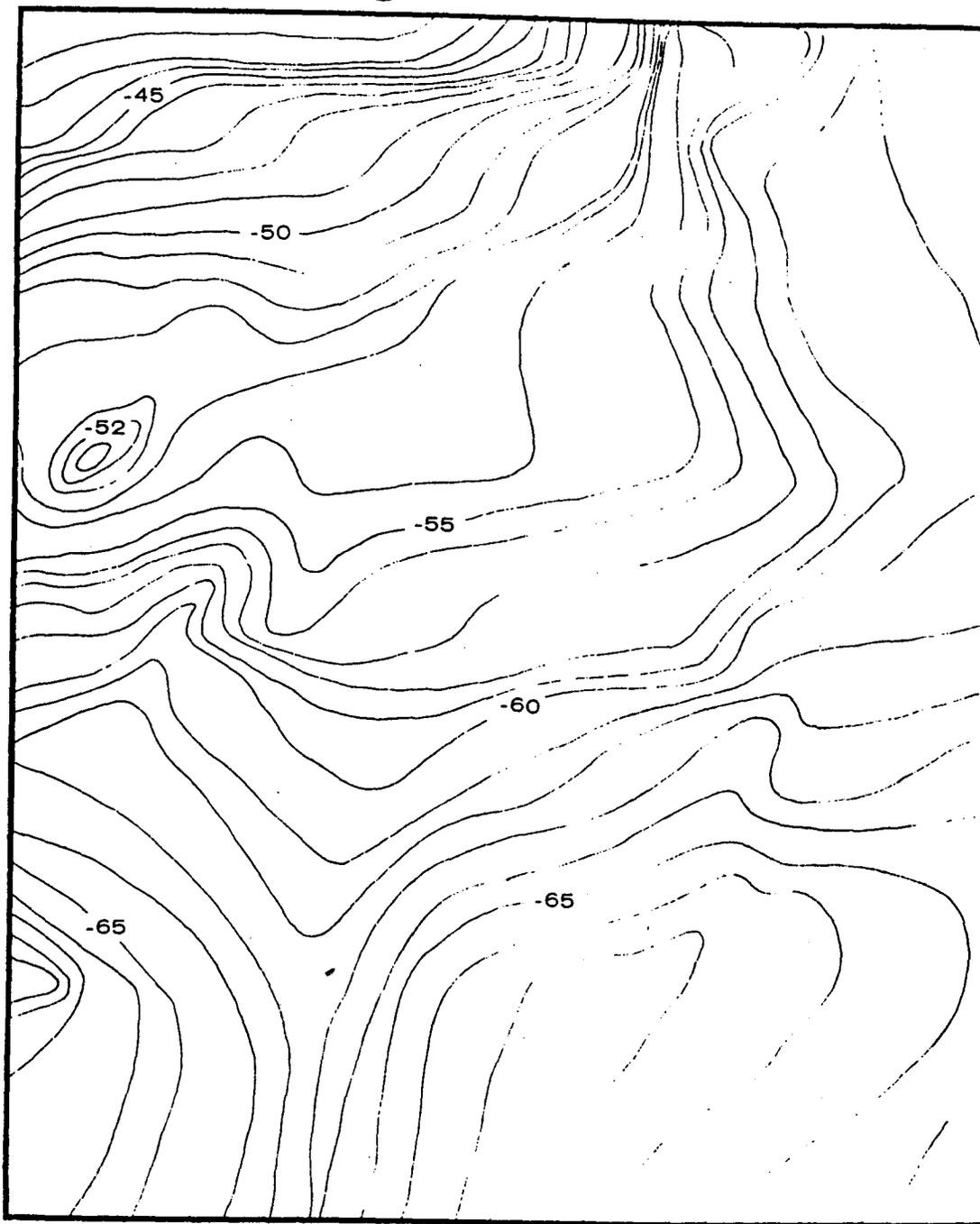
# BASE MAP OF NEMAHA COUNTY, KANSAS



Bouger Gravity Map  
Contour Interval = 1 milligal

