1980

Regional Tectonics and Seismicity of Eastern Nebraska, Annual Report July 1980 - June 1981

R. R. Burchett
University of Nebraska - Lincoln

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Regional Tectonics and Seismicity of Eastern Nebraska

Annual Report
July 1980 - June 1981

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Institute of Agriculture and Natural Resources
University of Nebraska-Lincoln

Prepared for
U.S. Nuclear Regulatory
Commission

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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 July 1, 1980, to June 30, 1981, 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 central Otoe County. 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 Otoe County were reexamined and reevaluated, and 22 test holes were drilled to determine the altitude of the upper surface of the Elmont Limestone of Pennsylvanian age;
2. One new seismograph was installed in eastern Nebraska;
3. Gravity surveys in eastern Nebraska were extended;
4. Ground magnetic surveys in Otoe County were made and evaluated.
5. Age dating of two Precambrian cores.

Discussion of the results of these studies constitute the remainder of this report.

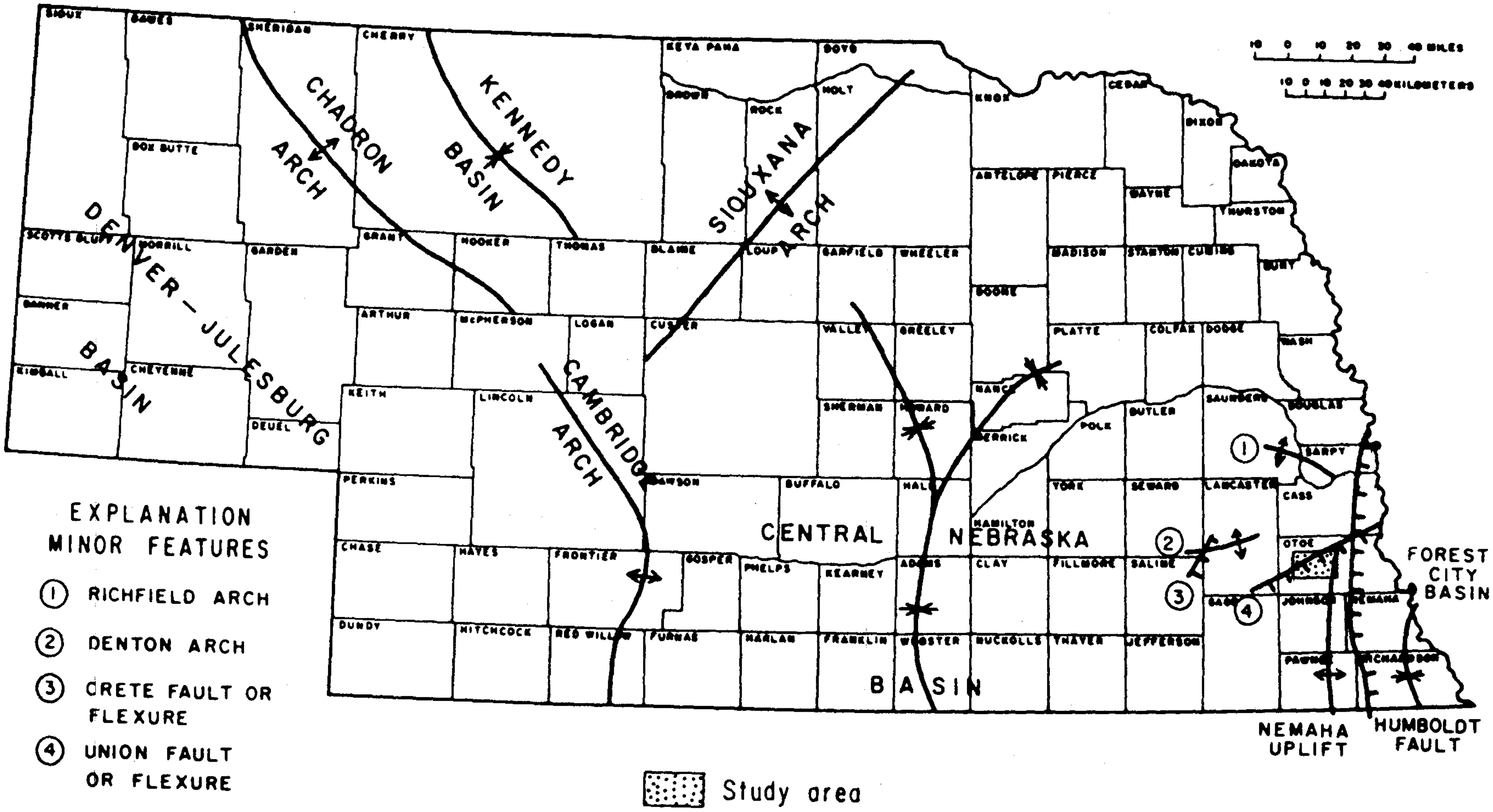
STRUCTURE OF THE ELMONT LIMESTONE IN CENTRAL OTOE COUNTY, NEBRASKA

R. R. Burchett and M. R. Bolitho

Introduction

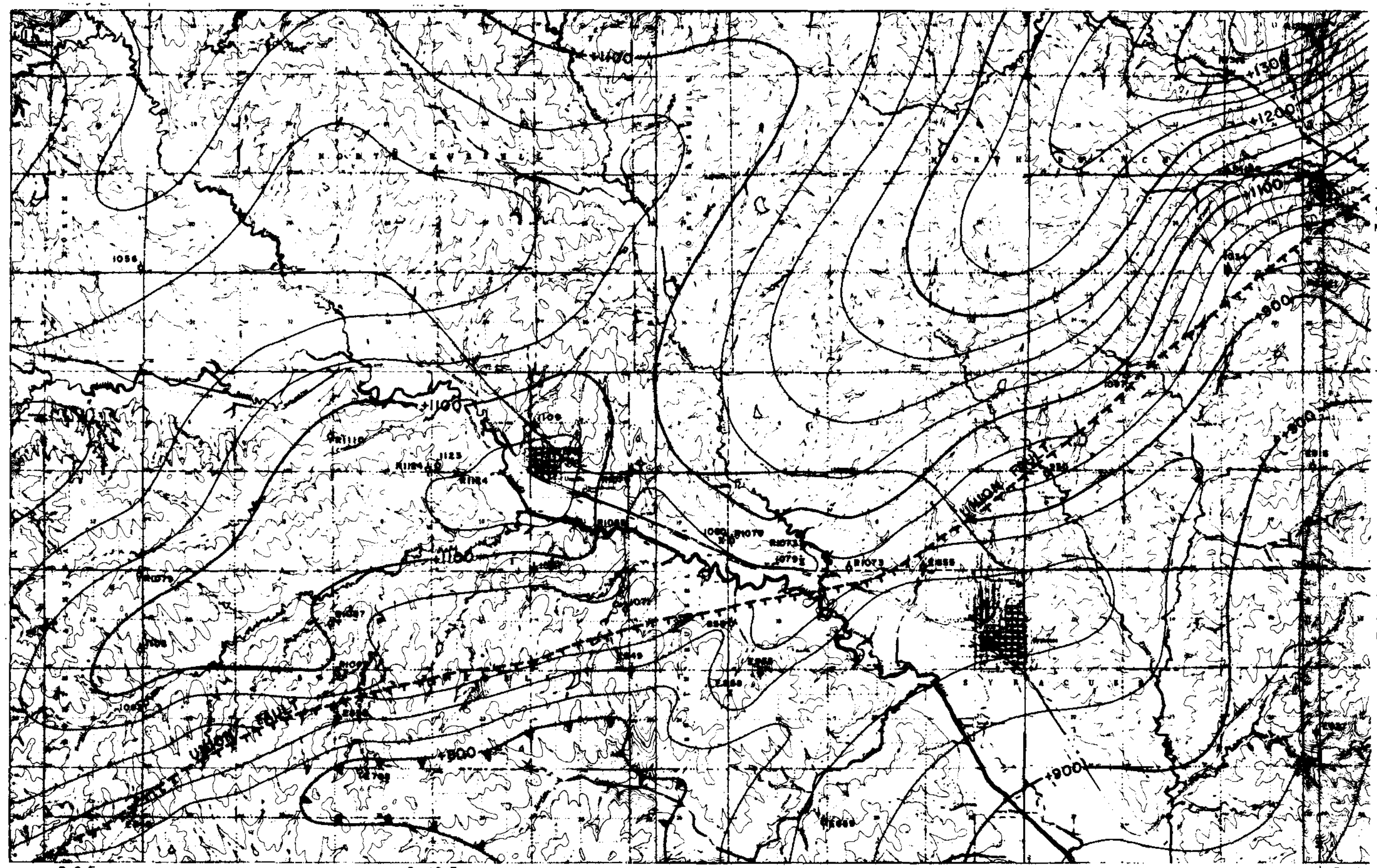
