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REGIONAL TECTONICS AND SEISMICITY OF EASTERN NEBRASKA

Annual Report

June 1977 - May 1978

R. R. Burchett
D. G. Maroney

Nebraska Geological Survey

Prepared for
U. S. Nuclear Regulatory Commission

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Prepared by
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ABSTRACT

This annual report presents and interprets the information obtained by the Conservation and Survey Division (Nebraska Geological Survey) during contract year June 1, 1977, to May 30, 1978, under contract NRC-04-76-315 with the U.S. Nuclear Regulatory Commission. The information pertains to the geology, structure, tectonics, and seismicity of eastern Nebraska with emphasis on the vicinity of the Humboldt Fault Zone in western Richardson and eastern Pawnee counties. Some of the information presented here results from a combination of studies begun in earlier years but the greater part results from studies begun during the contract year.

The scope of the studies is summarized as follows:

1. Rock outcrops in western Richardson and eastern Pawnee counties were reexamined and reevaluated, and 64 test holes were drilled to determine the altitude of the upper surface of the Tarkio Limestone of Pennsylvanian age;
2. The possible relation of earthquakes in eastern Nebraska to Pleistocene glaciation was evaluated;
3. Three new seismograph installations were established in southeastern Nebraska;
4. Gravity surveys of western Richardson and eastern Pawnee counties were extended to the northern end of the Humboldt Fault Zone and were evaluated;

. Ground magnetic surveys in western Richardson and eastern
Lawson counties were made and evaluated;
. Gravity and ground magnetic surveys of the Elk Creek Anomaly
were made and evaluated.
...sions of the results of these studies constitute the
...ainder of this report.

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STRUCTURE OF THE TARKIO LIMESTONE ALONG THE HUMBOLDT FAULT ZONE IN SOUTHEASTERN NEBRASKA

by
R. R. Burchett and J. L. Arrigo

Introduction

Southeastern Nebraska is a unique area in that outcrops (fig. 1) and subsurface information are available for detailed studies of the uppermost Paleozoic rocks. The Table Rock Arch, a post-Permian structural feature in the outcrop area, trends north-south over the buried Nemaha Uplift. The east margin of the Table Rock Arch is defined by the Humboldt Fault Zone, and eastward from it rock strata are downfaulted or dip steeply into the Forest City Basin (fig. 2). The depth to rocks of Precambrian age ranges from about 500 feet (152 m) near the Nemaha Ridge in eastern Pawnee County to more than 4,200 feet (1280 m) in southeastern Nemaha County, which is the deepest part of the Forest City Basin in Nebraska.

The primary purposes of this investigation were to acquire, by drilling test holes, subsurface data needed to correlate buried strata with strata that crop out and to gain a better understanding of buried structural features in southeastern Nebraska. The top of the Tarkio Limestone, a formation in the Wabaunsee Group of the Virgil Series of the Pennsylvanian System, was chosen as a datum plane for a structure map because the Tarkio underlies most of the study area at a shallow depth and is easily identified in rock cuttings and cores obtained by

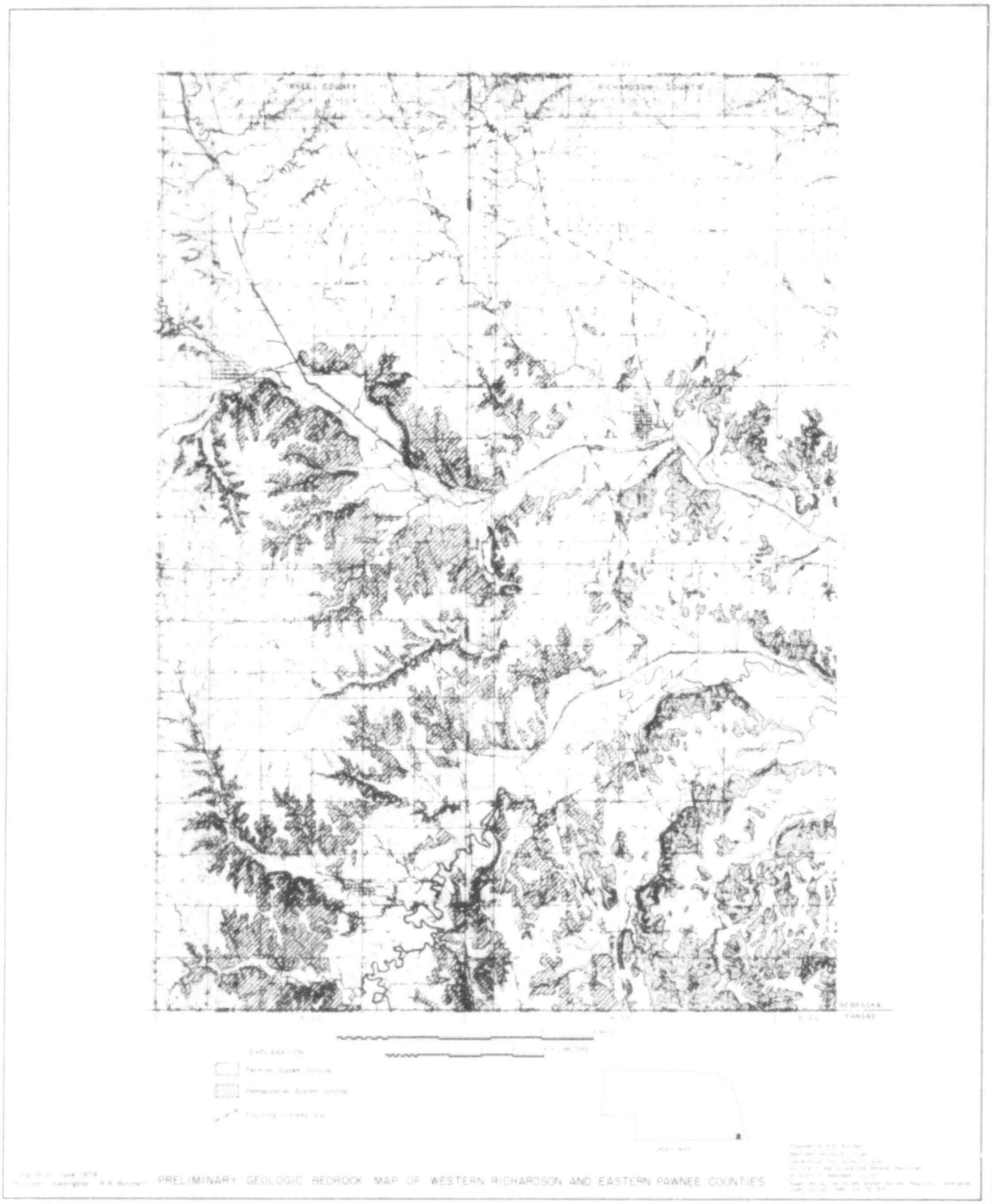
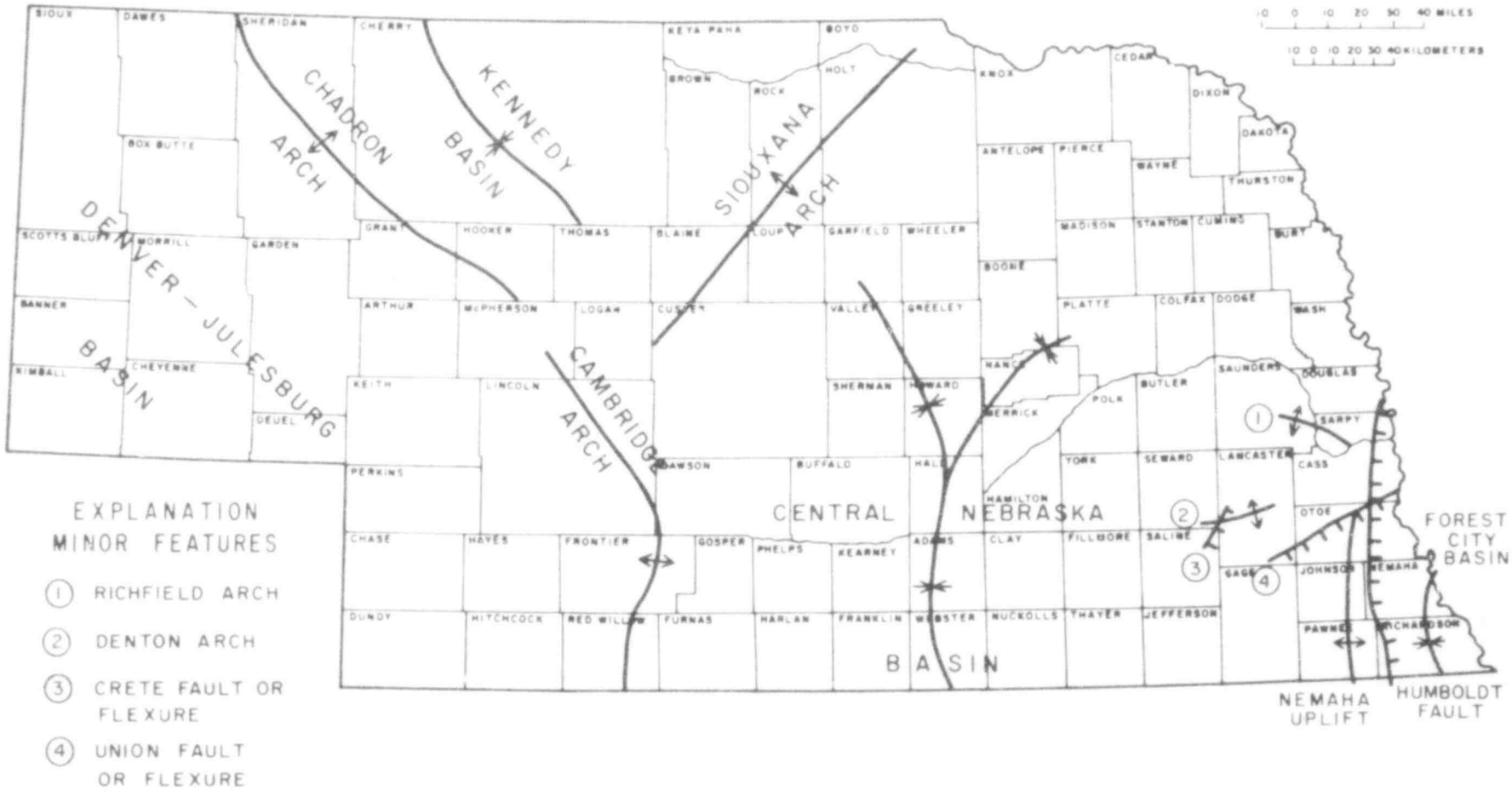


Figure 1



PRINCIPAL STRUCTURAL FEATURES OF NEBRASKA (Carlson, 1970)

Figure 2

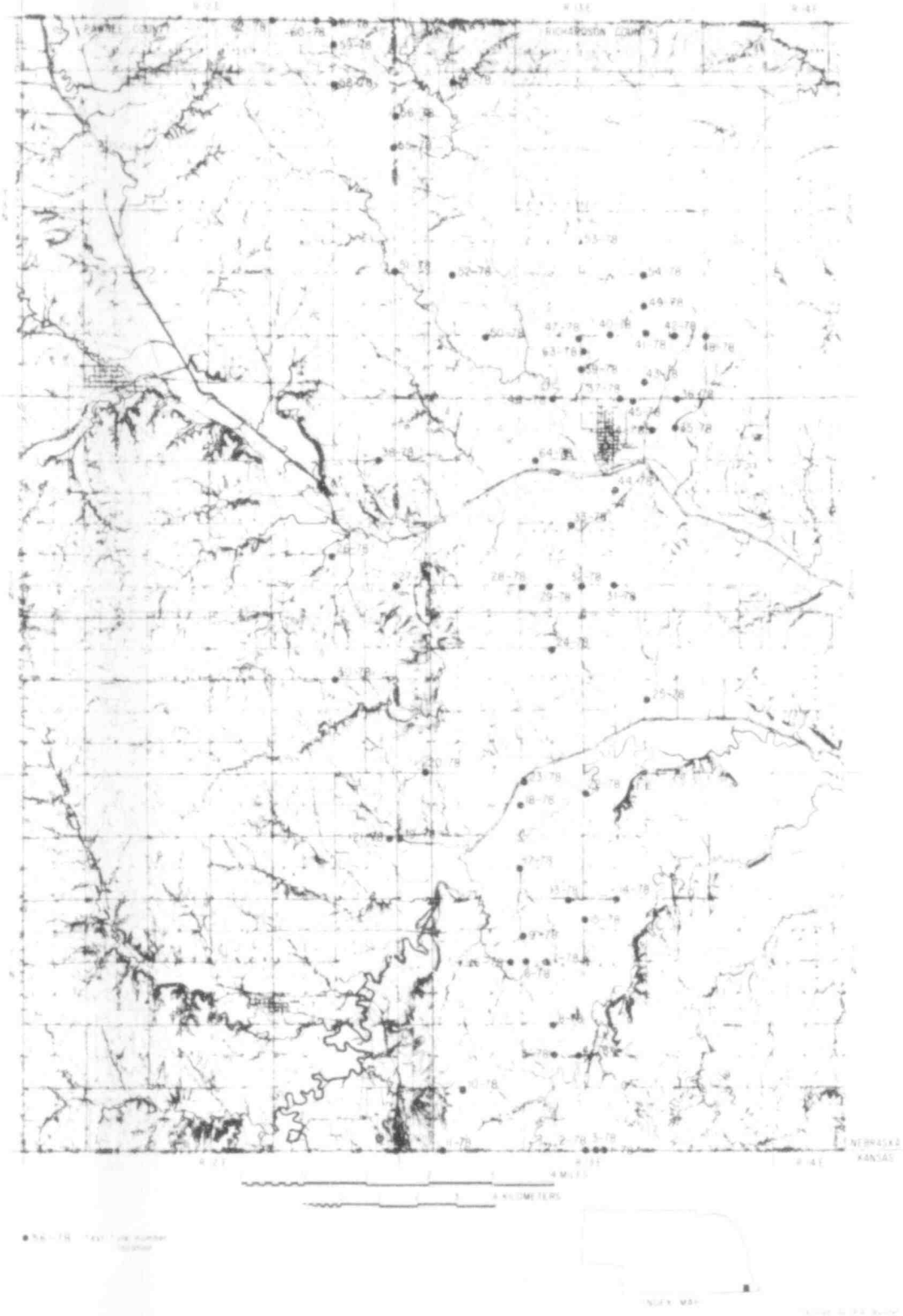
drilling. All available data on the altitude of this surface in outcrops and in test holes were used as control points for contour lines depicting the configuration of the Tarkio's upper surface.

Scope of Investigation

Sixty-four shallow rotary test holes were drilled in western Richardson and eastern Pawnee counties (fig. 3) by the Riescheck Drilling Company of Falls City, Nebraska. The holes averaged about 150 feet (45.5 m) in depth, and each was logged electrically as well as by visual examination of rock cuttings. Some of the holes penetrated the Tarkio Limestone; others were drilled to an identifiable horizon whose height above or depth below the Tarkio is known, which thus provided a Tarkio datum. The holes were drilled in April, May, and June of 1978 under a cooperative agreement between the Conservation and Survey Division (Nebraska Geological Survey) and the Nuclear Regulatory Commission.

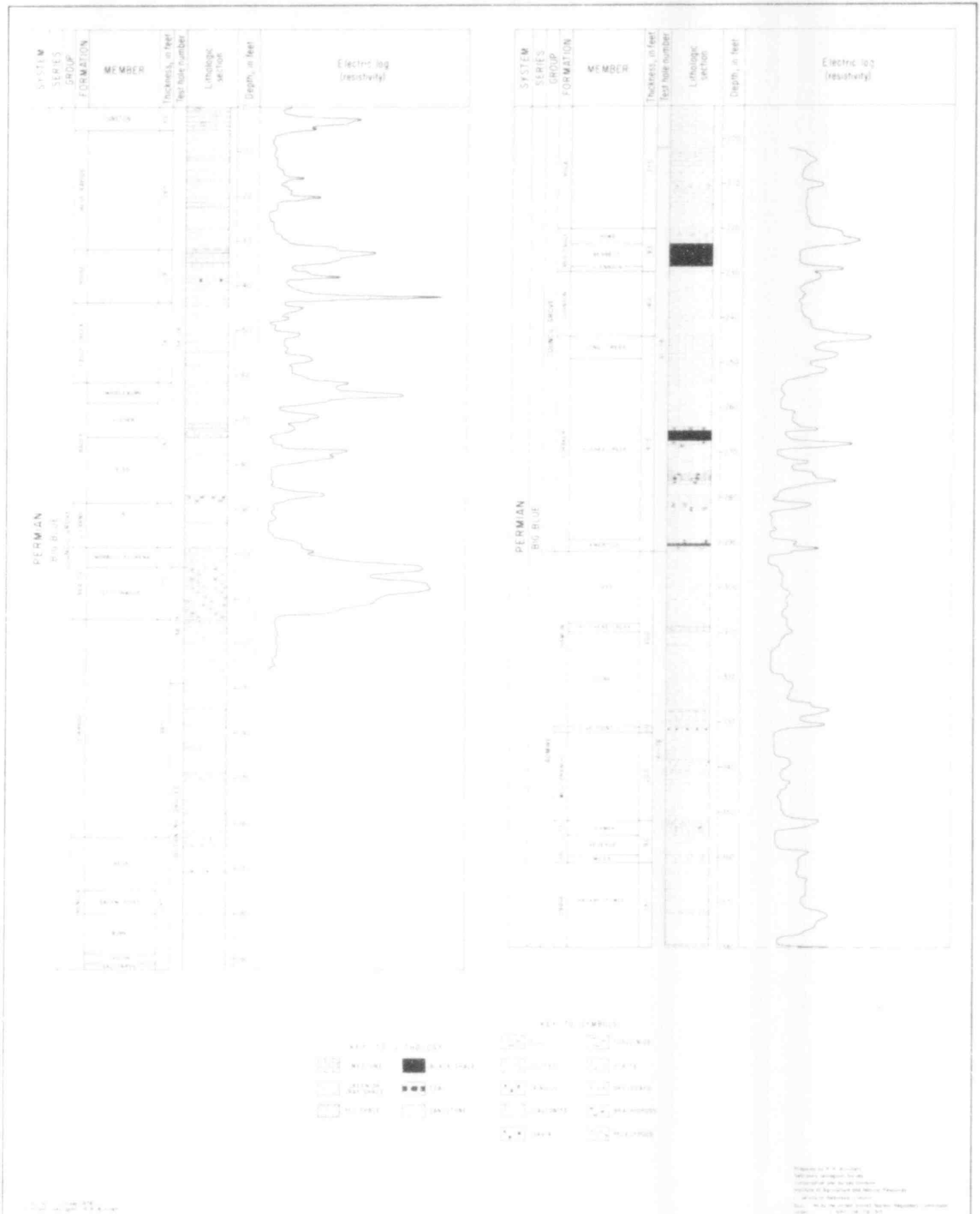
A binocular microscope was used for examination of the cuttings. Logs of the test holes, based on descriptions of the cuttings, are presented in appendix A. Figures 4 and 5 show a composite section of the Lower Permian and Upper Pennsylvanian rocks drilled in the study area, together with a composite electric log of the rocks penetrated.

A careful reexamination of outcrops along the Humboldt Fault Zone provided additional data for mapping purposes. By determining the altitude of many outcrops, the investigators



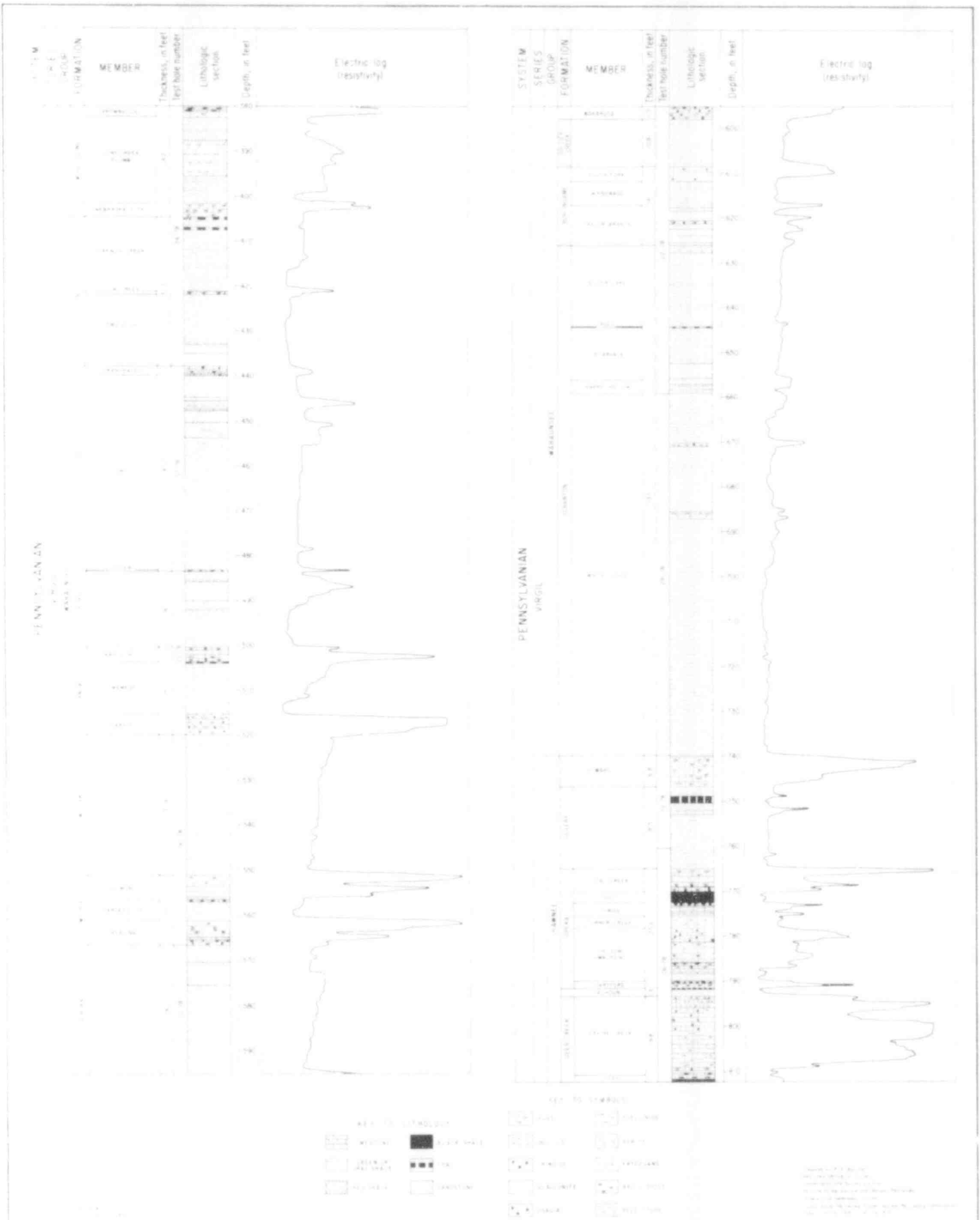
LOCATION OF TEST HOLES IN WESTERN RICHARDSON AND
EASTERN PAWNEE COUNTIES

Figure 3



COMPOSITE SECTION OF LOWER PERMIAN ROCKS IN WESTERN RICHARDSON AND EASTERN PAWNEE COUNTIES

Figure 4



COMPOSITE SECTION OF UPPER PENNSYLVANIAN ROCKS IN WESTERN RICHARDSON AND EASTERN PAWNEE COUNTIES

Figure 5

were able to establish more vertical control points for the structure map. Several structures not previously described became apparent.

Results of Investigation

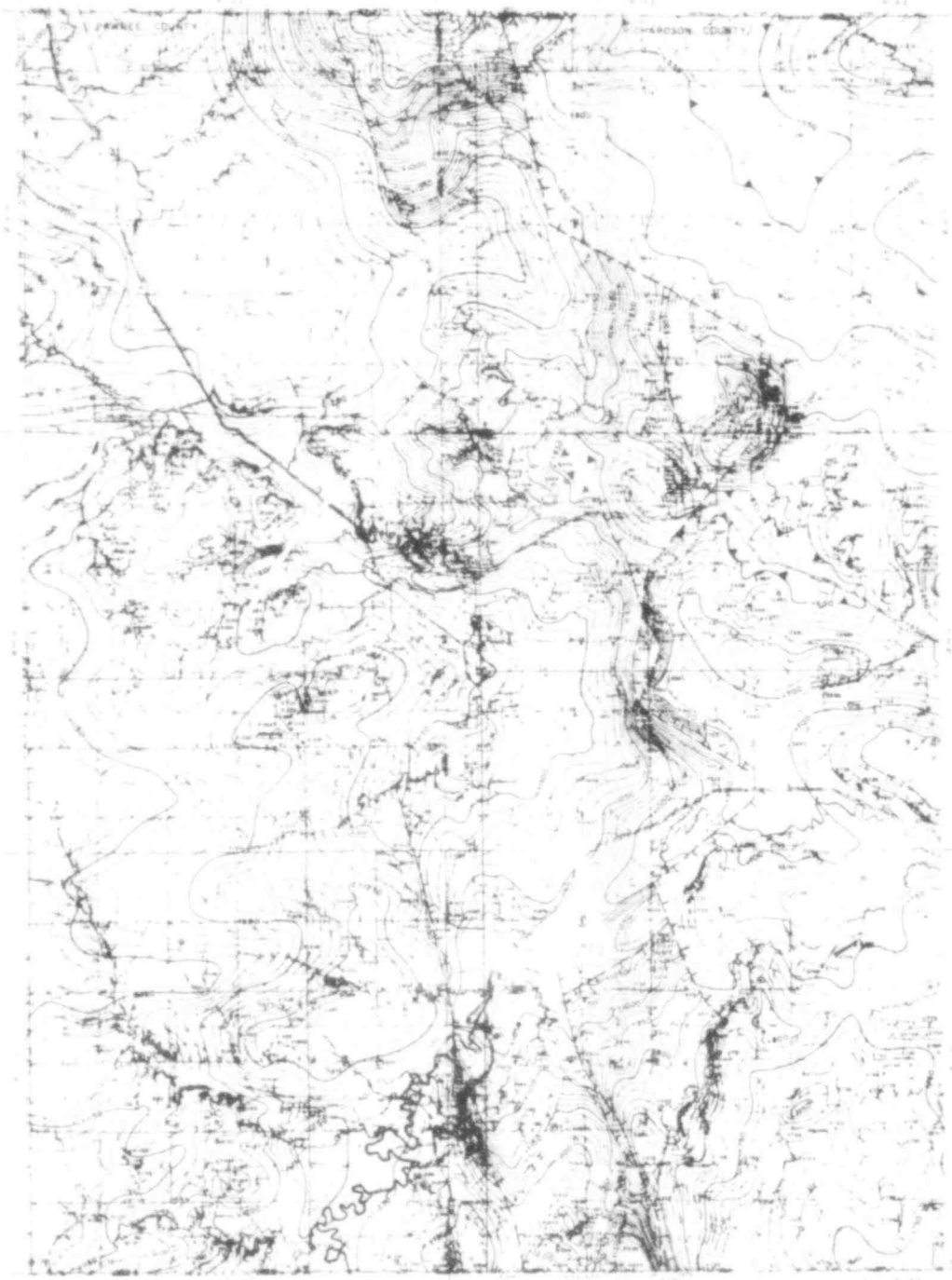
Interpretations of the Tarkio Structure Map (fig. 6) are summarized as follows:

(1) The Humboldt Fault probably is not a single structure, as previously interpreted. Instead, it is a complex zone of faults and steep dips.

(2) In addition to the north-south trending Table Rock Arch, two other major structural trends are evident. One is northwest-southeast and is more strongly developed than the other, which is southwest-northeast. The latter is more prominent north and east of the study area.

(3) The direction and angle of dip exhibited by Pennsylvanian and Permian strata on both sides of the Humboldt Fault Zone differ markedly within very short distances, thus indicating that the structural pattern is highly complex. The greatest dip measured, about 19° NE, was in the SW¼ sec. 34, T. 1 N., R. 13 E., which is adjacent to the state line.

(4) The altitude of the top of the Tarkio Limestone ranges from about 550 feet (168 m) above mean sea level on the downthrown side of the Humboldt Fault Zone in the northeastern part of the study area to about 1,300 feet (395 m) above mean sea level on the upthrown side near the center of the south border of the study area.



STRUCTURAL CONTOUR OF THE TOP OF THE TARKIO LIMESTONE IN WESTERN RICHARDSON AND EASTERN PAWNEE COUNTIES

Figure 6

(5) Faults and/or steep dips in the area probably reflect faulting and steep dips at depth. Deeper structures are indicated by contours drawn on the base of the Hertha Limestone, a formation in the Kansas City Group of the Missouri Series of the Pennsylvanian System (Burchett 1978) and on the surface of Precambrian rocks (Carlson 1967).

(6) Anticlines of low relief in the Tarkio Limestone reflect similar structures having steeper flanks and more closure at depth. In Richardson County, oil is or has been produced from anticlines in Devonian and older rocks. The abandoned Snethen Oil Field in sec. 29 and 30, T. 2 N., R. 14 E., was developed in one of these anticlines.

(7) The only fault actually observed in an outcrop within the study area is in the Cottonwood Limestone Member of the Beattie Limestone in the Council Grove Group of the Permian System. Located in the SW¼ sec. 36, T. 3 N., R. 13 E., this fault has a throw of 7.5 feet (2.29 m). The throw along the Humboldt Fault Zone about 0.5 mile (0.80 km) to the west is estimated to be about 50 feet (15.2 m).

(8) Displacements along the faults not observable in outcrops but indicated in figure 6 are interpretive for the following reasons: Thick glacial deposits mantle the bedrock throughout most of the study area; outcrops are of small areal extent and consist of strata so similar that their correlation is difficult; most individual faults appear

to be of short length; and the distance between outcrops and test holes available for interpretation ranges from 0.1 (0.161 km) to 1 mile (1.61 km). Whether faulting or folding has taken place generally cannot be determined. The greatest interpreted throw of the Tarkio Limestone, about 410 feet (125 m), is in sec. 17, T. 3 N., R. 13 E. A single fault is presupposed but cannot be demonstrated because its location is covered by alluvium and glacial deposits.

(9) The Humboldt Fault Zone has a significant effect on the mineral resources and groundwater supplies of the area. For 75 years the thicker limestone units of Permian age have been quarried in many places along and near the fault zone. Fractures in the bedrock, associated with the fault zone, serve as reservoirs for water.

(10) Microearthquakes recently recorded in Kansas and Nebraska indicate that the Humboldt Fault Zone is still active. Past earthquakes of greater magnitude also may have been associated with movements in the same fault zone.

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RELATION OF EARTHQUAKE EPICENTERS TO GLACIATION

by
R. R. Burchett

The theory that the earth's crust rebounds when the weight of glacial ice is relieved and the effect on seismicity has been debated for many years. In several parts of the world, studies have shown that glacial unloading has an effect on the earth's crust with the rate of uplift and seismic activity usually reaching its peak about the time of deglaciation. The possibility that earthquake epicenters in Nebraska and elsewhere in the Midcontinent may correlate with some aspect of glaciation merits consideration.

Figure 7 shows the distribution and thickness of glacial deposits in eastern Nebraska. Also shown are the locations of documented earthquake epicenters within and near the area overridden by glaciers. Dreeszen (1970, p. 14) wrote about the extent and thickness of Nebraska's glacial deposits as follows:

". . . . The maximum thickness of combined tills is slightly more than 300 feet [91.4 m] and is attained only in northeastern Nebraska. The thickness of combined tills in those areas of till occurrence on the rest of the map is generally less than 50 feet [15.2 m]. However, the same number of tills (often two or three as distinguished by soils, weathered horizons, pebble counts, or intermediate beds) is found in each of the thicker and thinner areas of till occurrence.

The present distribution and thickness of the tills are an

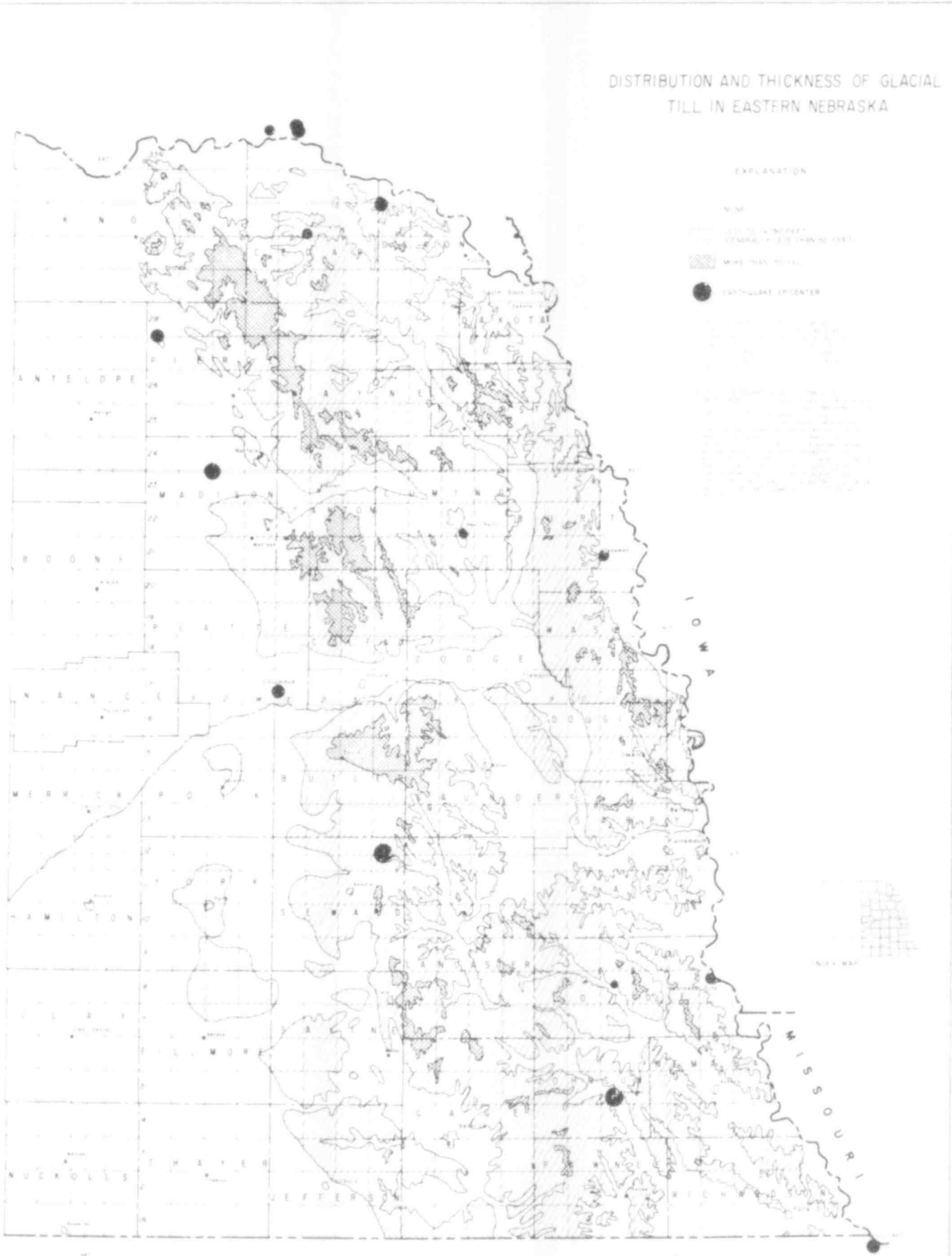
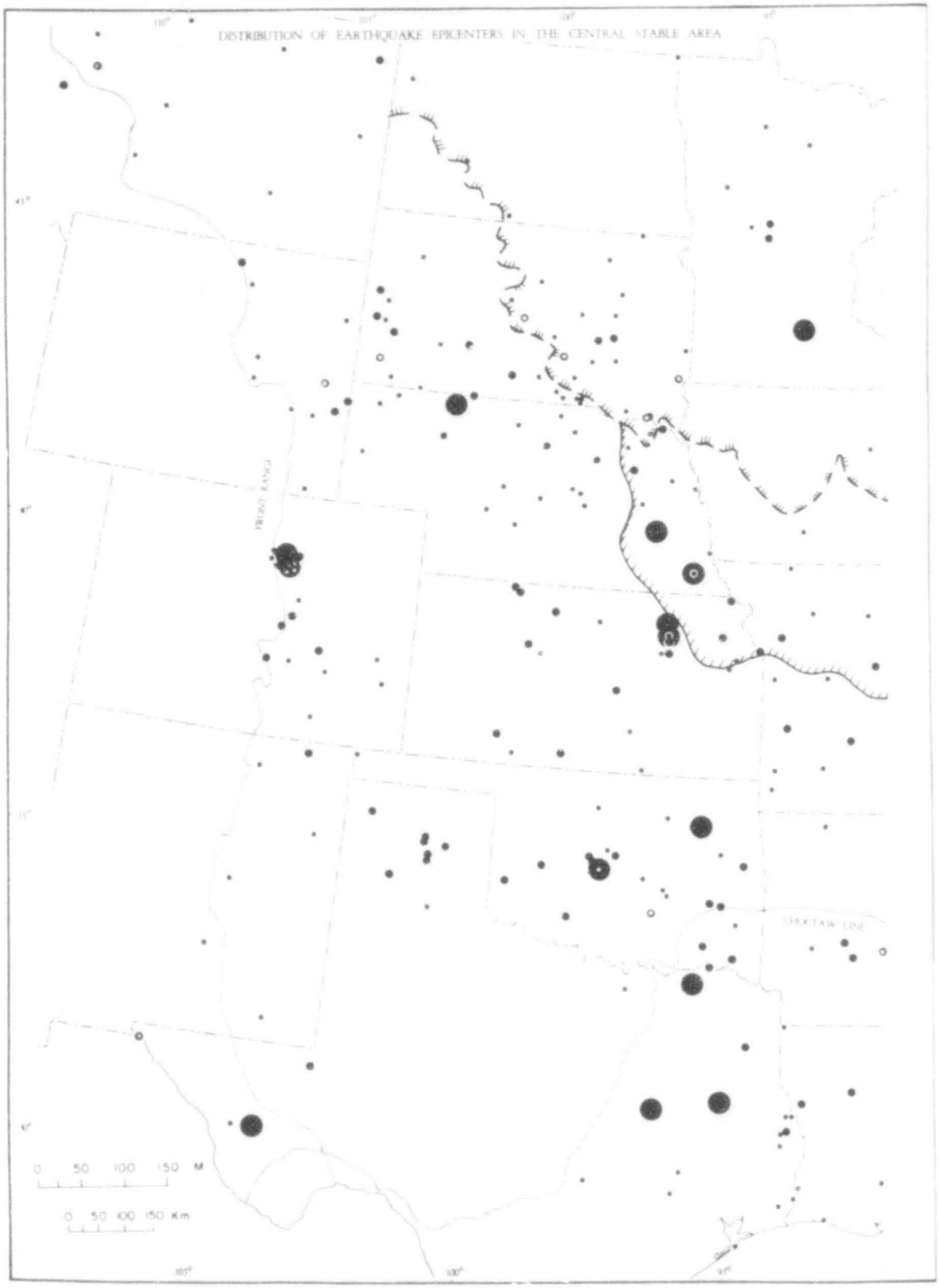


Figure 7

expression of extent of glacial advance, configuration of the surface overridden by the ice, original till thickness, and glacial, nonglacial, and post-glacial erosion. In parts of the area of thick tills, a single till with a thickness of more than 100 feet [30.5 m] fills preexisting valleys. The Nickerson Till of Kansan age is thin and occurs as outliers along the western margin of the glaciated area as the result of erosion by streams diverted southward by ice of later advances. Surely this route must have been followed by the Missouri River in Kansas time and much of Illinoian time. The Cedar Bluffs moraine-divide has been breached and till removed by headward erosion and capture of the Platte River in the central part of the area. The history of the development of the drainage system in the glaciated region of eastern Nebraska and adjacent areas is not known in detail. Preliminary analysis suggests that each of the major modern streams follows paths connecting segments of older drainages. Regional and local structure influenced the direction and extent of the earliest ice flows. Later stream patterns were re-established and controlled by divide ridges believed to be an expression of lateral and marginal moraines. Continental ice flow of the later episodes was controlled to some extent by the then existing drainage pattern. Although segments of the modern streams and some of the features of their valleys are inherited from pre-Pleistocene and later Pleistocene morphological features, the streams and their valleys are essentially Wisconsinan in age."