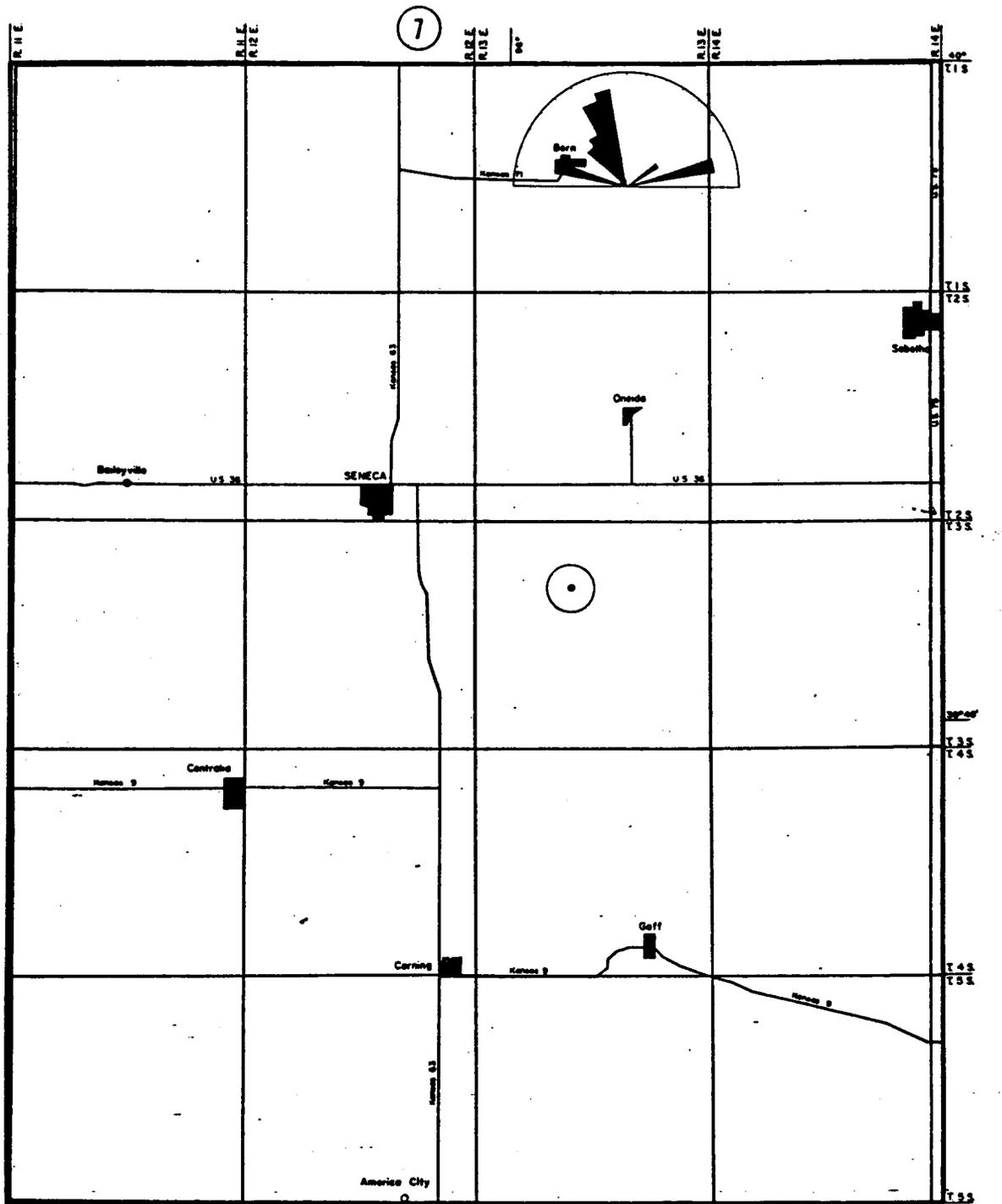


6

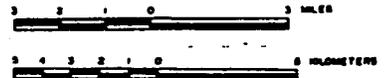


Bouguer Gravity Map  
Contour Interval = 1 milligal

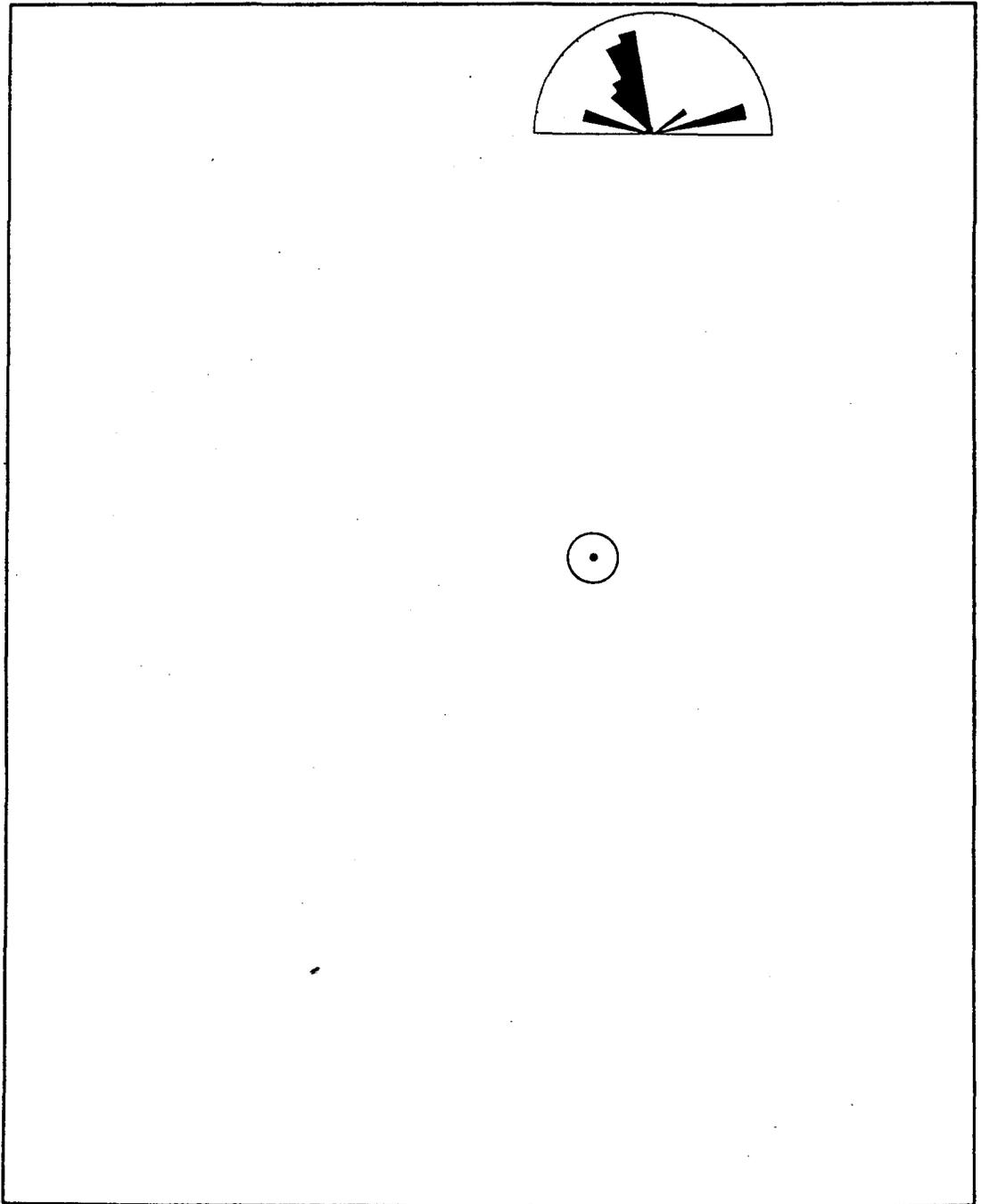