A specific site area in central Otoe County, Nebraska was chosen for study in 1980-81 because it overlies the southwestern extension of the Union Fault (fig. 1). The Union Fault defines the southern margin of the northeast-southwest trending midcontinent gravity anomaly. Southward from it the rock strata either are downthrown or dip steeply into the Forest City Basin.

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 eastern Nebraska. The top of the Elmont Limestone, a member of the Emporia Formation of the Wabaunsee Group (Virgil Series) of the Pennsylvanian System, was chosen as a datum plane for a structure map because the Elmont underlies most of the study area at a shallow depth and is easily identified in rock cuttings obtained by 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 Elmont's upper surface (fig. 2).



PRINCIPAL STRUCTURAL FEATURES OF NEBRASKA (Carlson, 1970)

Figure 1



R. 9 E. R. 10 E. R. 11 E. R.12E.

Compilation October 1981
Principal investigator. R.R. Burchett

1/2 0 1 2 MILES

1/2 0 1 2 KILOMETERS

Prepared by R.R. Burchett
Nebraska Geological Survey
Conservation and Survey Division
Institute of Agriculture and Natural Resources
University of Nebraska - Lincoln
Supported by the United States Nuclear Regulatory Commission under contract NRC-04-76-315

—+800— Contours on top of Elmont Limestone Interval is 25 feet. Datum is mean sea level

Closed area of lower structural value

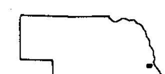
Fault (up / down)

x Outcrop

Stratigraphic test

Dry oil test

Number beside symbol is elevation. R indicates elevation is restored top of Elmont Limestone. E indicates elevation is estimated top of Elmont Limestone