A viewer's first impression of figure 7 might be that earthquakes in eastern Nebraska are residual seismic activity related to either glacial retreat or weight of glacial deposits. However, a different impression of the relation of seismic activity to glaciation is gained from figure 8, which shows the limits of pre-Wisconsinan and Wisconsinan glaciations superimposed on a map (Docekal, 1970, fig. 1-A) showing the location of all recorded earthquakes in the so-called Central Stable Area of the United States. With regard to the limits of glaciation, the epicenters appear to be randomly distributed. Those within the glaciated area are no more densely or widely spaced than those outside. Furthermore, large parts of the glaciated area (northern Iowa, southwestern Minnesota, and much of North Dakota) contain no epicenters whereas some parts contain several closely spaced ones. Certainly no strong case can be made for correlating recorded seismic activity in eastern Nebraska with crustal rebound. Evidence for stream privacy having been a factor in the development of surface drainage systems in eastern Nebraska indicates strongly that post-glacial crustal adjustments occurred, but whether any earthquakes were caused by those adjustments is an unresolvable question.



Modified from Docekal (1970) and the Glacial Map of the United States (1959)

Approximate limit of Wisconsinan glaciations

Approximate limit of Pre-Wisconsinan glaciations

Earthquake epicenters

Tectonic boundary

Figure 8

References

Dreeszen, V. H., 1970, The stratigraphic framework of Pleistocene glacial and periglacial deposits in the Central Plains in Pleistocene and Recent Environments of the Central Great Plains: Univ. of Kansas, Geol. Dept. Spec. Pub. 3, pp. 9-22.

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SEISMOLOGICAL STUDIES

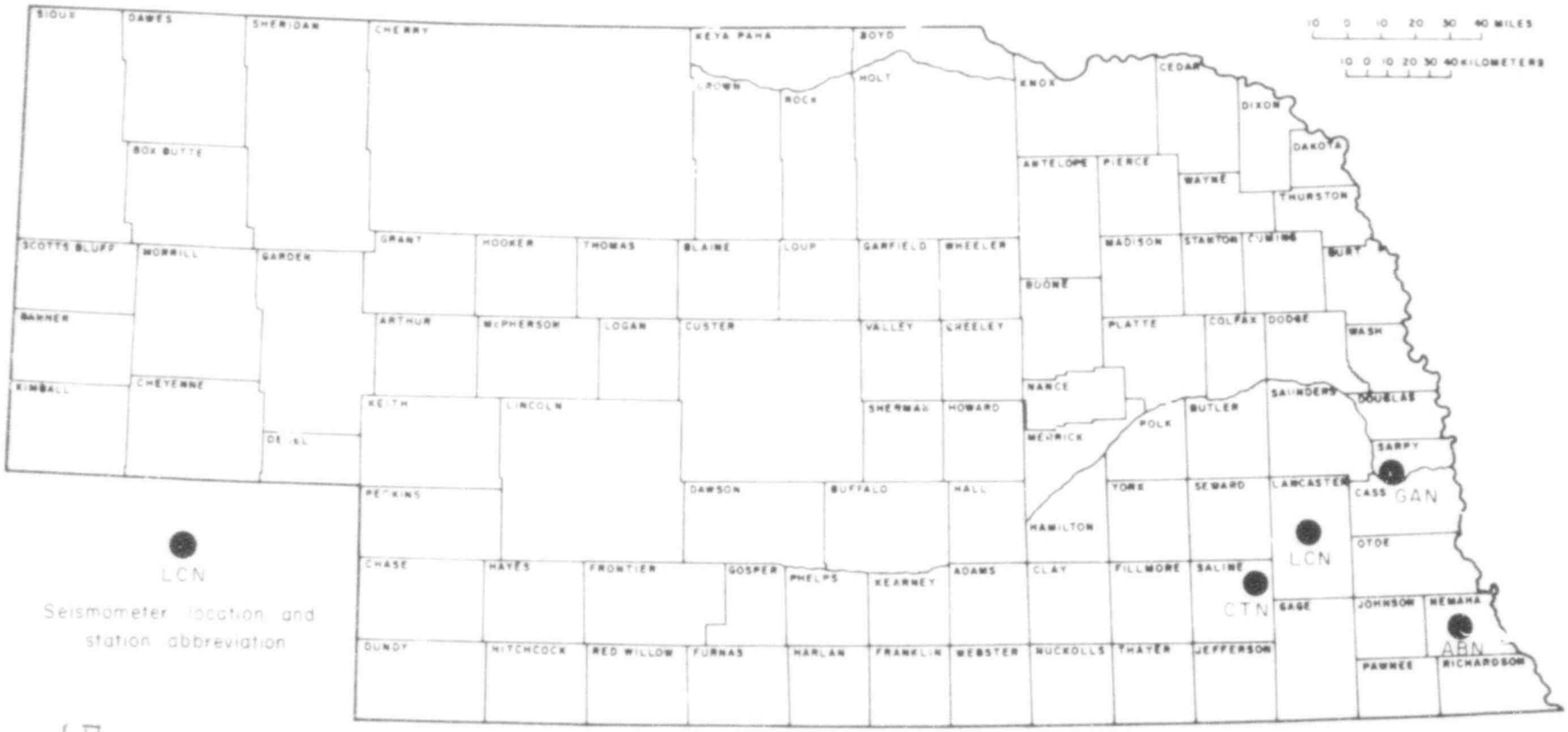
by
R. R. Burchett

The Conservation and Survey Division (Nebraska Geological Survey) and Dr. Russell Smith and Dr. John Clough of the Geology Department of Nebraska-Lincoln collaborated in the installation of three portable microearthquake stations in Nebraska during contract year 1977-78. All seismographic records are sent to the University of Nebraska-Lincoln for preliminary analysis and then are forwarded to the Kansas and Oklahoma Geological Surveys for more detailed analysis.

The approximate locations of the three new seismographs, also of the Lincoln (LCN) seismograph installed in spring 1977, are shown in figure 9. Together with seismographs in the adjacent part of Kansas, these seismographs provide continuous overlapping coverage of seismic activity along the buried Nemaha Ridge. Precise locations and other pertinent information about the three new seismographs are given below:

Site designation CTN. Location: SE NW NW sec. 35, T. 8 N., R. 4 E.; lat 40°37'20" N., long 96°56'54" W.; on Doane College campus at Crete in Saline County, Nebr. Instrument altitude: 1,415 ft (431 m) msl datum. Operation begun Nov. 15, 1977.

Site designation ABN. Location: NW NE NW sec. 21, T. 5 N. R. 14 E.; lat 40°23'28" N.; long 95°51'02" W.; on Auburn High School campus at Auburn in Nemaha County,



SEISMOMETER LOCATIONS AS OF JUNE 1, 1978

Figure 9

Nebr. Instrument altitude: 965 ft (294 m) msl datum. Operation begun Nov. 18, 1977.

Site designation GAN. Location: SW NE NE SW sec. 12, T. 12 N., R. 10 E.; lat 41°01'17" N., long 96°14'47" W.; in Schramm State Park Near Gretna in Sarpy County, Nebr. Instrument altitude: 1,098.5 ft (335 m) msl datum. Operation begun Dec. 16, 1977.

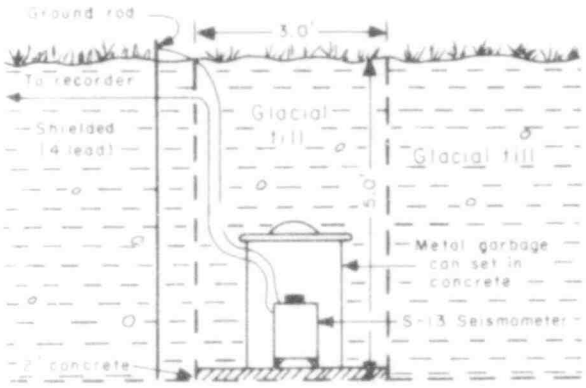
Additional details about the three seismometer installations are shown graphically in figure 10.

Equipment at each location consists of the following:

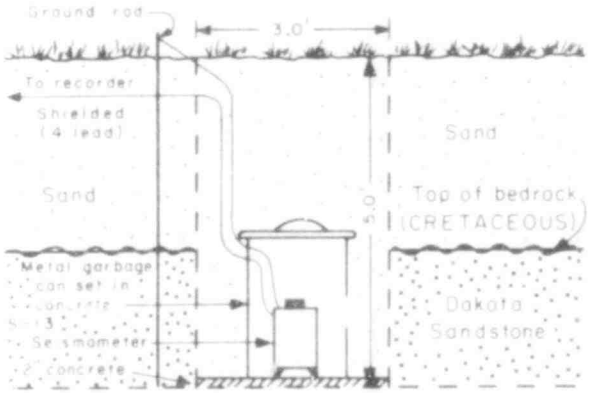
1. Seismometer: Geotech model S-13 with a 629 volt-sec/m generator constant and a natural frequency adjustable to a low of 0.75 Hz.
2. Amplifier-filter-recorder-clock system: Geotech Portacorder model RV-320.
3. Time-signal radio receiver: High-frequency WWV time cubes purchased from Radio Shack to provide and audio time to the observer.

Each station is operated by a volunteer who agreed to (1) permit installation of a seismometer vault on his property, (2) provide housing for the amplifier-filter-recorder-clock system and the WWV time-signal radio receiver, and (3) change the seismograph recorder charts, replenish the ink supply, and reset the clock whenever necessary on a 365-day-per-year basis.

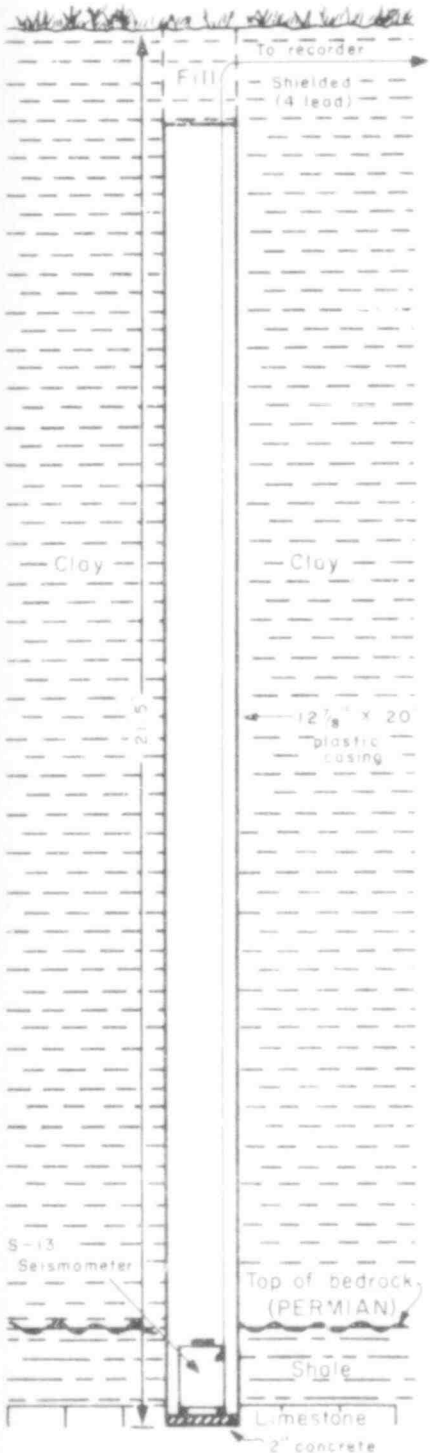
One earthquake in the vicinity of the buried Nemaha Ridge was recorded on January 12, 1978. Its epicenter was near the



Crete, Nebraska



Near Gretna, Nebraska



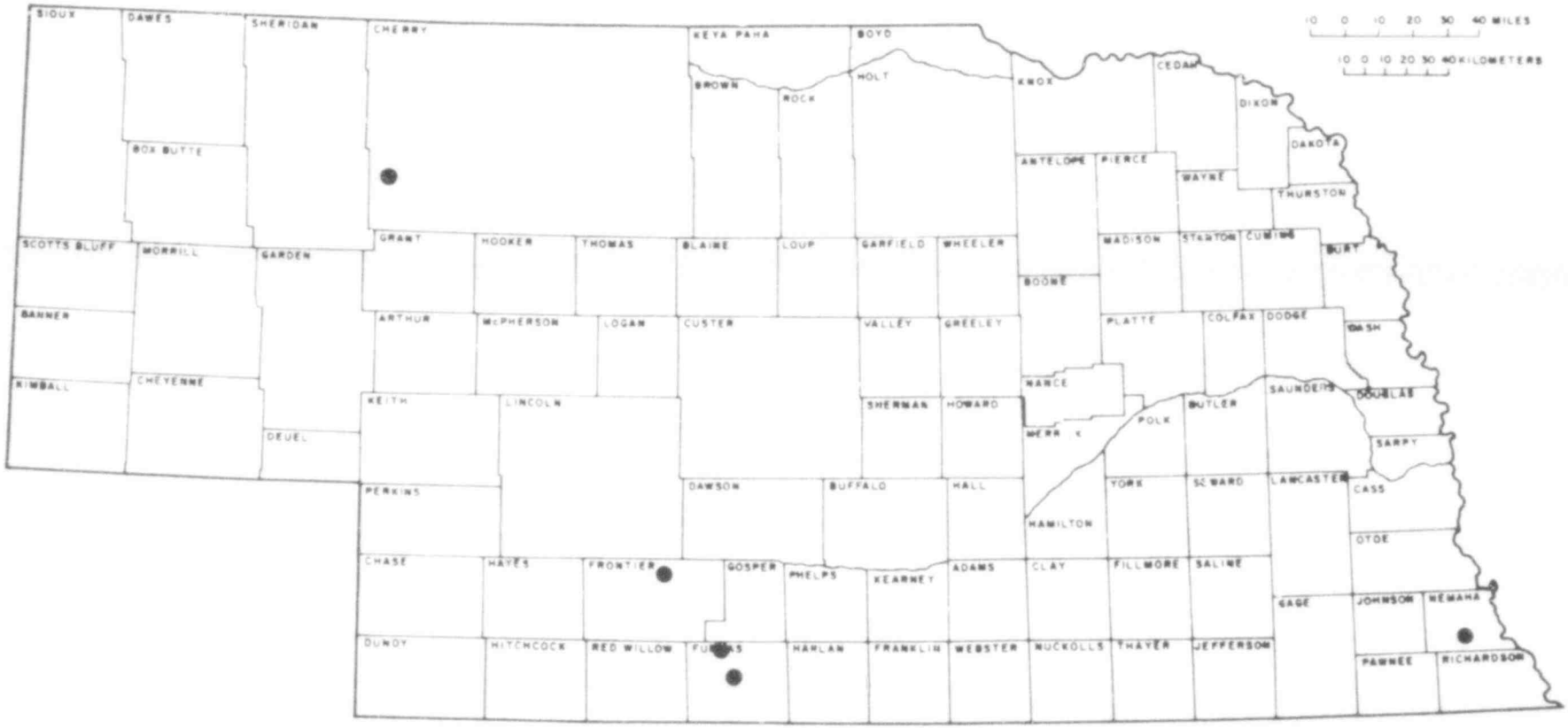
Auburn, Nebraska

SEISMOMETER INSTALLATIONS AT CRETE, AUBURN, AND NEAR GRETNA, NEBRASKA

Figure 10

community of Howe in south-central Nemaha County (fig. 11). Data on that earthquake and on four others that occurred along the Chadron-Cambridge Arch in Nebraska during the period December 1, 1977, to October 1, 1978, are given in table 1.

The largest of the five earthquakes was the one having its epicenter in southwestern Cherry County. It had a magnitude of 4.0 M_{blg} and affected parts of Cherry, Sheridan, Garden, Grant, Arthur, Keith, and Perkins Counties. Locations where the quake was felt and the intensities of the quake according to the modified Mercalli scale are indicated in figure 12. Although the maximum intensity on that scale was V, no major damage was reported.



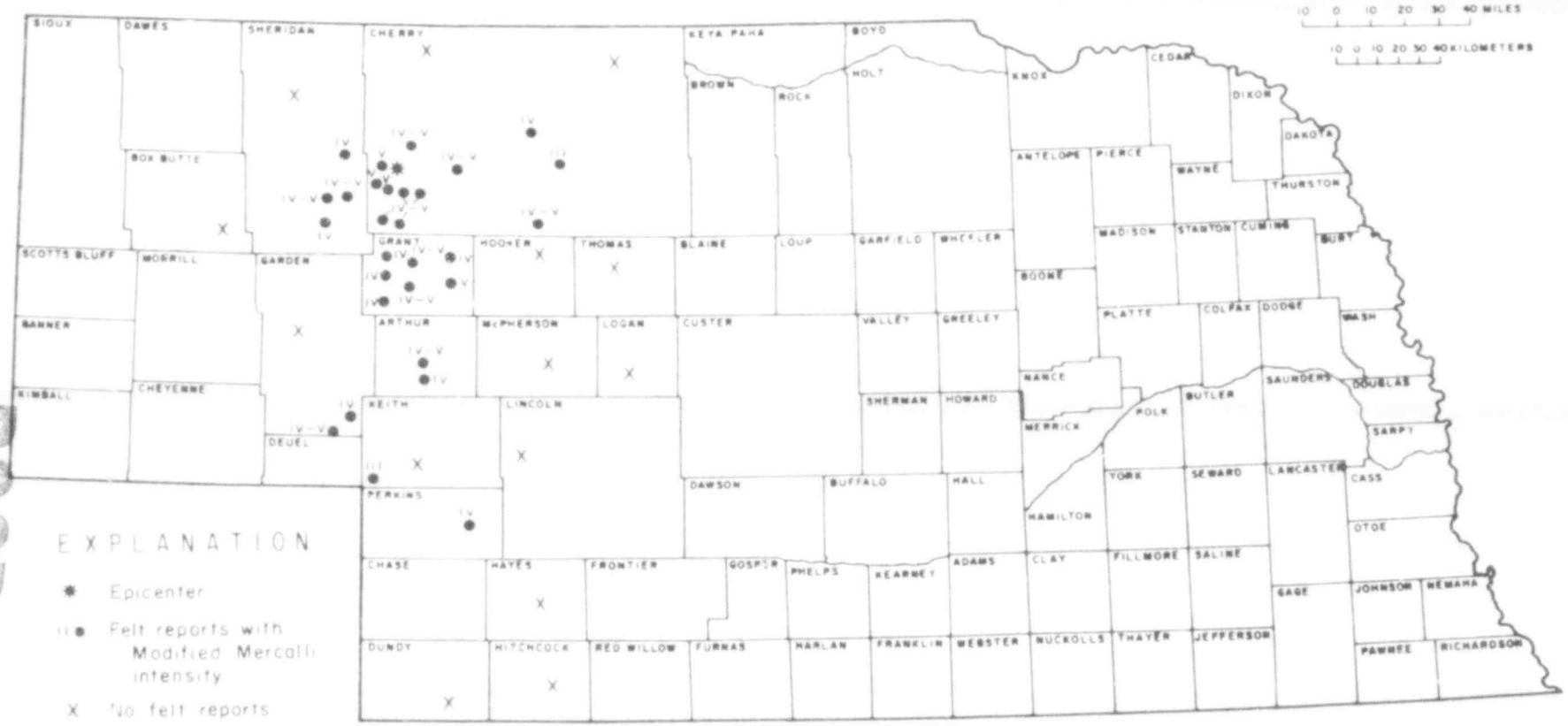
EPICENTERS OF EARTHQUAKES IN NEBRASKA BETWEEN DECEMBER 1, 1977 and October 1, 1978

Figure 11

Table 1. Earthquakes occurring in Nebraska from December 1, 1977, to October 1, 1978.

[Source: A, J. E. Lawson, Oklahoma Geophysical Observatory, personal communication; B, D. W. Steeples, Kansas Geological Survey, personal communication; C, National Earthquake Information Service.]

Date	Origin time (UTC)	Locality	Latitude	Longitude	Magnitude	Source
1 Dec. 1977	13:04:40.20	Furnas Co.	40.322N	99.941W	2.33 M_{blg}	A
1 Dec. 1977	13:22:45.38	Furnas Co.	40.225N	99.893W	2.66 M_{blg}	A
12 Jan. 1978	20:15:28.0	Howe	40.3N	95.8W	1.4 $\pm$0.3 M_{blg}	B
7 May 1978	16:06	SW Cherry Co.	42.34N	101.93W	4.0 M_{blg}	C
14 Sept. 1978	08:06	Frontier Co.	40.666N	100.283W	2.8 M_l	B



AREA AFFECTED BY THE MAY 7, 1978 EARTHQUAKE (INTENSITY V MM)

Figure 12

A DETAILED GEOPHYSICAL INVESTIGATION OF WESTERN RICHARDSON AND EASTERN PAWNEE COUNTIES IN SOUTHEASTERN NEBRASKA

by
D. G. Maroney and R. R. Burchett

The purpose of this investigation was to interpret geophysical data relating to the composition and structure of Precambrian and Paleozoic rocks associated with the Nemaha Ridge in western Richardson and eastern Pawnee counties, Nebraska (fig. 13). The geologic significance of that area, herein referred to as the site specific area, is described with reference to the seismicity and tectonics of the regional study area, which consists of the southeastern part of Nebraska.

Major structural features in the site specific area are parts of the Nemaha Ridge, the Humboldt Fault, and the Forest City Basin (Carlson, 1970). Two other structural features in and near the area have been postulated by Lidiak (1972) on his Precambrian lithologic map of Nebraska. Based on aeromagnetic data presented by King and Zeitz (1971) and drill-hole data in open files of the Conservation and Survey Division, University of Nebraska, these two features are grabens, one trending northwest-southeast across Pawnee and Richardson counties and the other trending northeast-southwest across Pawnee, Johnson, and Nemaha counties. Lidiak indicated also that cataclasis is common in Precambrian rocks in southeastern Nebraska. Although he did not have sufficient data to relate the cataclasis to

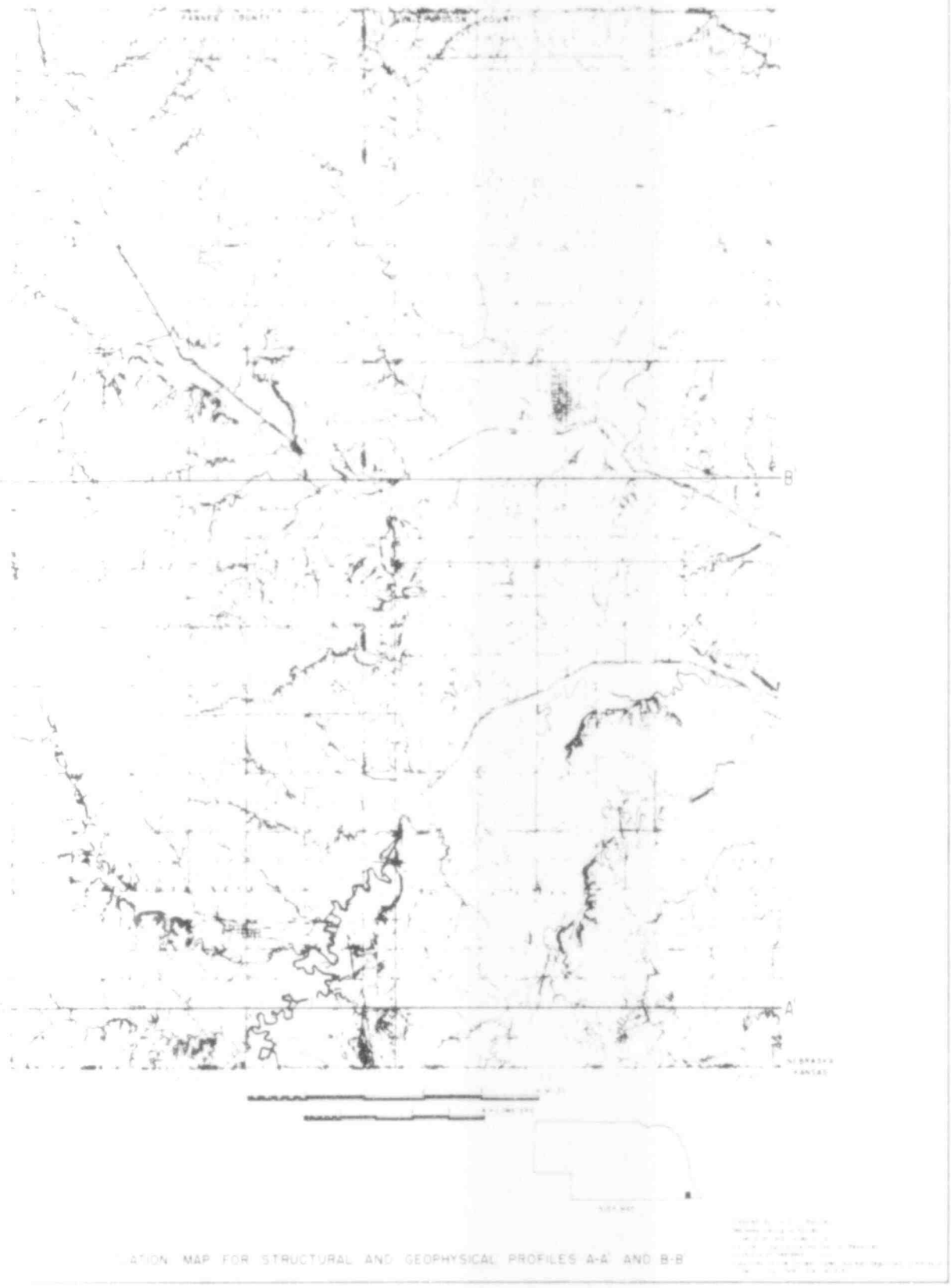


Figure 13

structural trends, he conjectured that it might be related to faulting along the Nemaha Ridge or to left lateral offset of the Midcontinent anomaly.

FIELD OPERATIONS AND DATA PROCESSING

Gravity Survey

Gravimetric surveying is a geophysical technique that aids interpretation of subsurface geologic structure. Used in this type of surveying is a very sensitive weighing device, a Worden Master, which measures differences in gravity intensity (acceleration) at specific points on the earth's surface. The principal causes of gravity anomalies generally are either the dissimilar compositions of crystalline basement rocks and overlying sedimentary rocks or density contrasts produced by vertical or horizontal displacements of rocks. However, other phenomena also can contribute to differences in gravity intensity and in combination with the principal causes can make gravity data somewhat ambiguous.

All gravity base stations in the Nebraska Gravity Network are tied to the National Gravity Network base station located at the Lincoln Municipal Airport. Gravity stations established during this study were located at section corners and half-mile section lines. Land-surface altitudes at most stations could be determined directly from 7.5-minute topographic quadrangles. For other stations, land-surface altitudes were estimated from topographic contours and are accurate within ±2 feet.

Field gravity data were corrected for latitude, meter drift

and elevation; earth tides were not considered. The maximum error in station altitudes was enough to produce variations of ±0.2 milligal. Slight inaccuracies in station locations--none greater than 0.1 minute of latitude--could have produced errors of no more than ±0.08 milligal. A ±0.02 milligal error was possible from either tidal or instrumental sources. Therefore, the maximum possible was ±0.3 milligal but generally was much less because some errors were compensatory.

Bouguer values were calculated from assumed computational density values of 2.5, 2.6, and 2.67 gm/cm^3. The average density value of 2.69 gm/cm^3 obtained by Muehlberger and others (1964) for two samples of Precambrian crystalline rocks indicated that 2.67 gm/cm^3 would be the most realistic Bouguer computational density value. Tests by the Nebraska Department of Roads yielded mean densities of 2.51 and 2.34 gm/cm^3 for Pennsylvanian and Permian rocks, respectively, in the site specific study area. These three densities were used to compute the effects of observed gravity versus theoretical gravity for anomaly interpretation.

In the site specific study area more than 800 gravity stations were used to produce computer-contoured and hand-contoured Bouguer gravity maps (figs. 14 and 15). In addition more than 1400 gravity stations were occupied in Cass, Sarpy, and Douglas counties (fig. 16). The data collected at these stations were integrated with previously collected data to generate a comprehensive regional Bouguer gravity map of southeastern Nebraska (fig. 17).

BOUGUER GRAVITY OF WESTERN RICHARDSON AND EASTERN PAWNEE COUNTIES

Figure 14

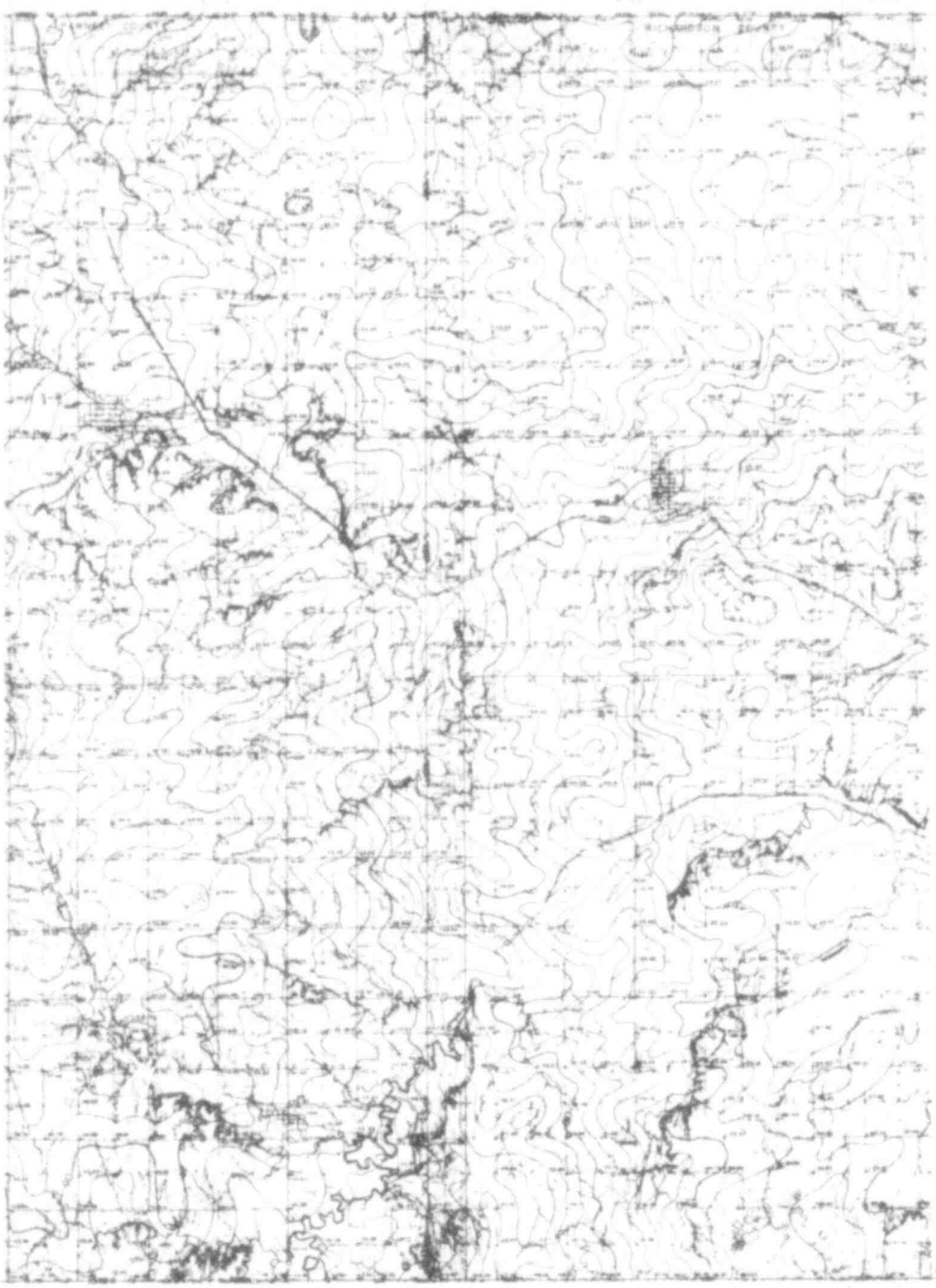


Figure 15

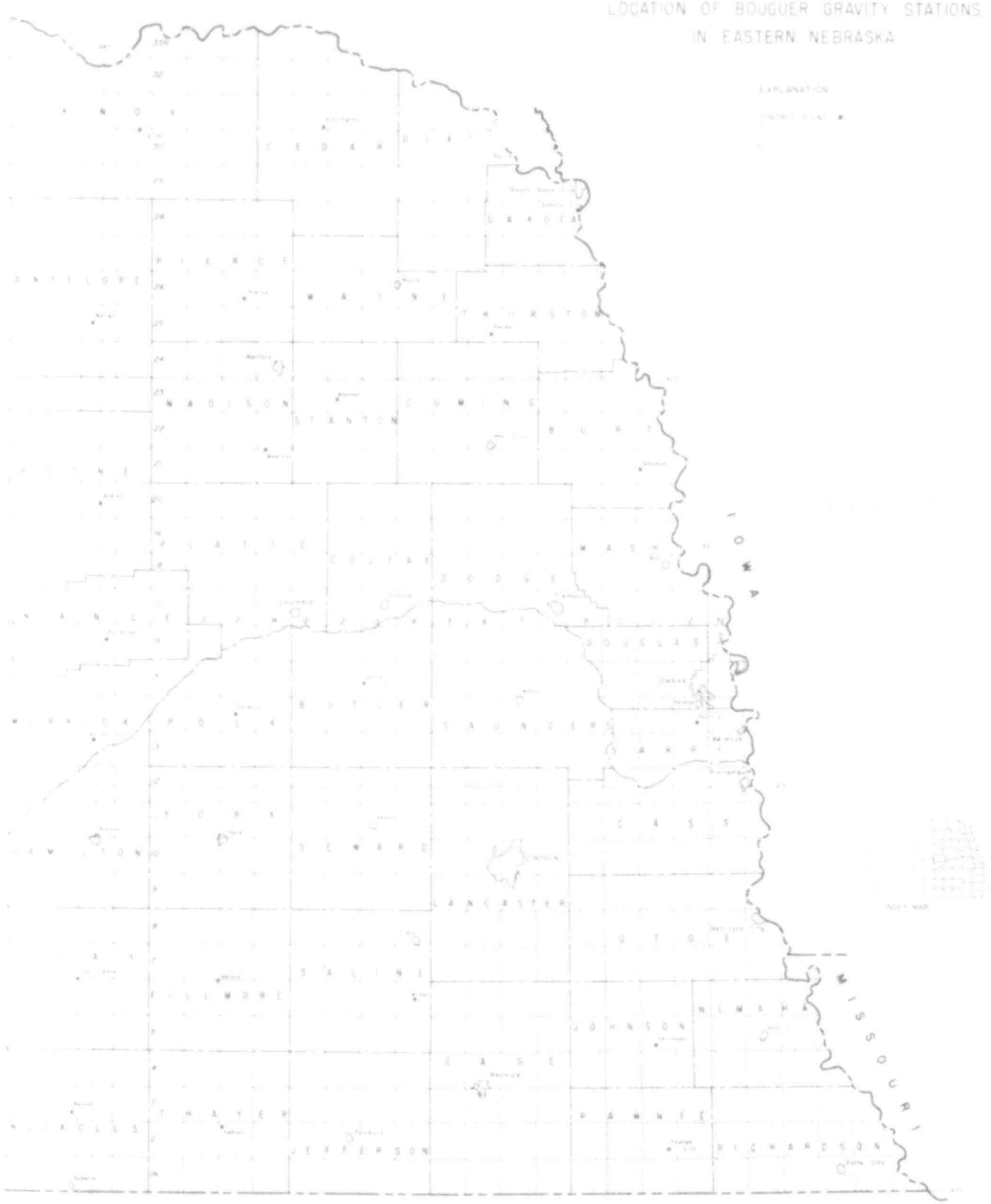


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Figure 16

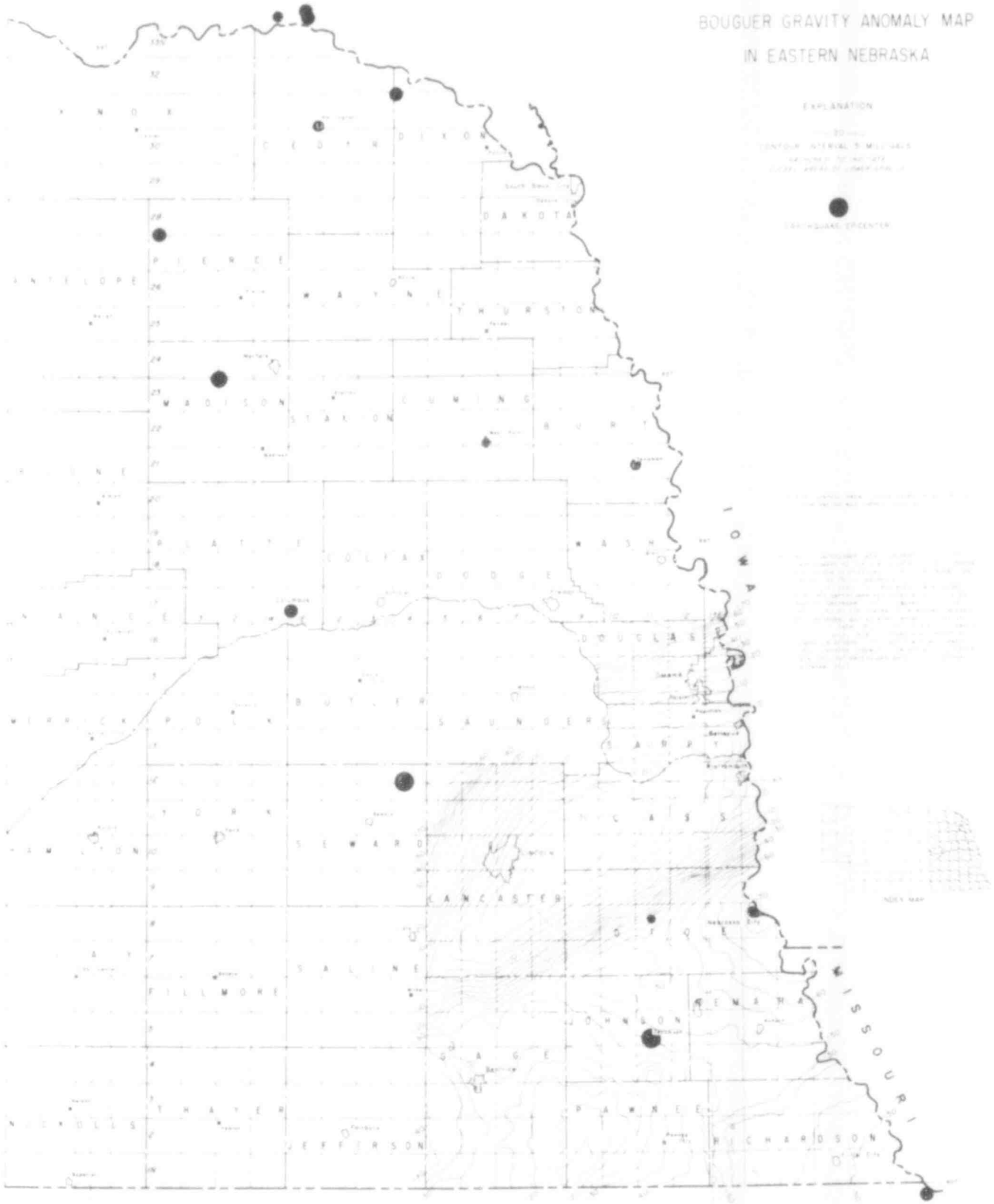

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Figure 17

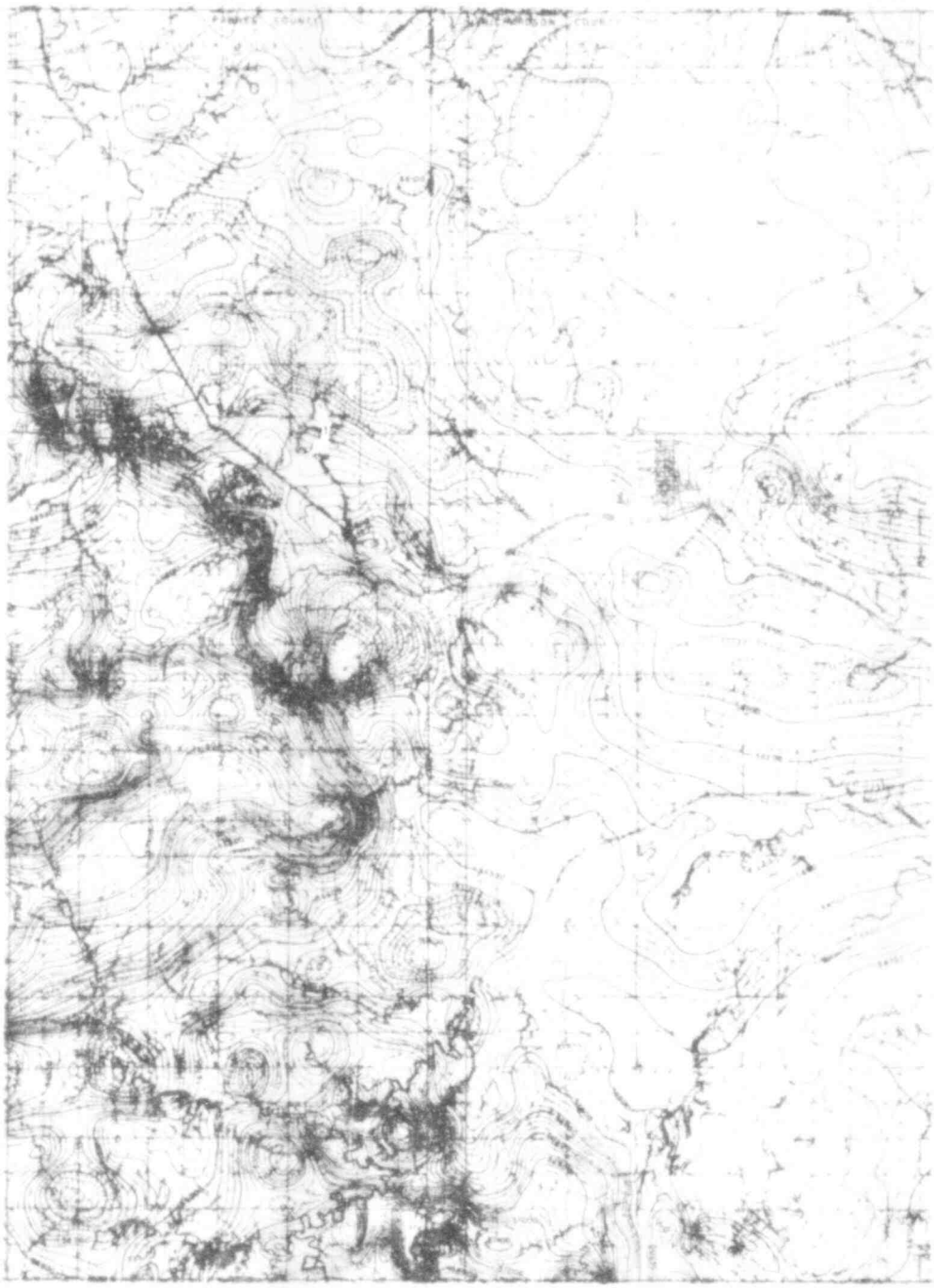
Ground Magnetic Survey

The instrument used in the ground magnetic survey was a Geometrics[R] 826 Proton Magnetometer. This instrument measures the total magnetic field with an accuracy of ±1 gamma. Magnetic anomalies are produced by differences in the degree of rock magnetization (polarization). Although, to a large extent, magnetic intensity is related directly to the percentage of the mineral magnetite in rocks, depth to the magnetic source rocks is another variable that affects the measurements.