# BASE MAP OF NEMAHA COUNTY, KANSAS



- A. Joint diagram, Bern area
- B. Microearthquake epicenter

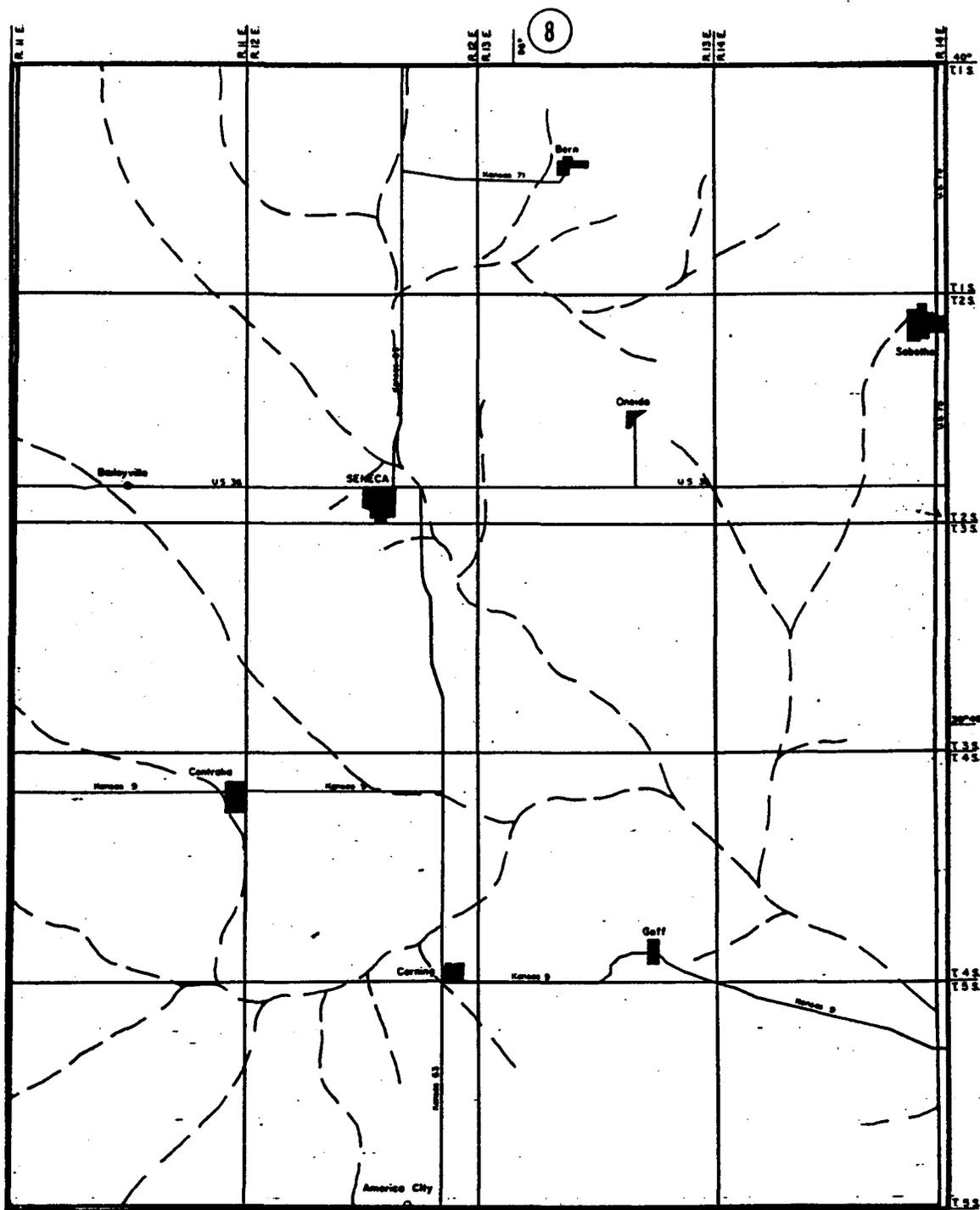