INDEX MAP

STRUCTURAL CONTOUR-TOP OF ELMONT LIMESTONE (PENNSYLVANIAN) IN CENTRAL OTOE COUNTY

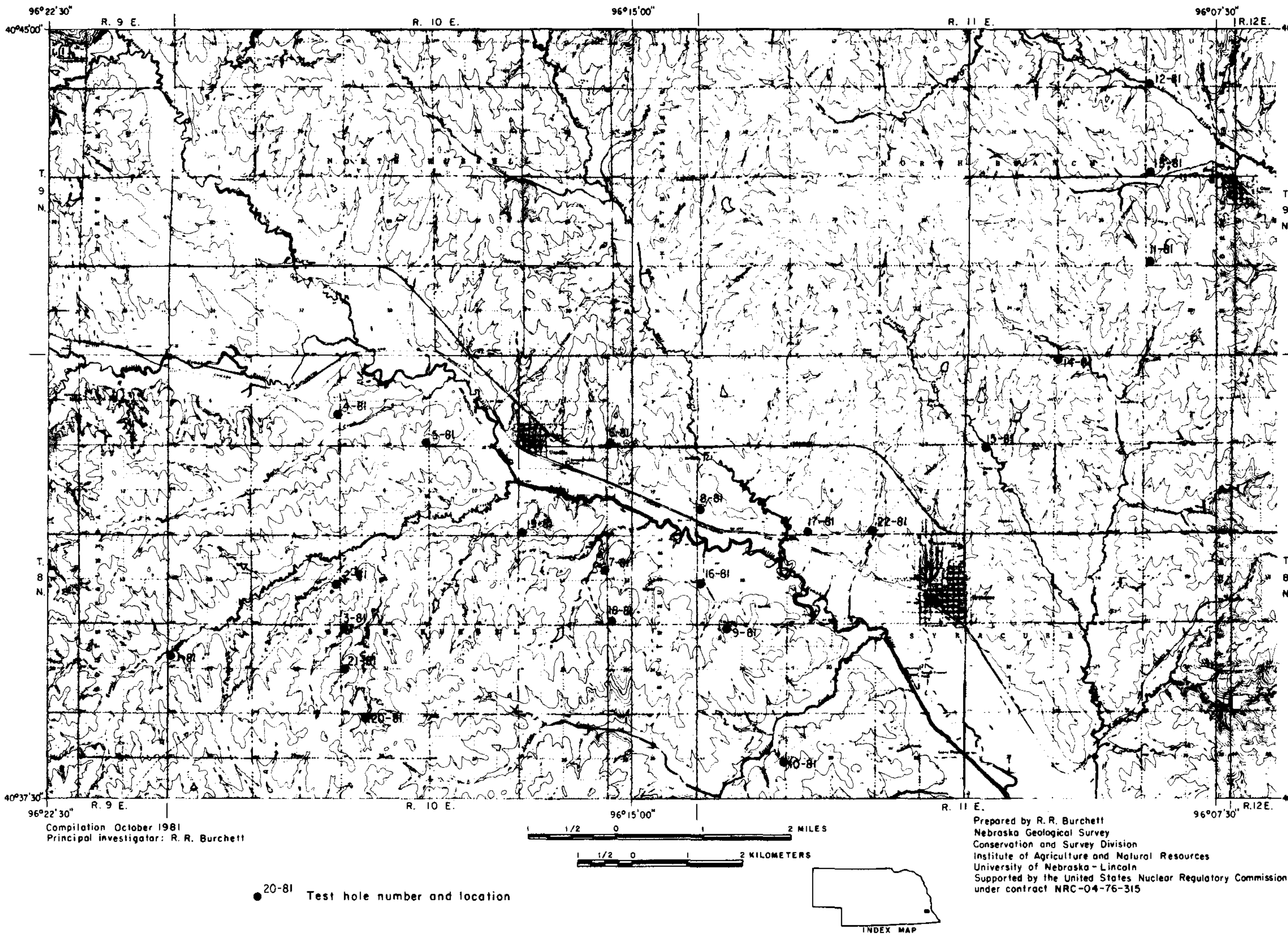
Figure 2

Scope of Investigation

Twenty-two shallow rotary test holes were drilled in central Otoe County (fig. 3) by the Rieschick Drilling Company of Falls City, Nebraska. The holes averaged about 182 feet (55.6 m) in depth, and each was logged electrically as well as thru visual examination of the rock cuttings. Some of the holes penetrated the Elmont Limestone; others were drilled to an identifiable horizon whose height above or depth below the Elmont is known, thus providing an Elmont datum. The holes were drilled in May and June of 1981 under a cooperative agreement between the Conservation and Survey Division (Nebraska Geological Survey) and the U.S. Nuclear Regulatory Commission (Contract NRC-04-76-315).

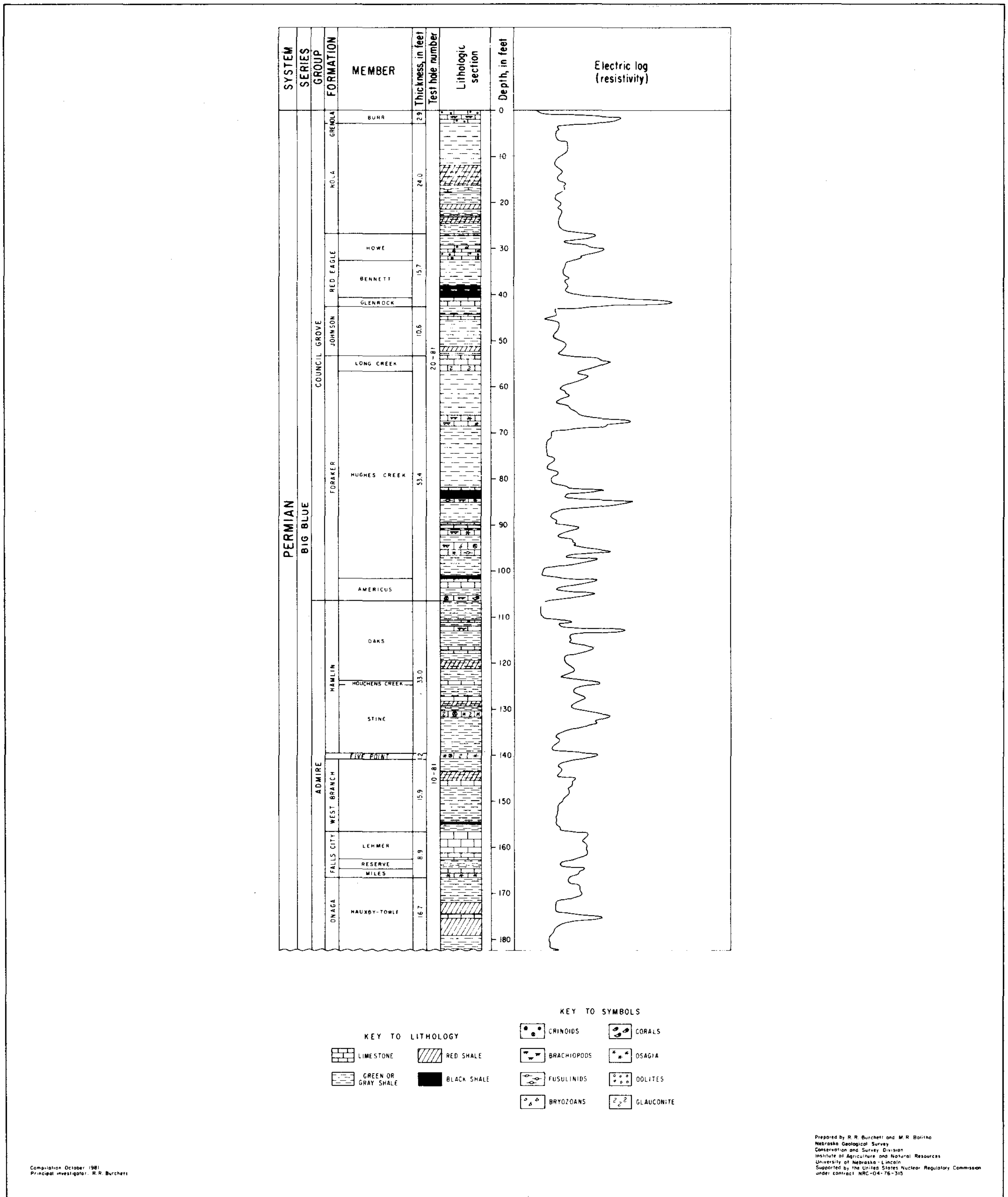
A binocular microscope was used for examination of the cuttings. Logs of the test holes, based on descriptions of the cuttings, are presented in Appendix A. Figures 4 and 5 show a composite section of the Lower Permian and Upper Pennsylvanian rocks drilled in the study area, together with a composite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