During field operations a few more than 800 magnetic stations were established at 0.5- and 0.25-mile spacings. Sites selected as magnetic stations were well-removed from artificial magnetic sources such as fences, power lines, and pipelines. Corrections for diurnal magnetic drift were made by making observations at a base station at 3-hour intervals and then using those observations to correct, by linear interpolation, the readings made at field stations between base stations. No corrections were made for latitude. The final magnetic intensity data were contoured by computer and by hand (figs. 18 and 19).

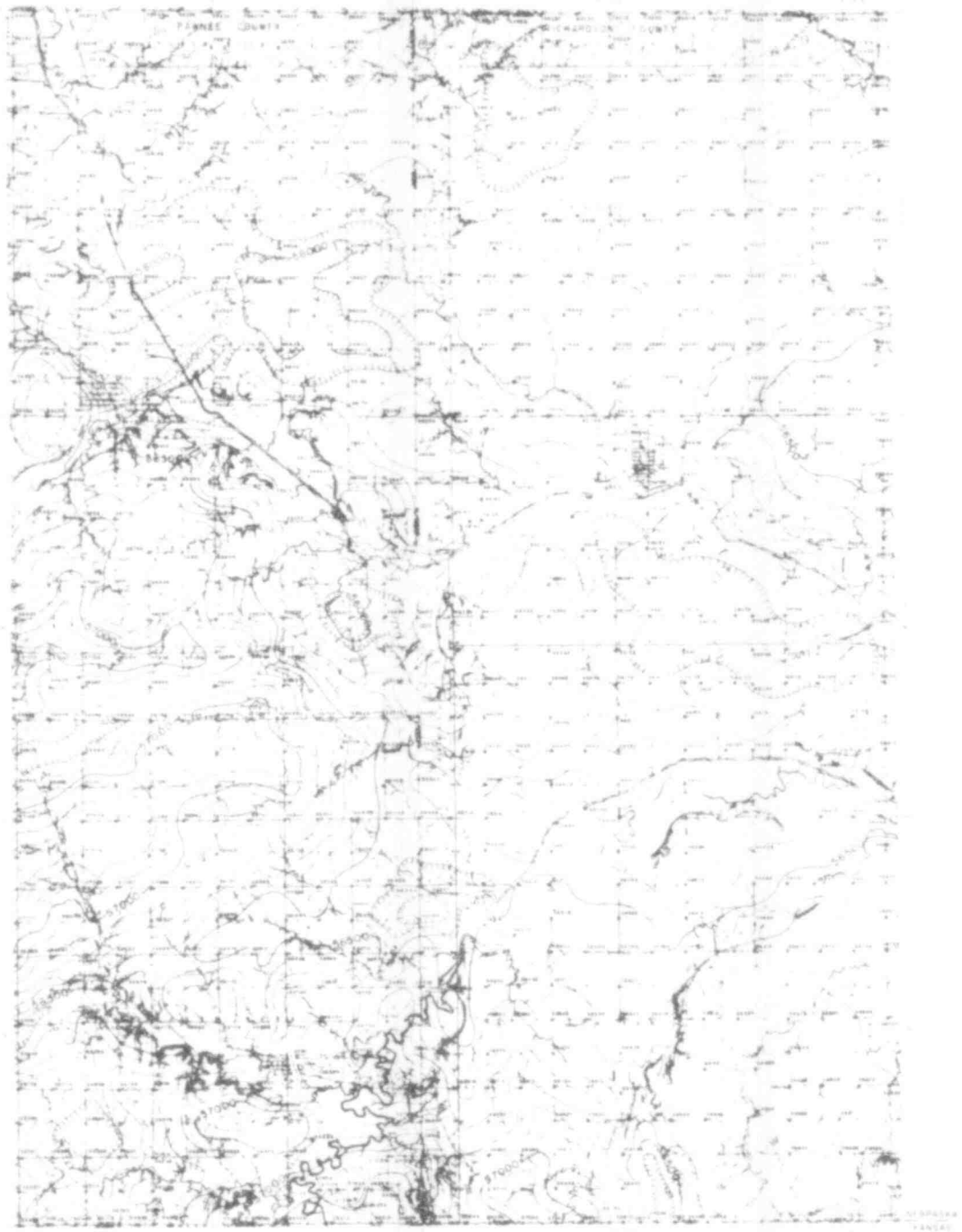
In order to identify potential sources of observed magnetic anomalies, values of magnetic susceptibility were obtained for several rock types in the study area by using a Bison Model/3101 Magnetic Susceptibility System. According to the manufacturer, the range of the system is from 0.00001 to 0.1 CGS units with accuracy approaching 5 to 10 percent.

Magnetic susceptibilities of two groups of rocks were determined. The first group consisted of representative samples



TOTAL MAGNETIC INTENSITIES OF WESTERN RICHARDSON AND EASTERN FRANKE COUNTIES

Figure 18



TOTAL MAGNETIC INTENSITIES OF WESTERN RICHARDSON AND EASTERN PAWNEE COUNTIES

Figure 19

of glacial drift and Paleozoic rocks obtained during drilling of oil and gas test wells. Because the samples were from cuttings, corrections for density were necessary. Although some of the Paleozoic rocks were ferruginous, none of the samples had susceptibilities large enough (> 0.0028 x 10^{-6} CGS) to produce discernible magnetic anomalies. The second group was composed of samples of acidic to basic rocks from the Precambrian basement. These samples, which consisted of cuttings recovered from deep oil and gas test wells, also required density corrections. Although the selection was limited, only fresh appearing rocks were selected for measurement. The values obtained showed a wide variation between samples; they ranged from 166.0 to 4160.0 x 10^{-6} CGS.

INTERPRETATION TECHNIQUES FOR GRAVITY AND GROUND MAGNETIC DATA

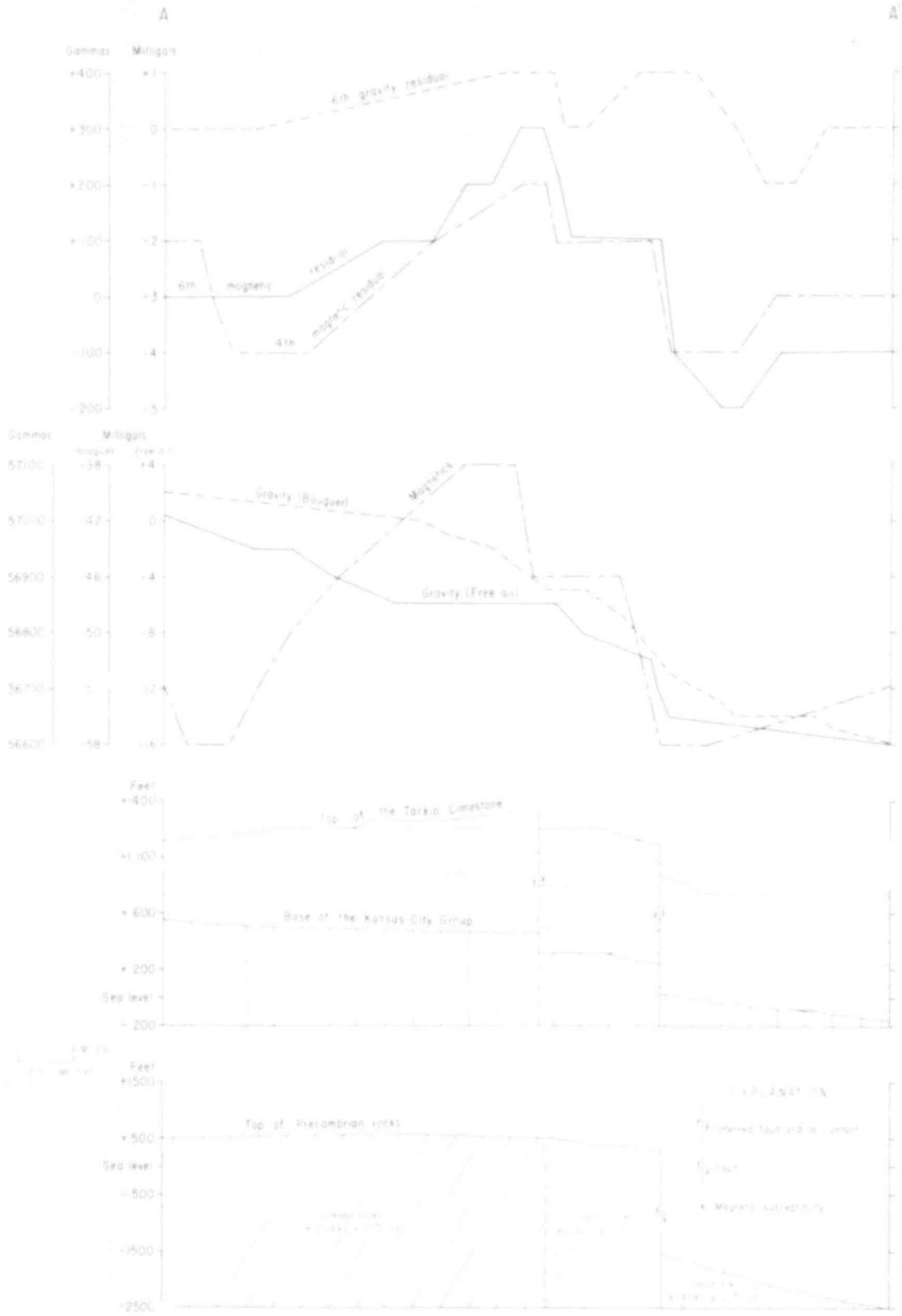
Interpretation of gravity and magnetic data is difficult because many different models for mass distribution and magnetic field variation can be applied to observed data. Therefore, all additional multisource data need to be used as aids in the geophysical interpretation. Woollard (1962) observed that an understanding of the composition and structure of the crystalline basement rocks is the most important consideration in the interpreting gravity data in the midcontinent. The same can be said for magnetic data. McGinnis and others (1966) pointed out that the inverse relationship existing between positive gravity anomalies and structural depressions in Illinois, Indiana, and Michigan could be isostatically related. However no such relationship holds true in Nebraska. Instead most positive gravity anomalies

correspond to structural "highs," as can be demonstrated by comparing the profiles showing Bouguer gravity and the top of Precambrian rocks. Also significant is the generally good correlation of positive magnetic anomalies and structural "highs" on the Precambrian surface (figs. 20 and 21).

Gravity and magnetic data for the site specific study area can include effects of glacial drift, Paleozoic and Precambrian rocks, and geologic structure. To remove the regional gravity and magnetic components from the local components, the data were subjected to trend-surface filtering based on the least squares functions (figs. 22 and 23). The intent was to enhance those local anomalies that may indicate geologic structure.

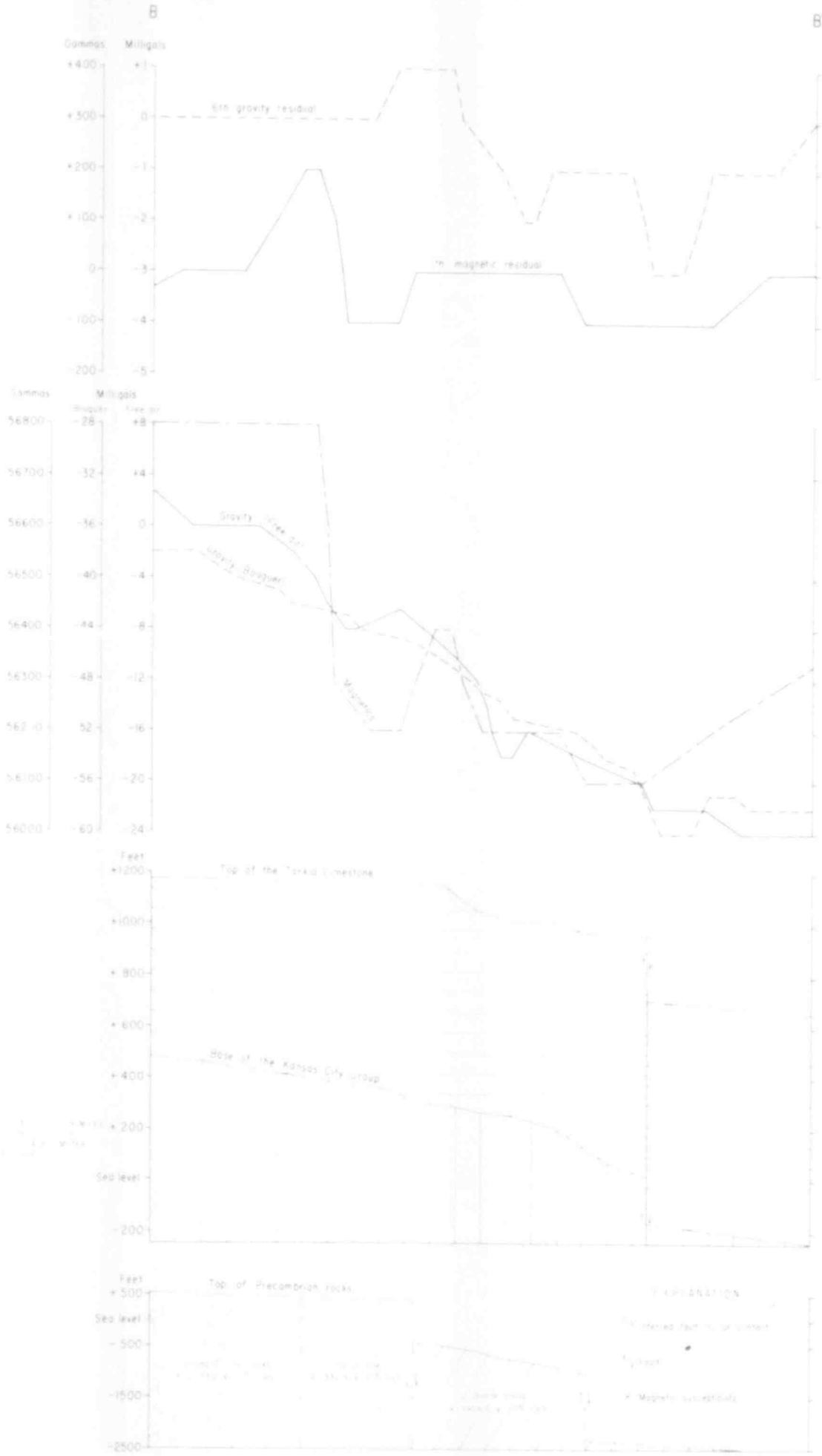
To examine the site specific study area in terms of isostatic equilibrium, it was necessary to establish the zero free-air anomaly. This was done by averaging free-air data in 2-mile radii about a point to smooth the effects of topography. The data then were contoured, the zero free-air contour line being depicted on figure 24. Two east-west free-air profiles (figs. 20 and 21) also were made.

According to Carlson (1967) 15 deep wells have been drilled into the Precambrian basement rocks within the site specific study area. Also, many oil and gas test wells have been drilled into the Paleozoic rocks (Burchett, 1978). Data obtained in the drilling of the wells were used for an interpretive base with geophysical data. Information on magnetic susceptibility, rock density, lithology, and structural configuration were used with geophysical data to produce a map showing Precambrian rock



PROFILE ALONG A–A'

Figure 20



PROFILE ALONG B–B'

Figure 21

43

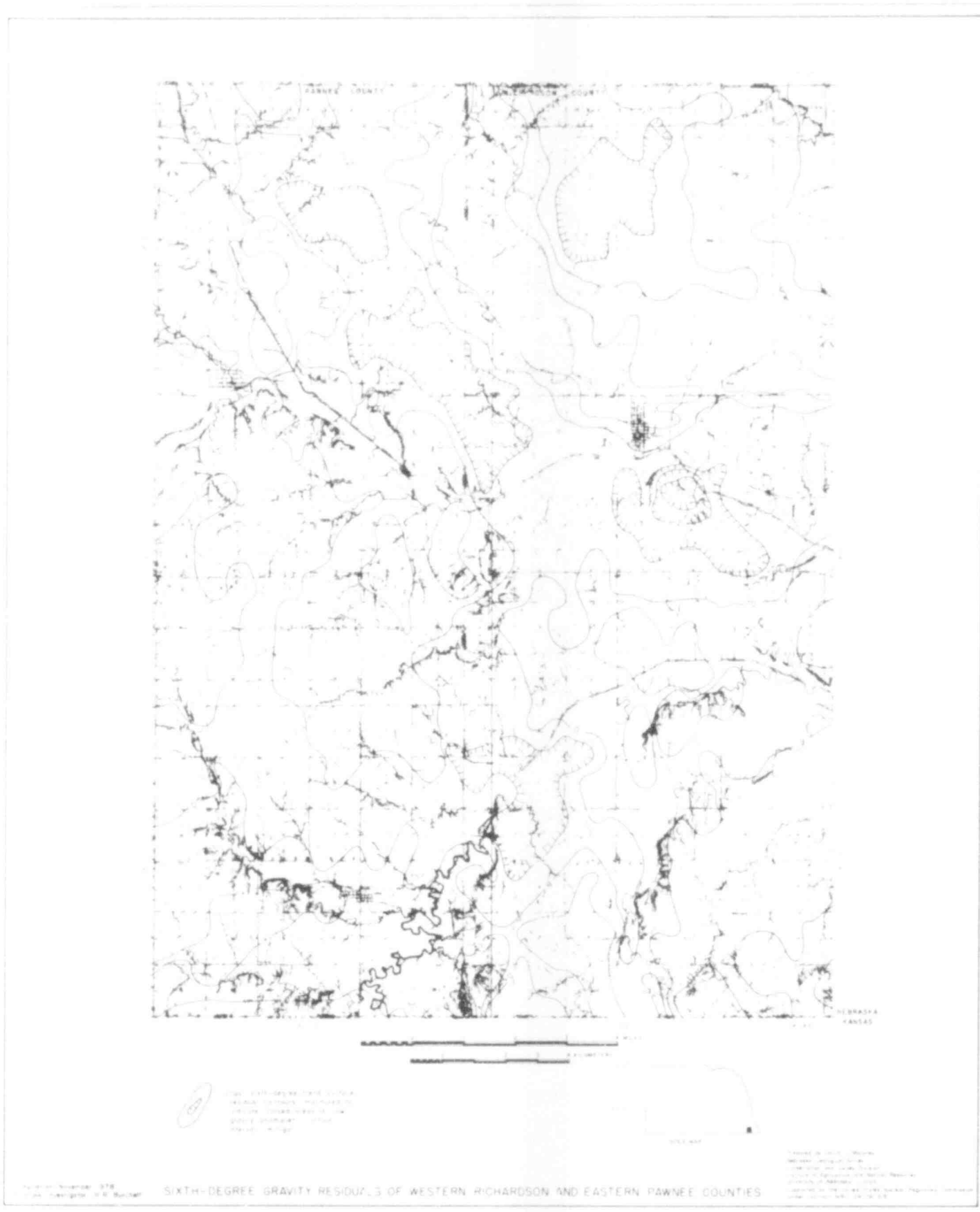


Figure 22

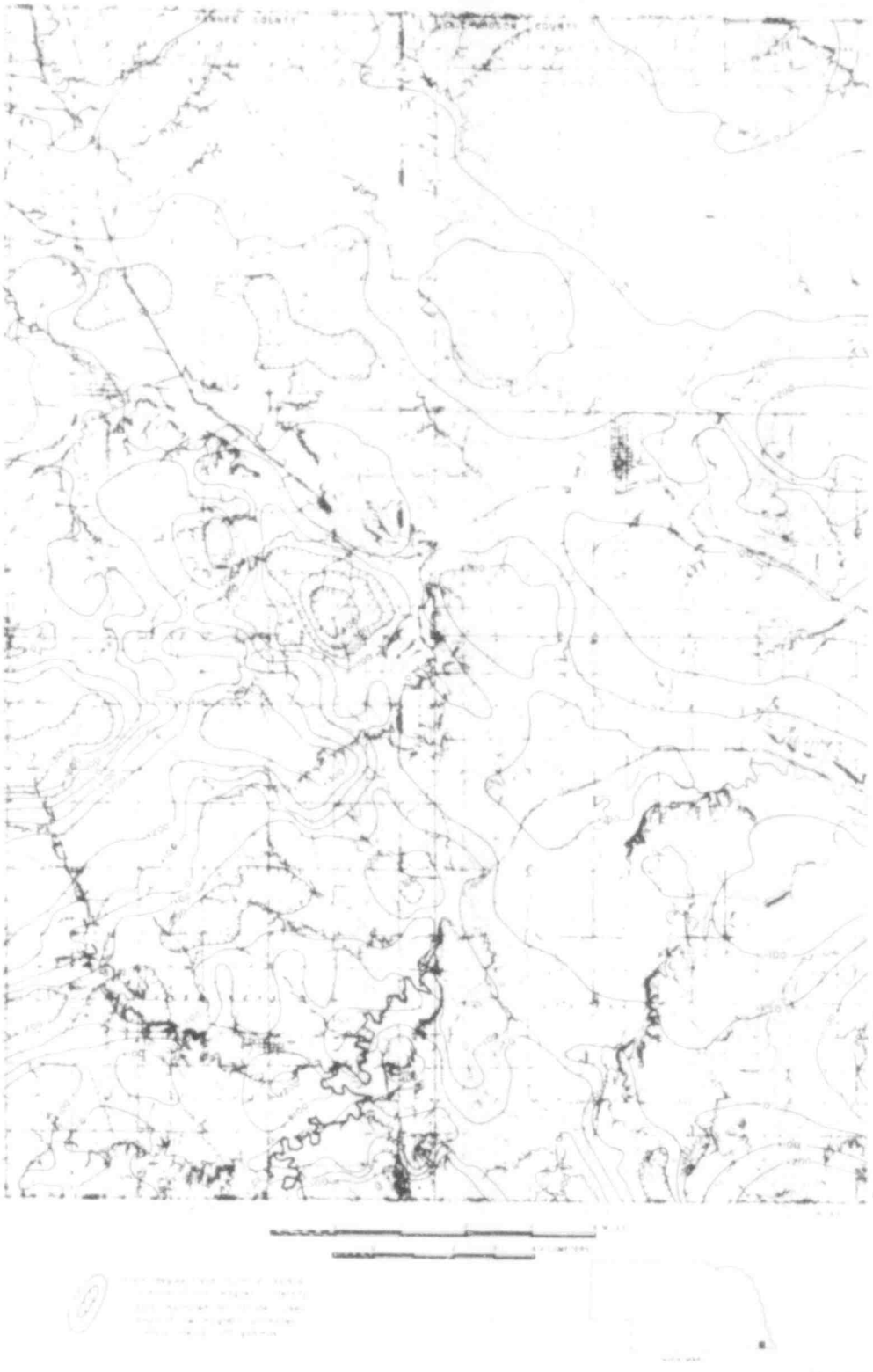
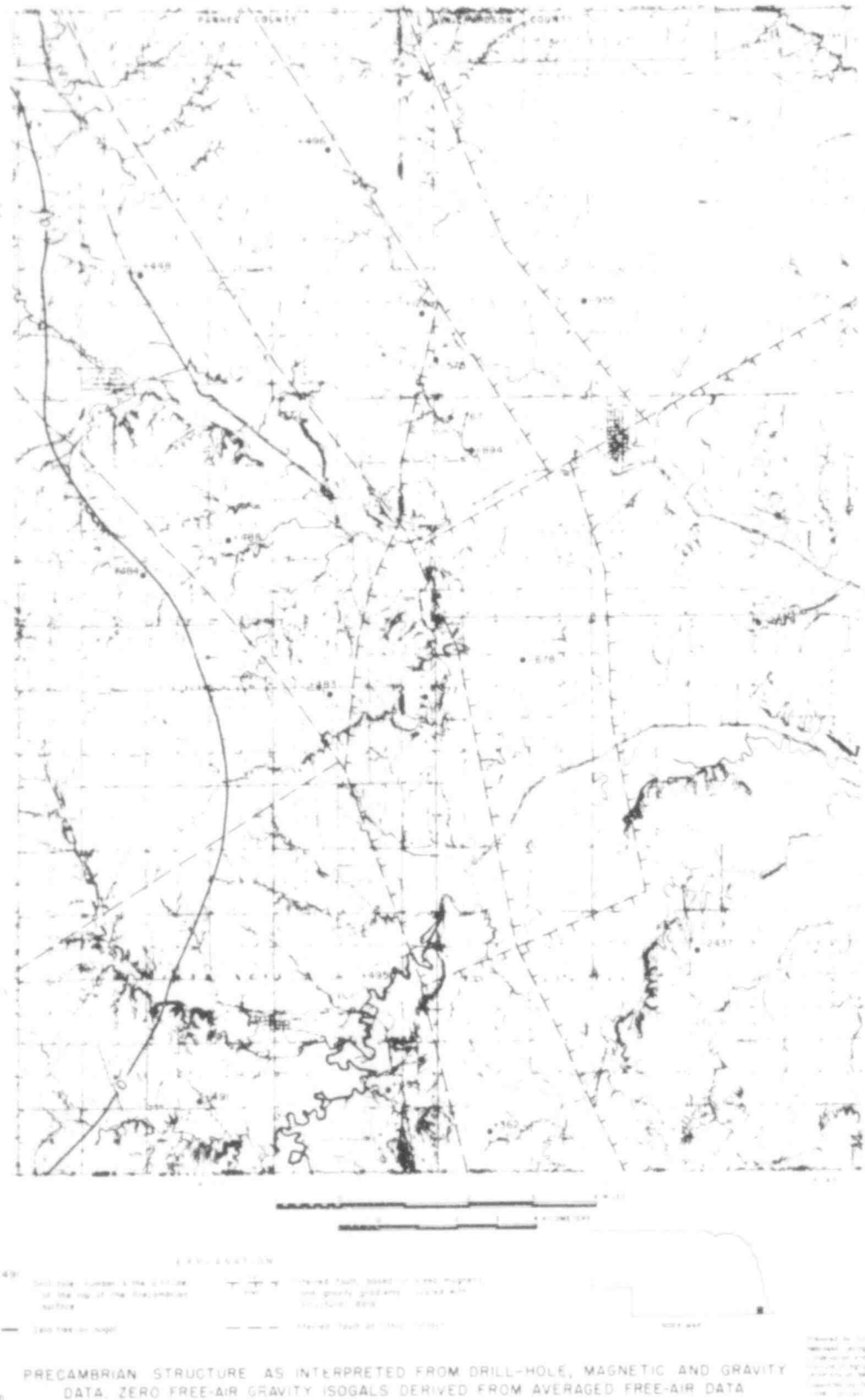


Figure 23



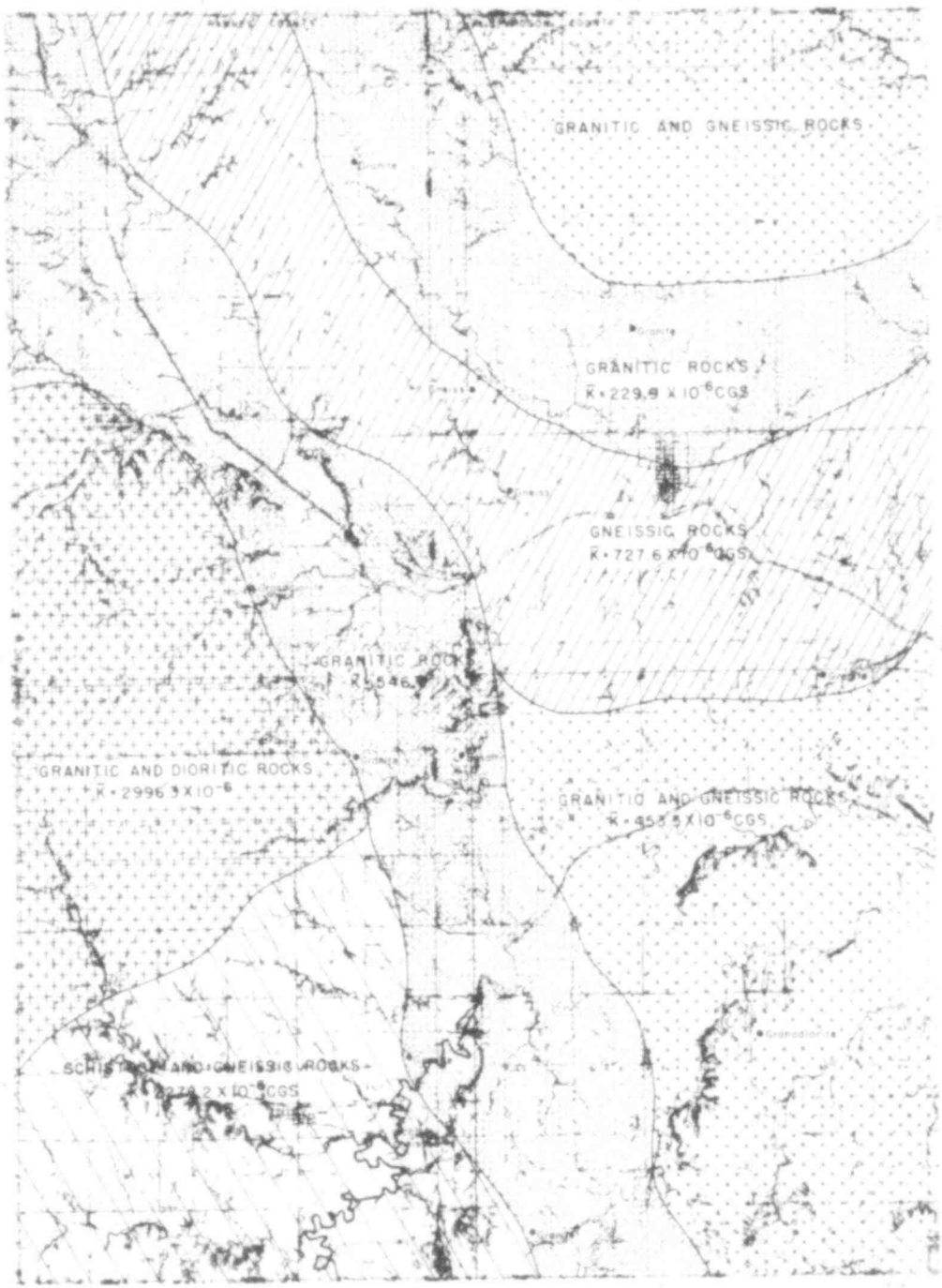
PRECAMBRIAN STRUCTURE AS INTERPRETED FROM DRILL-HOLE, MAGNETIC AND GRAVITY DATA. ZERO FREE-AIR GRAVITY ISOGALS DERIVED FROM AVERAGED FREE-AIR DATA

Figure 24

type and structure and two east-west geologic profiles (figs. 13, 20, 21, 24, and 25).

In order to identify quantitatively areas of steep magnetic and gravity gradients a series of profiles spaced 1 mile apart were made across magnetic intensity and Bouguer gravity maps perpendicular to contour lines. From these profiles strong laterally continuous magnetic and gravity gradients per horizontal distance (100 gammas/.3 mile and 1 milligal/.3 mile) were identified at points along the profiles. These points were then plotted on a base map and compared. A close relationship exists between areas of steep magnetic and gravity gradients suggesting a similar source of magnetic and gravitational intensity. These data were then combined with structural information to generate a Precambrian structural map of the site specific study area (fig. 24). Where structural relief is indicated, faults with vertical movement were postulated, faults and/or lithologic contacts were inferred where no structural relief could be demonstrated. Structural profiles on the top of Precambrian rocks (figs. 20 and 21) were made from figure 24, and the structural data for the base of Kansas City Group and for the top of the Tarkio Limestone were taken from Burchett, (1978, fig. 9) and this report (fig. 6).

Anomalies in the gravity field within the site specific study area cannot be accounted for by density contrasts between glacial drift and Paleozoic rocks or between Paleozoic and Precambrian rocks. Average gravity effects of the drift and Paleozoic rocks were computed from the average density values of 2.59 gm/cm^3



DISTRIBUTION OF PRECAMBRIAN ROCK TYPES
AS INTERPRETED FROM DRILL-HOLE, MAGNETIC, AND GRAVITY DATA
ADAPTED FROM CARLSON (1967) AND LIDIAK (1972)

Figure 25

for drift, 2.46 gm/cm^3 for Paleozoic rocks and 2.68 gm/cm^3 for Precambrian rocks. (The value for Paleozoic rocks actually is an average for Pennsylvanian and Permian rocks only but is assumed, because of lithologic similarities, to be characteristic of the entire Paleozoic sequence.) Use of the density contrast of 0.12 gm/cm^3 between drift and Paleozoic rocks and an average thickness of 100 feet for drift yields a gravity effect of less than 1 milligal. Similarly, if the density contrast of 0.21 gm/cm^3 between Paleozoic and Precambrian rocks and a maximum thickness of 2,500 feet for Paleozoic rocks are used, the gravity effect of the Paleozoic rocks, as computed from the horizontal slab formula of Nettleton (1976), is 1 milligal per 900 feet thickness or about 3 milligals for the maximum total thickness of the Paleozoic rocks in the site specific study area. Because the combined effects of the drift and Paleozoic rocks are too small to account for the anomalies in the gravity field, contrasting densities and elevational differences in Precambrian rocks must be the principal causes of those anomalies.

A comparison of gravitational gradient and sloping density contrasts of Nettleton (1976) is informative. From an elevation on the top the Precambrian of 362 feet above sea level, determined from drill hole data, to a second Precambrian elevation of 2437 feet below sea level there is approximately a 593 feet/mile structural gradient which has been interpreted as faulting or steeply dipping beds (Carlson, 1967). Between these same two data points there is an observed Bouguer gravity gradient of 2.5 milligals per mile. Using Nettleton's (p. 202, 1976)

formula for sloping density contrasts, a theoretical gradient of 0.91 milligal/mile was computed. The disparity between the observed and theoretical gradients can be best accounted for by faulting rather than by steep dip.

Variations of magnetic susceptibility values for glacial drift and Paleozoic rocks were insignificant. Therefore, it can be assumed that the Precambrian rocks strongly influence the configuration of the magnetic intensity map. Although there was no linear correspondence between high magnetic susceptibility values for Precambrian rocks and high total magnetic intensity, it was possible to see some relationship between depth to Precambrian, magnetic susceptibility, and total magnetic intensity. Comparison of profiles representing the top of Precambrian rocks with profiles of total magnetic intensity (figs. 20 and 21) indicates a generally positive correlation except for the western quarter of profile A-A' (fig. 20). An explanation for this exception is not apparent.

Figure 24 indicates a dominant northwest-southeast structural grain, also a minor northeast-southwest structural grain in the eastern part of the site specific study area. If the gravimetric and magnetic intensity data are assumed to reflect the structure and lithology of Precambrian rocks, several regional tectonic relationships can be postulated. For example, figure 24 indicates normal step faulting of Precambrian rocks between the Nemaha Ridge and the Forest City Basin; normal faulting, in turn implies isostatic adjustment. The subparallel conformity of the zero free-air anomaly contour to the structural grain of the study

area lends support to this postulation (fig. 24).

Several authors have suggested left-lateral offset of the northeast-southwest trending body of Keweenawan rocks (the mid-continent anomaly) by transform faulting but provided little evidence for strike-slip displacement of Precambrian rocks in the area. The geophysical data available as a result of this study can be interpreted as supportive of transform faulting. Furthermore, the 1.0 B.Y. radiometric date for a sample from a core of a gabbroic intrusive body near Steinauer, Nebraska (S. E. Treves, pers. comm., 1978) is consistent with the radiometric age determination for the Keweenawan rocks to the north. This intrusive body lies along a steep northeast-southwest trending aeromagnetic gradient that parallels the trend of the Keweenawan rocks, as indicated by King and Zietz (1971). The aeromagnetic gradient was interpreted by Lidiak (1972) as indicative of a graben that truncated another graben trending northwest from the site specific study area.