7



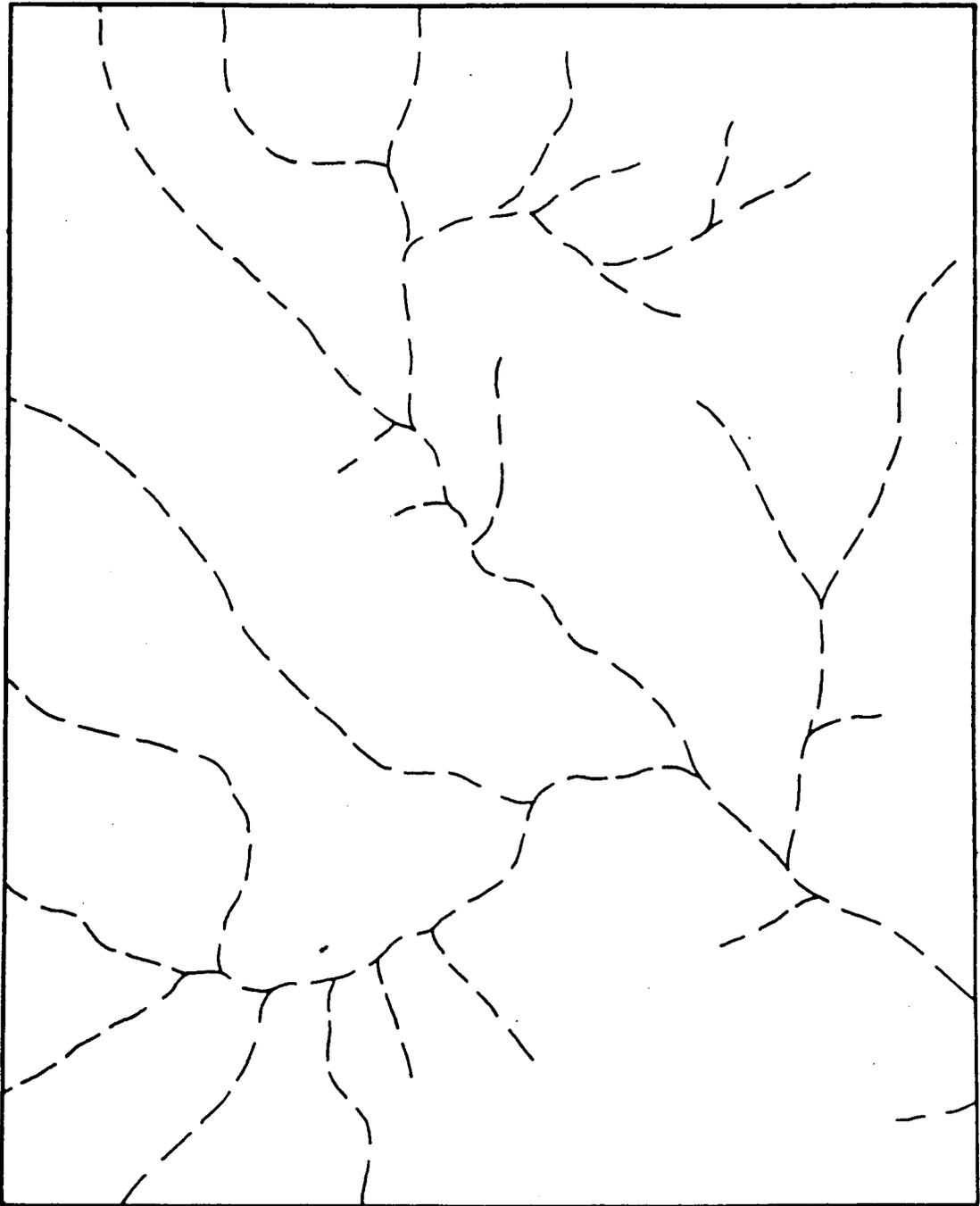
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# BASE MAP OF NEMAHA COUNTY, KANSAS