The geologic map illustrated in figure 6 shows the distribution of groups ranging in age from Late Pennsylvanian to Early Permian. Location of bedrock outcrops, mostly along valley sides, are shown in solid black. A careful reexamination of outcrops in the area provided additional data for mapping purposes. By determining the altitude of many outcrops, the investigators obtained additional vertical control points for the structure map.



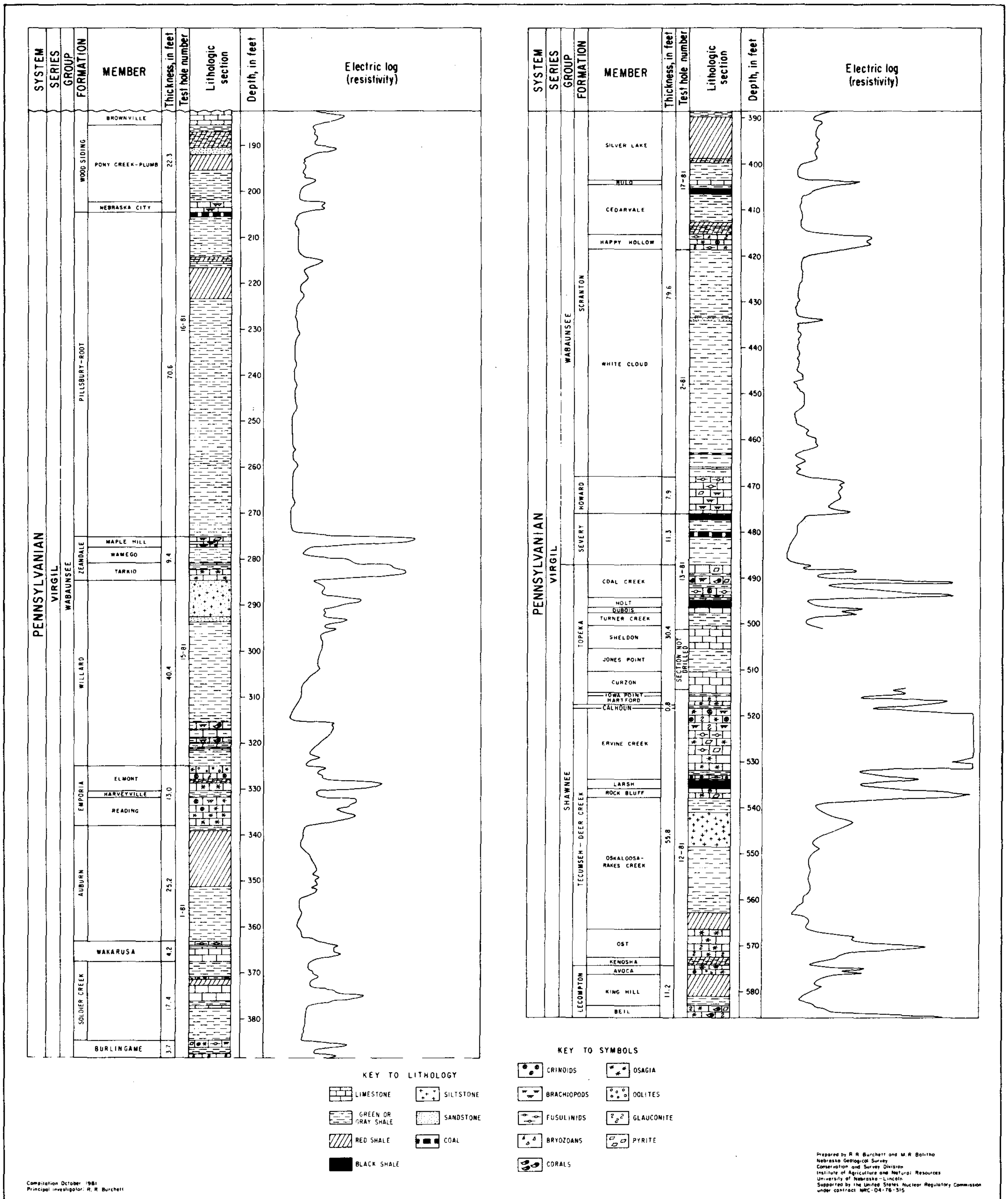
LOCATION OF TEST HOLES DRILLED DURING 1981 IN CENTRAL OTOE COUNTY

Figure 3



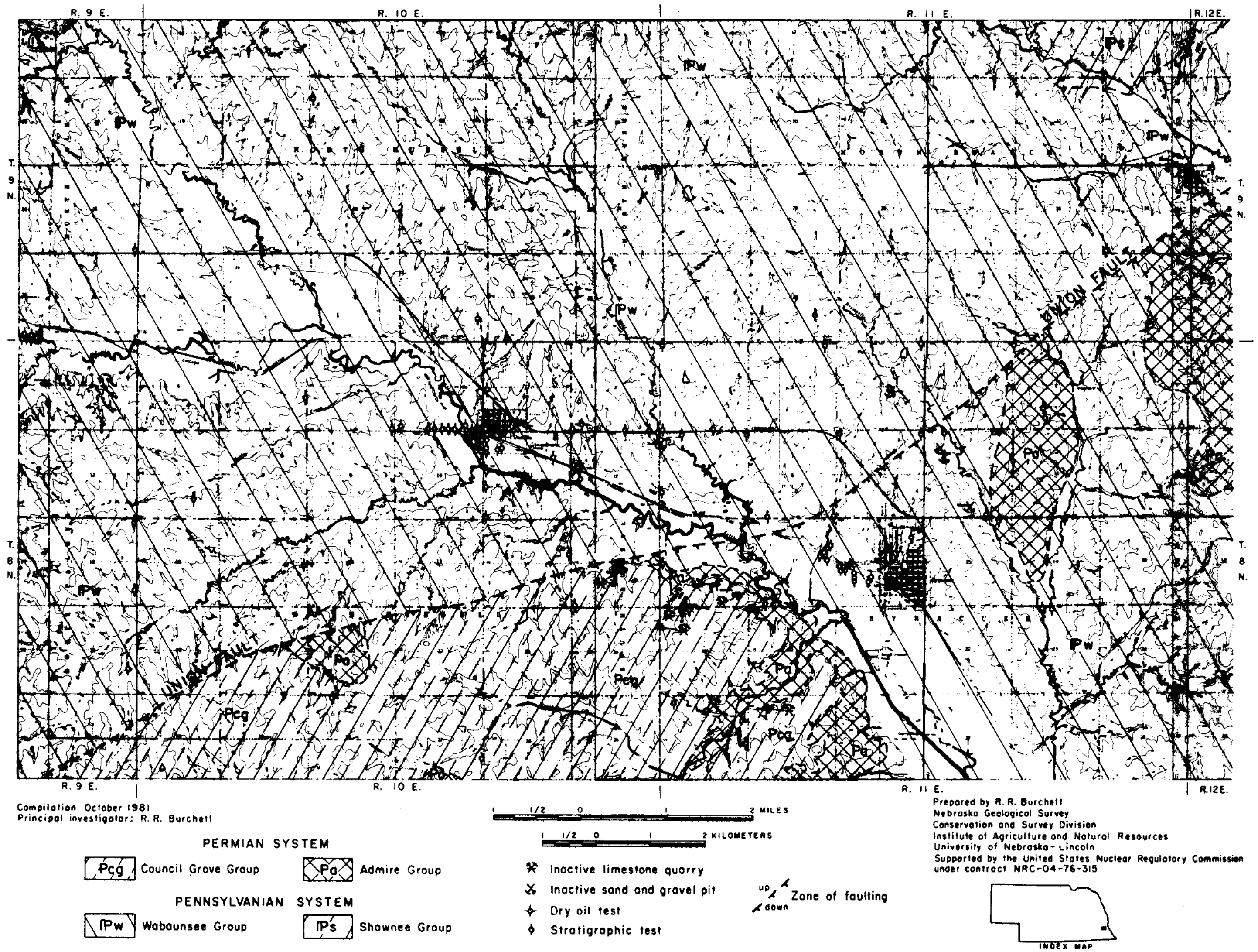
COMPOSITE SECTION OF PERMIAN ROCKS (BIG BLUE SERIES) DRILLED IN CENTRAL OTOE COUNTY

Figure 4



COMPOSITE SECTION OF PENNSYLVANIAN ROCKS (VIRGIL SERIES) DRILLED IN CENTRAL OTOE COUNTY

Figure 5



GEOLOGIC BEDROCK OF CENTRAL OTOE COUNTY

Figure 6

Most upland and lowland areas are mantled by unconsolidated Quaternary deposits such as loess, till, and alluvium. The maximum aggregate thickness of these deposits is 400 feet (122 m).

Results of Investigation

Interpretations based on drilling results and field observations during this investigation are summarized as follows:

(1) The Union Fault probably is not a single structure, as previously interpreted. Instead, it is a complex zone of faults and steep dips affecting rocks as young as Permian in age.

(2) Pennsylvanian and Permian age rocks are faulted along the Union Fault. The direction and angle of dip exhibited by these rocks, on both sides of the Union Fault, differ markedly within very short distances, thus indicating that the structural pattern is highly complex. The greatest dip measured about 15°SE, just east of the area of study, is in the SW sec. 6, T. 9 N., R. 13 E., in Otoe County (Burchett, 1980).

(3) Only two faults have actually been observed in outcrops near the study area, and both are located along the Union Fault. One is in the NW NW sec. 21, T. 10 N., R. 14 E., Cass County, and was observed by Condra and Reed (1938) many years ago before quarrying destroyed the outcrop. Throw along this fault was reported to be 8.8 feet (2.7 m) in the Deer Creek Formation of Pennsylvanian age, but no mention was made whether that or any other faults involved Quaternary deposits. The other fault is in the NE SW