A steep gravity gradient corresponding to the northwest aeromagnetic trend that passes through the Steinauer area and into the site specific study area is indicated by the detailed gravimetric survey of southeastern Nebraska (fig. 17). The southeast boundary of the northwest-southeast trending steep gravity and aeromagnetic trends is paralleled by the zero free-air isogal, which indicates that the configuration of the stress field coincides with the strike of the proposed transform fault that offsets the midcontinent anomaly. The seemingly anomalous occurrence of gabbro, carbonatite and basalt along the same

northwest-southeast trend (Carlson, 1967, Lidiak, 1972) may be related to the proposed transform faulting. From his examination of recorded earthquake epicenter and intensities in eastern Nebraska, Burchett (1978) detected a northwest-southeast trend to epicenters of V-VII MM (Modified Mercalli) intensities (fig. 17). This trend appears to coincide with the trend of the proposed transform fault. Dobecki and LaFountain (1975) report a similar relation between seismicity and offset of the midcontinent anomaly by transform faulting in Kansas and Nebraska.

The coincidence of northwest-southeast t ending aeromagnetic and gravity gradients and of epicenters of strong earthquakes together with the areal distribution and gabbroic and basaltic igneous rocks in the site specific and regional study areas are indicative of a zone of crustal weakness. More specifically, this zone is postulated to be an active left-lateral transform fault.

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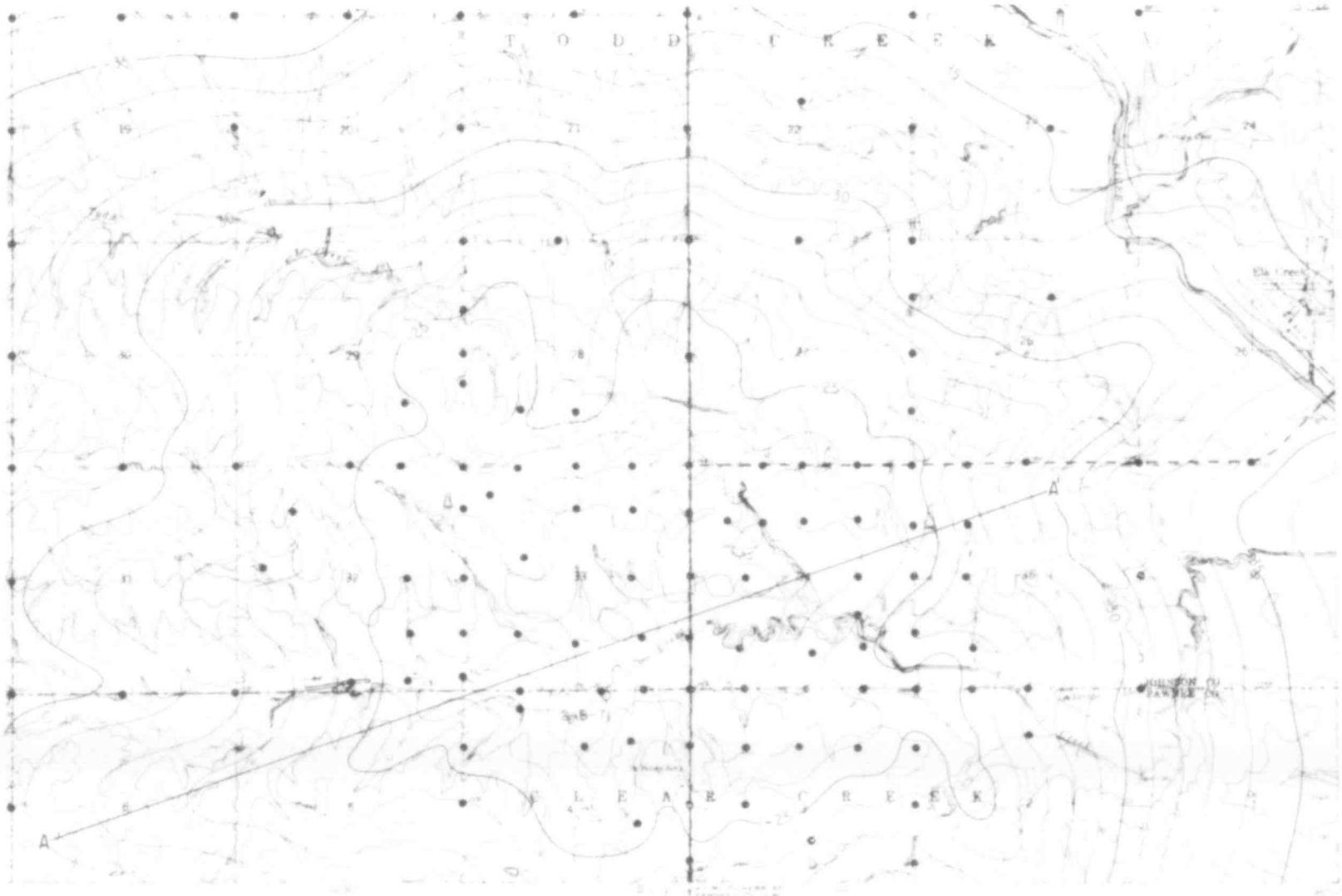
A GEOPHYSICAL STUDY OF THE ELK CREEK ANOMALY

By David G. Maroney and R. R. Burchett

Discovered by geophysical reconnaissance in 1970, the Elk Creek Anomaly was described initially as a positive circular gravity anomaly having a maximum relief of 8 mgal. A vertical magnetometer survey showed an 800-gamma positive anomaly closing in sec. 33, T. 4 N., R. 11 E., in Johnson County, Nebraska (Burfeind et al, 1971, Carlson, 1972a). Core drilling near maximum gravity and magnetic closures in the NE 1/4 sec. 4, T. 3 N., R. 12 E., Pawnee County, indicated about 45 feet of Quaternary glacial deposits and 583 feet of Upper and Middle Pennsylvania marine rocks overlying silicate-bearing, iron-rich carbonate rocks classed as a carbonatite (Treves et al, 1972a, 1972b, Brookins et al, 1975). Coring operations penetrated about 325 feet of carbonatite having nearly uniform lithology (Carlson et al, 1972b).

A detailed gravimetric and ground-magnetic study was undertaken in spring 1973 to map the extent and configuration of the anomaly in greater detail. To suppliment the existing data spaced at intervals of 0.5 mile, more than 100 additional gravity stations were occupied at sites accessible only on foot. Also occupied were 350 total magnetic field stations, most of which coincided with gravity station locations. A simple Bouguer gravity map (fig. 26) based on the data obtained indicates an east-west



EXPLANATION

Isogal contours showing Bouguer gravity field in milligals. Bouguer correction 2.67 g/cm³. Contour interval one milligal

Station location

Core hole (C-8-71)

See figure 28 for profile along line A–A'

LOCATION MAP

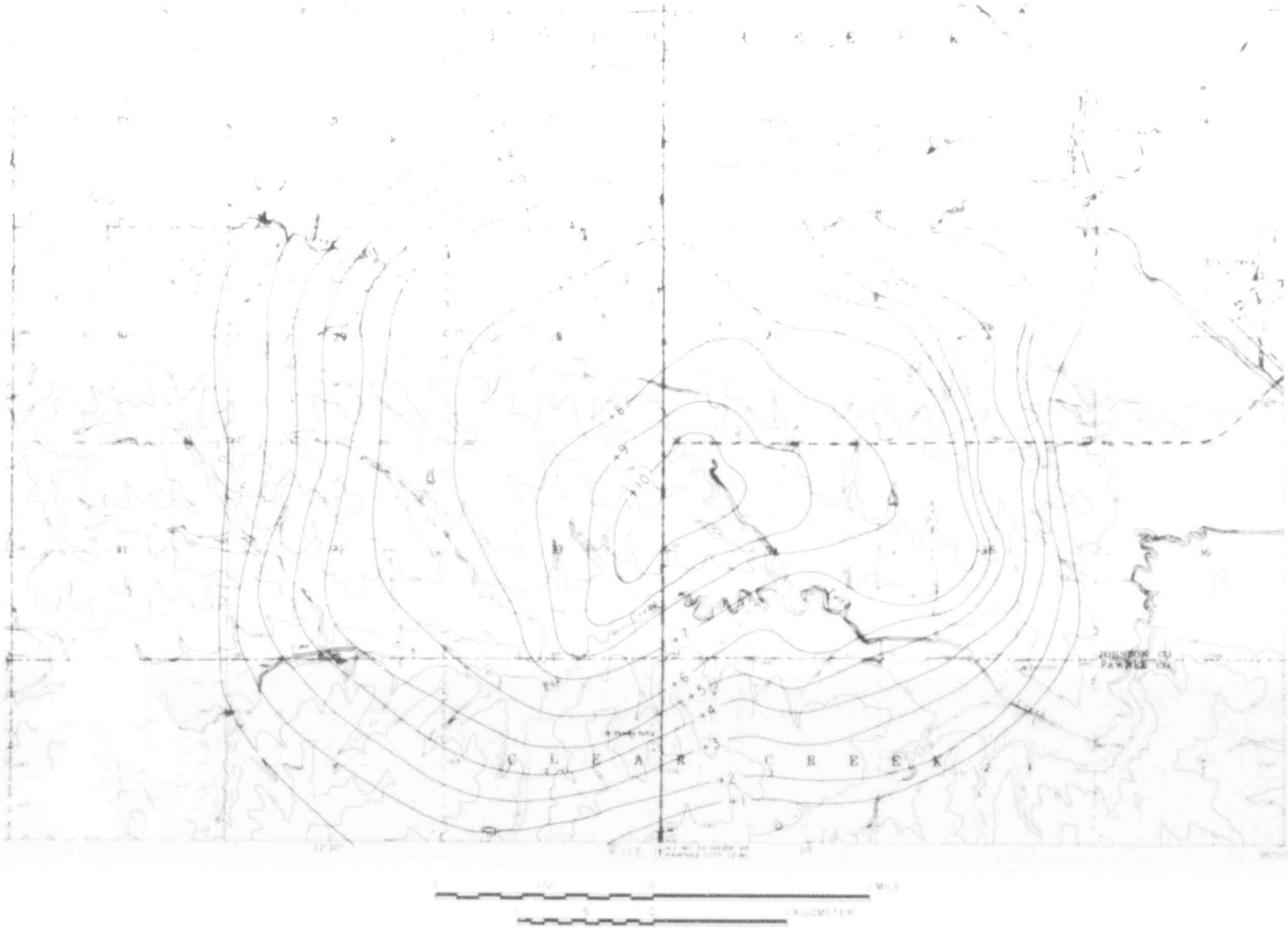
BOUGUER GRAVITY OF THE ELK CREEK ANOMALY

Figure 26

elongate elliptical area having maximum closure of about 1 square mile. Residual gravity based on a -30 mgal datum shifted the anomaly 0.25 mile northward and indicated a closure of 10 mgal (fig. 27). A northeast-southwest Bouguer gravity profile over the anomaly (fig. 28) demonstrates a steep east-trending gravity gradient that may indicate the igneous body dips to the east.

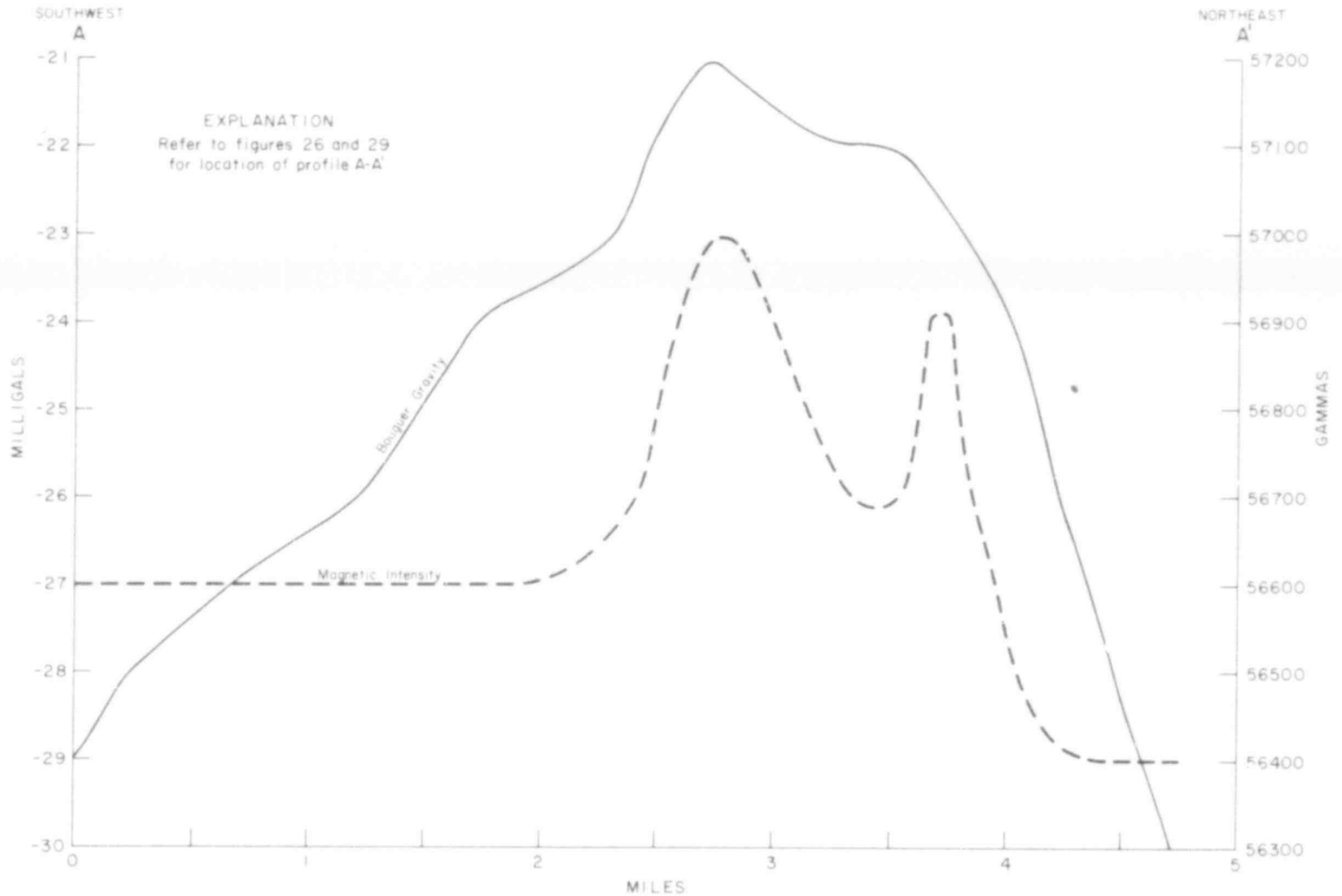
A density value of 3.28 gm/cc for the carbonatitic rocks was determined by the water immersion method. Density contrasts with surrounding Precambrian crystalline rocks range from 0.53 to 0.59 and account for the anomalous gravity values in the Elk Creek area.

A map showing total magnetic intensity (fig. 29) indicates a complex twin-lobed magnetic field pattern having closures of 300-400 gammas along a northeast-southwest trend. The steep magnetic gradient to the east-northeast shown by the northeast-southwest magnetic profile (fig. 28) also indicates that the igneous body dips generally eastward. A residual magnetic map (fig. 30) prepared by using a 60-gamma regional magnetic gradient to the northwest indicated two 600-gamma elliptical closures aligned northeast-southwest. The only carbonatite core available for analysis was obtained from a test hole drilled outside both high-amplitude closures. Magnetic susceptibility readings taken at 25 foot intervals along the 325 foot length of core averaged 442.0 x 10^{-7} cgs. Magnetic contrasts with overlying Pennsylvania rocks were nearly zero and with nearby granitic rocks were mostly zero or negative and thus could not account for the magnetic



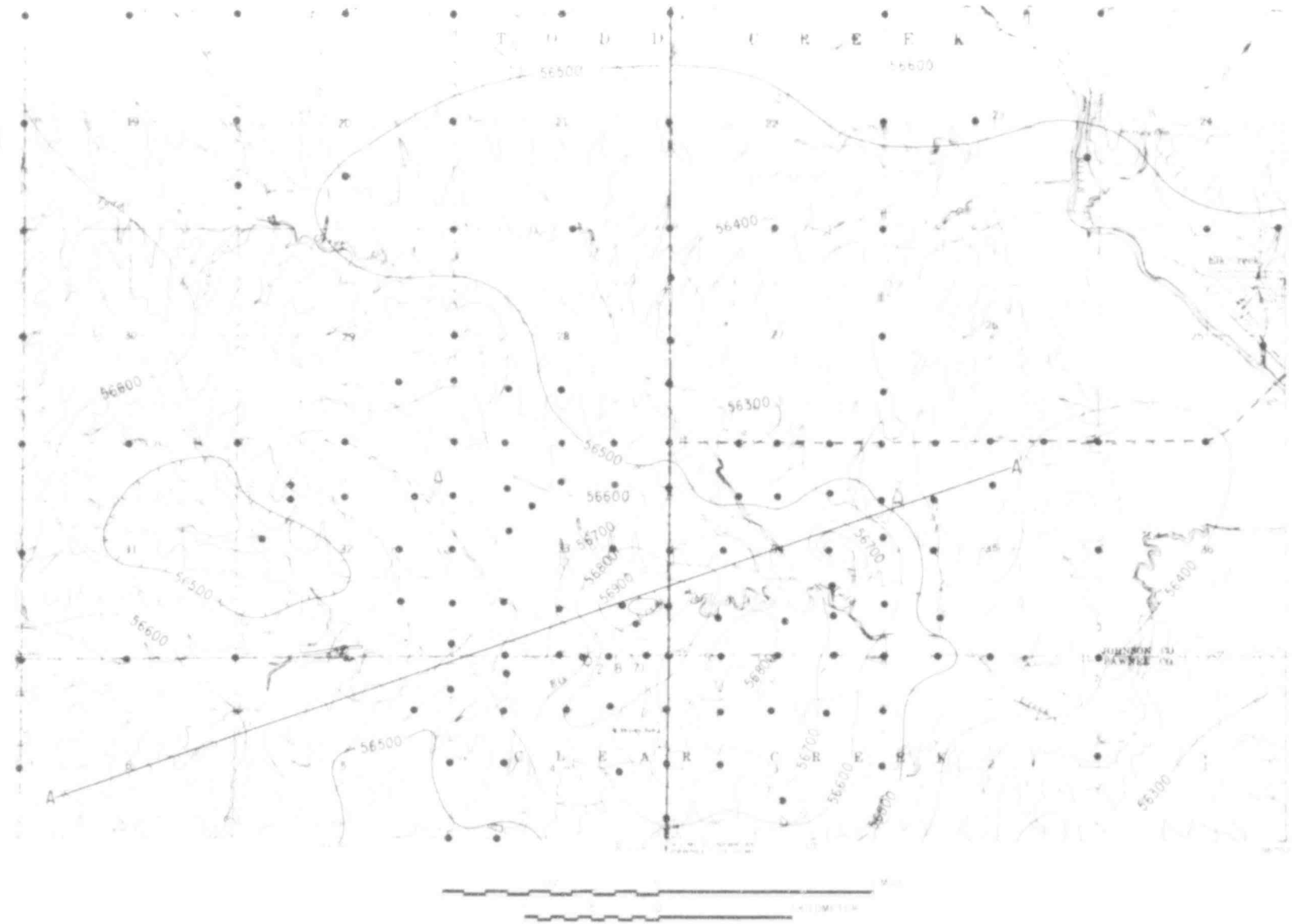
RESIDUAL GRAVITY OF THE ELK CREEK ANOMALY

Figure 27



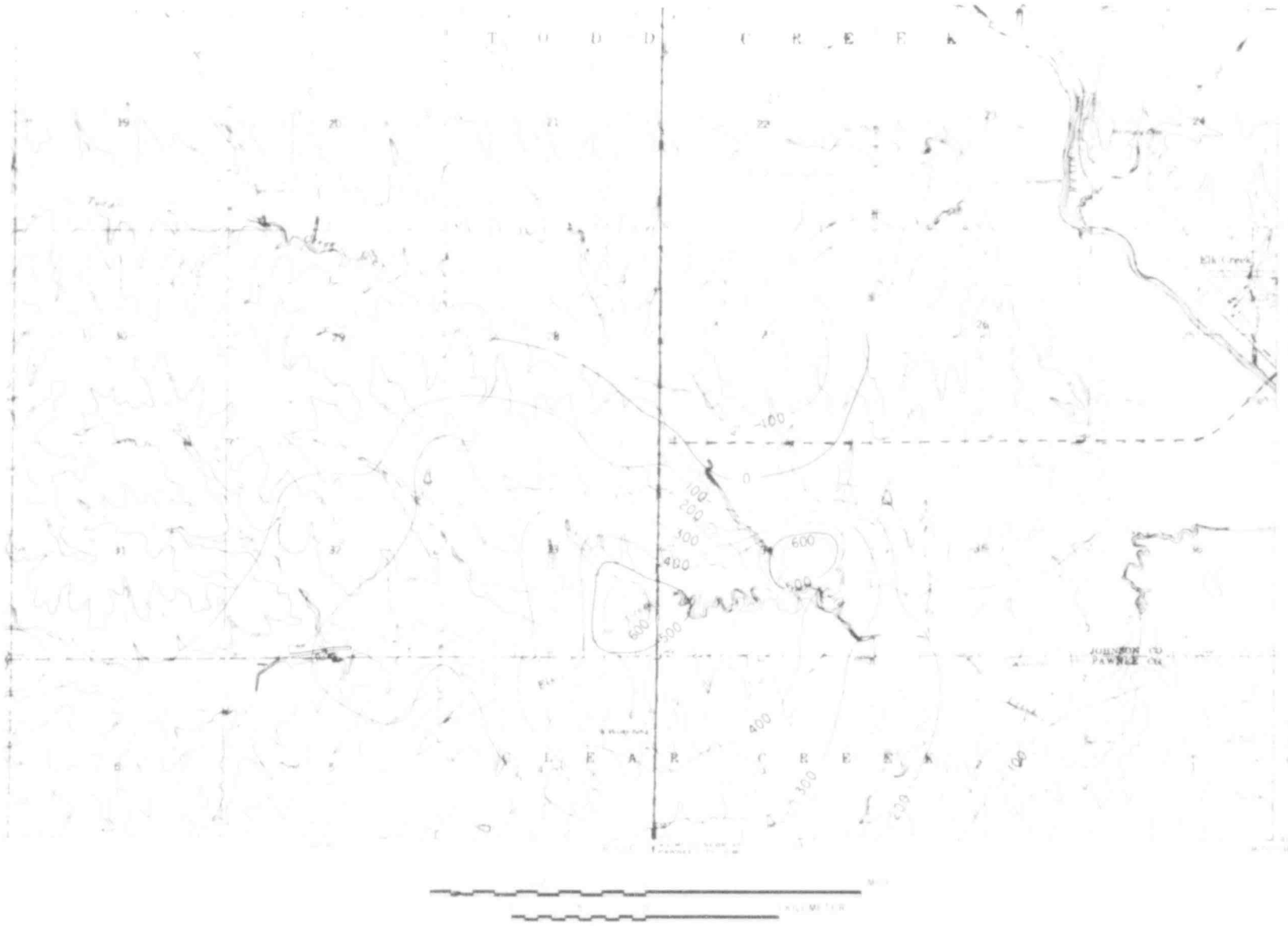
SOUTHWEST-NORTHEAST PROFILE OF BOUGUER GRAVITY AND TOTAL MAGNETIC INTENSITY OF THE ELK CREEK ANOMALY

Figure 28



TOTAL MAGNETIC INTENSITY OF THE ELK CREEK ANOMALY

Figure 29



Magnetic contours showing residual magnetic intensity in gammas. Hachured to indicate closed areas of lower magnetic intensity.

Regional magnetic gradient 60 gammas per mile, contour interval 100 gammas

RESIDUAL MAGNETIC INTENSITY OF THE ELK CREEK ANOMALY

Figure 30

anomaly at Elk Creek. Therefore the source of magnetism must be deep seated or due to lateral lithologic changes within the carbonatite body.

Because the Middle Pennsylvanian rocks overlying the carbonatite exhibit no evidence of contact metamorphism or cataclasis it is inferred that the Elk Creek carbonatite was emplaced in pre-Middle Pennsylvanian time.

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Appendix A

This appendix consists of descriptions of the sixty-four test holes drilled in western Richardson and eastern Pawnee counties. All locations are shown in figure 3 of the text.

All measurements in this appendix are expressed in feet. To convert to the International System of Units, multiply feet by .3048 to obtain meters.

Test Hole 1-78

Location: Richardson County, SW SW SE SW sec. 34, T. 1 N., R. 13 E., approximately 15 feet north of south section line and 1,495 feet east of west section line.

Ground-level elevation: 1,215.0 feet above mean sea level.

Started: April 21, 1978. Completed: April 21, 1978.

Total depth: 50.0 feet.

Description	Depth, in feet From		To
Quaternary System:			
Soil (no sample)	0	-	3.0
Permian System - Big Blue Series - Council Grove Group:			
Grenola Formation:			
Legion Member:			
Shale, yellowish olive	3.0	-	5.0
Salyards Member:			
Limestone, medium gray, finely crystalline	5.0	-	6.5
Roca Formation:			
Shale, yellowish brown	6.5	-	9.0
Shale, medium to dark gray	9.0	-	11.5
Limestone, light brown, finely crystalline to dense, soft	11.5	-	11.8
Shale, light to medium gray	11.8	-	15.0
Shale, light greenish gray; contains gypsum crystals	15.0	-	18.5
Limestone, very light gray to buff, dense, impure	18.5	-	21.5
Shale, medium gray	21.5	-	22.0
Limestone, very light gray to buff, dense, impure	22.0	-	24.0
Shale, light greenish gray	24.0	-	24.5
Limestone, buff to light brown, dense	24.5	-	26.5
Shale, light greenish gray	26.5	-	27.0
Limestone, light brown, dense	27.0	-	29.0
Shale, pale olive, mottled with red	29.0	-	35.5
Red Eagle Formation:			
Howe Member:			
Limestone, light gray to brown, irregularly crystalline, impure	35.5	-	39.5
Bennett Member:			
Shale, black, carbonaceous	39.5	-	44.0
Glenrock Member:			
Limestone, light brown, finely crystalline· contains brachiopods and fusulinids	44.0	-	45.0
Shale (lost circulation, no sample)	45.0	-	50.0

Test Hole 2-78

Location: Richardson County, SE corner sec. 33, T. 1 N., R. 13 E., approximately 35 feet north of south section line and 45 feet west of east section line.

Ground-level elevation: 1,183.0 feet above mean sea level.

Started: April 21, 1978. Completed: April 21, 1978.

Total depth: 77.0 feet

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample)	0 -	4.0
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Zeandale Formation:		
Wamego Member:		
Shale, brownish gray, silty	4.0 -	10.0
Shale, dark brown, silty	10.0 -	16.0
Shale, light gray	16.0 -	17.5
Tarkio Member:		
Limestone, brown, coarse to irregularly crystalline; contains fusulinids and brachiopods	17.5 -	18.0
Shale, light greenish gray	18.0 -	19.5
Limestone, brown, finely crystalline; contains brachiopods, fusulinids, and Osagia	19.5 -	20.0
Shale, orangish brown	20.0 -	21.0
Limestone, yellowish brown, finely crystalline; contains brachiopods, fusulinids, and Osagia	21.0 -	23.5
Willard Formation:		
Shale, light bluish gray	23.5 -	29.5
Shale, light to medium gray	29.5 -	45.0
Shale, medium gray	45.0 -	56.0
Shale, dark gray	56.0 -	57.0
Emporia Formation:		
Elmont Member:		
Limestone, tannish gray, finely crystalline to dense; contains fusulinids and brachiopods	57.0 -	59.5
Shale, light to medium gray	59.5 -	60.5
Limestone, light tannish gray, finely crystalline to dense	60.5 -	62.2
Harveyville Member:		
Shale, light to medium gray	62.2 -	66.5
Reading Member:		
Limestone, medium gray, finely crystalline; contains brachiopods and fusulinids	66.5 -	69.5
Shale, medium gray	69.5 -	70.0

Description	Depth, in feet	
	From	To
Limestone, light gray, finely crystalline to dense, impure; contains brachiopods.....	70.0	- 70.5
Shale, medium gray.....	70.5	- 71.5
Limestone, light gray, finely crystalline, impure; contains brachiopods and crinoids....	71.5	- 72.0
Auburn Formation:		
Shale, light gray.....	72.0	- 77.0

Test Hole 3-78

Location: Richardson County, SE SE SW SW sec. 34, T. 1 N., R. 13 E., approximately 15 feet north of south section line and 825 feet east of west section line.

Ground-level elevation: 1,187.0 feet above mean sea level.

Started: April 21, 1978. Completed: April 21, 1978.

Total depth: 77.0 feet.

Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample).....	0	- 2.0
Clay, light brown.....	2.0	- 4.0
Clay, reddish brown.....	4.0	- 7.0
Permian System - Big Blue Series - Admire Group:		
Onaga Formation:		
Towle Member:		
Shale, greenish gray; contains manganese staining.....	7.0	- 10.0
Shale, olive mottled with red.....	10.0	- 11.0
Shale, dark reddish brown.....	11.0	- 15.5
Shale, reddish brown mottled with olive and green.....	15.5	- 16.0
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Wood Siding Formation:		
Brownville Member:		
Limestone, light gray, irregularly crystalline, impure; contains brachiopods and algal material.....	16.0	- 18.5
Pony Creek-Plumb Members:		
Shale, pale olive.....	18.5	- 21.0
Shale, reddish gray mottled with green.....	21.0	- 23.5

Description	Depth, in feet	
	From	To
Shale, greenish gray mottled with orange.....	23.5	- 25.0
Shale, reddish gray.....	25.0	- 28.5
Shale, light greenish gray.....	28.5	- 29.5
Shale, red.....	29.5	- 35.0
Shale, red, interbedded with pale yellow and olive.....	35.0	- 36.0
Limestone, yellow brown, finely crystall , impure; contains brachiopods and algal materia	36.0	- 37.0
Shale, light greenish gray, silty.....	37.0	- 41.0
Shale, medium gray.....	41.0	- 43.3
Nebraska City Member:		
Limestone, dark gray, finely crystalline; contains brachiopods and crinoids.....	43.3	- 43.9
Rock Formation:		
French Creek Member:		
Coal, black, soft.....	43.9	- 44.1
Shale, light bluish gray.....	44.1	- 50.0
Shale, medium to dark gray.....	50.0	- 59.5
Jim Creek Member:		
Limestone, medium gray, finely crystalline; contains brachiopods and crinoids.....	59.5	- 60.5
Friedrich Member:		
Shale, light to medium gray.....	60.5	- 64.5
Shale, reddish brown.....	64.5	- 67.0
Shale, light greenish gray, interbedded with sandstone, light greenish gray, very finely micaceous.....	67.0	- 68.5
Sandstone, light tannish gray, very finely micaceous, interbedded with shale, greenish gray.....	68.5	- 70.5
Sandstone, light tannish gray, very finely micaceous, interbedded with shale, red.....	70.5	- 73.5
Shale, reddish brown.....	73.5	- 77.0

Test Hole 4-78

Location: Richardson County, NW NE NE SE sec. 28, T. 1 N., R. 13 E., approximately 2,655 feet south of north section line and 612 feet west of east section line.

Ground-level elevation: 1,068.0 feet above mean sea level.

Started: April 24, 1978. Completed: April 24, 1978.

Total depth: 126.0 feet.

Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample)	0	5.0
Clay, brownish gray, sandy	5.0	11.5
Permian System - Big Blue Series - Admire Group:		
Hamlin Formation:		
Oaks Member:		
Shale, greenish gray	11.5	15.0
Shale, pale yellowish brown mottled with olive and red	15.0	16.0
Shale, greenish gray	16.0	17.0
Houchens Creek Member:		
Shale, light bluish gray, interbedded with limestone, light gray, dense	17.0	21.0
Stine Member:		
Shale, greenish gray	21.0	29.0
Shale, medium gray	29.0	35.0
Limestone, medium to dark gray, medium to finely crystalline; contains brachiopods, interbedded with shale, dark gray	35.0	36.0
Shale, medium gray	36.0	36.7
Shale, greenish gray, interbedded with limestone, brownish gray, dense, thin	36.7	40.0
Shale, reddish brown	40.0	42.0
Shale, light greenish gray	42.0	42.5
Limestone, tannish gray, finely crystalline	42.5	43.5
Shale, light greenish gray	43.5	45.5
Shale, reddish gray	45.5	46.3
Shale, light greenish gray	46.3	46.6
Shale, olive	46.6	46.8
Five Point Formation:		
Limestone, light gray, irregularly crystalline; contains algal material	46.8	49.0
West Branch Formation:		
Shale, olive	49.0	50.5
Shale, light gray	50.5	56.5
Shale, greenish gray, interbedded with limestone, tannish gray, dense	56.5	60.0
Limestone, light gray, dense, soft	60.0	61.0
Shale, light greenish gray	61.0	63.3
Shale, dark greenish gray	63.3	63.5
Limestone, dark gray, impure	63.5	65.0
Shale, dark gray	65.0	73.5
Falls City Formation:		
Lehmer Member:		
Limestone, light gray, irregularly crystalline, interbedded with shale, gray	73.5	76.5
Reserve Member:		
Shale, medium gray	76.5	78.2

Description	Depth, in feet	
	From	To
Miles Member:		
Limestone, light gray, salt-and-pepper appearance	78.2	78.8
Onaga Formation:		
Shale, light greenish gray	78.8	79.5
Shale, reddish gray mottled with light greenish gray	79.5	87.2
Shale, greenish gray	87.2	93.2
Shale, red	93.2	98.0
Shale, olive gray	98.0	99.5
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Wood Siding Formation:		
Brownville Member:		
Limestone, light gray mottled with olive, very finely crystalline	99.5	101.7
Pony Creek-Plumb Members:		
Shale, olive	101.7	104.3
Shale, greenish gray	104.3	108.0
Shale, red	108.0	112.5
Shale, red interbedded with shale, greenish gray	112.5	117.0
Shale, olive	117.0	118.0
Shale, gray	118.0	119.2
Nebraska City Member:		
Limestone, medium gray, finely crystalline, impure; contains brachiopods and crinoids	119.2	120.0
Root Formation:		
French Creek Member:		
Shale, gray	120.0	120.9
Coal, black	120.9	121.2
Shale, medium gray	121.2	126.0

Test Hole 5-78

Location: Richardson County, SE corner NW sec. 28, T. 1 N., R. 13 E., approximately 2,630 feet south of north section line and 2,632 feet east of west section line.

Ground-level elevation: 1,132.0 feet above mean sea level.

Started: April 25, 1978. Completed: April 25, 1978.

Total depth: 62.0 feet.

Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample).....	0 -	2.0
Pennsylvanian System - Virgil Series - Wabaunsee Group		
Willard Formation:		
Shale, olive mottled with red.....	2.0 -	4.0
Shale, olive mottled with gray and yellow.....	4.0 -	10.0
Shale, brownish olive mottled with gray and yellow.....	10.0 -	25.0
Shale, light gray mottled with yellow.....	25.0 -	32.8
Emporia Formation:		
Elmont Member:		
Limestone, medium gray, finely crystalline; contains brachiopods and crinoids.....	32.8 -	35.5
Shale, medium gray, limy.....	35.5 -	36.8
Limestone, medium gray, finely crystalline; contains brachiopods and fusulinids.....	36.8 -	37.0
Harveyville Member:		
Shale, light gray.....	37.0 -	39.5
Shale, medium gray.....	39.5 -	43.7
Reading Member:		
Limestone, medium gray, finely crystalline; contains brachiopods and crinoids.....	43.7 -	45.9
Shale, medium gray.....	45.9 -	46.1
Limestone, medium gray, finely crystalline; contains brachiopods and crinoids.....	46.1 -	46.5
Shale, medium gray.....	46.5 -	47.2
Limestone, medium gray, finely crystalline; contains brachiopods and crinoids.....	47.2 -	48.8
Auburn Formation:		
Shale, medium gray.....	48.8 -	54.5
Limestone, light gray, finely crystalline; interbedded with shale, greenish gray.....	54.5 -	56.3
Shale, light greenish gray.....	56.3 -	56.5
Shale, light to medium gray.....	56.5 -	60.0
Shale, medium gray.....	60.0 -	62.0

Test Hole 6-78

Location: Richardson County, NW NW NW sec. 21, T. 1 N., R. 13 E., approximately 4 feet south of north section line and 282 feet east of west section line.

Ground-level elevation: 1,117.0 feet above mean sea level.

Started: April 25, 1978. Completed: April 25, 1978.

Total depth: 67.0 feet.

Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample).....	0 -	4.0
Permian System - Big Blue Series - Admire Group:		
Onaga Formation:		
Shale, reddish brown.....	4.0 -	5.0
Shale, pale olive.....	5.0 -	10.0
Shale, pale olive mottled with yellow.....	10.0 -	18.0
Shale, medium gray, interbedded with limestone, gray, thin.....	18.0 -	21.0
Shale, reddish brown.....	21.0 -	21.6
Limestone, dark yellowish brown, medium crystalline; contains manganese staining.....	21.6 -	22.6
Shale, reddish gray.....	22.6 -	24.2
Shale, pale olive mottled with yellow and gray.....	24.2 -	25.5
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Wood Siding Formation:		
Brownville Member:		
Limestone, pale yellow, finely crystalline; manganese staining contains brachiopods.....	25.5 -	28.0
Pony Creek Formation:		
Plumb Member:		
Shale, olive.....	28.0 -	31.0
Shale, medium gray.....	31.0 -	32.7
Shale, black; contains coal, black, soft.....	32.7 -	32.9
Shale, pale greenish gray.....	32.9 -	34.0
Shale, reddish brown.....	34.0 -	40.0
Shale, pale olive-gray.....	40.0 -	40.3
Shale, medium gray.....	40.3 -	41.2
Limestone, light tannish gray, finely crystalline; contains brachiopods.....	41.2 -	43.4
Shale, gray; contains black carbonaceous material.....	43.4 -	44.0
Shale, light gray.....	44.0 -	49.6
Nebraska City Member:		
Limestone, dark gray, finely crystalline, impure; contains brachiopods.....	49.6 -	50.7
Root Formation:		
French Creek Member:		
Coal, black.....	50.7 -	50.9
Shale, light gray.....	50.9 -	60.0
Shale, medium gray.....	60.0 -	64.4
Jim Creek Member:		
Limestone, light to medium gray, finely crystalline; contains brachiopods.....	64.4 -	66.5
Friedrich Member:		
Shale, light gray.....	66.5 -	67.0

Test Hole 7-78

Location: Richardson County, NW NE NE NW sec. 21, T. 1 N., R. 13 E., approximately 8 feet south of north section line and 2,100 feet east of west line.

Ground-level elevation: 1,177.0 feet above mean sea level.

Started: April 25, 1978. Completed: April 25, 1978.

Total depth: 80.0 feet.