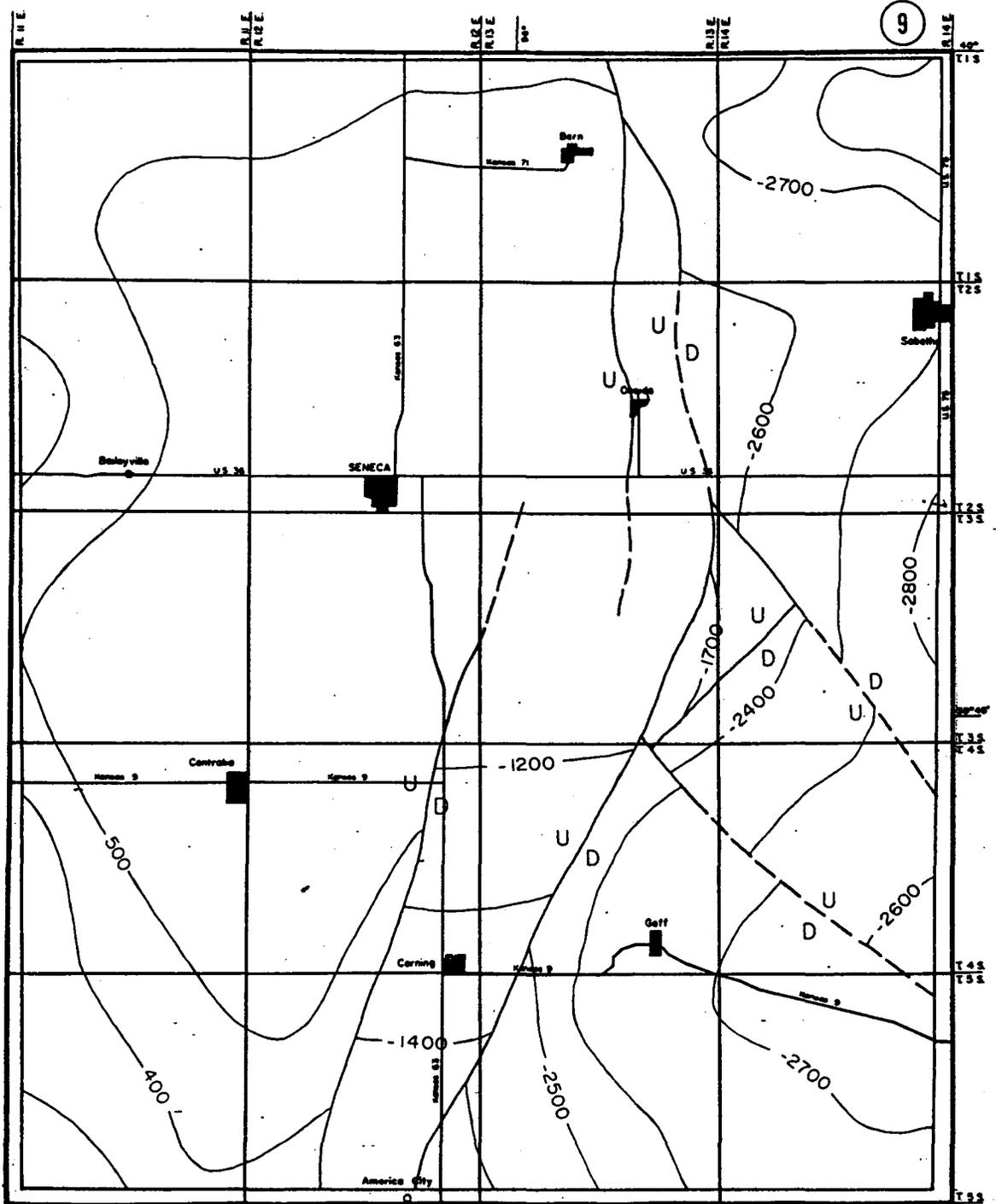
Buried Valleys (Ward, 1974)





Buried Valleys (Ward, 1974)