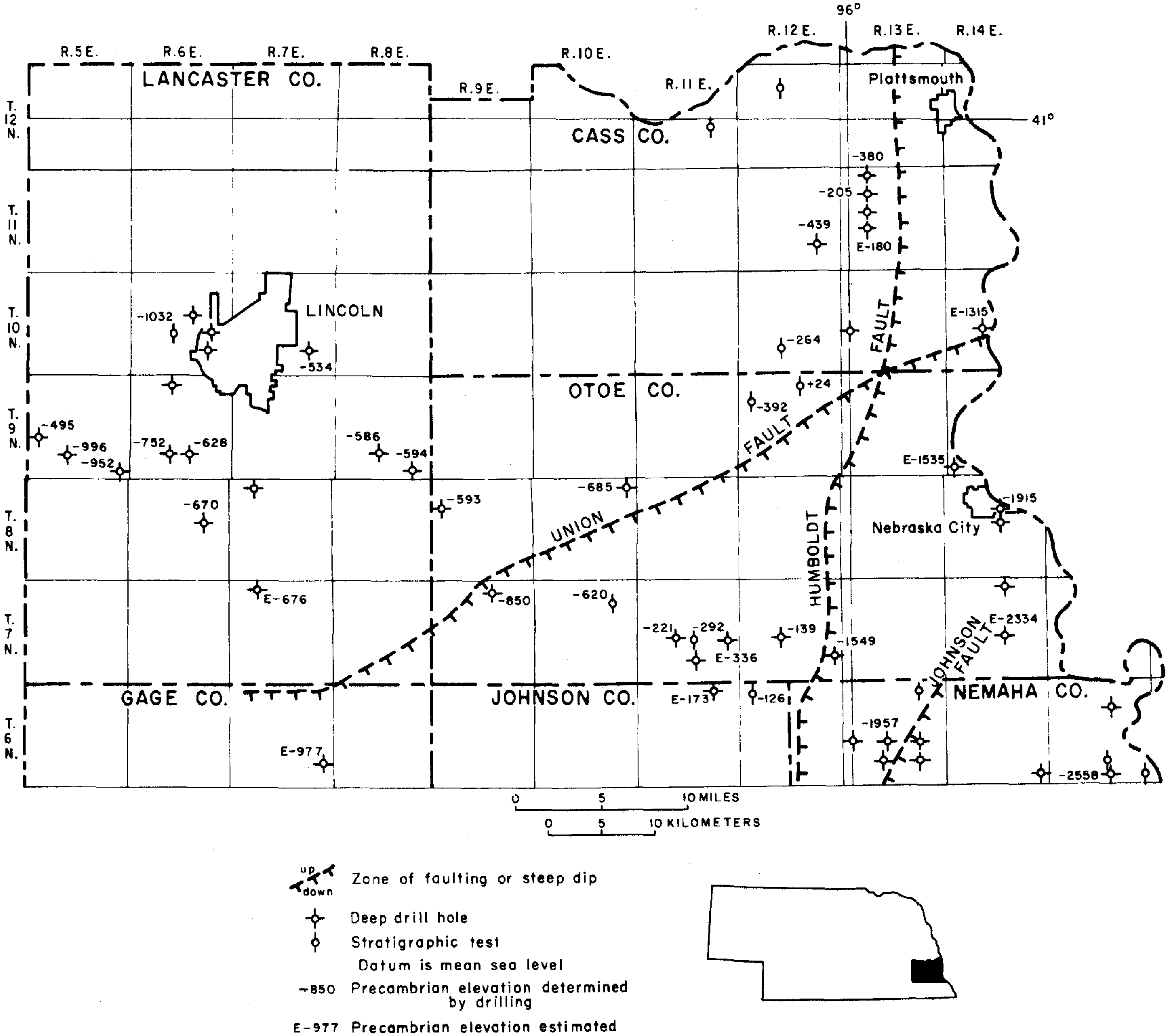
sec. 6, T. 9 N., R. 13 E., Otoe County. Here the Lecompton Formation of Pennsylvanian age is displaced about 3 feet (0.9 m). Overlying Quaternary deposits do not appear to be faulted.

(4) Displacements along the faults not observable in outcrops but indicated on figure 2 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; and the distance between outcrops and test holes available for interpretation ranges from 0.1 (0.161 km) to 1 mile (1.61 km). The greatest interpreted throw of the Elmont Limestone on the Union Fault, about 200 feet (61.0 m), is in the southwestern part of the study area.

(5) The altitude of the top of the Elmont Limestone (fig. 2) ranges from about 800 feet (243.8 m) above mean sea level in the southwestern part of the study area to more than 1100 feet (335.3 m) north of the Union Fault.

(6) 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).

(7) Several deep drill holes have penetrated the Precambrian age rocks in Cass, Otoe, Lancaster, and adjacent counties to the south. Locations of these holes and the elevation of the Precambrian surface are shown in figure 7.



ELEVATION OF PRECAMBRIAN SURFACE

Figure 7

Interpretation of these elevations indicates that faulting probably occurred in the Precambrian rocks along the Union Fault.