Description	Depth, in feet	
	From	To
Permian System - Big Blue Series - Council Grove Group:		
Foraker Formation:		
Hughes Creek Member:		
Limestone, pale yellow, soft, impure, highly weathered	0	1.0
Shale, pale olive	1.0	7.0
Shale, medium gray	7.0	9.0
Shale, olive	9.0	9.9
Americus Member:		
Limestone, medium to dark gray, finely crystalline; contains brachiopods and crinoids	9.9	11.1
Admire Group:		
Hamlin Formation:		
Oaks Member:		
Shale, dark gray to black mottled with olive	11.1	12.0
Limestone, yellow, finely crystalline; contains brachiopods and crinoids	12.0	12.2
Shale, olive mottled with yellowish brown and gray	12.2	13.0
Shale, gray mottled with olive	13.0	14.0
Shale, yellow	14.0	17.5
Shale, medium gray	17.5	18.0
Shale, yellow mottled with olive	18.0	20.0
Shale, greenish gray	20.0	24.0
Shale, yellow	24.0	24.5
Shale, red	24.5	25.5
Shale, pale olive mottled with dark reddish brown	25.5	27.5
Houchens Creek Member:		
Limestone, yellowish brown, finely crystalline to dense	27.5	28.0
Shale, greenish gray	28.0	28.3
Limestone, yellowish brown, finely crystalline to dense	28.3	29.0
Shale, greenish gray, interbedded with limestone brown	29.0	30.0

Description	Depth, in feet	
	From	To
Stine Member:		
Shale, olive	30.0	- 31.0
Shale, medium gray mottled with olive	31.0	- 35.0
Shale, light to medium gray	35.0	- 40.0
Shale, medium to dark gray	40.0	- 42.5
Limestone, medium gray, finely crystalline; contains brachiopods	42.5	- 44.0
Shale, medium to dark gray	44.0	- 46.5
Limestone, light greenish gray, finely crystalline	46.5	- 48.0
Shale, light greenish gray	48.0	- 49.0
Shale, reddish gray	49.0	- 50.7
Shale, medium gray	50.7	- 51.3
Limestone, light tannish gray, finely crystalline	51.3	- 51.9
Shale, light gray	51.9	- 52.5
Shale, olive	52.5	- 53.0
Shale, dark reddish brown	53.0	- 54.0
Shale, reddish yellow	54.0	- 55.5
Shale, medium gray	55.5	- 56.1
Five Point Formation:		
Limestone, light gray, finely crystalline; contains brachiopods, gastropods, and algal material	56.1	- 56.9
West Branch Formation:		
Shale, light greenish gray	56.9	- 57.2
Shale, medium gray	57.2	- 62.7
Limestone, light greenish gray, dense interbedded with shale, greenish gray	62.7	- 65.3
Shale, light greenish gray mottled with red	65.3	- 68.0
Shale, light greenish gray	68.0	- 68.3
Shale, medium to dark gray	68.3	- 77.5
Falls City Formation:		
Lehmer Member:		
Limestone, dark yellowish orange, soft, porous	77.5	- 78.0
Limestone, light to medium gray, finely crystalline; contains brachiopods	78.0	- 79.5
Shale, medium gray	79.5	- 80.0

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Test Hole 8-78

Location: Richardson County, NE corner NW sec. 28, T. 1 N., R. 13 E., approximately 20 feet south of north section line and 2,625 feet east of west section line.

Ground-level elevation: 1,127.0 feet above mean sea level.

Started: April 26, 1978. Completed: April 26, 1978.

Total depth: 130.0 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample)	0 -	1.0
Clay, brownish gray	1.0 -	6.0
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Stotler Formation:		
Dry Member:		
Shale, reddish brown	6.0 -	13.0
Limestone, cream and dark yellow, finely crystalline; contains crinoids and pyrite, interbedded with shale, reddish brown	13.0 -	17.0
Shale, pale olive gray	17.0 -	18.0
Shale, red mottled with olive	18.0 -	28.7
Shale, olive brown	28.7 -	31.3
Shale, medium gray	31.3 -	52.6
Dover Member:		
Limestone, bluish gray, finely crystalline; contains brachiopods and crinoids	52.6 -	53.7
Shale, light gray	53.7 -	54.7
Limestone, light tannish gray and light greenish gray, finely crystalline	54.7 -	54.9
Zeandale-Pillsbury Formations:		
Shale, light greenish gray to light gray	54.9 -	57.0
Shale, reddish brown	57.0 -	59.7
Shale, pale olive mottled with light gray	59.7 -	62.0
Shale, medium gray	62.0 -	72.0
Shale, light to medium gray	72.0 -	80.5
Tarkio Member:		
Limestone, medium gray; contains brachiopods	80.5 -	81.9
Shale, light greenish gray interbedded with shale, dark gray with black carbonaceous streaks	81.9 -	82.4
Limestone, brownish gray, finely crystalline; contains brachiopods and crinoids	82.4 -	82.9
Shale, light greenish gray	82.9 -	84.0
Shale, reddish brown	84.0 -	85.4
Limestone, cream to white, finely crystalline; contains glauconite, fusulinids, and Osagia	85.4 -	90.0

Description	Depth, in feet	
	From	To
Willard Formation:		
Siltstone, light greenish gray, very finely micaceous	90.0 -	94.0
Shale, light and dark olive mottled with yellow and gray	94.0 -	98.0
Shale, light to medium gray	98.0 -	117.5
Shale, light to medium gray, interbedded with limestone, brown, dense, thin	117.5 -	117.6
Shale, medium gray	117.6 -	122.5
Emporia Formation:		
Elmont Member:		
Limestone, brownish gray, very finely crystalline; contains brachiopods	122.5 -	123.9
Shale, medium gray	123.9 -	124.2
Limestone, light gray, very finely crystalline; contains brachiopods	124.2 -	126.5
Shale, greenish gray	126.5 -	127.0
Limestone, light brownish gray, irregularly crystalline; contains pyrite	127.0 -	127.5
Harveyville Member:		
Shale, light to medium gray mottled with olive	127.5 -	130.0

Test Hole 9-78

Location: Richardson County, SW NW NW SW sec. 16, T. 1 N., R. 13 E., approximately 2,040 feet north of south section line and 15 feet east of west section line.

Ground-level elevation: 1,040.0 feet above mean sea level.

Started: April 26, 1978. Completed: April 26, 1978.

Total depth: 58.0 feet.

Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample)	0 -	2.0
Clay, reddish brown	2.0 -	5.0
Clay, reddish brown; contains sand and gravel	5.0 -	12.0
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Pillsbury Formation:		
Limestone, reddish brown, irregularly crystalline; contains brachiopods	12.0 -	12.5
Shale, olive	12.5 -	15.5
Shale, red	15.5 -	20.0

Description	Depth, in feet	
	From	To
Shale, olive	20.0 -	21.3
Shale, medium gray	21.3 -	32.1
Zeandale Formation:		
Maple Hill Member:		
Limestone, bluish gray, finely crystalline, contains brachiopods, crinoids, and fusulinids	32.1 -	33.5
Wamego Member:		
Coal, black	33.5 -	33.7
Shale, light greenish gray	33.7 -	34.2
Sandstone, greenish gray, very finely micaceous	34.2 -	36.8
Shale, light greenish gray	36.8 -	37.8
Shale, light greenish gray, very finely micaceous; contains black carbonaceous material	37.8 -	43.0
Shale, light gray	43.0 -	43.5
Shale, medium to dark gray	43.5 -	46.5
Tarkio Member:		
Limestone, medium to dark gray, finely crystalline; contains brachiopods, crinoids and pyrite	46.5 -	47.3
Shale, light greenish gray mottled with red	47.3 -	48.8
Limestone, cream, finely crystalline; contains fusulinids and Osagia, interbedded with shale, light greenish gray	48.8 -	54.5
Willard Formation:		
Shale, light greenish gray	54.5 -	56.0
Shale, light greenish gray interbedded with red	56.0 -	58.0

Test Hole 10-78

Location: Richardson County, NW corner sec. 32, T. 1 N . R. 13 E., approximately 12 feet south of north section line and 10 feet east of west section line.

Ground-level elevation: 1,205.0 feet above mean sea level.

Started: April 26, 1978. Completed: April 26, 1978.

Total depth: 56.0 feet.

Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample)	0 -	3.0
Clay, brownish gray and yellow; contains sand and gravel	3.0 -	10.0

Description	Depth, in feet	
	From	To
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Zeandale Formation:		
Wamego Member:		
Shale, brownish gray.....	10.0	- 11.0
Tarkio Member:		
Limestone, yellowish brown, finely crystalline; contains fusulinds and Osagia.....	11.0	- 15.0
Limestone, yellowish brown, finely crystalline, interbedded with shale, olive.....	15.0	- 16.0
Willard Formation:		
Shale, olive.....	16.0	- 21.0
Shale, olive interbedded with gray.....	21.0	- 22.0
Shale, medium gray.....	22.0	- 48.8
Shale, black; contains black carbonaceous material.....	48.8	- 49.0
Shale, medium gray.....	49.0	- 49.5
Emporia Formation:		
Elmont Member:		
Limestone, medium gray, finely crystalline; contains brachiopods and fusulinids.....	49.5	- 51.0
Shale, greenish gray.....	51.0	- 52.9
Limestone, light tannish gray, finely crystalline; contains brachiopods and fusulinids....	52.9	- 53.4
Harveyville Member:		
Shale, medium gray.....	53.4	- 56.0

Test Hole 11-78

Location: Richardson County, SE SE SW SE sec. 31, T. 1 N., R. 13 E., approximately 23 feet north of south section line and 1,480 feet west of east section line.

Ground-level elevation: 1,229.0 feet above mean sea level.

Started: April 27, 1978. Completed: April 27, 1978.

Total depth: 107.0 feet.

Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample).....	0	- 1.0
Clay, orangish brown; silty; contains sand and gravel.....	1.0	- 7.0

Description	Depth, in feet	
	From	To
Clay, orangish brown, silty; contains lime nodules	7.0	13.0
Clay, yellowish brown, silty, contains sand and gravel	13.0	23.0
Clay, olive-yellow, silty	23.0	26.5
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Burlingame Formation:		
South Fork Member:		
Limestone, yellowish brown, very finely crystalline, highly weathered; contains brachiopods and pelecypods	26.5	29.5
Winnebago Member:		
Shale, olive gray	29.5	32.5
Limestone, yellow, finely crystalline	32.5	33.0
Shale, olive gray	33.0	34.3
Shale, dark gray	34.3	35.0
Taylor Branch Member:		
Limestone, medium gray, finely crystalline	35.0	35.5
Shale, dark gray to black	35.5	35.7
Limestone, light to medium bluish gray, very finely crystalline; contains pyrite and brachiopods	35.7	37.8
Shale, greenish gray	37.8	38.1
Limestone, light gray, very finely crystalline	38.1	38.9
Scranton Formation:		
Silver Lake Member:		
Sandstone, light brown, silty	38.9	41.1
Shale, medium gray, sandy	41.1	46.0
Shale, light to medium gray	46.0	53.0
Shale, medium gray	53.0	55.2
Rulo Member:		
Limestone, light brownish gray, very finely crystalline; contains brachiopods, crinoids, and fusulinids	55.2	55.9
Cedarvale Member:		
Shale, medium gray	55.9	59.8
Shale, greenish gray	59.8	67.5
Happy Hollow Member:		
Limestone, light greenish gray, very finely crystalline, interbedded with shale, light greenish gray	67.5	70.0
White Cloud Member:		
Shale, very light greenish gray	70.0	75.0
Shale, light to medium gray	75.0	83.0
Shale, light gray	83.0	88.2
Sandstone, medium gray, silty	88.2	88.3
Shale, medium gray, silty, sandy	88.3	92.0
Shale, medium gray, silty	92.0	107.0

Test Hole 12-78

Location: Pawnee County, SW SE SE SE sec. 36, T. 1 N., R. 12 E., approximately 5 feet north of south section line and 200 feet east of west section line.

Ground-level elevation: 1,185.0 feet above mean sea level.

Started: April 27, 1978. Completed: April 27, 1978.

Total depth: 127.5 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample)	0 -	1.5
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Scranton Formation:		
Rulo Member:		
Limestone, yellow, fine to very finely crystalline, highly weathered; contains algal material	1.5 -	2.0
Cedarvale-White Cloud Members:		
Shale, olive brown	2.0 -	3.0
Coal, black; contains black carbonaceous material	3.0 -	3.5
Shale, light to medium gray	3.5 -	7.0
Shale, light gray	7.0 -	11.0
Sandstone, reddish brown, interbedded with shale, gray	11.0 -	19.0
Silt, light gray, interbedded with sandstone; very fine grained; contains organic material	19.0 -	22.5
Shale, medium gray, silty, sandy	22.5 -	32.0
Shale, medium gray, interbedded with siltstone, light gray	32.0 -	39.9
Sandstone, brown, very fine grained	39.9 -	40.0
Shale, light gray, sandy, interbedded with siltstone, brown	40.0 -	44.0
Shale, olive brown, interbedded with sandstone, brown	44.0 -	48.0
Sandstone, orangish brown, interbedded with shale, brown	48.0 -	50.0
Shale, light gray, silty	50.0 -	53.0
Sandstone, brown, very fine grained, interbedded with silt, orangish brown	53.0 -	58.0
Shale, light greenish gray; contains trace of coal, black, thin	58.0 -	62.5
Sandstone, white to light gray, very fine grained, lime cemented; contains black carbonaceous material	62.5 -	64.9
Silt, light gray, interbedded with sandstone, gray, very fine grained	64.9 -	68.0

Description	Depth, in feet	
	From	To
Shale, light to medium gray, interbedded with siltstone, gray	68.0	71.0
Siltstone, gray, interbedded with shale, light gray	71.0	77.0
Siltstone, gray and greenish gray	77.0	83.0
Siltstone, greenish gray, sandy	83.0	86.5
Sandstone, light greenish gray	86.5	87.2
Siltstone, greenish gray, interbedded with sandstone, gray, very fine grained	87.2	88.0
Limestone, light tannish gray, very finely crystalline to dense	88.0	89.0
Shale, medium gray, silty	89.0	102.0
Shale, medium gray, interbedded with sandstone, gray, very fine grained	102.0	113.0
Shale, medium gray, silty; contains black carbonaceous material	113.0	116.8
Sandstone, light gray, very fine to fine grained; contains black carbonaceous material	116.8	117.5
Shale, medium gray, silty	117.5	118.0
Shale, light gray	118.0	122.5
Howard Formation:		
Limestone, bluish gray, irregularly crystalline, contains brachiopods, crinoids, and fusulinids	122.5	123.5
Shale, light gray	123.5	125.0
Limestone, bluish gray, irregularly crystalline; contains brachiopods, crinoids, and fusulinids	125.0	127.5

Test Hole 13-78

Location: Richardson County, SE SE SW SE sec. 9, T. 1 N., R. 13 E., approximately 33 feet north of south section line and 1,366 feet west of east section line.

Ground-level elevation: 1,120.0 feet above mean sea level.

Started: April 28, 1978. Completed: April 28, 1978.

Total depth: 103.0 feet.

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Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample)	0 -	1.0
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Stotler-Root Formations:		
French Creek Member:		
Shale, olive brown	1.0 -	11.0
Shale, olive gray	11.0 -	12.7
Shale, black	12.7 -	13.5
Shale, brown	13.5 -	14.0
Jim Creek Member:		
Limestone, medium gray mottled with brown, finely crystalline; contains brachiopods	14.0 -	14.4
Friedrich-Dry Members:		
Shale, brown	14.4 -	14.8
Shale, light gray; contains limy nodules and brachiopods	14.8 -	16.0
Shale, light gray	16.0 -	19.0
Shale, reddish brown	19.0 -	22.8
Shale, light greenish gray, interbedded with limestone, tannish gray, dense	22.8 -	25.5
Shale, red interbedded with light green	25.5 -	27.0
Shale, reddish brown	27.0 -	39.0
Shale, olive	39.0 -	41.0
Shale, medium gray	41.0 -	62.2
Dover Member:		
Limestone, medium to dark gray, finely crystalline; contains brachiopods	62.2 -	63.0
Pillsbury Formation:		
Shale, light greenish gray, silty, sandy, limy	63.0 -	65.0
Shale, reddish brown	65.0 -	69.0
Shale, olive	69.0 -	71.0
Shale, medium gray	71.0 -	79.5
Zeandale Formation:		
Maple Hill Member:		
Limestone, bluish gray, finely crystalline; contains brachiopods, crinoids, and fusulinids	79.5 -	81.4
Wamego Member:		
Coal, black	81.4 -	81.6
Shale, light gray	81.6 -	89.0
Shale, medium gray	89.0 -	91.2
Tarkio Member:		
Limestone, medium to dark gray, finely crystalline, pebbly texture; contains brachiopods	91.2 -	92.0
Shale, light gray interbedded with reddish brown	92.0 -	93.3
Shale, reddish brown	93.3 -	95.0
Limestone, white to cream, finely crystalline; contains glauconite, fusulinids, and *Osagia*	95.0 -	100.5

Description	Depth, in feet	
	From	To
Willard Formation:		
Shale, light greenish gray interbedded with sandstone, tan, very fine grained.....	100.5	-101.3
Shale, olive interbedded with gray and brown...	101.3	-103.0

Test Hole 14-78

Location: Richardson County, SE corner SW sec. 10, T. 1 N., R. 13 E., approximately 25 feet north of south line and 2,614 feet east of west section line.

Ground-level elevation: 1,050.0 feet above mean sea level.

Started: April 28, 1978. Completed: April 28, 1978.

Total depth: 137.0 feet.

Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample).....	0	2.0
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Wood Siding Formation:		
Pony Creek-Plumb Members:		
Shale, brownish gray.....	2.0	- 6.0
Shale, reddish brown.....	6.0	- 15.2
Shale, olive interbedded with gray.....	15.2	- 19.0
Nebraska City Member:		
Limestone, medium gray, finely crystalline: contains brachiopods.....	19.0	- 20.0
Root Formation:		
French Creek Member:		
Shale, olive brown.....	20.0	- 20.4
Coal, black.....	20.4	- 21.0
Shale, light gray.....	21.0	- 24.5
Shale, medium gray.....	24.5	- 26.5
Limestone, medium gray, finely crystalline; contains brachiopods and pyrite.....	26.5	- 27.1
Coal, black.....	27.1	- 27.2
Shale, light gray.....	27.2	- 36.0
Shale, medium gray.....	36.0	- 41.3
Jim Creek Member:		
Limestone, medium gray, finely crystalline; contains brachiopods.....	41.3	- 43.0
Friedrich Member:		
Shale, light gray.....	43.0	- 48.0
Shale, reddish brown.....	48.0	- 51.0

Description	Depth, in feet	
	From	To
Shale, reddish brown interbedded with greenish gray	51.0 -	51.5
Stotler Formation:		
Grandhaven Member:		
Limestone, cream and light gray, interbedded with shale, red	51.5 -	54.0
Dry Member:		
Shale, light greenish gray, limy	54.0 -	55.0
Shale, reddish brown	55.0 -	66.0
Shale, olive mottled with gray	66.0 -	67.3
Shale, light to medium gray	67.3 -	91.6
Dover Member:		
Limestone, medium to dark gray, very finely crystalline; contains brachiopods and crinoids	91.6 -	92.5
Pillsbury Formation:		
Shale, light greenish gray	92.5 -	95.5
Shale, reddish brown	95.5 -	99.0
Shale, olive	99.0 -	100.0
Shale, medium gray	100.0 -	112.0
Zeandale Formation:		
Maple Hill Member:		
Limestone, medium gray, finely crystalline; contains brachiopods, crinoids, and glauconite	112.0 -	113.2
Wamego Member:		
Shale, medium to dark gray	113.2 -	115.0
Limestone, bluish gray, irregularly crystalline; contains brachiopods and crinoids	115.0 -	115.4
Shale, light gray	115.4 -	119.0
Shale, medium gray	119.0 -	120.9
Tarkio Member:		
Limestone, dark gray, irregularly crystalline; pebbly texture; contains brachiopods and crinoids	120.9 -	121.6
Shale, light gray	121.6 -	122.7
Shale, reddish brown	122.7 -	124.0
Shale, greenish gray	124.0 -	124.4
Limestone, cream, irregularly crystalline; contains fusulinids and Osagia	124.4 -	129.0
Willard Formation:		
Shale, light greenish gray	129.0 -	131.0
Shale, olive interbedded with red	131.0 -	133.0
Shale, light greenish gray	133.0 -	135.0
Shale, light to medium gray	135.0 -	137.0

Test Hole 15-78

Location: Richardson County, SE NE SE NE sec. 16, T. 1 N., R. 13 E., approximately 1,670 feet south of north section line and 26 feet west of east section line.

Ground-level elevation: 1,090.0 feet above mean sea level.

Started: May 2, 1978. Completed: May 2, 1978.

Total depth: 107.0 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample)	0	1.0
Clay, brown, sandy	1.0	7.9
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Wood Siding Formation:		
Brownville Member:		
Limestone, dark yellow, very finely crystalline; contains brachiopods and crinoids	7.9	8.1
Pony Creek-Plumb Members:		
Shale, olive gray mottled with yellow	8.1	13.4
Limestone, yellowish brown, highly weathered; contains algal material	13.4	13.6
Shale, light greenish gray	13.6	15.5
Shale, reddish brown	15.5	21.0
Shale, olive gray	21.0	22.0
Shale, medium gray	22.0	23.7
Nebraska City Member:		
Limestone, medium to dark gray, finely crystalline; contains brachiopods and crinoids	23.7	25.5
Root Formation:		
French Creek Member:		
Coal, black	25.5	25.7
Shale, light gray	25.7	31.5
Shale, light gray, limy	31.5	31.9
Shale, light gray interbedded with black; contains traces of coal	31.9	32.1
Shale, light gray	32.1	38.0
Shale, medium gray	38.0	42.0
Shale, medium gray interbedded with dark gray	42.0	45.9
Jim Creek Member:		
Limestone, light to medium gray; contains brachiopods	45.9	46.2
Friedrich Member:		
Shale, light gray	46.2	51.5
Shale, reddish brown	51.5	55.1

Description	Depth, in feet From	To
Stotler Formation:		
Grandhaven Member:		
Limestone, light greenish gray, very finely crystalline; contains brachiopods.....	55.1 -	58.2
Dry Member:		
Shale, light greenish gray.....	58.2 -	59.2
Shale, reddish brown.....	59.2 -	71.0
Shale, ligh' gray interbedded with olive.....	71.0 -	72.0
Shale, medium gray.....	72.0 -	77.0
Shale, light to medium gray.....	77.0 -	82.0
Shale, light gray.....	82.0 -	94.7
Dover Member:		
Limestone, medium to dark bluish gray, irregularly crystalline; contains brachiopods and crinoids.....	94.7 -	95.7
Pillsbury Formation:		
Shale, light greenish gray.....	95.7 -	97.0
Shale, olive interbedded with greenish gray....	97.0 -	99.0
Shale, reddish brown interbedded with greenish gray and olive.....	99.0 -	102.0
Shale, olive interbedded with medium gray.....	102.0 -	104.0
Shale, medium gray.....	104.0 -	107.0

Test Hole 16-78

Location: Richardson County, NE NW NE NE sec. 20, T. 1 N., R. 13 E., approximately 11 feet south of north section line and 895 feet west of east section line.

Ground-level elevation: 1,0[illegible]7.0 feet above mean sea level.

Started: May 2, 1978. Completed: May 2, 1978.

Total depth: 197.0 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample).....	0 -	.0
Clay, reddish brown, silty; contains sand and gravel.....	2.0 -	7.0

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Description	Depth, in feet	
	From	To
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Topeka Formation:		
Tecumseh Member:		
Limestone, pale yellow, finely crystalline, highly weathered; contains fusulinids, crinoids, and Osagia	7.0 -	11.0
Willard Formation:		
Shale, olive mottled with yellow, brown, and red	11.0 -	13.0
Shale, light olive	13.0 -	19.0
Shale, medium gray	19.0 -	41.9
Virgilia Formation:		
Elmont Member:		
Limestone, brownish gray, finely to very finely crystalline; contains brachiopods and fusulinids	41.9 -	44.2
Shale, medium gray	44.2 -	45.2
Limestone, gray, finely to very finely crystalline; contains brachiopods, crinoids, bryozoans, and pyrite	45.2 -	46.5
Shale, light greenish gray	46.5 -	47.1
Limestone, light brown, finely crystalline; contains brachiopods	47.1 -	47.5
Harveyville Member:		
Shale, light greenish gray	47.5 -	49.0
Shale, medium gray	49.0 -	52.0
Reading Member:		
Limestone, medium gray, finely crystalline	52.0 -	54.5
Shale, medium gray	54.5 -	54.7
Limestone, medium gray, finely to very finely crystalline; contains brachiopods and crinoids	54.7 -	55.5
Limestone, medium gray, finely crystalline, interbedded with shale, gray	55.5 -	55.9
Shale, medium gray	55.9 -	56.0
Limestone, light gray, very finely crystalline and bluish gray, irregularly crystalline; contains algal material	56.0 -	57.0
Auburn Formation:		
Shale, light to medium gray, limy	57.0 -	62.3
Limestone, light gray, finely crystalline, interbedded with shale, greenish gray	62.3 -	63.0
Shale, light greenish gray	63.0 -	70.0
Shale, medium gray	70.0 -	80.0
Wakarusa Formation:		
Limestone, light gray, irregularly crystalline; contains brachiopods, fusulinids, and bryozoans	80.0 -	83.6

Description	Depth, in feet	
	From	To
Soldier Creek Formation:		
Shale, medium gray	83.6 -	90.0
Shale, light greenish gray	90.0 -	93.0
Burlingame Formation:		
South Fork Member:		
Limestone, cream and light tannish gray, fine to very finely crystalline; contains algal material	93.0 -	96.0
Winnebago Member:		
Shale, light greenish gray mottled with olive	96.0 -	100.0
Shale, medium gray	100.0 -	102.0
Taylor Branch Member:		
Limestone, medium gray, very finely crystalline; contains brachiopods	102.0 -	103.4
Shale, medium gray	103.4 -	104.5
Limestone, bluish gray, irregularly crystalline; contains brachiopods, crinoids, and pyrite	104.5 -	105.6
Shale, medium gray	105.6 -	107.0
Limestone, light gray, very finely crystalline; contains brachiopods	107.0 -	107.5
Scranton Formation:		
Shale, light greenish gray	107.5 -	111.0
Shale, light to medium gray	111.0 -	128.5
Shale, light greenish gray interbedded with dark greenish gray	128.5 -	140.0
Siltstone, medium gray	140.0 -	140.2
Shale, light greenish gray, silty	140.2 -	141.0
Shale, medium gray, silty, sandy	141.0 -	147.0
Shale, medium gray, interbedded with siltstone, greenish gray	147.0 -	152.5
Siltstone, medium gray, interbedded with sandstone, light greenish gray, very finely micaceous	152.5 -	156.2
Sandstone, light greenish gray, limy	156.2 -	160.0
Silt, medium gray, sandy	160.0 -	178.0
Sandstone, light gray, very fine grained, limy; contains black carbonaceous material	178.0 -	180.5
Silt, medium gray to light greenish gray, interbedded with sandstone, medium gray, very fine grained	180.5 -	197.0

Test Hole 17-78

Location: Richardson County, NE corner SE sec. 8, T. 1 N., R. 13 E., approximately 2,649 feet south of north section line and 20 feet west of east section line.

Ground-level elevation: 986.0 feet above mean sea level.

Started: May 3, 1978. Completed: May 3, 1978.

Total depth: 148.0 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample)	0 -	5.0
Clay, light brown	5.0 -	12.0
Clay, light grayish brown, silty	12.0 -	17.5
Clay, dark gray, silty	17.5 -	20.0
Clay, brownish gray, very silty; contains sand and gravel	20.0 -	22.0
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Auburn Formation:		
Shale, light gray	22.0 -	27.0
Shale, light gray interbedded with greenish gray	27.0 -	33.2
Wakarusa Formation:		
Limestone, yellowish brown, finely crystalline; contains brachiopods	33.2 -	35.9
Soldier Creek Formation:		
Shale, olive	35.9 -	36.0
Shale, light gray	36.0 -	39.5
Shale, light gray, limy	39.5 -	42.0
Shale, light to medium gray	42.0 -	48.0
Burlingame Formation:		
South Fork Member:		
Limestone, cream, fine to very fine crystalline; contains glauconite and algal material.	48.0 -	49.0
Winnebago Member:		
Shale, light greenish gray	49.0 -	50.0
Shale, olive mottled with gray	50.0 -	53.0
Shale, light to medium gray	53.0 -	56.0
Taylor Branch Member:		
Limestone, light to medium gray, finely crystalline; contains pyrite	56.0 -	57.0
Shale, light to medium gray	57.0 -	59.0
Limestone, bluish gray, irregularly crystalline; contains brachiopods and algal material	59.0 -	61.5

Description	Depth, in feet	
	From	To
Scranton Formation:		
Cedarvale Member:		
Shale, light gray, limy.....	61.5 -	63.0
Shale, medium to dark gray.....	63.0 -	65.0
Shale, light gray.....	65.0 -	80.2
Rulo Member:		
Limestone, bluish gray, irregularly crystalline; contains crinoids and pyrite.....	80.2 -	81.0
White Cloud Member:		
Shale, light gray.....	81.0 -	85.0
Shale, very light gray to white, limy.....	85.0 -	87.0
Shale, light and dark greenish gray.....	87.0 -	92.0
Shale, light greenish gray, interbedded with limestone, greenish gray, dense.....	92.0 -	97.0
Shale, light greenish gray.....	97.0 -	100.0
Shale, light to medium gray.....	100.0 -	115.0
Shale, medium gray, silty.....	115.0 -	120.0
Shale, medium gray, silty, interbedded with sandstone, medium gray, very fine grained....	120.0 -	135.0
Shale, medium gray, silty; contains black carbonaceous material.....	135.0 -	141.5
Shale, medium gray, silty, interbedded with sandstone, medium gray, very fine grained....	141.5 -	148.0

Test Hole 18-78

Location: Richardson County, NE corner SE sec. 5, T. 1 N., R. 13 E., approximately 2,642 feet south of north section line and 8 feet west of east section line.

Ground-level elevation: 980.0 feet above mean sea level.

Started: May 4, 1978. Completed: May 4, 1978.

Total depth: 122.0 feet.

Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample).....	0 -	3.0
Clay, brown, silty, sandy.....	3.0 -	23.0
Clay, light gray, silty, sandy.....	23.0 -	26.0
Clay, greenish gray, silty.....	26.0 -	29.0
Clay, brown, silty.....	29.0 -	32.0
Sand, medium to very coarse, and gravel, fine to medium; contains reworked shell fragments.....	32.0 -	44.0

Description	Depth, in feet	
	From	To
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Burlingame Formation:		
Taylor Branch Member:		
Shale, light gray	44.0	- 45.0
Limestone, light to medium gray, coarse to very finely crystalline	45.0	- 45.7
Scranton Formation:		
Silver Lake-Cedarvale Members:		
Shale, olive	45.7	- 46.5
Limestone, light gray, very finely crystalline	46.5	- 47.0
Shale, medium to dark gray	47.0	- 52.0
Shale, light to medium gray	52.0	- 57.0
Shale, light gray, interbedded with limestone, gray, dense	57.0	- 62.0
Shale, light gray	62.0	- 70.0
Shale, reddish brown	70.0	- 73.0
Shale, light greenish gray	73.0	- 75.0
Shale, reddish brown	75.0	- 79.5
Happy Hollow Member:		
Limestone, white with red staining, very finely crystalline, interbedded with sandstone, red, very fine grained	79.5	- 80.0
Shale, reddish brown	80.0	- 80.6
Limestone, white with red staining, very finely crystalline, interbedded with sandstone, red, very fine grained	80.6	- 81.0
White Cloud Member:		
Shale, light reddish brown	81.0	- 83.0
Shale, greenish gray	83.0	- 86.0
Shale, light gray, silty	86.0	- 92.0
Shale, light gray, silty, sandy	92.0	- 97.2
Limestone, medium to dark gray, irregularly crystalline; contains brachiopods, crinoids, and bryozoans	97.2	- 98.0
Shale, light gray	98.0	-107.0
Shale, medium gray, silty, sandy	107.0	-122.0

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Test Hole 19-78

Location: Richardson County, NW corner sec. 7, T. 1 N., R. 13 E., aproximately 16 feet south of north section line and 58 feet east of west section line.

Ground-level elevation: 1,010.0 feet above mean sea level.

Started: May 4, 1978. Completed: May 4, 1978.

Total depth: 92.0 feet.

Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample)	0	1.0
Clay, yellowish brown; contains sand and gravel	1.0	11.0
Clay, yellow mottled with olive; contains sand and gravel	11.0	16.0
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Soldier Creek Formation:		
Shale, olive	16.0	21.0
Shale, medium gray	21.0	23.0
Shale, light gray	23.0	24.5
Burlingame Formation:		
South Fork Member:		
Limestone, light gray, very finely crystalline; contains manganese staining and algal material	24.5	28.6
Winnebago Member:		
Shale, light gray mottled with olive	28.6	31.0
Shale, medium gray	31.0	33.2
Taylor Branch Member:		
Limestone, medium gray, very finely crystalline; contains brachiopods	33.2	34.3
Shale, medium to dark gray	34.3	38.0
Limestone, light tannish gray, very finely crystalline	38.0	39.2
Shale, light greenish gray, limy	39.2	40.2
Limestone, light gray, very finely crystalline; contains pyrite	40.2	41.0
Scranton Formation:		
Silver Lake Member:		
Shale, light gray	41.0	57.5
Rulo Member:		
Limestone, gray and brownish gray, very finely crystalline; contains brachiopods and crinoids	57.5	58.0
Cedarvale-White Cloud Members:		
Shale, light gray	58.0	61.0

Description	Depth, in feet	
	From	To
Shale, light greenish gray.....	61.0 -	68.0
Shale, light red interbedded with greenish gray.....	68.0 -	68.5
Shale, light greenish gray mottled with olive..	68.5 -	69.5
Shale, light greenish gray.....	69.5 -	72.0
Shale, light gray.....	72.0 -	82.0
Shale, light gray, silty.....	82.0 -	92.0

Test Hole 20-78

Location: Richardson County, Center South Line SE SE SW sec. 31, T. 2 N., R. 13 E., approximately 25 feet north of south section line and 2,305 feet east of west section line.

Ground-level elevation: 1,097.0 feet above mean sea level.

Started: May 4, 1978. Completed: May 4, 1978.

Total depth: 77.0 feet.

Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample).....	0 -	3.0
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Zeandale Formation:		
Wamego Member:		
Shale, yellowish brown.....	3.0 -	10.0
Shale, gray mottled with olive.....	10.0 -	13.0
Tarkio Member:		
Limestone, yellow and reddish gray, finely crystalline; contains brachiopods and crinoids...	13.0 -	14.0
Shale, reddish brown.....	14.0 -	15.0
Limestone, yellowish brown, very finely crystalline; contains Osagia, fusulinids, and manganese staining.....	15.0 -	16.5
Willard Formation:		
Shale, reddish gray mottled with greenish gray.....	16.5 -	17.0
Shale, reddish brown.....	17.0 -	20.0
Shale, greenish gray.....	20.0 -	22.0
Shale, reddish gray.....	22.0 -	23.0
Shale, greenish gray.....	23.0 -	26.0
Shale, light to medium gray mottled with olive.....	26.0 -	29.0

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Description	Depth, in feet	
	From	To
Shale, light to medium gray.....	29.0	- 43.0
Shale, medium gray, limy.....	43.0	- 50.5
Emporia Formation:		
Elmont Member:		
Limestone, bluish gray, very finely crystalline; contains brachiopods and fusulinids.....	50.5	- 52.7
Shale, medium gray.....	52.7	- 56.0
Limestone, light gray, very finely crystalline.....	56.0	- 56.2
Harveyville Member:		
Shale, light to medium gray mottled with olive.....	56.2	- 60.6
Reading Member:		
Limestone, gray, very finely crystalline; contains brachiopods and crinoids.....	60.6	- 63.5
Shale, medium gray.....	63.5	- 64.4
Limestone, light to medium gray, irregularly crystalline; contains brachiopods and crinoids.....	64.4	- 66.4
Auburn Formation:		
Shale, medium gray.....	66.4	- 68.5
Limestone, bluish gray, irregularly crystalline; contains brachiopods and crinoids.....	68.5	- 68.9
Shale, greenish gray.....	68.9	- 69.2
Shale, reddish brown.....	69.2	- 74.0
Shale, olive mottled with gray.....	74.0	- 76.0
Shale, medium gray.....	76.0	- 77.0

Test Hole 21-78

Location: Pawnee County, NE NW NE NE sec. 1, T. 1 N., R. 12 E., approximately 16 feet south of north section line and 665 feet west of east section line.

Ground-level elevation: 1,025.0 feet above mean sea level.

Started: May 5, 1978. Completed: May 5, 1978.

Total depth: 77.0 feet.

Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample).....	0	- 2.0
Clay, reddish brown, silty, sandy.....	2.0	- 7.0
Clay, brown, silty, sandy.....	7.0	- 12.0
Clay, yellowish brown, silty, sandy.....	12.0	- 17.0

Description	Depth, in feet	
	From	To
Clay, reddish brown, silty, sandy.....	17.0	- 27.0
Clay, reddish brown, silty, sandy; contains gravel.....	27.0	- 31.5
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Wakarusa Formation:		
Limestone, yellowish gray, very finely crystalline; contains crinoids.....	31.5	- 32.2
Soldier Creek Formation:		
Shale, olive.....	32.2	- 36.0
Shale, light to medium gray.....	36.0	- 41.0
Shale, light gray.....	41.0	- 43.0
Burlingame Formation:		
South Fork Member:		
Limestone, light greenish gray, very finely crystalline to dense; contains crinoids.....	43.0	- 46.0
Winnebago Member:		
Shale, light gray.....	46.0	- 50.5
Taylor Branch Member:		
Limestone, light to medium gray, very finely crystalline; contains brachiopods and bryozoan.....	50.5	- 51.6
Shale, medium to dark gray.....	51.6	- 53.4
Limestone, medium to dark gray, pebbly texture; contains brachiopods and bryozoans.....	53.4	- 53.6
Shale, dark gray.....	53.6	- 55.5
Limestone, light brownish gray, very finely crystalline to dense.....	55.5	- 56.6
Scranton Formation:		
Silver Lake Member:		
Shale, light gray to light greenish gray mottled with olive.....	56.6	- 60.0
Shale, light to medium gray.....	60.0	- 74.7
Rulo Member:		
Limestone, brownish gray, very finely crystalline; contains brachiopods.....	74.7	- 75.1
Cedarvale-White Cloud Members:		
Shale, light to medium gray.....	75.1	- 77.0

Test Hole 22-78

Location: Richardson County, Center West Line NW SW NW sec. 3, T. 1 N., R. 13 E., approximately 1,724 feet south of north section line and 49 feet east of west section line.

Ground-level elevation: 975.0 feet above mean sea level.

Started: May 5, 1978. Completed: May 5, 1978.

Total depth: 152.0 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample)	0	5.0
Sand, brown, very fine, silty	5.0	30.0
Sand, very fine to very coarse and gravel, fine to very coarse; interbedded with silt, brown	30.0	34.0
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Willard Formation:		
Shale, medium gray	34.0	35.0
Emporia Formation:		
Elmont Member:		
Limestone, light gray, very finely crystalline to dense; contains algal material	35.0	36.1
Shale, greenish gray interbedded with gray	36.1	39.0
Limestone, light gray, very finely crystalline; contains pyrite	39.0	39.5
Harveyville Member:		
Shale, medium gray mottled with olive	39.5	44.4
Reading Member:		
Limestone, medium to dark gray, very finely crystalline; contains brachiopods	44.4	47.4
Shale, medium to dark gray	47.4	48.0
Limestone, bluish gray, very finely crystalline; contains brachiopods, algal material, and pyrite	48.0	49.5
Auburn Formation:		
Shale, medium gray	49.5	52.3
Shale, greenish gray	52.3	53.0
Shale, reddish brown	53.0	58.0
Shale, olive	58.0	61.0
Shale, light to medium gray	61.0	66.0
Shale, medium gray	66.0	77.5
Wakarusa Formation:		
Limestone, bluish gray, irregularly crystalline; contains brachiopods, crinoids, and fusulinids	77.5	80.5
Soldier Creek Formation:		
Shale, greenish gray	80.5	85.0
Shale, medium gray	85.0	90.8
Burlingame Formation:		
South Fork Member:		
Limestone, cream, irregularly crystalline; contains algal material	90.8	94.0
Winnebago Member:		
Shale, olive mottled with gray	94.0	96.0
Shale, medium to dark gray	96.0	99.5

Description	Depth, in feet	
	From	To
Taylor Branch Member:		
Limestone, medium gray, very finely crystalline	99.5	100.8
Shale, medium to dark gray	100.8	102.7
Limestone, bluish gray, pebbly texture; contains brachiopods and algal material	102.7	103.5
Shale, medium gray	103.5	104.9
Limestone, light tannish gray, very finely crystalline; contains dark brown inclusions	104.9	106.2
Shale, light greenish gray	106.2	107.7
Limestone, light gray, fine to very finely crystalline	107.7	108.2
Scranton Formation:		
Silver Lake Member:		
Shale, maroon to red interbedded with light greenish gray	108.2	110.0
Shale, olive	110.0	112.0
Shale, medium gray	112.0	122.0
Shale, light to medium gray	122.0	126.3
Rulo Member:		
Limestone, brownish gray, very finely crystalline; contains brachiopods and pyrite	126.3	126.5
Cedarvale Member:		
Shale, light to medium gray	126.5	134.0
Shale, light greenish gray	134.0	135.0
Happy Hollow Member:		
Limestone, light greenish gray, very finely crystalline, interbedded with shale, red and green	135.0	141.5
White Cloud Member:		
Shale, reddish brown mottled with gray, green and olive	141.5	143.0
Shale, greenish gray mottled with olive	143.0	146.0
Shale, light to medium gray, interbedded with siltstone, gray	146.0	152.0

Test Hole 23-78

Location: Richardson County, NW SW NW NW, sec. 4, T. 1 N., R. 13 E., approximately 750 feet south of north section line and 10 feet east of west section line.