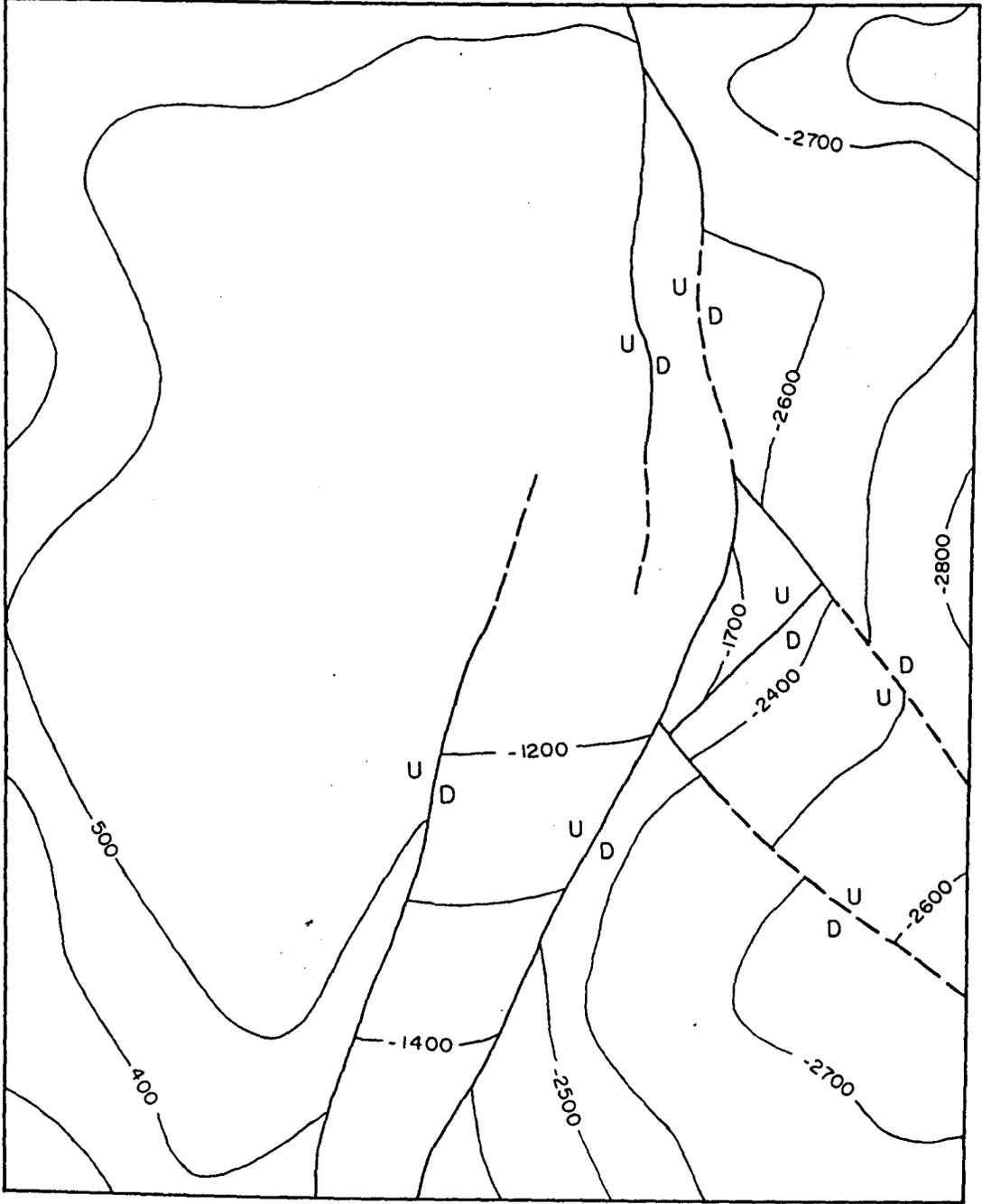
# BASE MAP OF NEMAHA COUNTY, KANSAS



Precambrian Surface Inferred from  
Surface, Subsurface, and Geophys-  
ical Data

Contour Interval: 100 feet

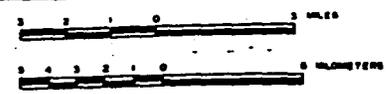
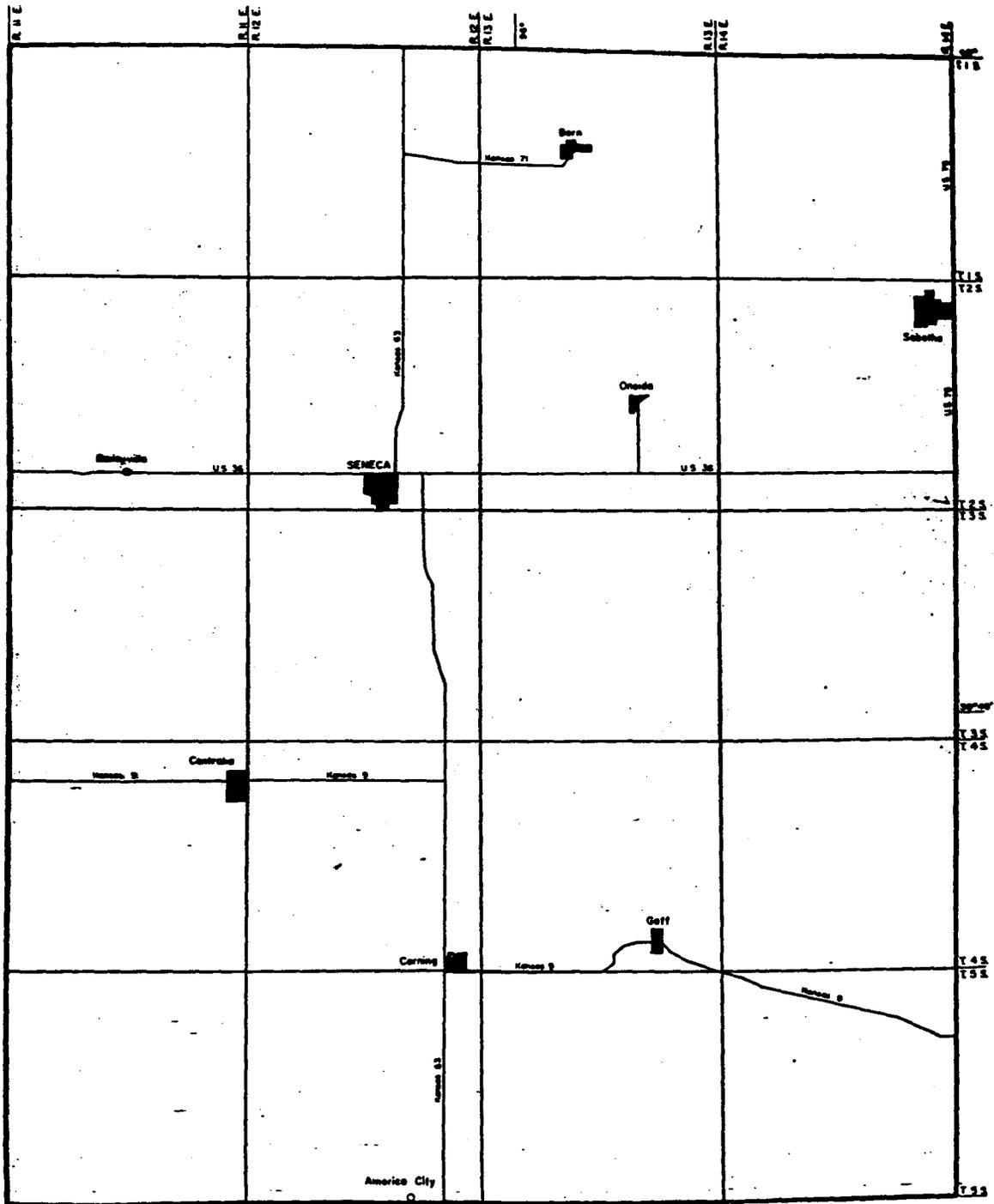