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EARTHQUAKE MONITORING NETWORK IN NEBRASKA

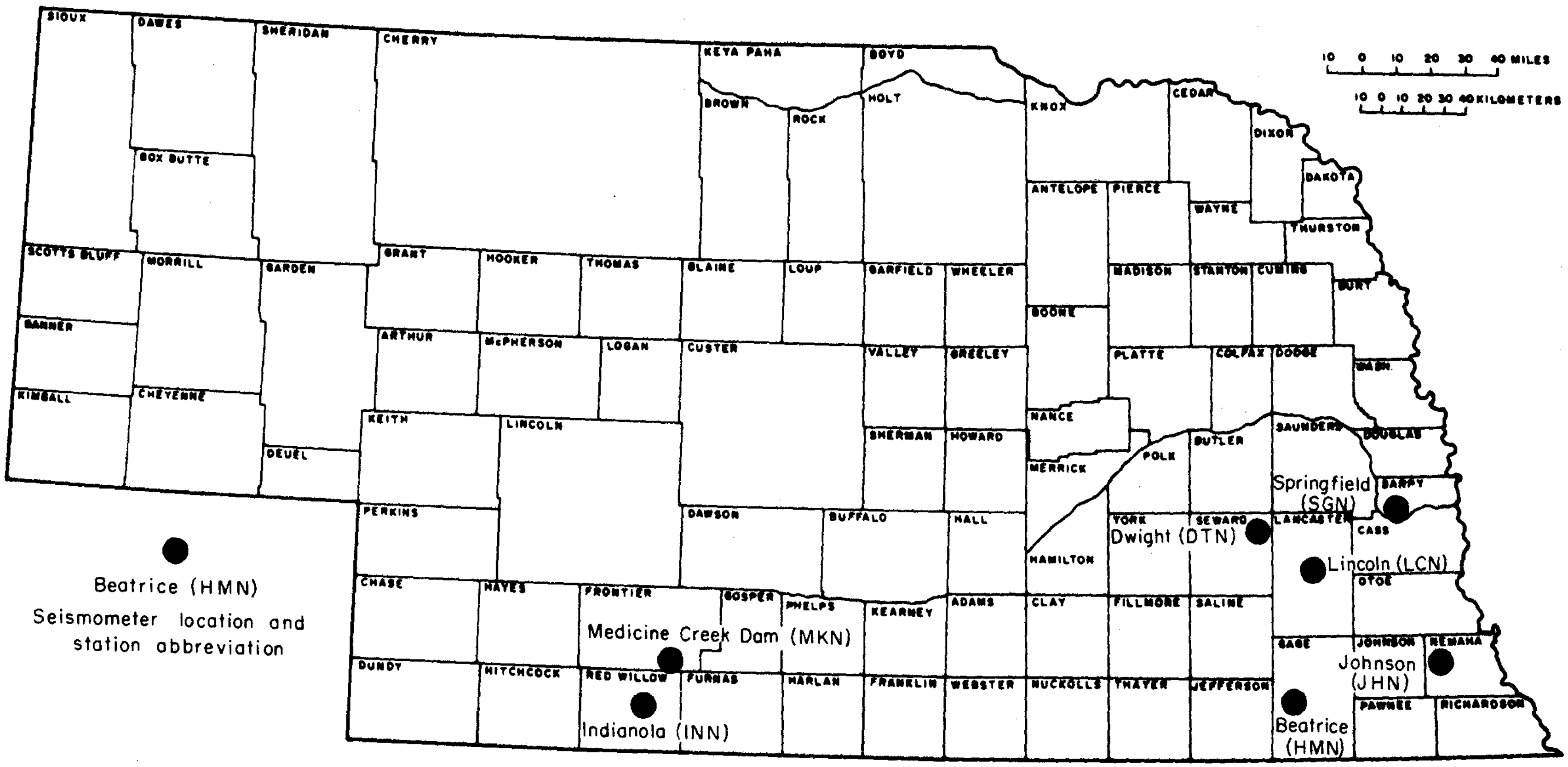
R. R. Burchett & Russell Smith

The Conservation and Survey Division (Nebraska Geological Survey) and the Geology Department of the University of Nebraska-Lincoln collaborated in the installation of a portable micro-earthquake station in Nebaska during contract year 1980-81. This station, near Dwight, was a replacement for the station near Columbus which developed high background noise.

As of July 1, 1981, a total of seven earthquake monitoring stations were operating in Nebraska. Locations of these stations are shown in figure 8. Precise location and other pertinent information about these stations are given below:

Site designation LCN. Location: E/2 NE NE SE sec. 23, T. 10 N., R. 6 E., lat. 40° 48' 42" N., long. 96° 42' 07" W.; on University of Nebraska-Lincoln campus at Lincoln in Lancaster County, Nebraska. Instrument altitude: 1,165 ft. (355 m) msl datum. Operation begun September 1, 1977.

Site designation DTN: Location: Center SE NW SW sec. 6, T. 12 N., R. 4 E.; lat. 41° 01' 18" N., long. 97° 02' 09" W.; on James Tesina farm near Dwight, in Seward County, Nebraska. Instrument altitude: 1,523 ft. (464 m) msl datum. Operation begun August 25, 1980.



LOCATION OF EARTHQUAKE MONITORING STATIONS IN NEBRASKA AS OF JULY 1, 1980

Figure 8

Site designation JHN. Location: NW corner SW NE sec. 36, T. 6 N., R. 12 E.; lat. 40° 26' 49" N., long. 96° 01' 03" W.; on Douglas Boellstorff farm near Johnson in Nemaha County, Nebraska. Instrument altitude: 1,080 ft. (329 m) msl datum. Operation begun December 5, 1978.

Site designation HMN. Location. NW SW SE NW sec. 26, T. 4 N., R. 5 E.; lat. 40° 17' 11" N., long. 96° 50' 08" W.; on Homestead National Monument of America Site near Beatrice in Gage County, Nebraska. Instrument altitude: 1,207 ft. (368 m) msl datum. Operation begun June 20, 1979.

Site designation SGN. Location: SE NW NE SE sec. 30, T. 13 N., R. 11 E.; lat. 41° 3' 57" N., long. 96° 13' 7" W.; on Leroy Nielson farm near Springfield in Sarpy County, Nebraska. Instrument altitude: 1,140 ft. (348 m) msl datum. Operation begun June 20, 1980.

Site designation MKN. Location: NW SE NW sec. 25, T. 5 N., R. 26 W.; lat. 40° 22.44' N., 100° 13.50' W.; near Medicine Creek Dam in Frontier County, Nebraska. Instrument altitude 2,395 ft. (730 m) msl datum. Operation begun March 11, 1979.

Site designation INN. Location. NW SW SW sec. 29, T. 3 N., R. 27 W.; lat. 40° 11.55' N., 100° 24.01' W.; near Indianola in Red Willow County, Nebraska. Instrument altitude 2,500 ft. (762 m) msl datum. Operation begun September 15, 1979.

All stations are equipped with Geotech Portacorders model RV-320 and Geotech model S-13 seismometers except the HMN and MKN stations are equipped with Geotech model S-500 seismometers and INN with a GSC-20D seismometer.

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. All seismographic records with the exception of Medicine Creek and Indianola are sent to the University of Nebraska-Lincoln for preliminary analysis and then are forwarded to the Kansas Survey for more detailed analysis. The seismographic records from Medicine Creek and Indianola are sent directly to the Kansas Geological Survey.

The Nebraska seismometers, together with seismometers in the adjacent part of Kansas, provide continuous coverage of seismic activity along the buried Nemaha Ridge.