Ground-level elevation: 977.0 feet above mean sea level.

Started: May 9, 1978. Completed: May 9, 1978.

Total depth: 167.0 feet.

Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample)	0 -	3.0
Clay, grayish brown	3.0 -	23.0
Clay, dark gray, sandy	23.0 -	28.0
Sand, fine to very coarse and gravel, fine to very coarse	28 -	42.0
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Scranton Formation:		
Silver Lake Member:		
Shale, medium gray	42.0 -	44.0
Rulo Member:		
Limestone, brownish gray, very finely crystalline; contains brachiopods and pyrite	44.0 -	44.1
Cedarvale Member:		
Shale, medium gray	44.1 -	51.0
Shale, light greenish gray	51.0 -	52.0
Shale, reddish brown	52.0 -	55.0
Happy Hollow Member:		
Limestone, light greenish gray, very finely crystalline, interbedded with shale, red and green	55.0 -	56.2
White Cloud Member:		
Shale, light greenish gray	56.2 -	56.5
Shale, reddish brown mottled with olive	56.5 -	58.0
Shale, reddish brown	58.0 -	62.0
Shale, light gray	62.0 -	75.0
Limestone, dark gray, irregularly crystalline; contains brachiopods, crinoids, and fusulinids	75.0 -	75.5
Shale, light gray, silty, sandy	75.5 -	103.5
Claystone, dark brown	103.5 -	103.7
Shale, light gray, silty	103.7 -	117.0
Shale, light gray, silty, sandy	117.0 -	127.0
Shale, light gray, silty, sandy, interbedded with claystone, dark brown	127.0 -	132.0
Shale, light gray, silty	132.0 -	146.2
Howard Formation:		
Limestone, bluish gray, irregularly crystalline; contains brachiopods, fusulinids, pyrite, and black inclusions	146.2 -	153.0
Severy Formation:		
Shale, light gray	153.0 -	154.0
Shale, medium to dark gray	154.0 -	155.0
Coal, black	155.0 -	156.5
Shale, light to medium gray	156.5 -	158.2
Sandstone, light gray, very fine grained, lime cemented; contains black carbonaceous material	158.2 -	159.1
Shale, light gray, silty	159.1 -	167.0

Test Hole 24-78

Location: Richardson County, NW corner NE sec. 28, T. 2 N., R. 13 E., approximately 17 feet south of north section line and 2,630 feet west of east section line.

Ground-level elevation: 1,105.0 feet above mean sea level.

Started: May 9, 1978. Completed: May 9, 1978.

Total Depth: 125.0 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample)	0 -	1.0
Clay, yellowish brown	1.0 -	8.5
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Zeandale Formation:		
Maple Hill Member:		
Limestone, yellowish brown, irregularly crystalline; highly weathered, contains brachiopods and crinoids	8.5 -	9.5
Wamego Member:		
Shale, olive yellow	9.5 -	16.0
Shale, medium gray	16.0 -	24.5
Tarkio Member:		
Limestone, white to cream, irregularly crystalline; contains fusulinids and Osagia	24.5 -	26.0
Shale, light bluish gray	26.0 -	26.2
Limestone, light gray, finely crystalline	26.2 -	27.0
Willard Formation:		
Shale, reddish brown interbedded with olive and greenish gray	27.0 -	32.0
Shale, light gray	32.0 -	58.9
Emporia Formation:		
Elmont Member:		
Limestone, bluish gray, irregularly crystalline; contains brachiopods, crinoids, and fusulinids	58.9 -	61.0
Shale, light gray	61.0 -	62.5
Shale, light greenish gray	62.5 -	63.5
Limestone, light greenish gray, very finely crystalline and light tannish gray, irregular crystalline	63.5 -	65.0
Harveyville Member:		
Shale, light to medium gray	65.0 -	68.8
Reading Member:		
Limestone, gray, fine to very finely crystalline; contains brachiopods, crinoids, and bryozoans	68.8 -	72.0

Description	Depth, in feet	
	From	To
Shale, medium gray	72.0 -	73.0
Limestone, light to medium gray, finely to very finely crystalline; contains brachiopods and crinoids	73.0 -	74.1
Auburn Formation:		
Shale, light gray	74.1 -	78.0
Shale, light greenish gray	78.0 -	79.0
Shale, reddish gray	79.0 -	82.0
Shale, olive	82.0 -	85.0
Shale, light to medium gray	85.0 -	97.5
Wakarusa Formation:		
Limestone, light to medium bluish gray, finely to very finely crystalline; contains brachiopods, crinoids, and fusulinids	97.5 -	100.4
Shale, dark gray to black	100.4 -	100.5
Limestone, light to medium bluish gray, very finely crystalline; contains brachiopods and crinoids	100.5 -	101.0
Soldier Creek Formation:		
Shale, light gray	101.0 -	108.5
Burlingame Formation:		
South Fork Member:		
Limestone, brownish gray, very finely crystalline to dense	108.5 -	109.5
Shale, reddish gray	109.5 -	110.0
Limestone, white to light gray, finely crystalline; contains algal material	110.0 -	112.5
Winnebago Member:		
Shale, light to medium gray	112.5 -	119.5
Taylor Branch Member:		
Limestone, medium gray, very finely crystalline; contains brachiopods and pyrite	119.5 -	120.5
Shale, medium gray	120.5 -	122.5
Limestone, bluish gray, pebbly texture; contains algal material	122.5 -	123.5
Shale, light to medium gray	123.5 -	125.0

Test Hole 25-78

Location: Richardson County, NW NW SW SW sec. 26, T. 2 N., R. 13 E., approximately 1,056 feet north of south section line and 20 feet east of west section line.

Ground-level elevation: 973.0 feet above mean sea level.

Started: May 11, 1978. Completed: May 11, 1978.

Total depth: 122.0 feet.

Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample)	0 -	4.0
Clay, brown, sandy	4.0 -	7.0
Sand, very fine to very coarse	7.0 -	12.0
Sand, very fine to very coarse and gravel, very fine to medium	12.0 -	17.0
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Stotler Formation:		
Dry Member:		
Shale, reddish brown	17.0 -	18.0
Shale, reddish brown mottled with olive	18.0 -	19.0
Shale, medium gray	19.0 -	34.3
Dover Member:		
Limestone, medium to dark gray, irregularly crystalline; contains brachiopods and crinoids	34.3 -	35.0
Pillsbury Formation:		
Shale, olive gray	35.0 -	37.0
Shale, light greenish gray	37.0 -	39.0
Shale, reddish brown	39.0 -	43.0
Shale, reddish brown mottled with green, gray and olive	43.0 -	45.0
Shale, medium gray	45.0 -	54.5
Zeandale Formation:		
Maple Hill Member:		
Limestone, medium gray, irregularly crystalline; contains brachiopods, crinoids, and fusulinids	54.5 -	56.3
Wamego Member:		
Coal, black	56.3 -	56.4
Shale, light gray	56.4 -	62.0
Shale, light to medium gray	62.0 -	65.5
Tarkio Member:		
Limestone, cream, iregularly crystalline; contains fusulinids and Osagia	65.5 -	70.0
Willard Formation:		
Sandstone, reddish brown interbedded with greenish gray, very fine grained	70.0 -	72.0
Shale, light gray	72.0 -	76.0
Shale, light to medium gray, silty, interbedded with sandstone, gray, very fine grained, thin	76.0 -	92.0
Shale, light to medium gray, slightly silty	92.0 -	103.0
Emporia Formation:		
Elmont Member:		
Limestone, light to medium bluish gray, irregularly crystalline; contains brachiopods and fusulinids	103.0 -	105.3
Shale, light gray	105.3 -	107.0
Limestone, light gray and light greenish gray, very finely crystalline	107.0 -	109.0

Description	Depth, in feet	
	From	To
Harveyville Member:		
Shale, medium gray.....	109.0 -	113.6
Reading Member:		
Limestone, bluish gray, irregularly crystalline; contains brachiopods and crinoids.....	113.6 -	116.8
Shale, medium gray.....	116.8 -	117.6
Limestone, medium gray, irregularly crystalline; contains brachiopods and crinoids.....	117.6 -	118.6
Auburn Formation:		
Shale, medium gray.....	118.6 -	122.0

Test Hole 26-78

Location: Pawnee County, NE corner SE sec. 14, T. 2 N., R. 12 E., approximately 1,330 feet south of north section line and 8 feet east of west section line.

Ground-level elevation: 991.0 feet above mean sea level.

Started: May 11, 1978. Completed: May 11, 1978.

Total depth: 122.0 feet.

Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample).....	0 -	5.0
Clay, brown.....	5.0 -	15.0
Clay, brown, sandy.....	15.0 -	20.0
Clay, greenish brown, very sandy.....	20.0 -	28.5
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Scranton Formation:		
White Cloud Member:		
Shale, dark olive gray.....	28.5 -	33.0
Shale, light to medium gray.....	33.0 -	40.3
Howard Formation:		
Limestone, bluish gray, irregularly crystalline; contains brachiopods, crinoids, fusulinids...	40.3 -	42.7
Severy Formation:		
Coal, black.....	42.7 -	43.1
Shale, light gray.....	43.1 -	43.5
Shale, light gray; contains black carbonaceous material.....	43.5 -	45.0
Shale, light gray, interbedded with sandstone, gray, very fine grained.....	45.0 -	48.0
Shale, light gray to light greenish gray; contains black carbonaceous material.....	48.0 -	62.0

Description	Depth, in feet	
	From	To
Shale, light gray.....	62.0 -	74.3
Shawnee Group:		
Topeka Formation:		
Coal Creek Member:		
Limestone, light to medium bluish gray, irregularly crystalline; contains fusulinids.....	74.3 -	76.1
Shale, light gray, sandy.....	76.1 -	77.5
Limestone, bluish gray, very finely crystalline; contains brachiopods and crinoids.....	77.5 -	78.5
Shale, dark gray to black.....	78.5 -	78.7
Limestone, bluish gray, very finely crystalline; contains brachiopods and crinoids.....	78.7 -	79.4
Holt Member:		
Shale, black.....	79.4 -	82.0
DuBois Member:		
Limestone, bluish gray, irregularly crystalline; contains brachiopods and crinoids.....	82.0 -	82.8
Shale, medium gray.....	82.8 -	83.0
Limestone, light gray, very finely crystalline.....	83.0 -	83.7
Shale, medium gray.....	83.7 -	84.3
Limestone, light tannish gray, very finely crystalline to dense.....	84.3 -	84.9
Turner Creek Member:		
Shale, light greenish gray, limy.....	84.9 -	87.5
Sheldon-Iowa Point Members:		
Limestone, light gray and light bluish gray, irregularly to very finely crystalline, interbedded with shale, gray; contains brachiopods and algal material.....	87.5 -	95.4
Limestone, bluish gray, finely crystalline; contains brachiopods and fusulinids.....	95.4 -	96.5
Shale, medium gray.....	96.5 -	97.2
Limestone, medium gray, very finely crystalline; contains brachiopods.....	97.2 -	97.5
Shale, light gray.....	97.5 -	99.1
Hartford Member:		
Limestone, bluish gray, irregularly crystalline; contains brachiopods and pyrite.....	99.1 -	99.6
Shale, light gray; contains black carbonaceous material.....	99.6 -	99.9
Limestone, light tannish gray, irregularly crystalline; contains brachiopods.....	99.9 -	100.7
Calhoun Formation:		
Shale, dark gray.....	100.7 -	101.0
Shale, light greenish gray.....	101.0 -	102.2

Description	Depth, in feet From	To
Deer Creek Formation:		
Ervine Creek Member:		
Limestone, light gray to light tannish gray, irregularly crystalline; contains Osagia, algal material, and black inclusions.....	102.2 -	110.0
Limestone, light tannish gray, finely to very finely crystalline; contains crinoids and fusulinids.....	110.0 -	119.0
Shale, dark gray; contains black carbonaceous material.....	119.0 -	119.6
Limestone, light to medium gray, finely crystalline; contains brachiopods.....	119.6 -	120.0
Larsh Member:		
Shale, light gray; contains black carbonaceous material.....	120.0 -	121.0
Shale, black.....	121.0 -	122.0

Test Hole 27-78

Location: Richardson County, NW corner sec. 19, T. 2 N., R. 13 E., approximately 35 feet south of north section line and 12 feet east of west section line.

Ground-level elevation: 1,047.0 feet above mean sea level.

Started: May 14, 1978. Completed: May 14, 1978.

Total depth: 177.5 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample).....	0 -	4.0
Clay, brown, sandy.....	4.0 -	11.0
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Scranton Formation:		
Silver Lake-Cedarvale Members:		
Shale, yellowish olive.....	11.0 -	17.0
Shale, medium gray mottled with olive.....	17.0 -	19.0
Shale, light gray.....	19.0 -	21.0
Shale, light greenish gray.....	21.0 -	23.0
Shale, reddish brown.....	23.0 -	26.4
Happy Hollow Member:		
Limestone, light greenish gray, very finely crystalline, stained red and green.....	26.4 -	27.6

Description	Depth, in feet	
	From	To
Scranton-Severy Formations:		
Shale, reddish brown	27.6 -	28.0
Shale, yellowish olive	28.0 -	30.0
Shale, red mottled with olive	30.0 -	31.0
Shale, light gray	31.0 -	34.0
Shale, medium gray	34.0 -	39.5
Limestone, dark bluish gray, irregularly crystalline; contains brachiopods, crinoids, and fusulinids	39.5 -	41.4
Shale, light gray	41.4 -	53.0
Shale, light gray interbedded with sandstone, gray, very fine grained	53.0 -	57.2
Sandstone, light gray, very fine to fine grained, limy, interbedded with shale, light gray, silty	57.2 -	59.2
Shale, light gray, silty	59.2 -	77.0
Shale, light gray, silty, sandy	77.0 -	92.0
Shale, light to medium gray, silty, sandy	92.0 -	104.5
Shale, light gray, limy; contains black carbonaceous material	104.5 -	106.5
Shale, light greenish gray, silty	106.5 -	132.0
Shale, light to medium gray interbedded with sandstone, gray, very fine, grained	132.0 -	152.0
Shawnee Group:		
Topeka Formation:		
Coal Creek Member:		
Limestone, medium to dark gray, irregularly crystalline; contains brachiopods and fusulinids	152.0 -	156.0
Holt Member:		
Shale, black	156.0 -	158.8
DuBois Member:		
Limestone, bluish gray, fine to very finely crystalline; contains brachiopods and crinoids	158.8 -	161.2
Turner Creek Member:		
Shale, light greenish gray	161.2 -	164.6
Sheldon-Curzon Members:		
Limestone, cream, irregularly crystalline and medium gray, finely crystalline, interbedded with shale, greenish gray; contains brachiopods and algal material	164.6 -	171.0
Limestone, light to medium gray, irregularly crystalline interbedded with shale, gray; contains brachiopods, crinoids, and fusulinids	171.0 -	177.5

Test Hole 28-78

Location: Richardson County, NW corner sec. 21, T. 2 N., R. 13 E., approximately 65 feet south of north section line and 15 feet east of west section line.

Ground-level elevation: 1,133.0 feet above mean sea level.

Started: May 15, 1978. Completed: May 15, 1978.

Total depth: 212.0 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample)	0 -	2.0
Clay, yellowish brown, silty, sandy	2.0 -	12.0
Sand, fine to very coarse and gravel, fine to coarse; contains reworked limestone	12.0 -	19.5
Clay, brownish gray	19.5 -	32.0
Clay, medium gray, silty	32.0 -	47.0
Silt, medium gray, clayey	47.0 -	62.0
Silt, medium to dark gray, clayey, limy	62.0 -	67.0
Sand, medium to very coarse and gravel, fine to very coarse; contains reworked limestone	67.0 -	79.0
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Auburn Formation:		
Shale, olive	79.0 -	81.0
Shale, medium to dark gray mottled with olive	81.0 -	86.0
Shale, medium to dark gray	86.0 -	95.3
Wakarusa Formation:		
Limestone, gray, very finely crystalline; contains brachiopods, crinoids, and fusulinids	95.3 -	98.4
Soldier Creek Formation:		
Shale, medium gray	98.4 -	106.0
Shale, medium gray interbedded with brown	106.0 -	108.0
Burlingame Formation:		
South Fork Member:		
Limestone, cream, irregularly crystalline; contains algal material	108.0 -	110.0
Winnebago Member:		
Shale, light greenish gray	110.0 -	112.0
Shale, medium to dark gray	112.0 -	115.0
Taylor Branch Member:		
Limestone, gray, very finely crystalline	115.0 -	115.5
Shale, medium gray	115.5 -	116.5
Limestone, gray, very finely crystalline; contains brachiopods	116.5 -	117.5
Shale, medium to dark gray	117.5 -	120.7
Limestone, bluish gray, irregularly crystalline; contains brachiopods and algal material	120.7 -	121.5

Description	Depth, in feet	
	From	To
Shale, medium to dark gray, sandy	121.5	122.8
Limestone, light greenish gray, very finely crystalline	122.8	123.5
Shale, medium to dark gray	123.5	125.5
Limestone, light brownish gray, very finely crystalline; contains red staining	125.5	127.0
Scranton Formation:		
Silver Lake-Cedarvale Members:		
Shale, light to medium gray	127.0	132.0
Shale, medium to dark gray, silty	132.0	142.0
Shale, light gray	142.0	149.0
Shale, light greenish gray	149.0	151.0
Shale, reddish brown	151.0	157.6
Happy Hollow Member:		
Limestone, light greenish gray, very finely crystalline, stained red and yellow, interbedded with shale reddish yellow and green	157.6	161.0
White Cloud Member:		
Shale, medium gray	161.0	169.5
Limestone, bluish gray, irregularly crystalline; contains brachiopods, crinoids, and fusulinids	169.5	170.6
Shale, light to medium gray	170.6	181.0
Shale, medium gray, silty, interbedded with sandstone, gray, very fine grained, thin	181.0	191.0
Shale, light to medium gray, silty, sandy	191.0	212.0

Test Hole 29-78

Location: Richardson County, NE corner NW sec. 21, T. 2 N., R. 13 E., approximately 25 feet south of north section line and 2,639 feet east of west section line.

Ground-level elevation: 1,125.0 feet above mean sea level.

Started: May 15, 1978 Completed: May 16, 1978.

Total depth: 302.0 feet.

Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample)	0	4.0
Sand, brown, very fine to medium grained, silty	4.0	9.0

Description	Depth, in feet	
	From	To
Sand, fine to very coarse, and gravel, fine to medium....	9.0 -	26.0
Silt, brownish olive, sandy.....	26.0 -	34.0
Silt, light gray, sandy.....	34.0 -	74.0
Silt, light bluish gray.....	74.0 -	84.0
Silt, light bluish gray interbedded with brownish gray.....	84.0 -	90.0
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Willard Formation:		
Shale, light to medium gray.....	90.0 -	99.2
Emporia Formation:		
Limestone, bluish gray, irregularly crystalline; contains brachiopods, crinoids, and fusulinids.....	99.2 -	101.6
Shale, light gray.....	101.6 -	103.0
Limestone, light gray to cream, irregularly crystalline; contains algal material.....	103.0 -	105.5
Harveyville Member:		
Shale, light to medium gray.....	105.5 -	109.2
Reading Member:		
Limestone, medium gray, finely to very finely crystalline; contains brachiopods and crinoids.....	109.2 -	112.5
Shale, medium gray.....	112.5 -	113.0
Limestone, light to medium gray, finely to very finely crystalline; contains brachiopods and crinoids.....	113.0 -	114.6
Willard Formation:		
Shale, medium gray.....	114.6 -	117.4
Shale, light greenish gray.....	117.4 -	117.6
Shale, reddish brown.....	117.6 -	122.0
Shale, olive mottled with red.....	122.0 -	125.0
Shale, medium to dark gray.....	125.0 -	138.5
Wakarusa Formation:		
Limestone, bluish gray, finely to very finely crystalline; contains brachiopods, crinoids, and fusulinids.....	138.5 -	142.0
Soldier Creek Formation:		
Shale, medium gray.....	142.0 -	147.0
Shale, light to medium gray.....	147.0 -	150.0
Limestone, brownish gray, very finely crystalline to dense.....	150.0 -	151.0
Shale, reddish brown mottled with olive.....	151.0 -	152.0
Burlingame Formation:		
South Fork Member:		
Limestone, white to light gray, finely to very finely crystalline; contains algal material..	152.0 -	154.0

Description	Depth, in feet	
	From	To
Winnebago Member:		
Shale, light greenish gray	154.0	158.0
Shale, medium gray	158.0	160.5
Taylor Branch Member:		
Limestone, medium gray, very finely crystalline; contains brachiopods and pyrite	160.5	162.2
Shale, medium to dark gray	162.2	164.8
Limestone, light gray, very finely crystalline; contains algal material	164.8	167.4
Shale, medium gray	167.4	169.5
Limestone, light tannish gray, very finely crystalline to dense	169.5	170.5
Scranton Formation:		
Silver Lake-Cedarvale Members:		
Shale, medium gray	170.5	189.1
Shale, medium gray interbedded with siltstone, brown	189.1	195.0
Shale, light greenish gray	195.0	197.0
Shale, reddish brown	197.0	202.2
Happy Hollow Member:		
Limestone, light greenish gray, very finely crystalline to dense, stained red, interbedded with shale, reddish gray	202.2	203.0
White Cloud Member:		
Shale, light olive gray	203.0	206.0
Shale, light to medium gray	206.0	214.2
Limestone, bluish gray, pebbly texture contains brachiopods, crinoids, fusulinids, and pyrite	214.2	215.0
Shale, light to medium gray	215.0	229.5
Shale, light gray, limy	229.5	231.0
Shale, light gray, silty	231.0	262.0
Shale, light to medium gray, silty	262.0	283.2
Howard Formation:		
Limestone, dark bluish gray, irregular crystalline; contains brachiopods, crinoids, fusulinids, and pyrite	283.2	285.6
Severy Formation:		
Coal, black	285.6	286.2
Shale, light to medium gray, silty	286.2	292.0
Shale, light gray, silty interbedded with sandstone, gray, very fine grained, thin	292.0	302.0

Test Hole 30-78

Location: Pawnee County, NE corner SE sec. 26, T. 2 N., R. 12 E., approximatel 2,655 feet south of north section line and 5 feet west of east section line.

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Ground-level elevation: 1,178.0 feet above mean sea level.

Started: May 16, 1978. Completed: May 16, 1978.

Total depth: 122.0 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample)	0 -	2.0
Clay, yellowish brown, silty, sandy	2.0 -	7.0
Clay, reddish brown, silty, sandy	7.0 -	12.0
Clay, light brown, silty, sandy	12.0 -	18.0
Sand, fine to very coarse and gravel very fine to medium	18.0 -	25.0
Clay, olive brown, silty, sandy	25.0 -	32.0
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Auburn Formation:		
Shale, reddish brown mottled with olive	32.0 -	37.0
Shale, olive yellow	37.0 -	39.5
Shale, medium gray	39.5 -	47.0
Shale, medium to dark gray mottled with gray	47.0 -	51.5
Wakarusa Formation:		
Limestone, bluish gray, irregularly crystalline; contains brachiopods, crinoids, fusulinids, and pyrite	51.5 -	54.5
Soldier Creek Formation:		
Shale, light to medium gray	54.5 -	61.0
Shale, reddish brown	61.0 -	63.0
Burlingame Formation:		
South Fork Member:		
Limestone, white to cream, finely to very finely crystalline; contains algal material	63.0 -	65.0
Winnebago Member:		
Shale, maroon interbedded with limestone, pale red, dense, thin	65.0 -	67.0
Shale, medium gray	67.0 -	73.1
Taylor Branch Member:		
Limestone, medium gray, very finely crystalline; contains brachiopods	73.1 -	74.2
Shale, medium gray	74.2 -	76.0
Limestone, bluish gray, irregularly crystalline; pebbly, contains brachiopods, crinoids, and algal material	76.0 -	77.9
Shale, medium gray	77.9 -	82.5
Shale, light gray, limy, interbedded with limestone, gray, dense, thin	82.5 -	83.5
Scranton Formation:		
Silver Lake-Cedarvale Members:		
Shale, light gray	83.5 -	86.0
Shale, medium gray	86.0 -	99.2

Description	Depth, in feet	
	From	To
Shale, medium gray, interbedded with siltstone, brown	99.2	100.5
Shale, light gray, limy	100.5	103.0
Shale, light greenish gray	103.0	104.0
Shale, reddish brown	104.0	107.0
Happy Hollow Member:		
Limestone, light tannish gray, very finely crystalline to dense	107.0	107.2
White Cloud Member:		
Shale, reddish brown	107.2	108.0
Shale, light greenish gray	108.0	109.0
Shale, olive interbedded with red	109.0	110.0
Shale, olive gray	110.0	115.0
Shale, medium to light gray	115.0	119.8
Limestone, dark bluish gray, irregularly crystalline; contains brachiopods, crinoids, fusulinids, and algal material	119.8	121.0
Shale medium gray, interbedded with siltstone, gray	121.0	122.0

Test Hole 31-78

Location: Richardson County, SE corner SW sec. 15, T. 2 N., R. 13 E., approximately 60 feet north of south section line and 2,630 feet east of west section line.

Ground-level elevation: 1,120.0 feet above mean sea level.

Started: May 17, 1978. Completed: May 17, 1978.

Total depth: 32.0 feet.

Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample)	0	1.0
Clay, light brown, silty	1.0	3.0
Clay, dark brown, silty	3.0	9.5
Silt, light brown, sandy	9.5	12.5
Permian System - Big Blue Series - Council Grove Group:		
Beattie Formation:		
Cottonwood Member:		
Limestone, pale yellow, finely to very finely crystalline; contains fusulinids	12.5	17.0

Description	Depth, in feet	
	From	To
Eskridge Formation:		
Shale, light olive	17.0	- 22.0
Shale, reddish brown	22.0	- 26.2
Shale, light olive	26.2	- 29.5
Limestone, light tannish gray, very finely crystalline to dense	29.5	- 30.4
Shale, olive	30.4	- 32.0

Test Hole 32-78

Location: Richardson County, NE corner sec. 21, T. 2 N., R. 13 E., approximately 91 feet south of north section line and 49 feet west of east section line.

Ground-level elevation: 1,115.0 feet above mean sea level.

Started: May 18, 1978. Completed: May 18, 1978.

Total depth: 100.0 feet.

Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample)	0	- 2.0
Clay, reddish brown, silty	2.0	- 6.5
Clay, light brown, silty	6.5	- 14.0
Clay, brownish gray	14.0	- 22.8
Permian System - Big Blue Series - Admire Group:		
Five Point Formation:		
Limestone, cream, irregularly crystalline; contains algal material	22.8	- 23.4
West Branch Formation:		
Shale, light olive	23.4	- 26.7
Shale, dark greenish gray, interbedded with siltstone, dark brown	26.7	- 28.0
Shale, light olive gray	28.0	- 31.0
Shale, yellow	31.0	- 32.0
Shale, light olive gray to greenish gray	32.0	- 36.0
Shale, medium to dark gray	36.0	- 45.0
Shale, olive mottled with yellow	45.0	- 45.3
Falls City Formation:		
Lehmer Member:		
Limestone, yellow, very finely crystalline; pseudo-oolitic	45.3	- 46.2
Reserve Member:		
Shale, medium gray	46.2	- 51.0

Description	Depth, in feet	
	From	To
Miles Member:		
Limestone, bluish gray, pebbly texture; contains black inclusions	51.0 -	51.4
Cnaga Formation:		
Hauxby-Towle Members:		
Shale, light greenish gray	51.4 -	55.4
Shale, greenish gray interbedded with reddish gray	55.4 -	63.5
Shale, reddish brown	63.5 -	68.5
Shale, greenish gray	68.5 -	69.0
Shale, olive mottled with gray	69.0 -	70.0
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Wood Siding Formation:		
Brownville Member:		
Limestone, light gray, very finely crystalline; contains brachiopods and glauconite	70.0 -	72.1
Pony Creek-Plumb Members:		
Shale, medium to light gray	72.1 -	75.0
Shale, reddish brown mottled with olive	75.0 -	75.4
Shale, olive mottled with gray	75.4 -	76.0
Shale, medium gray	76.0 -	76.5
Shale, reddish brown interbedded with gray	76.5 -	87.0
Shale, light greenish gray mottled with olive	87.0 -	88.0
Shale, medium gray	88.0 -	90.5
Nebraska City Member:		
Limestone, medium gray, very finely crystalline; contains brachiopods and crinoids	90.5 -	92.5
Root Formation:		
French Creek Member:		
Coal, black	92.5 -	93.0
Shale, light greenish gray	93.0 -	98.0
Coal, black	98.0 -	98.1
Shale, medium to light gray	98.1 -	100.0

Test Hole 33-78

Location: Richardson County, NE NW NE NE sec. 16, T. 2 N., R. 13 E., approximately 15 feet south of north section line and 650 feet west of east section line.

Ground-level elevation: 1,004.0 feet above mean sea level.

Started: May 18, 1978. Completed: May 18, 1978.

Total depth: 107 0 feet.

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Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample).....	0 -	5.0
Clay, reddish brown, silty.....	5.0 -	15.0
Clay, reddish brown, silty, sandy.....	15.0 -	20.0
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Root Formation:		
French Creek Member:		
Shale, medium to dark gray.....	20.0 -	25.5
Jim Creek Member:		
Limestone, bluish gray, irregularly crystalline; contains brachiopods and crinoids.....	25.5 -	26.2
Friedrich Member:		
Shale, light gray.....	26.2 -	38.0
Shale, light gray mottled with red.....	38.0 -	40.0
Shale, light gray.....	40.0 -	46.0
Shale, reddish gray.....	46.0 -	46.5
Limestone, light gray stained pale red, very finely crystalline.....	46.5 -	46.7
Shale, maroon interbedded with gray.....	46.7 -	47.2
Shale, light greenish gray.....	47.2 -	48.7
Shale, reddish brown.....	48.7 -	49.5
Stotler Formation:		
Grandhaven Member:		
Limestone, reddish brown, dense, interbedded with shale, reddish brown.....	49.5 -	51.0
Dry Member:		
Shale, reddish brown.....	51.0 -	56.0
Shale, olive.....	56.0 -	57.0
Shale, light gray.....		62.0
Shale, light to medium gray.....	[illegible] -	67.5
Dover Member:		
Limestone, bluish gray, irregularly crystalline; contains brachiopods and crinoids.....	67.5 -	68.4
Pillsbury Formation:		
Shale, light gray.....	68.4 -	70.0
Shale, light greenish gray.....	70.0 -	70.5
Shale, reddish brown.....	70.5 -	75.5
Shale, olive.....	75.5 -	76.5
Shale, light to medium gray.....	76.5 -	85.1
Zeandale Formation:		
Maple Hill Member:		
Limestone, medium gray, very finely crystalline; contains brachiopods and crinoids.....	85.1 -	85.4
Shale, dark gray.....	85.4 -	86.5
Limestone, bluish gray to medium gray, fine to very finely crystalline; contains brachiopods, crinoids, and fusulinids.....	86.5 -	88.1
Wamego Member:		
Shale, light gray.....	88.1 -	100.0

Description	Depth, in feet	
	From	To
Larkio Member:		
Limestone, cream, irregularly crystalline; contains fusulinids and Osagia.....	100.0 -	104.5
Willard Formation:		
Shale - light gray.....	104.5 -	107.0

Test Hole 34-78

Location: Richardson County, NE NW NW SW sec. 2, T. 2 N., R. 13 E., approximately 2,660 feet south of north section line and 650 feet east of west section line.

Ground-level elevation: 1,013.0 feet above mean sea level.

Started: May 19, 1978. Completed: May 19, 1978.

Total depth: 92.0 feet.

Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample).....	0 -	2.0
Permian System - Big Blue Series - Admire Group:		
Falls City Formation:		
Lehmer Member:		
Limestone, dark yellow, pebbly texture, porous.....	2.0 -	3.0
Reserve Member:		
Shale, light olive.....	3.0 -	7.7
Niles Member:		
Limestone, light tannish gray, irregularly crystalline; contains brachiopods and bryozoans.....	7.7 -	8.3
Onaga Formation:		
Rauxby-Towle Members:		
Shale, yellowish olive.....	8.3 -	10.7
Shale, olive.....	10.7 -	14.0
Shale, greenish gray mottled with red.....	14.0 -	16.0
Shale, greenish gray and light gray mottled with olive.....	16.0 -	18.5
Shale, reddish brown mottled with olive.....	18.5 -	20.0
Shale, reddish brown.....	20.0 -	26.0
Shale, olive gray.....	26.0 -	26.8

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Description	Depth, in feet	
	From	To
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Wood Siding Formation:		
Brownville Member:		
Limestone, pale yellow, very finely crystalline; contains brachiopods and manganese staining..	26.3	- 29.0
Pony Creek-Plumb Members:		
Shale, olive mottled with gray.....	29.0	- 32.0
Shale, medium gray.....	32.0	- 34.0
Shale, reddish brown interbedded with greenish gray.....	34.0	- 42.0
Shale, olive.....	42.0	- 43.0
Shale, light gray.....	43.0	- 45.0
Shale, medium gray.....	45.0	- 48.0
Nebraska City Member:		
Limestone, medium to dark gray, finely crystalline, impure; contains brachiopods.....	48.0	- 51.0
Root Formation:		
French Creek Member:		
Coal, black.....	51.0	- 51.5
Shale, light gray.....	51.5	- 53.2
Coal, black.....	53.2	- 53.5
Shale, light gray.....	53.5	- 64.0
Shale, light to medium gray.....	64.0	- 67.2
Jim Creek Member:		
Limestone, medium gray, very finely crystalline, impure; contains brachiopods.....	67.2	- 68.0
Friedrich Member:		
Shale, light gray.....	68.0	- 78.0
Shale, light greenish gray.....	78.0	- 79.0
Shale, reddish brown.....	79.0	- 81.0
Shale, light gray.....	81.0	- 83.5
Stotler Formation:		
Grandhaven Member:		
Limestone, light gray, very finely crystalline.....	83.5	- 83.8
Shale, light gray.....	83.8	- 86.5
Limestone, light gray, very finely crystalline; contains red and green staining.....	86.5	- 86.8
Dry Member:		
Shale, light gray mottled with red.....	86.8	- 87.5
Shale, light gray.....	87.5	- 92.0

Test Hole 35-78

Location: Richardson County, SE corner NW sec. 2, T. 2 N., R. 13 E., approximately 2,595 feet south of north section line and 2,545 feet east of west section line.

Ground-level elevation: 990.0 feet above mean sea level.

Started: May 19, 1978. Completed: May 19, 1978.

Total depth: 167.0 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample)	0 -	5.0
Silt, dark brown, clayey, sandy	5.0 -	22.0
Silt, light brown, clayey, sandy	22.0 -	40.0
Clay, light gray	40.0 -	45.0
Sand, fine to very coarse, and gravel, very fine to medium, interbedded with silt, dark gray	45.0 -	55.0
Permian System - Big Blue Series - Admire Group:		
Hamlin Formation:		
Stine Member:		
Shale, olive mottled with gray	55.0 -	60.0
Shale, light reddish brown mottled with olive	60.0 -	61.0
Shale, light gray	61.0 -	63.0
Five Point Formation:		
Limestone, white to light gray, irregularly crystalline; contains brachiopods and algal material	63.0 -	63.5
West Branch Formation:		
Shale, light greenish gray	63.5 -	64.0
Shale, light gray	64.0 -	67.0
Shale, light greenish gray, limy	67.0 -	70.0
Shale, light greenish gray interbedded with pale reddish brown	70.0 -	72.0
Shale, light greenish gray, limy	72.0 -	76.0
Shale, medium gray, limy	76.0 -	79.0
Shale, light to medium gray	79.0 -	86.0
Falls City Formation:		
Lehmer Member:		
Limestone, light gray, finely to very finely crystalline, pseudo-oolitic in part	86.0 -	88.2
Shale, light gray	88.2 -	88.4
Limestone, light gray, very finely crystalline	88.4 -	89.1
Reserve Member:		
Shale, medium gray	89.1 -	92.5

Description	Depth, in feet	
	From	To
Miles Member:		
Shale, light greenish gray; contains hard limy zones	92.5	93.5
Onaga Formation:		
Hauxby-Towle Members:		
Shale, light greenish gray	93.5	98.0
Shale, light gray interbedded with red and green	98.0	103.0
Shale, light gray to light greenish gray	103.0	106.0
Shale, brown	106.0	112.0
Shale, olive mottled with gray	112.0	113.5
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Wood Siding Formation:		
Brownville Member:		
Limestone, pale yellowish gray, finely to very finely crystalline; contains brachiopods and bryozoans	113.5	116.0
Shale, olive mottled with gray	116.0	118.2
Limestone, yellow, finely crystalline, sandy; contains bryozoans	118.2	118.8
Pony Creek-Plumb Members:		
Shale, light gray	118.8	121.0
Shale, light greenish gray	121.0	122.0
Shale, reddish brown interbedded with greenish gray	122.0	130.0
Shale, olive	130.0	131.0
Shale, light gray	131.0	132.0
Shale, light to medium gray	132.0	136.4
Nebraska City Member:		
Limestone, medium to dark gray, very finely crystalline, impure; contains brachiopods, crinoids, and bryozoans	136.4	137.3
Root Formation:		
French Creek Member:		
Coal, black	137.3	137.5
Shale, light gray	137.5	140.0
Coal, black	140.0	140.2
Shale, light gray	140.2	143.0
Sandstone, light gray, very fine grained, lime cemented, very finely micaceous	143.0	144.0
Shale, medium gray, silty	144.0	152.0
Shale, medium gray	152.0	156.3
Jim Creek Member:		
Limestone, medium gray, very finely crystalline; contains brachiopods and crinoids	156.3	158.0
Friedrich Member:		
Shale, light greenish gray	158.0	163.0
Shale, light gray	163.0	167.0

Test Hole 36-78

Location: Richardson County, SE corner SW sec. 35, T. 3 N., R. 13 E., approximately 85 feet north of south section line and 2,515 feet east of west section line.

Ground-level elevation: 1,071.0 feet above mean sea level.

Started: May 24, 1978. Completed: May 24, 1978.

Total depth: 92.0 feet.