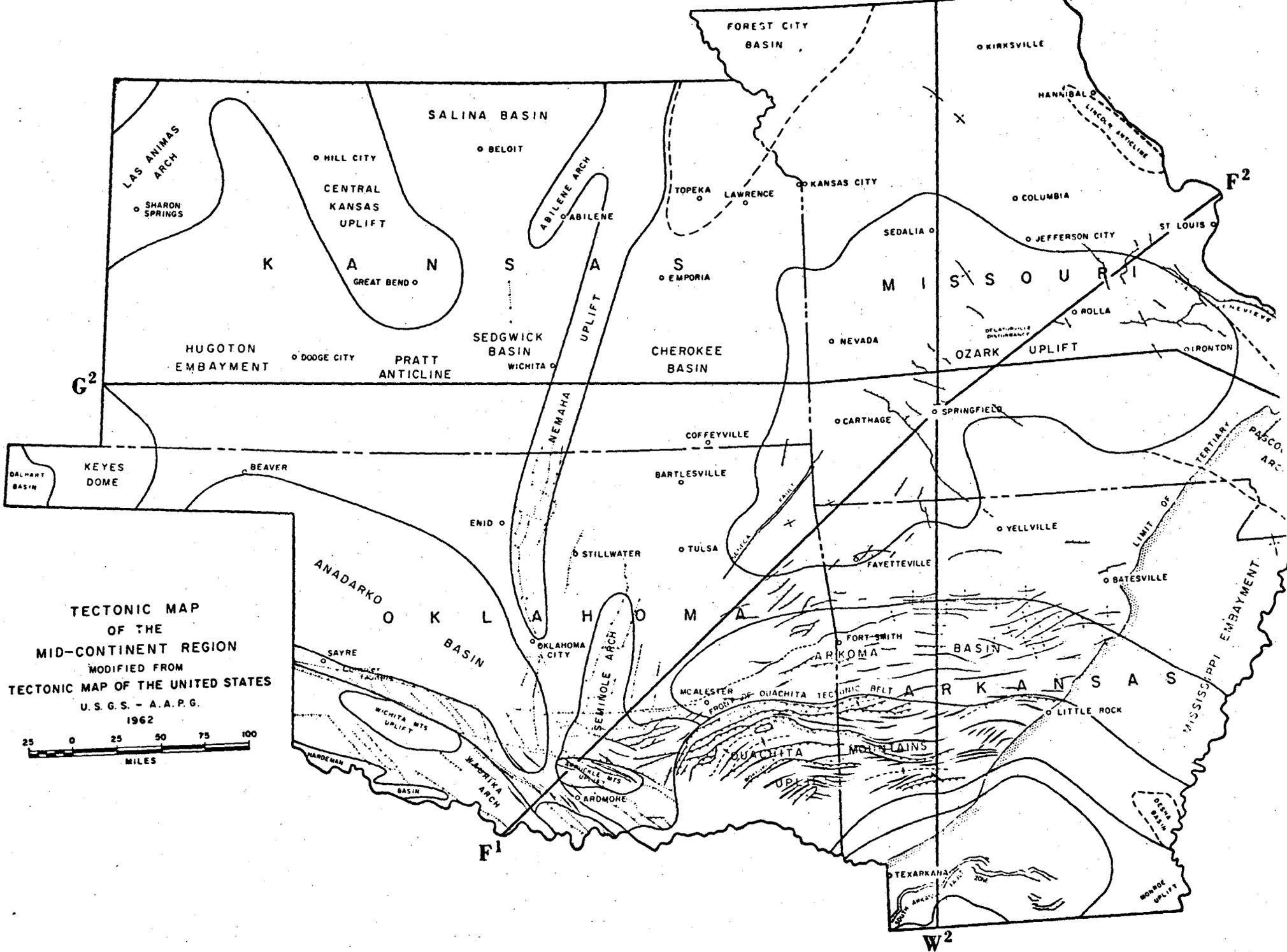


Precambrian Surface Inferred from  
Surface, Subsurface, and Geophysical  
Data

Contour Interval: 100 feet

# BASE MAP OF NEMAHA COUNTY, KANSAS

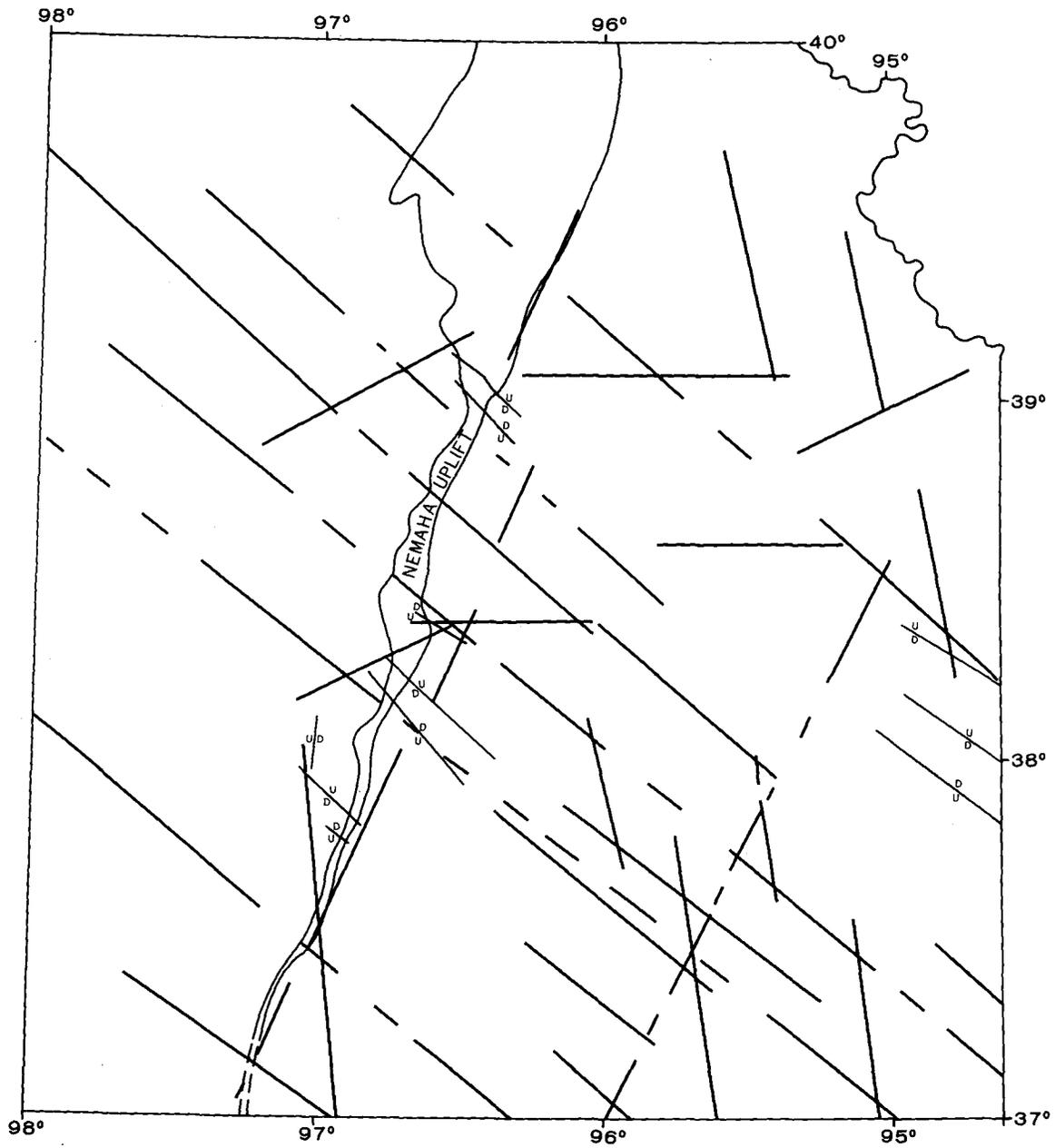




TECTONIC MAP  
OF THE  
MID-CONTINENT REGION  
MODIFIED FROM  
TECTONIC MAP OF THE UNITED STATES  
U. S. G. S. - A. A. P. G.  
1962



TECTONIC MAP



— LINEAMENTS  
 —<sup>u</sup>/<sub>d</sub>— IDENTIFIED BASEMENT FAULTS

0 10 30 50  
 KILOMETERS