Description	Depth, in feet From	To
Quaternary System:		
Clay, yellowish brown, silty, sandy.....	0 -	2.5
Permian System - Big Blue Series - Admire Group:		
Hamlin Formation:		
Stine member:		
Limestone, dark brown, irregularly crystalline.	2.5 -	3.0
Shale, light gray.....	3.0 -	4.0
Limestone, light tannish gray, very finely crystalline.....	4.0 -	4.3
Shale, light greenish gray.....	4.3 -	5.0
Shale, light gray.....	5.0 -	6.0
Limestone, light gray, very finely crystalline; contains fossil fragments.....	6.0 -	6.2
Shale, olive mottled with gray and brown.....	6.2 -	9.5
Limestone, pale yellow, irregularly crystalline; contains algal material.....	9.5 -	9.6
Shale, gray mottled with red, brown, and olive.....	9.6 -	13.2
Five Point Formation:		
Limestone, cream, irregularly crystalline; contains brachiopods and algal material.....	13.2 -	14.1
West Branch Formation:		
Shale, olive gray.....	14.1 -	15.5
Shale, medium gray.....	15.5 -	18.0
Shale, greenish gray.....	18.0 -	21.0
Shale, pale reddish brown.....	21.0 -	21.5
Shale, light greenish gray, limy.....	21.5 -	25.4
Shale, dark gray.....	25.4 -	27.2
Shale, light gray, limy.....	27.2 -	30.0
Shale, dark gray.....	30.0 -	31.0
Shale, medium gray.....	31.0 -	34.7
Falls City Formation:		
Lehmer Member:		
Limestone, light and medium gray, irregularly to very finely crystalline; contains pelecypods.	34.7 -	37.5
Reserve Member:		
Shale, dark gray.....	37.5 -	41.2

Description	Depth, in feet	
	From	To
Miles Member:		
Limestone, light to medium gray, irregularly crystalline; contains brachiopods.....	41.2	- 41.8
Onaga Formation:		
Hauxby-Towle Members:		
Shale, light greenish gray.....	41.8	- 47.0
Shale, light greenish gray interbedded with pale red.....	47.0	- 52.0
Shale, light greenish gray to light gray.....	52.0	- 54.0
Shale, reddish brown.....	54.0	- 58.0
Shale, greenish gray mottled with olive.....	58.0	- 59.5
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Wood Siding Formation:		
Brownville Member:		
Limestone, light greenish gray and yellow, very finely crystalline; contains brachiopods and glauconite.....	59.5	- 61.3
Pony Creek-Plumb Members:		
Shale, olive mottled with green and gray.....	61.3	- 68.0
Shale, reddish brown.....	68.0	- 76.0
Shale, olive.....	76.0	- 76.5
Shale, light to medium gray.....	76.5	- 79.0
Nebraska City Member:		
Limestone, medium to dark gray, finely crystalline, impure; contains brachiopods....	79.0	- 80.2
Root Formation:		
French Creek Member:		
Shale, light gray.....	80.2	- 80.7
Coal, black.....	80.7	- 81.2
Shale, light gray.....	81.2	- 85.0
Coal, black.....	85.0	- 85.3
Shale, light greenish gray.....	85.3	- 86.0
Shale, light gray, silty.....	86.0	- 92.0

Test Hole 37-78

Location: Richardson County, SE SW SW SE sec. 34, T. 3 N., R. 13 E., approximately 75 feet north of south section line and 2,040 feet west of east section line.

Ground-level elevation: 1,068.0 feet above mean sea level.

Started: May 24, 1968. Completed: May 24, 1978.

Total depth: 107.0 feet.

Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample)	0	4.0
Clay, light brown, silty	4.0	7.0
Clay, reddish brown, silty	7.0	12.0
Clay, yellowish olive, silty	12.0	17.5
Permian System - Big Blue Series - Council Grove Group:		
Foraker Formation:		
Americus Member:		
Limestone, medium gray, very finely crystalline; contains brachiopods and crinoids	17.5	18.0
Admire Group:		
Hamlin Formation:		
Oaks-Stine Members:		
Shale, black	18.0	19.0
Shale, brownish olive	19.0	19.3
Shale, medium gray	19.3	23.0
Shale, light gray	23.0	24.0
Shale, light greenish gray	24.0	29.0
Shale, light greenish gray interbedded with pale red	29.0	32.0
Shale, light greenish gray, interbedded with siltstone, tan	32.0	36.0
Shale, light greenish gray	36.0	43.0
Shale, medium to dark gray	43.0	47.4
Limestone, light to medium gray, very finely crystalline; contains brachiopods	47.4	48.0
Shale, medium gray	48.0	50.5
Limestone, light to medium gray, very finely crystalline	50.5	52.2
Shale, greenish gray	52.2	54.0
Limestone, light gray, fine to very finely crystalline	54.0	54.5
Shale, gray interbedded with greenish gray	54.5	58.0
Shale, olive	58.0	61.7
Shale, medium gray	61.7	62.4
Five Point Formation:		
Limestone, white to light gray, irregularly crystalline; contains brachiopods and algal material	62.4	67.0
West Branch Formation:		
Shale, light greenish gray, interbedded with claystone, gray	67.0	69.5
Shale, light greenish gray	69.5	75.0
Shale, light to medium gray	75.0	84.2
Falls City Formation:		
Lehmer Member:		
Limestone, medium to dark gray, pebbly texture, porous	84.2	87.8
Reserve Member:		
Shale, medium to dark gray	87.8	92.0

Description	Depth, in feet	
	From	To
Miles Member:		
Limestone, light to medium gray, irregularly crystalline; contains brachiopods, crinoids, algal material, and black inclusions.....	93.0 -	93.2
Onaga Formation:		
Hauxby-Towle Members:		
Shale, light greenish gray interbedded with pale red.....	93.2 -	97.0
Shale, light greenish gray.....	97.0 -	102.0
Shale, reddish brown.....	102.0 -	107.0

Test Hole 38-78

Location: Pawnee County, SE SW SE sec. 1, T. 2 N., R. 12 E., approximately 15 feet north of south section line and 1,640 feet west of east section line.

Ground-level elevation: 1,107.0 feet above mean sea level.

Started: May 24, 1978. Completed: May 24, 1978.

Total depth: 100.0 feet.

Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample).....	0 -	0.5
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Wakarusa Formation:		
Limestone, yellowish brown, fine to very finely crystalline, highly weathered; contains brachiopods, crinoids, and fusulinids.....	0.5 -	3.5
Burlingame-Soldier Creek Formations:		
Shale, olive yellow.....	3.5 -	8.0
Shale, gray mottled with olive, red, and green.....	8.0 -	15.0
Shale, light gray.....	15.0 -	20.0
Shale, medium gray.....	20.0 -	26.5
Taylor Branch Member:		
Limestone, bluish gray, irregularly crystalline; contains brachiopods and algal material.....	26.5 -	27.3
Shale, light gray.....	27.3 -	28.0
Limestone, light gray, very finely crystalline.....	28.0 -	28.8
Shale, light greenish gray.....	28.8 -	29.0
Shale, medium to dark gray.....	29.0 -	30.4

Description	Depth, in feet	
	From	To
Limestone, light tannish gray, dense; contains glauconite.....	30.4 -	32.0
Scranton Formation:		
Shale, light greenish gray, silty.....	32.0 -	34.0
Shale, light gray, silty.....	34.0 -	44.0
Shale, medium gray, silty interbedded with sandstone, gray, very fine grained, thin.....	44.0 -	66.0
Limestone, light tannish gray, very finely crystalline to dense.....	66.0 -	66.8
Shale, light greenish gray.....	66.8 -	73.0
Shale, reddish brown.....	73.0 -	76.0
Limestone, light tannish gray, very finely crystalline; contains brachiopods and fusulinids.....	76.0 -	77.3
Shale, olive.....	77.3 -	79.0
Shale, medium gray.....	79.0 -	92.0
Shale, medium gray, silty interbedded with sandstone, gray, very fine grained, thin.....	92.0 -	100.0

Test Hole 39-78

Location: Richardson County, SE corner NE, sec. 33, T. 3 N., R. 13 E., approximately 2,565 feet south of north section line and 10 feet west of east section line.

Ground-level elevation: 1,055.0 feet above mean sea level.

Started: May 25, 1978. Completed: May 25, 1978.

Total depth: 92.0 feet.

Description	Depth, in feet	
	From	To
Quaternary System:		
Road fill (no sample).....	0 -	4.0
Sand, very fine to medium silty.....	4.0 -	7.0
Clay, brown, silty, sandy.....	7.0 -	20.0
Permian(?)-Pennsylvanian(?) Systems:		
Shale, light gray, silty.....	20.0 -	25.0
Shale, light gray mottled with olive.....	25.0 -	30.0
Shale, light gray, silty, interbedded with sandstone, brown very fine grained.....	30.0 -	35.0
Shale, light gray, silty.....	35.0 -	46.7
Sandstone, light gray, very fine grained, lime cemented, interbedded with silt, gray.....	46.7 -	49.6
Shale, light gray, silty interbedded with sandstone, gray, very fine grained.....	49.6 -	70.2

Description	Depth, in feet	
	From	To
Sandstone, medium gray fine to medium grained; contains black carbonaceous material.....	70.2	- 73.0
Coal, black.....	73.0	- 73.2
Shale, light gray.....	73.2	- 74.0
Shale, medium gray.....	74.0	- 79.0
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Zeandale Formation:		
Maple Hill Member:		
Limestone, light to medium gray, irregularly crystalline; contains brachiopods, crinoids, fusulinids, and pyrite.....	79.0	- 81.0
Wamego Member:		
Coal, black.....	81.0	- 82.0
Shale, light gray.....	82.0	- 86.0
Shale, light to medium gray.....	86.0	- 92.0

Test Hole 40-78

Location: Richardson County, SE corner SW sec. 27, T. 3 N., R. 13 E., approximately 10 feet north of south section line and 2,900 feet west of east section line.

Ground-level elevation: 1,113.0 feet above mean sea level.

Started: May 25, 1978. Completed: May 25, 1978.

Total depth: 107.0 feet.

Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample).....	0	- 2.0
Silt, yellowish brown, sandy.....	2.0	- 9.6
Permian System - Big Blue Series - Council Grove Group:		
Foraker Formation:		
Long Creek Member:		
Limestone, yellow, very finely crystalline, highly weathered.....	9.6	- 10.0
Hughes Creek Member:		
Shale, yellow.....	10.0	- 17.0
Shale, yellowish olive.....	17.0	- 22.5
Shale, light gray.....	22.5	- 24.4
Limestone, medium to dark gray, very finely crystalline; contains brachiopods.....	24.4	- 25.0
Shale, black.....	25.0	- 27.0
Shale, light to medium gray.....	27.0	- 27.5

Description	Depth, in feet	
	From	To
Limestone, light gray, finely crystalline; contains brachiopods and fusulinids.....	27.5 -	29.0
Shale, medium gray.....	29.0 -	32.0
Shale, medium gray, interbedded with limestone, gray, irregularly crystalline; contains brachiopods.....	32.0 -	.0
Limestone, light gray, irregularly crystalline; contains brachiopods, interbedded with shale, medium gray.....	35.0 -	39.0
Shale, medium to dark gray.....	39.0 -	42.0
Limestone, bluish gray, pebbly texture; contains brachiopods, crinoids, and algal material.....	42.0 -	42.8
Shale, medium gray.....	42.8 -	50.6
Americus Member:		
Limestone, dark gray, irregularly crystalline, impure; contains brachiopods and crinoids....	50.6 -	51.5
Shale, light gray.....	51.5	52.0
Limestone, medium to dark gray, irregularly crystalline; contains brachiopods and crinoids.....	52.0 -	53.0
Shale, dark gray to black.....	53.0 -	53.8
Limestone, bluish gray, irregularly crystalline; contains brachiopods and crinoids.....	53.8 -	54.1
Admire Group:		
Hamlin Formation:		
Shale, dark gray.....	54.1 -	57.5
Shale, light gray, limy.....	57.5 -	62.0
Shale, greenish gray, limy.....	62.0 -	63.0
Shale, pale red, limy.....	63.0 -	65.0
Shale, light greenish gray, limy.....	65.0 -	70.0
Shale, pale reddish brown, limy.....	70.0 -	70.7
Shale, light gray to light greenish gray.....	70.7 -	74.0
Shale, medium gray.....	74.0 -	82.0
Shale, medium gray, limy.....	82.0 -	85.9
Limestone, light gray, very finely crystalline.....	85.9 -	88.0
Shale, light gray to light greenish gray.....	88.0 -	90.0
Shale, light gray interbedded with olive.....	90.0 -	92.0
Shale, medium to dark gray.....	92.0 -	93.5
Five Point Formation:		
Limestone, cream, finely crystalline; contains brachiopods and crinoids.....	93.5 -	94.0
West Branch Formation:		
Shale, olive gray.....	94.0 -	98.0
Shale, pale red.....	98.0 -	98.4
Shale, greenish gray.....	98.4 -	100.0
Limestone, cream, very finely crystalline; contains glauconite.....	100.0 -	100.5
Shale, greenish gray.....	100.5 -	101.0

Description	Depth, in feet	
	From	To
Shale, greenish gray interbedded with pale red.....	101.0 -	104.0
Shale, greenish gray.....	104.0 -	105.0
Shale, light to medium gray.....	105.0 -	107.0

Test Hole 41-78

Location: Richardson County, SW corner sec. 26, T. 3 N., R. 13 E., approximately 20 feet north of south section line and 100 feet east of west section line.

Ground-level elevation: 1,142.0 feet above mean sea level.

Started: May 25, 1978. Completed: May 25, 1978.

Total depth: 152.0 feet.

Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample).....	0 -	2.0
Clay, light brown.....	2.0 -	9.0
Clay, reddish brown, silty.....	9.0 -	14.0
Clay, reddish brown, silty, sandy.....	14.0 -	17.0
Sand, medium to coarse.....	17.0 -	36.5
Permian System - Big Blue Series - Council Grove Group:		
Foraker Formation:		
Hughes Creek Member:		
Limestone, medium gray, very finely crystalline, impure; contains brachiopods.....	36.5 -	37.0
Shale, medium gray.....	37.0 -	40.5
Limestone, medium gray, finely crystalline; contains crinoids.....	40.5 -	41.0
Shale, light to medium gray, limy.....	41.0 -	46.0
Shale, medium to dark gray.....	46.0 -	50.0
Limestone, medium to dark gray, finely crystalline; contains brachiopods and crinoids.....	50.0 -	52.0
Shale, light to medium gray.....	52.0 -	59.3
Shale, medium gray, limy.....	59.3 -	61.0
Americus Member:		
Limestone, medium to dark gray, finely crystalline; contains brachiopods and crinoids.....	61.0 -	61.7
Shale, dark gray.....	61.7 -	62.5
Limestone, medium to dark gray, irregularly crystalline; contains brachiopods and crinoids, interbedded with shale, black.....	62.5 -	63.0

Description	Depth, in feet	
	From	To
Admir Group:		
Hamlin Formation:		
Oaks Member:		
Shale, medium gray.....	63.0 -	66.0
Shale, greenish gray.....	66.0 -	70.0
Shale, light gray interbedded with pale red, limy.....	70.0 -	75.0
Shale, light greenish gray to cream, limy.....	75.0 -	78.0
Houchens Creek Member:		
Limestone, light tannish gray, very finely crystalline.....	78.0 -	79.5
Stine Member:		
Shale, light gray.....	79.5 -	83.0
Shale, light to medium gray.....	83.0 -	88.0
Shale, medium to dark gray.....	88.0 -	93.0
Limestone, light to medium gray, very finely crystalline; contains brachiopods.....	93.0 -	93.5
Shale, light gray.....	93.5 -	96.0
Limestone, light gray, very finely crystalline.....	96.0 -	97.0
Shale, light gray.....	97.0 -	97.5
Limestone, light gray, very finely crystalline.....	97.5 -	99.5
Shale, medium gray.....	99.5 -	101.0
Five Point Formation:		
Limestone, cream, irregularly crystalline.....	101.0 -	101.8
West Branch Formation:		
Shale, light gray.....	101.8 -	108.0
Shale, light greenish gray interbedded with pale red, limy.....	108.0 -	111.0
Shale, light to medium gray.....	111.0 -	113.6
Shale, light gray, limy.....	113.6 -	115.0
Shale, medium gray.....	115.0 -	122.0
Falls City Formation:		
Lehmer Member:		
Limestone, gray, very finely crystalline.....	122.0 -	124.5
Reserve Member:		
Shale, light gray.....	124.5 -	129.0
Miles Member:		
Limestone, light to medium gray, irregularly crystalline; contains black inclusions.....	129.0 -	131.0
Onaga Formation:		
Hausby-Towle Members:		
Shale, light greenish gray, limy.....	131.0 -	134.0
Shale, light greenish gray interbedded with pale red.....	134.0 -	138.0
Shale, reddish brown.....	138.0 -	143.0

Description	Depth, in feet	
	From	To
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Wood Siding Formation:		
Brownville Member:		
Limestone, light gray and greenish gray, very finely crystalline; contains brachiopods and glauconite	143.0	145.0
Pony Creek-Plumb Members:		
Shale, olive	145.0	147.0
Shale, reddish brown	147.0	152.0

Test Hole 42-78

Location: Richardson County, NE corner NW sec. 35, T. 3 N., R. 13 E., approximately 15 feet south of north section line and 2,695 feet west of east section line.

Ground-level elevation: 1,112.0 feet above mean sea level.

Started: May 26, 1978. Completed: May 26, 1978.

Total depth: 152.0 feet.

Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample)	0	5.0
Silt, yellowish brown, silty, sandy	5.0	10.0
Sandstone, yellowish brown, very fine grained, highly weathered	10.0	15.3
Permian System - Big Blue Series - Council Grove Group:		
Foraker Formation:		
Long Creek Member:		
Limestone, yellow, irregularly crystalline, porous, vuggy	15.3	16.0
Silt, yellow	16.0	19.5
Limestone, pale yellow, very finely crystalline	19.5	20.0
Hughes Creek Member:		
Shale, light gray	20.0	25.0
Shale, medium gray	25.0	29.5
Shale, light gray	29.5	33.0
Limestone, medium to dark gray, finely crystalline; contains brachiopods	33.0	33.6
Shale, black	33.6	36.0
Limestone, light to medium gray, finely to very finely crystalline; contains brachiopods	36.0	37.0
Shale, light gray	37.0	40.0

Description	Depth, in feet	
	From	To
Limestone, medium gray, finely crystalline; contains brachiopods and crinoids.....	40.0 -	40.4
Shale, light gray.....	40.4 -	42.0
Limestone, medium gray, finely crystalline; contains brachiopods, crinoids, and fusulinids.....	42.0 -	42.6
Shale, light gray.....	42.6 -	43.5
Limestone, medium gray, finely crystalline; contains brachipods.....	43.5 -	44.9
Shale, dark gray.....	44.9 -	49.0
Limestone, bluish gray, irregularly crystalline; pebbly texture; contains brachiopods and algal material.....	49.0 -	51.0
Shale, medium to dark gray.....	51.0 -	56.0
Shale, dark gray.....	56.0 -	59.0
Americus Member:		
Limestone, medium gray, finely crystalline; contains brachiopods and crinoids.....	59.0 -	60.2
Shale, black.....	60.2 -	61.0
Limestone, medium gray, irregularly crystalline; contains brachiopods and algal material.....	61.0 -	61.2
Admire Group:		
Hamlin Formation:		
Oaks Member:		
Shale, medium gray.....	61.2 -	65.0
Shale, greenish gray.....	65.0 -	69.5
Shale, light gray interbedded with pale red....	69.5 -	72.0
Shale, light greenish gray.....	72.0 -	76.0
Houchens Creek Member:		
Limestone, tannish gray, very finely crystalline.....	76.0 -	77.0
Stine Member:		
Shale, light gray to greenish gray, silty.....	77.0 -	80.0
Shale, medium gray.....	80.0 -	87.0
Shale, dark gray.....	87.0 -	88.0
Shale, light gray, limy.....	88.0 -	90.0
Shale, medium gray, silty.....	90.0 -	92.0
Shale, light gray, limy.....	92.0 -	94.5
Gypsum, white.....	94.5 -	95.8
Shale, light gray to greenish gray.....	95.8 -	98.0
Shale, olive.....	98.0 -	100.0
Shale, medium gray.....	100.0 -	102.0
Five Point Formation:		
Limestone, cream, irregularly crystalline; contains brachiopods and algal material.....	102.0 -	104.0
West Branch Formation:		
Shale, light gray.....	104.0 -	108.0
Shale, greenish gray.....	108.0 -	109.0
Shale, light greenish gray interbedded pale red, limy.....	109.0 -	114.0
Shale, dark gray to black.....	114.0 -	115.0

Description	Depth, in feet	
	From	To
Shale, light gray, limy	115.0	120.0
Shale, light gray	120.0	123.0
Falls City Formation:		
Lehmer Member:		
Limestone, gray, very finely crystalline, oolitic	123.0	126.0
Reserve Member:		
Shale, medium to light gray	126.0	130.0
Miles Member:		
Limestone, bluish gray, finely crystalline, pebbly texture; contains black inclusions	130.0	132.0
Onaga Formation:		
Hauxby-Towle Members:		
Shale, greenish gray	132.0	135.0
Shale, medium gray interbedded with pale red	135.0	137.0
Shale, light gray interbedded with greenish gray, limy	137.0	139.0
Limestone, cream, very finely crystalline	139.0	140.0
Shale, reddish brown	140.0	145.5
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Wood Siding Formation:		
Brownville Member:		
Limestone, pale yellowish gray, finely to very finely crystalline; contains brachiopods and crinoids	145.5	147.5
Pony Creek-Plumb Members:		
Shale, light gray	147.5	148.0
Shale, olive	148.0	149.5
Shale, light gray mottled with red	149.5	150.0
Shale, light greenish gray	150.0	152.0

Test Hole 43-78

Location: Richardson County, SW NW SW sec. 35, T. 3 N., R. 13 E., approximately 1,700 feet north of south section line and 20 feet east of west section line.

Ground-level elevation: 1,110.0 feet above mean sea level.

Started: May 26, 1978. Completed: May 26, 1978.

Total depth: 92.0 feet.

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Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample).....	0 -	1.0
Permian System - Big Blue Series - Council Grove Group:		
Foraker Formation:		
Long Creek Member:		
Limestone, yellow, very finely to irregularly crystalline, porous, vuggy.....	1.0 -	2.0
Shale, yellow.....	2.0 -	6.0
Limestone, pale yellow, irregularly crystalline.....	6.0 -	7.5
Hughes Creek Member:		
Shale, yellow brown.....	7.5 -	10.0
Shale, olive yellow.....	10.0 -	14.0
Shale, medium gray.....	14.0 -	17.0
Shale, olive.....	17.0 -	21.2
Limestone, medium to dark gray, very finely crystalline; contains brachiopods.....	21.2 -	21.7
Shale, black.....	21.7 -	23.0
Shale, medium gray.....	23.0 -	24.0
Limestone, light to medium gray, fine crystalline; contains brachiopods.....	24.0 -	26.0
Shale, medium gray.....	26.0 -	28.5
Limestone, medium gray, finely crystalline; contains brachiopods and crinoids.....	28.5 -	29.5
Shale, medium gray.....	29.5 -	32.0
Limestone, medium gray, finely crystalline: contains brachiopods, crinoids, and fusulinids.....	32.0 -	33.0
Shale, light gray, limy.....	33.0 -	35.0
Shale, medium to dark gray.....	35.0 -	39.0
Limestone, bluish gray, finely crystalline; contains brachiopods, crinoids, and fusulinids.....	39.0 -	41.0
Shale, medium to dark gray.....	41.0 -	48.4
Americus Member:		
Limestone, bluish gray, irregularly crystalline contains brachiopods, crinoids, and algal material.....	48.4 -	49.1
Shale, black.....	49.1 -	50.0
Limestone, dark gray, finely crystalline; contains brachiopods and crinoids.....	50.0 -	50.1
Admire Group:		
Hamlin Formation:		
Oaks-Stine Members:		
Shale, medium gray.....	50.1 -	54.0
Shale, greenish gray.....	54.0 -	58.0
Shale, greenish gray interbedded with pale red.....	58.0 -	61.0
Shale, greenish gray, interbedded with limestone, tan, dense.....	61.0 -	66.0

Description	Depth, in feet	
	From	To
Shale, light greenish gray, silty.....	66.0	- 70.0
Shale, light to medium gray.....	70.0	- 74.0
Shale, medium to dark gray.....	74.0	- 78.0
Limestone, light brownish gray, very finely crystalline.....	78.0	- 78.4
Shale, light gray.....	78.4	- 81.0
Limestone, light brownish gray, very finely crystalline.....	81.0	- 82.3
Shale, light greenish gray.....	82.3	- 83.7
Limestone, light tannish gray, very finely crystalline; contains fossil fragments.....	83.7	- 84.1
Shale, light greenish gray.....	84.1	- 84.6
Shale, medium gray.....	84.6	- 85.0
Shale, greenish gray mottled with olive.....	85.0	- 87.0
Limestone, cream, irregularly crystalline.....	87.0	- 89.0
Shale, pale reddish brown.....	89.0	- 91.0
Shale, dark gray.....	91.0	- 92.0

Test Hole 44-78

Location: Richardson County, SW corner NE sec. 10, T. 2 N., R. 13 E., approximately 2,440 feet south of north section line and 2,665 feet east of west section line.

Ground-level elevation: 980.0 feet above mean sea level.

Started: May 30, 1978. Completed: May 30, 1978.

Total depth: 152.0 feet.

Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample).....	0	- 10.0
Silt, dark brown, clayey.....	10.0	- 16.0
Silt, light brown, clayey.....	16.0	- 21.0
Silt, dark gray to dark brown.....	21.0	- 31.0
Silt, dark greenish gray.....	31.0	- 36.0
Sand, medium to coarse and gravel, very fine to medium.....	36.0	- 40.0
Permian System - Big Blue Series - Council Grove Group:		
Foraker Formation:		
Hughes Creek Member:		
Shale, black.....	40.0	- 41.0
Shale, medium gray.....	41.0	- 42.7

Description	Depth, in feet	
	From	To
Limestone, light to medium gray, very finely crystalline; contains brachiopods, fusulinids, and pelecypods	42.7	44.0
Shale, medium gray, interbedded with sandstone, gray, very fine grained	44.0	54.0
Shale, dark gray	54.0	59.0
Shale, medium to dark gray	59.0	66.0
Americus Member:		
Limestone, medium gray, very finely crystalline; contains brachiopods, crinoids, and pelecypods	66.0	68.3
Shale, black	68.3	69.0
Shale, medium gray	69.0	72.8
Admire Group:		
Hamlin Formation:		
Oaks-Stine Members:		
Limestone, medium to dark gray, finely crystalline, interbedded with shale, greenish gray	72.8	73.1
Shale, greenish gray, limy	73.1	77.0
Shale, greenish gray to medium gray	77.0	80.0
Shale, light gray interbedded with pale red; contains gypsum	80.0	85.0
Shale, light greenish gray, interbedded with claystone, tan	85.0	88.0
Shale, light to medium gray	88.0	92.0
Shale, medium to dark gray	92.0	96.0
Limestone, medium gray, very finely crystalline; contains fossil fragments, interbedded with shale, greenish gray	96.0	100.5
Limestone, light tannish gray, very finely crystalline	100.5	101.0
Shale, medium to dark gray	101.0	105.0
Shale, olive	105.0	107.0
Shale, medium to dark gray	107.0	109.0
Five Point Formation:		
Limestone, cream, irregularly crystalline; contains algal material	109.0	109.3
West Branch Formation:		
Shale, medium gray	109.3	112.5
Shale, greenish gray	112.5	113.0
Shale, medium to dark gray interbedded with pale red	113.0	117.0
Shale, medium gray, limy	117.0	122.0
Shale, medium gray	122.0	128.7
Falls City Formation:		
Lehmer Member:		
Limestone, gray, very finely crystalline, porous; contains gypsum	128.7	131.0
Reserve Member:		
Shale, medium gray	131.0	133.3

Description	Depth, in feet From	To
Miles Member:		
Limestone, light gray, very finely crystalline, interbedded with shale, greenish gray.....	133.3 -	134.5
Onaga Formation:		
Shale, greenish gray, limy.....	134.5 -	139.0
Shale, greenish gray interbedded with pale red.....	139.0 -	141.0
Shale, light greenish gray.....	141.0 -	144.0
Shale, reddish brown.....	144.0 -	149.6
Shale, light gray mottled with olive.....	149.6 -	152.0

Test Hole 45-78

Location: Richardson County, NW NE NE sec. 3, T. 2 N., R. 13 E., approximately 20 feet south of north section line and 780 feet west of east section line.

Ground-level elevation: 1,068.0 feet above mean sea level.

Started: May 30, 1978. Completed: May 30, 1978.

Total depth: 100.0 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample).....	0 -	1.0
Permian System - Big Blue Series - Admire Group:		
Hamlin Formation:		
Oaks-Stine Members:		
Shale, greenish gray.....	1.0 -	3.0
Shale, reddish brown.....	3.0 -	4.0
Shale, yellowish brown.....	4.0 -	10.0
Shale, yellowish brown interbedded with greenish gray.....	10.0 -	12.0
Shale, pale olive.....	12.0 -	15.0
Shale, light to medium gray.....	15.0 -	20.0
Shale, medium to dark gray.....	20.0 -	24.0
Limestone, medium gray, very finely crystalline; contains brachiopods.....	24.0 -	24.5
Shale, medium gray.....	24.5 -	26.8
Limestone, light to medium gray, very finely crystalline.....	26.8 -	29.0
Shale, greenish gray.....	29.0 -	29.5
Limestone, light gray, very finely crystalline; contains fossil fragments.....	29.5 -	30.2
Shale, olive.....	30.2 -	34.0

Description	Depth, in feet	
	From	To
Shale, medium to dark gray.....	34.0 -	36.2
Five Point Formation:		
Limestone, cream, irregularly crystalline; contains algal material.....	36.2 -	37.0
West Branch Formation:		
Shale, light gray.....	37.0 -	41.0
Shale, greenish gray.....	41.0 -	45.0
Shale, light greenish gray interbedded with pale red.....	45.0 -	48.0
Shale, medium gray, interbedded with claystone, tan.....	48.0 -	54.0
Shale, light gray.....	54.0 -	58.0
Falls City Formation:		
Lehmer Member:		
Limestone, medium to dark gray, irregularly crystalline; contains fossil fragments.....	58.0 -	61.0
Reserve Member:		
Shale, medium gray.....	61.0 -	65.1
Miles Member:		
Limestone, light to medium gray, irregularly crystalline, impure; contains brachiopods....	65.1 -	66.0
Onaga Formation:		
Hauxby-Towle Members:		
Shale, light greenish gray, limy.....	66.0 -	70.0
Shale, light greenish gray interbedded with pale red.....	70.0 -	75.0
Shale, reddish brown.....	75.0 -	81.0
Shale, greenish gray interbedded with olive....	81.0 -	82.0
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Wood Siding Formation:		
Brownville Member:		
Limestone, light greenish gray, very finely crystalline; contains brachiopods and glauconite.....	82.0 -	84.0
Pony Creek-Plumb Members:		
Shale, olive.....	84.0 -	87.0
Sandstone, yellowish brown, very fine grained..	87.0 -	87.5
Shale, greenish gray interbedded with pale red.....	87.5 -	90.0
Shale, reddish brown.....	90.0 -	99.0
Shale, olive.....	99.0 -	100.0

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Test Hole 46-78

Location: Richardson County, NW corner NE sec. 4, T. 2 N., R. 13 E., approximately 15 feet south of north section line and 2,565 feet west of east section line.

Ground-level elevation: 1,005.0 feet above mean sea level.

Started: May 30, 1978. Completed: May 30, 1978.

Total depth: 92.0 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample)	0 -	3.0
Clay, reddish brown, silty	3.0 -	9.0
Silt, brownish gray, sandy	9.0 -	10.0
Sand, fine to very coarse, and gravel, very fine to fine	10.0 -	23.0
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Zeandale Formation:		
Wamego Group:		
Shale, yellowish brown	23.0 -	24.0
Shale, light gray	24.0 -	32.0
Shale, medium gray	32.0 -	37.0
Shale, greenish gray	37.0 -	37.3
Tarkio Member:		
Limestone, cream, irregularly crystalline; contains fusulinids, Osagia, pseudo-oolites, and glauconite	37.3 -	41.6
Willard Formation:		
Shale, reddish brown	41.6 -	42.7
Shale, greenish gray, silty	42.7 -	47.0
Shale, medium gray	47.0 -	62.0
Shale, medium gray, interbedded with siltstone, gray	62.0 -	67.0
Shale, medium gray	67.0 -	75.0
Emporia Formation:		
Elmont Member:		
Limestone, light to medium bluish gray, finely to very finely crystalline; contains brachiopods and crinoids	75.0 -	77.1
Shale, light gray	77.1 -	79.0
Limestone, light tannish gray, very finely crystalline to dense	79.0 -	79.5
Shale, light greenish gray	79.5 -	81.0
Limestone, light greenish gray to tannish gray, very finely crystalline	81.0 -	81.6

Description	Depth, in feet From	To
Harveyville Member:		
Shale, greenish gray	81.6 -	84.4
Shale, medium gray	84.4 -	84.8
Reading Member:		
Limestone, bluish gray, fine to very finely crystalline; contains brachiopods, crinoids, and pyrite	84.8 -	86.7
Shale, medium gray	86.7 -	89.0
Limestone, bluish gray, irregularly crystalline; contains brachiopods and crinoids	89.0 -	90.2
Auburn Formation:		
Shale, greenish gray to light gray	90.2 -	92.0

Test Hole 47-78

Location. Richardson County, NE corner sec. 33, T. 3 N., R. 13 E., approximately 15 feet south of north section line and 80 feet west of east section line.

Ground-level elevation: 1,101.0 feet above mean sea level.

Started: May 30, 1978. Completed: May 30, 1978.

Total depth: 137.0 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample)	0 -	2.0
Silt, reddish brown, clayey, sandy	2.0 -	7.0
Silt, reddish brown, sandy	7.0 -	11.0
Sand, fine to very coarse, and gravel very fine to medium, interbedded with silt, brown.	11.0 -	16.0
Silt, light brown, clayey	16.0 -	26.0
Silt, light tan, clayey	26.0 -	62.5
Permian(?) - Pennsylvanian(?) Systems:		
Shale, medium gray	62.5 -	67.0
Shale, medium gray, silty	67.0 -	70.9
Sandstone, light gray, very fine to fine grained, lime cemented; contains black carbonaceous material	70.9 -	72.0
Shale, light gray, silty	72.0 -	77.0
Shale, light gray, silty, interbedded with sandstone, gray, very fine grained	77.0 -	82.0
Shale, light gray, silty	82.0 -	116.0
Sandstone, light gray, very fine to fine grained; contains pyrite	116.0 -	116.4

Description	Depth, in feet	
	From	To
Shale, light gray, silty.....	116.4 -	127.0
Shale, light gray, silty; contains trace of coal.....	127.0 -	132.8
Sandstone, light gray, very fine to fine grained, lime cemented; contains pyrite.....	132.8 -	133.9
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Coal, black.....	133.9 -	134.8
Shale, light gray.....	134.8 -	137.0

Test Hole 48-78

Location: Richardson County, NE corner sec. 35, T. 3 N., R. 13 E., approximately 15 feet south of north section line and 190 feet west of east section line.

Ground-level elevation: 1,153.0 feet above mean sea level.

Started: June 5, 1978. Completed: June 5, 1978.

Total depth: 137.0 feet.

Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample).....	0 -	3.0
Sand, very fine to very coarse, and gravel, very fine to medium.....	3.0 -	22.0
Sand, very fine to fine, silty.....	22.0 -	32.0
Silt, yellowish brown, sandy.....	32.0 -	48.0
Silt, medium gray and yellowish brown, sandy..	48.0 -	55.0
Permian System - Big Blue Series - Council Grove Group:		
Crouse Formation:		
Limestone, cream, irregularly crystalline, contains brachiopods and algal material.....	55.0 -	56.7
Easly Creek Formation:		
Shale, light gray, silty.....	56.7 -	60.0
Shale, light olive gray.....	60.0 -	63.0
Shale, reddish brown.....	63.0 -	64.0
Shale, light greenish gray.....	64.0 -	64.5
Shale, reddish brown.....	64.5 -	66.0
Shale, greenish gray.....	66.0 -	66.5
Shale, reddish brown.....	66.5 -	70.0
Shale, olive gray, silty.....	70.0 -	72.0

Description	Depth, in feet	
	From	To
Bader Formation:		
Middleburg Member:		
Limestone, yellow, coarse to very finely crystalline, porous	72.0 -	74.0
Hooser Member:		
Shale, light gray to olive gray	74.0 -	77.0
Shale, white to light gray, interbedded with sandstone, light gray, very fine grained	77.0 -	79.0
Shale, gray interbedded with green, red and olive	79.0 -	84.9
Eiss Member:		
Limestone, white, very finely crystalline, porous	84.9 -	87.3
Shale, light olive	87.3 -	89.0
Shale, medium gray	89.0 -	94.5
Limestone, medium gray, finely to very finely crystalline; contains brachiopods	94.5 -	96.3
Stearns Formation:		
Shale, light gray and greenish gray	96.3 -	102.0
Shale, reddish brown	102.0 -	105.0
Shale, cream, limy	105.0 -	108.0
Beattie Formation:		
Morrill-Florena Members:		
Limestone, light tannish gray, very finely crystalline	108.0 -	108.6
Shale, light gray to white	108.6 -	109.0
Limestone, light tannish gray, very finely crystalline; contains gypsum	109.0 -	111.0
Cottonwood Member:		
Limestone, cream to light gray, finely to irregularly crystalline; contains fusulinids	111.0 -	122.5
Eskridge Formation:		
Shale, pale red interbedded with gray	122.5 -	128.0
Shale, greenish gray	128.0 -	137.0

Test Hole 49-78

Location: Richardson County, SW corner NW sec. 26, T. 3 N., R. 13 E., approximately 2,635 feet south of north section line and 20 feet east of west section line

Ground-level elevation: 1,145.0 feet above mean sea level.

Started: June 6, 1978. Completed: June 6, 1978.

Total depth: 152.0 feet.

Description	Depth, to feet	
	From	To
Quaternary System:		
Soil (no sample)	0 -	2.0
Silt, brown, clayey	2.0 -	9.0
Silt, reddish brown, sandy	9.0 -	14.0
Sand, medium to very coarse and gravel, very fine to coarse, interbedded with clay, brown	14.0 -	25.0
Sand, medium to very coarse, and gravel, very fine to coarse	25.0 -	53.0
Permian System - Big Blue Series - Council Grove Group:		
Red Eagle Formation:		
Bennett Member:		
Shale, pale yellow, sandy, silty	53.0 -	55.0
Shale, black	55.0 -	59.7
Glenrock Member:		
Limestone, pale yellow, very finely crystalline	59.7 -	60.2
Shale, light gray, limy	60.2 -	62.0
Johnson Formation:		
Shale, yellowish olive	62.0 -	74.5
Foraker Formation:		
Long Creek Member:		
Limestone, yellowish brown, irregularly to very finely crystalline, porous, vuggy; contains algal material	74.5 -	80.0
Hughes Creek Member:		
Shale, pale yellow, interbedded with limestone, yellow, dense	80.0 -	84.0
Shale, light to medium gray	84.0 -	92.0
Shale, light gray	92.0 -	96.5
Limestone, medium to dark gray, finely crystalline; contains brachiopods	96.5 -	97.5
Shale, black	97.5 -	100.0
brachiopods and fusulinids	100.0 -	101.2
Shale, medium gray	101.2 -	104.0
Limestone, medium gray, finely crystalline; contains brachiopods and crinoids	104.0 -	104.5
Shale, light gray	104.5 -	106.0
mestone, medium gray, finely crystalline; contains brachiopods and crinoids	106.0 -	109.3
Shale, medium gray	109.3 -	113.5
Limestone, medium gray, finely crystalline; contains brachiopods and algal material	113.5 -	115.5
Shale, medium gray	115.5 -	124.5
Americus Member:		
Limestone, bluish gray, irregularly crystalline; contains brachiopods and crinoids	124.5 -	125.0
Shale, black	125.0 -	125.5
Limestone, light to medium gray, finely crystalline; contains brachiopods and crinoids	125.5 -	126.0

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Description	Depth, in feet	
	From	To
Admire Group:		
Hamlin Formation:		
Oaks-Stine Members:		
Shale, medium to dark gray	126.0	129.4
Shale, light gray, limy	129.4	130.3
Shale, greenish gray, limy	130.3	135.0
Shale, greenish gray interbedded with pale red	135.0	139.0
Shale, light tan to cream	139.0	143.0
Shale, light tan to cream, interbedded with siltstone, tan	143.0	146.0
Shale, medium gray	146.0	149.0
Shale, olive gray	149.0	152.0

Test Hole 50-78

Location: Richardson County, NE corner NW sec. 32, T. 3 N., R. 13 E., approximately 20 feet south of north section line and 2,560 feet east of west section line.

Ground-level elevation: 1,085.0 feet above mean sea level.

Started: June 6, 1978. Completed: June 6, 1978.

Total depth: 152.0 feet.

Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample)	0	2.0
Silt, reddish brown, clayey	2.0	7.0
Silt, pale brown, sandy	7.0	15.0
Sand, medium to coarse, and gravel, very fine to fine	15.0	16.0
Clay, light brown	16.0	29.0
No sample, lost circulation	29.0	42.0
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Willard Formation:		
Shale, pale olive, interbedded with siltstone, olive	42.0	44.0
Shale, medium gray, silty	44.0	47.0
Shale, medium gray mottled with olive	47.0	62.0
Shale, light gray	62.0	72.0

Description	Depth, to feet	
	From	To
Emporia Formation:		
Elmont Member:		
Limestone, brownish gray, very finely crystalline, contains brachiopods, fusulinids, and pyrite..	72.0 -	74.3
Shale, medium to light gray.....	74.3 -	76.3
Claystone, light gray.....	76.3 -	77.0
Limestone, light tannish gray, very finely crystalline.....	77.0 -	77.5
Claystone, light greenish gray.....	77.5 -	78.5
Limestone, light gray, very finely crystalline.....	78.5 -	79.3
Harveyville Member:		
Shale, greenish gray.....	79.3 -	79.7
Shale, medium gray.....	79.7 -	81.3
Reading Member:		
Limestone, medium gray, very finely crystalline; contains brachiopods and crinoids.....	81.3 -	84.5
Shale, medium gray.....	84.5 -	85.5
Limestone, light gray, irregularly crystalline; contains brachiopods, crinoids, and pyrite...	85.5 -	86.5
Auburn Formation:		
Shale, medium gray.....	86.5 -	88.0
Shale, greenish gray.....	88.0 -	91.3
Shale, dark reddish brown.....	91.3 -	94.0
Shale, reddish brown mottled with green and brown.....	94.0 -	95.3
Shale, greenish gray, interbedded with limestone, greenish brown, dense.....	95.3 -	102.0
Shale, light gray.....	102.0 -	107.0
Shale, medium gray.....	107.0 -	117.2
Wakarusa Formation:		
Limestone, light to medium gray, irregularly crystalline; contains brachiopods, crinoids, fusulinids, and pyrite, interbedded with shale, gray.....	117.2 -	121.3
Soldier Creek Formation:		
Shale, light gray.....	121.3 -	128.0
Burlingame Formation:		
South Fork Member:		
Limestone, tan, very finely crystalline to dense.....	128.0 -	129.0
Shale, light greenish gray.....	129.0 -	130.8
Limestone, cream, irregularly crystalline; contains Osagia, oolites, and algal material.....	130.8 -	132.5
Winnebago Member:		
Shale, light greenish gray, interbedded with limestone, tan dense.....	132.5 -	138.0
Taylor Branch Member:		
Limestone, medium to dark gray, very finely crystalline to dense; contains bryozoans.....	138.0 -	138.4

Description	Depth, in feet	
	From	To
Shale, light gray	138.4	139.0
Limestone, medium gray, very finely crystalline to dense	139.0	141.0
Shale, light gray	141.0	147.0
Shale, medium gray	147.0	150.0
Limestone, dark gray, irregularly crystalline; contains algal material and brachiopods	150.0	152.0

Test Hole 51-78

Location: Pawnee County, SE corner sec. 24, T. 3 N., R. 12 E., approximately 150 feet north of south section line and 60 feet west of east section line.

Mean sea-level elevation: 1,074.0 feet above mean sea level.

Started: June 7, 1978. Completed: June 7, 1978.

Total depth: 182.0 feet.

Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample)	0	3.0
Silt, brown, clayey	3.0	17.0
Silt, medium gray	17.0	27.0
Silt, medium gray, sandy	27.0	32.0
Sand, fine to very coarse and gravel, very fine to medium	32.0	36.0
Silt, medium gray, sandy	36.0	62.0
Silt, light gray	62.0	96.0
Sand, fine to very coarse and gravel very fine to medium.	96.0	107.0
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Scranton Formation:		
White Cloud Member:		
Shale, light to medium gray	107.0	122.0
Limestone, brownish gray, very finely crystalline to dense	122.0	122.1
Shale, light to medium gray	122.1	155.0
Howard Formation:		
Limestone, medium to dark bluish gray, irregularly crystalline; contains brachiopods, crinoids, fusulinids, and pyrite	155.0	160.0

Description	Depth, in feet	
	From	To
Severy Formation:		
Shale, black	160.0	161.0
Shale, light gray, silty	161.0	162.0
Shale, black	162.0	163.0
Coal, black	163.0	164.0
Shale, light gray	164.0	167.0
Sandstone, light gray, very fine grained, interbedded with shale, light gray	167.0	168.2
Shale, light gray, silty, sandy	168.2	172.0
Shale, light to medium gray, silty	172.0	182.0

Test Hole 52-78

Location: Richardson County, NE corner sec. 30, T. 3 N., R. 13 E., approximately 90 feet south of north section line and 15 feet west of east section line.

Ground-level elevation: 1,125.0 feet above mean sea level.

Started: June 8, 1978. Completed: June 8, 1978.

Total depth: 197.0 feet.

Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample)	0	2.0
Silt, reddish brown, clayey	2.0	7.0
Silt, reddish brown, sandy	7.0	12.0
Silt, brown, clayey, sandy	12.0	52.0
Silt, medium gray	52.0	62.0
Silt, brownish gray	62.0	67.0
Silt, light gray, sandy	67.0	72.0
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Soldier Creek Formation:		
Shale, greenish gray interbedded with olive	72.0	78.0
Burlingame Formation:		
South Fork Member:		
Limestone, light gray to cream, finely crystalline, porous; contains crinoids, interbedded with shale, red and green	78.0	85.0
Winnebago Member:		
Shale, brown	85.0	86.0
Shale, medium gray	86.0	92.0
Shale, medium to dark gray	92.0	97.0

Description	Depth, in feet	
	From	To
Taylor Branch Member:		
Limestone, dark gray, irregularly crystalline; contains algal material	97.0 -	98.0
Shale, medium gray	98.0 -	98.5
Limestone, light gray, very finely crystalline	98.5 -	99.3
Shale, medium gray	99.3 -	101.8
Limestone, light tannish gray, finely crystalline to dense	101.8 -	103.0
Scranton Formation:		
Cedarvale-White Cloud Members:		
Shale, medium to light gray	103.0 -	107.0
Shale, medium gray, silty	107.0 -	112.0
Shale, medium gray, silty, interbedded with sandstone, gray, very fine grained	112.0 -	117.0
Shale, medium gray, silty	117.0 -	134.5
Shale, black	134.5 -	135.0
Shale, medium gray	135.0 -	139.7
Limestone, light greenish gray, very finely crystalline, interbedded with shale, greenish gray	139.7 -	150.0
Limestone, cream, irregularly crystalline; contains algal material	150.0 -	151.2
Shale, brownish olive	151.2 -	153.0
Shale, medium to dark gray	153.0 -	154.0
Limestone, bluish gray, irregularly crystalline; contains crinoids and fusulinids	154.0 -	155.5
Shale, medium gray	155.5 -	181.4
Shale, medium gray, interbedded with limestone, brown, dense, thin	181.4 -	197.0

Test Hole 53-78

Location: Richardson County, SE corner NE sec. 21, T. 3 N., R. 13 E., approximately 5 feet north of south section line and 22 feet west of east section line.

Ground-level elevation: 1,107.0 feet above mean sea level.

Started: June 8, 1978. Completed: June 8, 1978.

Total depth: 122.0 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample)	0 -	1.0
Clay, brown, silty	1.0 -	13.0
Sand, fine to very coarse, and gravel, very fine to medium	13.0 -	54.0
Silt, light tan	54.0 -	58.0
Silt, gray	58.0 -	66.0
Permian System - Big Blue Series - Council Grove Group:		
Stearns Formation:		
Shale, light greenish gray	66.0 -	68.0
Shale, reddish brown	68.0 -	70.0
Shale reddish brown interbedded with greenish gray	70.0 -	72.0
Beattie Formation:		
Morrill-Florena Members:		
Shale, cream to white	72.0 -	74.3
Limestone, white to light gray, very finely crystalline	74.3 -	75.0
Limestone, white to light gray, very finely crystalline, interbedded with shale, light gray	75.0 -	76.2
Limestone, white to light gray, very finely crystalline, porous	76.2 -	77.0
Cottonwood Member:		
Limestone, cream, fine to irregularly crystalline; contains fusulinids	77.0 -	88.0
Eskridge Formation:		
Shale, light bluish gray	88.0 -	93.0
Shale, reddish brown	93.0 -	99.0
Shale, light gray	99.0 -	102.0
Shale, gray interbedded with black	102.0 -	103.2
Limestone, medium gray, very finely crystalline	103.2 -	104.0
Shale, dark gray	104.0 -	104.8
Limestone, brownish gray, very finely crystalline to dense	104.8 -	105.5

Description	Depth, in feet	
	From	To
Shale, medium gray, interbedded with limestone, tannish gray, dense	105.5 -	107.0
Shale, yellowish olive, silty	107.0 -	112.0
Shale, green interbedded with red	112.0 -	114.0
Limestone, light tannish gray, very finely crystalline to dense	114.0 -	116.0
Limestone, light greenish gray, dense	116.0 -	116.7
Shale, pale olive	116.7 -	117.5
Shale, reddish brown	117.5 -	120.0
Shale, greenish gray, limy	120.0 -	122.0

Test Hole 54-78

Location: Richardson County, NW corner sec. 26, T. 3 N., R. 13 E., approximately 15 feet south of north section line and 10 feet east of west section line.

Ground-level elevation: 1,154.[illegible] feet above mean sea level.

Started: June 8, 1978. Completed: June 8, 1978.

Total depth: 137.0 feet.

Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample)	0 -	3.0
Silt, brown, clayey	3.0 -	8.0
Silt, reddish brown, clayey	8.0 -	12.0
Silt, orangish brown, clayey	12.0 -	19.0
Permian System - Big Blue Series - Council Grove Group:		
Funston Formation:		
Limestone, pale yellow, irregularly crystalline; porous	19.0 -	24.0
Blue Rapids Formation:		
Shale, greenish gray	24.0 -	30.5
Limestone, pale yellow, coarsely crystalline	30.5 -	31.0
Shale, pale olive	31.0 -	35.0
Limestone, light gray, very finely crystalline	35.0 -	35.4
Shale, olive interbedded with beige	35.4 -	39.0
Limestone, light gray, very finely crystalline	39.0 -	40.0
Shale, yellowish olive	40.0 -	41.0
Shale, reddish brown mottled with gray	41.0 -	46.0
Shale, medium gray	46.0 -	48.0
Shale, light greenish gray	48.0 -	50.5

Description	Depth, in feet	
	From	To
Crouse Formation:		
Limestone, white to light gray, finely to very finely crystalline	50.5	51.0
Limestone, light tan, dense, interbedded with shale, cream	51.0	54.0
Shale, yellowish olive	54.0	56.5
Limestone, medium gray, finely to very finely crystalline; contains crinoids	56.5	57.4
Shale, dark gray	57.4	59.0
Shale, dark gray mottled with olive	59.0	61.1
Limestone, light tannish gray, very finely crystalline to dense	61.1	62.4
Easly Creek Formation:		
Shale, brown	62.4	63.0
Shale, cream	63.0	69.0
Shale, pale olive	69.0	71.0
Shale, pale olive interbedded with gray	71.0	73.0
Shale, reddish brown	73.0	76.0
Shale, reddish brown interbedded with greenish gray	76.0	78.0
Shale, olive interbedded with sandstone, brown, fine grained	78.0	80.0
Bader Formation:		
Middleburg Member:		
Limestone, light gray, fine to very finely crystalline; contains red and yellow staining	80.0	81.5
Shale, medium gray	81.5	82.5
Limestone, light to medium gray, very finely crystalline	82.5	84.2
Hooser Member:		
Shale, light to medium gray	84.2	87.5
Shale, light gray, limy	87.5	90.0
Shale, reddish brown mottled with greenish gray	90.0	92.0
Eiss Member:		
Limestone, cream, finely to coarsely crystalline; contains red staining	92.0	96.0
Shale, medium gray	96.0	105.0
Limestone, light to medium gray, finely to very finely crystalline; contains brachiopods	105.0	106.5
Stearns Formation:		
Shale, light greenish gray	106.5	111.0
Shale, reddish brown	111.0	116.6
Beattie Formation:		
Morrill-Florena Members:		
Limestone white, very finely crystalline to dense, interbedded with shale, greenish gray	116.6	121.3
Cottonwood Member:		
Limestone, cream, irregularly crystalline; porous; contains fusulinids and gypsum	121.3	132.0

Description	Depth, in feet	
	From	To
Eskridge Formation:		
Shale, olive gray	132.0	133.0
Shale, light gray	133.0	137.0

Test Hole 55-78

Location: Pawnee County, SE corner sec. 12, T. 3 N., R. 12 E., approximately 15 feet north of south section line and 30 feet west of east section line.

Ground-level elevation: 1,156.0 feet above mean sea level.

Started: June 9, 1978. Completed: June 9, 1978.

Total depth: 257.0 feet.

Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample)	0	5.0
Silt, brown, clayey	5.0	27.0
Silt, grayish brown, clayey sandy	27.0	32.0
Silt, grayish brown, clayey	32.0	37.0
Silt, gray, clayey	37.0	47.0
Silt, medium to dark gray	47.0	58.0
Sand, medium to very coarse, and gravel, fine to very coarse	58.0	76.0
Clay, brown	76.0	77.0
Sand, medium to very coarse, and gravel, fine to very coarse	77.0	98.0
Silt, medium gray	98.0	107.0
Silt, light gray	107.0	120.0
Sand, fine to very coarse, and gravel, fine to medium	120.0	122.0
Silt, light gray	122.0	132.0
Silt, light gray interbedded with brown	132.0	137.0
Silt, light gray, sandy	137.0	142.0
Sand, medium to very coarse, and gravel, fine to medium	142.0	152.0
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Burlingame Formation:		
Winnebago Member:		
Shale, medium gray	152.0	161.5
Taylor Branch Member:		
Limestone, light gray, finely crystalline	161.5	164.0
Shale, light gray	164.0	165.8

Description	Depth, in feet	
	From	To
Limestone, light tannish gray, finely crystalline to dense	165.8	168.0
Scranton Formation:		
Cedarvale-White Cloud Members:		
Shale, light to medium gray, silty	168.0	193.0
Shale, black	193.0	194.0
Shale, light to medium gray	194.0	197.0
Shale, light greenish gray	197.0	199.0
Shale, light greenish gray interbedded with olive and gray	199.0	202.0
Shale, medium to dark gray	202.0	213.5
Limestone, dark gray, finely crystalline; contains brachiopods, bryozoans, and fusulinids.	213.5	215.0
Shale, light gray	215.0	230.0
Limestone, brownish gray, very finely crystalline	230.0	230.5
Shale, light gray	230.5	234.0
Limestone, brown, dense	234.0	234.5
Shale, light to medium gray	234.5	242.0
Shale, medium gray, silty	242.0	257.0

Test Hole 56-78

Location: Richardson County, SW corner NW sec. 7, T. 3 N., R. 13 E., approximately 2,590 feet south of north section line and 22 feet east of west section line.

Ground-level elevation: 1,135.0 feet above mean sea level.

Started: June 12, 1978. Completed: June 12, 1978.

Total depth: 242.0 feet.

Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample)	0	2.0
Silt, brown, clayey	2.0	8.0
Sand, very fine to medium	8.0	62.0
Sand, very fine to very coarse, and gravel, fine to medium	62.0	92.0
Sand, very fine to coarse, interbedded with clay, brown	92.0	108.0
Silt, light brown, sandy	108.0	130.0
Sand, very fine to very coarse, and gravel, fine to medium	130.0	138.0

Description	Depth, in feet	
	From	To
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Willard Formation:		
Shale, medium gray	138.0	139.0
Emporia Formation:		
Limestone, light to medium gray, finely crystalline; contains brachiopods, crinoids, and fusulinids	139.0	141.0
Shale, light gray	141.0	142.9
Limestone, light gray, finely to very finely crystalline	142.9	143.5
Shale, light greenish gray	143.5	144.2
Limestone, light tannish gray, finely crystalline to dense	144.2	144.6
Harveyville Member:		
Shale, medium gray	144.6	147.2
Reading Member:		
Limestone, medium gray, finely to very finely crystalline; contains brachiopods, crinoids, fusulinids, algal material, pyrite, and black inclusions	147.2	152.4
Auburn Formation:		
Shale, medium gray interbedded with greenish gray	152.4	155.5
Shale, reddish brown	155.5	159.0
Shale, medium gray	159.0	176.0
Wakarusa Formation:		
Limestone, medium gray, very finely crystalline, contains brachiopods, crinoids, and fusulinids	176.0	180.0
Burlingame-Soldier Creek Formations:		
Shale, light bluish gray	180.0	184.5
Shale, reddish brown	184.5	186.0
Siltstone, greenish gray	186.0	190.0
Shale, greenish gray mottled with olive	190.0	194.0
Shale, medium gray	194.0	204.0
Taylor Branch Member:		
Limestone, medium to dark gray, irregularly crystalline; contains brachiopods, crinoids, and algal material	204.0	204.5
Shale, medium gray	204.5	206.0
Limestone, light tannish gray, very finely crystalline to dense	206.0	208.5
Scranton Formation:		
Cedarvale-White Cloud Members:		
Shale, light to medium gray, silty	208.5	221.0
Shale, black	221.0	222.0
Shale, greenish gray	222.0	225.0
Shale, greenish gray mottled with red, olive, and yellow	225.0	235.0
Shale light gray	235.0	242.0

Test Hole 57-78

Location: Richardson County, SE SE SE SE sec. 6, T. 3 N., R. 13 E., approximately 300 feet north of south section line and 2 feet west of east section line.

Ground-level elevation: 1,110.0 feet above mean sea level.

Started: June 12, 1978. Completed: June 13, 1978.

Total depth: 212.0 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample)	0 -	2.0
Sand, very fine to very coarse, silty, clayey	2.0 -	7.0
Silt, brown, sandy	7.0 -	17.0
Sand, medium to very coarse, and gravel, fine to coarse	17.0 -	32.0
Silt, beige, clayey	32.0 -	42.0
Silt, gray, clayey	42.0 -	57.0
Silt, medium to dark gray, clayey	57.0 -	67.0
Silt, light bluish gray, clayey	67.0 -	82.0
Silt, light bluish gray interbedded with yellowish green, clayey	82.0 -	87.0
Silt, medium gray, clayey	87.0 -	96.0
Sand, very fine to medium	96.0 -	97.0
Silt, medium gray, clayey	97.0 -	107.0
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Root Formation:		
French Creek Member:		
Shale, reddish brown	107.0 -	109.0
Shale, light gray mottled with olive	109.0 -	113.0
Shale, medium gray, interbedded with black	113.0 -	116.5
Sandstone, light gray, very fine grained	116.5 -	118.0
Shale, light gray	118.0 -	127.0
Shale, dark gray	127.0 -	129.3
Jim Creek Member:		
Limestone, medium gray, very finely crystalline, impure; contains brachiopods, crinoids, and bryozoans	129.3 -	129.8
Friedrich Member:		
Shale, light gray	129.8 -	139.5
Stotler Formation:		
Grandhaven Member:		
Limestone, light gray to cream, finely to very finely crystalline; contains brachiopods, crinoids, and red and green sta	139.5 -	141.5

Description	Depth, in feet	
	From	To
Dry Member:		
Shale, reddish brown interbedded with gray.....	141.5	146.2
Limestone, light gray to cream, very finely cyrstalline, contains black inclusions and red and green staining.....	146.2	149.0
Shale, reddish brown.....	149.0	152.0
Shale, reddish brown, interbedded with limestone, greenish brown, dense.....	152.0	155.0
Shale, olive interbedded with limestone, gray, finely crystalline.....	155.0	157.7
Shale, light to medium gray.....	157.7	167.0
Shale, light gray.....	167.0	177.0
Shale, light gray, silty.....	177.0	184.0
Dover Member:		
Limestone, medium gray, finely crystalline; contains brachiopods.....	184.0	184.5
Pillsbury Formation:		
Shale, light gray.....	184.5	186.5
Shale, light greenish gray, interbedded with limestone, greenish gray, dense.....	186.5	190.0
Shale, olive and gray, interbedded with limestone, tan, dense.....	190.0	193.0
Shale, greenish gray.....	193.0	194.0
Shale, medium gray.....	194.0	198.0
Zeandale Formation:		
Maple Hill Member:		
Limestone, light to medium gray, finely to very finely crystalline; contains brachiopods, crinoids, fusulinids, and pyrite.....	198.0	200.5
Shale, medium to dark gray.....	200.5	203.0
Limestone, medium gray, finely crystalline; contains brachiopods, crinoids, fusulinids, and black carbonaceous material.....	203.0	208.0
Wamego Member:		
Coal, black.....	208.0	209.5
Shale, light gray.....	209.5	212.0

Test Hole 58-78

Location: Pawnee County, NW corner sec. 12, T. 3 N., R. 12 E., approximately 61 feet south of north section line and 18 feet east of west section line.

Ground-level elevation: 1,186.0 feet above mean sea level.

Started: June 13, 1978. Completed: June 14, 1978.

Total depth: 376.0 feet.

Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample)	0 -	2.0
Silt, yellowish brown, clayey	2.0 -	27.0
Silt, yellowish brown, sandy	27.0 -	32.0
Silt, yellowish brown	32.0 -	47.0
Sand, fine to very coarse, and gravel, fine to medium	47.0 -	57.0
Silt, gray to olive gray	57.0 -	83.0
Sand, medium to very coarse, and gravel, very fine to fine	83.0 -	145.0
Clay, light gray	145.0 -	152.0
Clay, light gray, interbedded with silt, medium gray	152.0 -	165.0
Sand, very fine to coarse, and gravel, very fine to fine	165.0 -	202.0
Permian(?) - Pennsylvanian (?) Systems:		
Shale, light gray to white	202.0 -	207.0
Shale, medium to dark gray	207.0 -	216.0
Shale, medium gray, interbedded with siltstone, light gray	216.0 -	217.2
Shale, medium gray	217.2 -	222.7
Shale, light greenish gray	222.7 -	225.0
Shale, light greenish gray interbedded with pale red	225.0 -	227.0
Shale, greenish gray mottled with red, olive and brown	227.0 -	235.0
Shale, light gray to white, interbedded with sandstone, light gray, very fine grained	235.0 -	240.0
Shale, light gray	240.0 -	242.0
Shale, reddish brown	242.0 -	259.0
Shale, reddish brown mottled with olive and gray	259.0 -	263.0
Shale, medium to dark gray	263.0 -	282.0
Shale, medium gray interbedded with greenish gray, limy	282.0 -	284.0
Limestone, light tannish gray, irregularly crystalline, contains brachiopods and crinoids	284.0 -	285.0
Shale, light greenish gray	285.0 -	288.0
Shale, olive brown	288.0 -	291.0
Shale, medium gray	291.0 -	317.0
Shale, light gray	317.0 -	327.0
Pensylvanian System - Virgil Series - Wabaunsee Group:		
Stotler Formation:		
Dover Member:		
Limestone, dark gray, finely crystalline; contains brachiopods and pyrite	327.0 -	327.6
Pillsbury Formation:		
Shale, light greenish gray interbedded with light gray	327.6 -	331.0

Description	Depth, in feet	
	From	To
Shale, reddish brown mottled with olive	331.0	334.0
Shale, light gray	334.0	337.5
Zeandale Formation:		
Maple Hill Member:		
Limestone, medium gray, finely crystalline, impure; contains brachiopods, crinoids, and pyrite	337.5	338.3
Wamego Member:		
Coal, black	338.3	338.9
Shale, light gray interbedded with greenish gray	338.9	346.1
Sandstone, light gray, very fine grained	346.1	348.0
Shale, light gray	348.0	358.3
Tarkio Member:		
Limestone, cream, finely crystalline; contains fusulinids and Osagia	358.3	365.5
Willard Formation:		
Shale, medium gray mottled with red	365.5	370.0
Shale, medium gray	370.0	376.0

Test Hole 59-78

Location: Pawnee County, SW NW SW NW sec. 1, T. 3 N., R. 12 E., approximately 1,915 feet south of north section line and 18 feet east of west section line.

Ground-level elevation: 1,173.0 feet above mean sea level.

Started: June 14, 1978. Completed: June 14, 1978.

Total depth: 242.0 feet.

Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample)	0	5.0
Silt, brown, clayey	5.0	20.0
Sand, very fine to medium	20.0	42.0
Sand, very fine to very coarse	42.0	72.0
Sand, very fine to very coarse, and gravel, very fine to medium	72.0	107.0
Sand, very fine to medium	107.0	135.5

504 265

Description	Depth, in feet	
	From	To
Permian System - Big Blue Series - Council Grove Group:		
Foraker Formation:		
Americus Member:		
Limestone, medium to dark gray, finely crystalline; contains brachiopods	135.5	136.0
Shale, light to medium gray	136.0	136.2
Limestone, light to medium gray, irregularly crystalline; contains brachiopods and crinoids	136.2	138.1
Shale, black	138.1	138.5
Limestone, bluish gray, finely crystalline; contains brachiopods and crinoids	138.5	138.9
Admire Group:		
Hamlin Formation:		
Oaks-Stine Members:		
Shale, medium gray	138.9	143.0
Limestone, bluish gray, finely crystalline: contains algal material and black inclusions	143.0	143.5
Shale, cream to light gray, limy	143.5	145.0
Shale, light greenish gray, limy	145.0	149.0
Limestone, light greenish gray, very finely crystalline, interbedded with shale, greenish gray [illegible] ndy	149.0	156.0
[illegible] ave mottled with green	156.0	158.0
Sh[illegible] brownish olive	158.0	161.0
Sh[illegible]e, light gray	161.0	163.0
Shale, medium to dark gray	163.0	164.0
Limestone, light to medium gray, very finely crystalline	164.0	164.5
Shale, light gray	164.5	166.0
Limestone, light to medium gray, very finely crystalline	166.0	167.0
Shale, medium gray	167.0	167.9
Limestone, bluish gray, irregularly crystalline; contains algal material and black inclusions	167.9	168.5
Shale, greenish gray	168.5	169.1
Limestone, light tannish gray, very finely crystalline	169.1	170.2
Shale, reddish brown interbedded with gray	170.2	172.3
Five Point Formation:		
Limestone, cream, irregularly crystalline; contains brachiopods, algal material, and glauconite	172.3	173.6
West Branch Formation:		
Shale, pale red interbedded with olive, gray and brown	173.6	180.5
Shale, medium gray	180.5	182.0
Limestone, cream, irregularly crystalline; contains algal material	182.0	182.8

Description	Depth, in feet	
	From	To
Shale, medium gray	182.8	183.0
Shale, green	183.0	185.0
Limestone, white, very finely crystalline; interbedded with shale, greenish gray	185.0	192.0
Shale, dark gray	192.0	194.0
Shale, medium to dark gray, interbedded with limestone, gray, dense	194.0	197.0
Shale, medium gray	197.0	201.5
Falls City Formation:		
Lehmer Member:		
Limestone, light gray, very finely crystalline, porous; contains oolites and gypsum	201.5	204.2
Onaga Formation:		
Shale, medium gray	204.2	206.5
Shale, greenish gray, limy	206.5	212.0
Shale, reddish brown	212.0	215.7
Shale, greenish gray, limy	215.7	216.7
Shale, reddish brown	216.7	224.1
Wood Siding Formation:		
Brownville Member:		
Limestone, pale yellow, finely to very finely crystalline; contains brachiopods and glauconite	224.1	226.0
Pony Creek-Plumb Members:		
Shale, light gray	226.0	228.0
Sandstone, light gray to greenish gray, very fine grained	228.0	229.0
Shale, light greenish gray	229.0	230.0
Claystone, light greenish gray	230.0	231.0
Shale, reddish brown	231.0	239.0
Shale, dark olive gray, interbedded with limestone, gray, dense	239.0	242.0

Test Hole 60-78

Location: Nemaha County, SE corner SW SE sec. 35, T. 4 N., R. 12 E., approximately 15 feet north of south section line and 1,345 feet west of east section line.

Ground-level elevation: 1,203.0 feet above mean sea level.

Started: June 20, 1978. Completed: June 20, 1978.

Total depth: 148.0 feet.

504 267

Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample)	0 -	2.0
Silt, yellowish brown, clayey	2.0 -	12.0
Silt, yellowish brown, sandy	12.0 -	16.0
Sand, fine to very coarse, and gravel, very fine to medium	16.0 -	19.0
Clay, brown	19.0 -	24.0
Silt, brownish gray, silty	24.0 -	34.0
Sand, medium to very coarse	34.0 -	37.0
Silt, olive brown, clayey	37.0 -	42.0
Sand, medium to very coarse, and gravel, very fine to coarse	42.0 -	59.0
Silt, olive gray	59.0 -	62.0
Silt, medium gray	62.0 -	87.0
Silt, dark gray	87.0 -	96.0
Silt, brown, clayey	96.0 -	101.0
Permian System - Big Blue Series Council Grove Group:		
Roca Formation:		
Limestone, white to pale yellow, irregularly crystalline	101.0 -	102.0
Shale, medium gray	102.0 -	105.0
Limestone, tannish gray, very finely crystalline to dense	105.0 -	107.1
Shale, yellowish green, clayey	107.1 -	116.5
Red Eagle Formation:		
Howe Member:		
Limestone, dark yellowish orange, irregularly crystalline	116.5 -	118.0
Bennett Member:		
Shale, black	118.0 -	123.0
Glenrock Member:		
Limestone, medium gray, finely crystalline; contains fusulinids	123.0 -	124.0
Johnson Formation:		
Shale, light to medium gray	124.0 -	126.5
Shale, light bluish gray, silty	126.5 -	131.5
Shale, light beige	131.5 -	135.6
Foraker Formation:		
Limestone, pale olive, finely to very finely crystalline	135.6 -	137.0
No sample, lost circulation	137.0 -	148.0

Test Hole 61-78

Location: Nemaha County, SW corner sec. 36, T. 4 N., R. 12 E., approximately 10 feet north of south section line and 35 feet east of west section line.

Ground-level elevation: 1,178.0 feet above mean sea level.

Started: June 21, 1978. Completed: June 21, 1978.

Total depth: 242.0 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample)	0 -	2.0
Silt, grayish brown, clayey, sandy	2.0 -	17.0
Sand, fine to very coarse and gravel, very fine to medium	17.0 -	28.0
Silt, dark olive gray	28.0 -	42.0
Silt, medium gray	42.0 -	57.0
Silt, pale brown	57.0 -	75.0
Permian System - Big Blue Series - Council Grove Group:		
Roca Formation:		
Limestone, white to yellow, finely crystalline, interbedded with shale, pale yellow	75.0 -	79.2
Shale, reddish brown mottled with pale green	79.2 -	82.5
Shale, pale green, interbedded with limestone, tan, dense	82.5 -	84.2
Shale, pale green mottled with red	84.2 -	88.0
Shale, pale green to light olive	88.0 -	93.0
Red Eagle Formation:		
Howe Member:		
Limestone, pale yellow, finely crystalline, porous, vuggy	93.0 -	96.3
Bennett Member:		
Shale, brownish gray, silty	96.3 -	101.5
Glenrock Member:		
Limestone, pale yellow, finely to very finely crystalline, porous	101.5 -	102.3
Johnson Formation:		
Shale, pale olive	102.3 -	116.5
Foraker Formation:		
Long Creek Member:		
Limestone, pale yellow, finely to very finely crystalline, porous, vuggy	116.5 -	122.0
Hughes Creek Member:		
Shale, light to medium gray, limy	122.0 -	127.0
Shale, medium gray	127.0 -	137.0
Limestone, dark gray, very finely crystalline; contains brachiopods	137.0 -	137.9

Description	Depth, in feet	
	From	To
Shale, dark gray to black	137.9	140.0
Limestone, light to medium gray, very finely crystalline; contains brachiopods	140.0	141.5
Shale, medium gray	141.5	146.7
Shale, light gray, interbedded with limestone, light gray, dense	146.7	149.5
Shale, medium gray	149.5	153.5
Limestone, light to medium gray, finely crystalline; contains brachiopods and crinoids	153.5	155.2
Shale, medium gray	155.2	161.7
Americus Member:		
Limestone, medium to dark gray, finely crystalline; contains brachiopods and crinoids	161.7	162.7
Shale, dark gray to black	162.7	163.3
Limestone, bluish gray, finely crystalline; contains brachiopods and crinoids	163.3	164.2
Admire Group:		
Hamlin Formation:		
Oaks-Stine Members:		
Shale, medium gray	164.2	169.0
Shale, light gray, limy	169.0	176.0
Shale, light greenish gray, interbedded with limestone, tan, dense	176.0	182.0
Shale, light gray interbedded with olive	182.0	185.0
Shale, light to medium gray, limy	185.0	195.0
Shale, pale brown	195.0	196.0
Shale, light greenish gray	196.0	197.3
Five Point Formation:		
Limestone, cream, irregularly crystalline; contains brachiopods, algal material, and glauconite	197.3	199.2
West Branch Formation:		
Shale, pale brown and greenish gray, interbedded with limestone, gray, dense	199.2	202.0
Shale, olive mottled with red, green, and gray	202.0	205.0
Shale, medium gray	205.0	207.7
Limestone, light greenish gray, finely crystalline; contains brachiopods	207.7	208.5
Shale, medium gray	208.5	212.0
Shale, light greenish gray, limy	212.0	218.0
Shale, medium to light gray, limy	218.0	227.0
Falls City Formation:		
Lehmer Member:		
Limestone, dark gray, pebbly texture; contains pseudo-oolites, interbedded with limestone, medium to dark gray, very finely crystalline	227.0	232.0

Description	Depth, in feet	
	From	To
Onaga Formation:		
Shale, light greenish gray	232.0	235.0
Shale, pale red, limy	235.0	242.0

Test Hole 62-78

Location: Nemaha County, SW corner sec. 35, T. 4 N., R. 12 E., approximately 67 feet north of south section line and 24 feet east of west section line.

Ground-level elevation: 1,240.0 feet above mean sea level.

Started: June 21, 1978. Completed: June 22, 1978.

Total depth: 250.0 feet.

Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample)	0	3.0
Silt, reddish brown, clayey	3.0	10.0
Sand, fine to very coarse	10.0	14.0
Silt, light brown, clayey, sandy	14.0	37.0
Clay, yellowish brown, silty	37.0	42.0
Silt, brownish gray, sandy	42.0	67.0
Sand, very fine to medium	67.0	92.0
Sand, very fine to coarse and gravel, very fine to coarse	92.0	107.0
Sand, very coarse, and gravel, very fine to coarse	107.0	137.0
Sand, medium to very coarse, and gravel, very fine to fine	137.0	217.0
Sand, medium to coarse, and gravel, very fine to very coarse	217.0	227.0
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Zeandale Formation:		
Wamego Member:		
Shale, medium gray.	227.0	230.4
Tarkio Member:		
Limestone, cream, irregularly crystalline; contains fusulinids and Osagia	230.4	237.5
Willard Formation:		
Shale, reddish brown mottled with gray, green and olive	237.5	239.0
Shale, light bluish gray, silty	239.0	242.0
Shale, medium gray	242.0	250.0

Test Hole 63-78

Location: Richardson County, SW SW NW NW sec. 34, T. 3 N., R. 13 E., approximately 1,205 feet south of north section line and 20 feet east of west section line.

Ground-level elevation: 1,103.0 feet above mean sea level.

Started: June 23, 1978. Completed: June 23, 1978.

Total depth: 205.0 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample)	0 -	2.0
Silt, reddish brown, clayey	2.0 -	7.0
Silt, yellowish brown, clayey	7.0 -	11.0
Silt, grayish brown	11.0 -	17.0
Silt, light brown	17.0 -	31.0
Permian(?) - Pennsylvanian(?) Systems:		
Limestone, brownish gray, irregularly crystalline; contains fossil fragments	31.0 -	32.0
Shale, reddish brown	32.0 -	35.0
Shale, pale olive	35.0 -	40.0
Limestone, yellowish brown, finely crystalline; contains brachiopods	40.0 -	41.2
Shale, olive-gray	41.2 -	46.0
Shale, medium to light gray	46.0 -	62.0
Shale, medium gray, silty, sandy	62.0 -	114.2
Sandstone, medium gray, very fine grained	114.2 -	116.0
Shale, greenish gray, silty, limy	116.0 -	122.0
Shale, medium gray	122.0 -	127.5
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Zeandale Formation:		
Maple Hill Member:		
Limestone, dark gray, very finely crystalline; contains brachiopods, crinoids, fusulinids, and pyrite	127.5 -	128.5
Wamego Member:		
Coal, black	128.5 -	129.3
Sandstone, gray to greenish gray, very fine grained	129.3 -	133.3
Shale, light gray, silty	133.3 -	146.1
Tarkio Member:		
Limestone, medium to dark gray, irregularly crystalline, pebbly, impure; contains fossil fragments	146.1 -	146.7
Shale, greenish gray, interbedded with limestone, tan, dense	146.7 -	149.2

Description	Depth, in feet	
	From	To
Limestone, light gray to cream, very finely to irregularly crystalline; contains fusulinids, Osagia, and glauconite	149.2	152.0
Willard Formation:		
Shale, light gray to greenish gray, silty, sandy, limy	152.0	157.0
Shale, medium gray, silty	157.0	183.4
Emporia Formation:		
Elmont Member:		
Limestone, medium gray to tannish gray, irregularly to very finely crystalline; contains brachiopods and crinoids	183.4	185.5
Shale, medium gray	185.5	188.0
Limestone, light greenish gray to tannish gray, very finely crystalline	188.0	190.2
Harveyville Member:		
Shale, dark greenish gray	190.2	193.8
Reading Member:		
Limestone, medium gray, very finely crystalline; contains brachiopods and crinoids	193.8	196.5
Shale, dark gray	196.5	197.8
Limestone, medium gray, irregularly crystalline; contains brachiopods	197.8	198.2
Auburn Formation:		
Shale, medium gray interbedded with greenish gray, limy	198.2	201.0
Shale, reddish brown	201.0	205.0

Test Hole 64-78

Location: Richardson County, SE corner SW SW sec. 4, T. 2 N., R. 13 E., approximately 22 feet north of south section line and 1,285 feet east of west section line.

Ground-level elevation: 985.0 feet above mean sea level.

Started: June 23, 1978. Completed: June 23, 1978.

Total depth: 107.0 feet.

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Description	Depth, in feet	
	From	To
Quaternary System:		
Soil (no sample).....	0 -	5.0
Silt, light brown, clayey.....	5.0 -	17.0
Silt, gray to greenish gray.....	17.0 -	28.0
Sand, fine to very coarse, and gravel, very fine to medium.....	28.0 -	32.0
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Willard Formation:		
Shale, medium gray, silty.....	32.0 -	59.0
Emporia Formation:		
Elmont Member:		
Limestone, light brownish gray, very finely crystalline; contains brachiopods.....	59.0 -	61.5
Shale, medium gray.....	61.5 -	62.7
Limestone, light gray, finely to very finely crystalline; contains calcite crystals.....	62.7 -	64.0
Shale, light greenish gray.....	64.0 -	64.5
Limestone, light greenish gray, very finely crystalline.....	64.5 -	65.0
Harveyville Member:		
Shale, medium gray.....	65.0 -	68.2
Reading Member:		
Limestone, medium gray to tannish gray, finely to very finely crystalline; contains brachiopods, crinoids, algal materials, and pyrite, interbedded with shale, gray.....	68.2 -	73.5
Auburn Formation:		
Shale, medium gray.....	73.5 -	76.0
Shale, reddish brown.....	76.0 -	81.0
Shale, olive to greenish gray.....	81.0 -	83.0
Shale, medium gray.....	83.0 -	96.0
Wakarusa Formation:		
Limestone, light to medium bluish gray, finely crystalline; contains brachiopods, crinoids, and fusulinids.....	96.0 -	100.0
Soldier Creek Formation:		
Shale, medium gray to dark greenish gray.....	100.0 -	107.0

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The report information pertains to the geology, structure, tectonics, and seismicity of eastern Nebraska with emphasis on the vicinity of the Humboldt Fault Zone in western Richardson and eastern Pawnee counties.

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