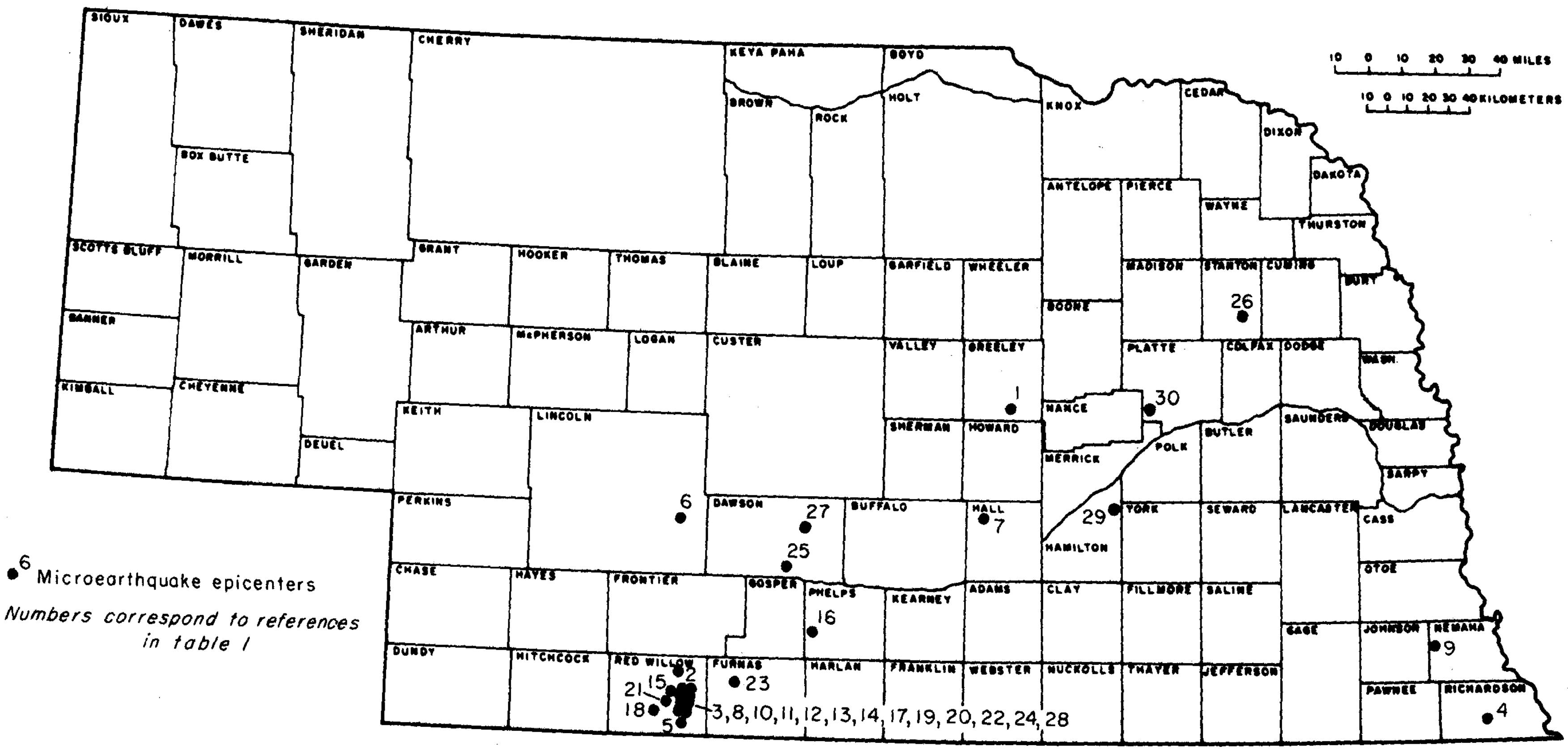
Thirty microearthquakes centering in Nebraska were recorded between August 1977 and July 1981. Table 1 and figure 9 show the location of these microearthquakes.

TABLE 1

MICROEARTHQUAKES IN NEBRASKA

Map Ref.	Date	Origin Time (UTC)[1]	Latitude Degrees North	Longitude Degrees West	Depth[2] (Km)	Magnitude[3]
1	1977 Aug 18	10:34:25.21	41:24.90	98:28.07	5.00	2.5
2	1977 Dec 1	13:04:34.20	40:18.53	100:22.00	5.00	2.3
3	1977 Dec 1	13:22:38.57	40:12.52	100:17.87	5.00	2.4
4	1978 Jan 13	20:15:33.39	40:05.58	95:42.00	5.00	1.7
5	1978 Feb 3	0:25:47.62	40:01.92	100:20.00	5.00	2.4
6	1978 Sep 14	8:06:18.59	40:53.76	100:22.00	5.00	2.2
7	1979 Apr 8	22:46:10.41	40:58.12	98:33.83	0.67	2.4
8	1979 Jun 6	16:16:21.91	40:08.61	100:20.88	1.00	2.5
9	1979 Jun 12	11:13:11.88	40:24.33	96:03.26	2.07	1.8
10	1979 Jul 16	0:03:48.18	40:10.07	100:17.22	5.00	2.7
11	1979 Jul 16	1:34:20.32	40:11.59	100:20.70	5.00	2.5
12	1979 Jul 16	5:27.01.42	40:11.45	100:20.00	9.08	1.3
13	1979 Jul 16	6:08:09.89	40:11.32	100:20.73	11.09	1.5
14	1979 Jul 16	7:05:56.02	40:12.00	100:19.90	7.08	1.1
15	1979 Jul 24	4:16:46.09	40:12.47	100:26.00	0.88	2.2
16	1979 Jul 24	8:04:46.26	40:27.94	99:37.38	0.87	1.9
17	1979 Aug 2	4:16:21.66	40:10.34	100:21.44	0.84	2.5
18	1979 Aug 13	11:09:47.65	40:06.80	100:30.10	1.50	1.7
19	1979 Aug 14	23:59:31.37	40:10.39	100:20.58	1.76	1.5
20	1979 Aug 15	6:45:53.87	40:08.68	100:20.34	1.51	1.5
21	1979 Aug 15	16:07:07.14	40:08.49	100:26.43	1.23	1.3
22	1979 Aug 31	8:00:11.70	40:08.31	100:20.22	1.53	2.2
23	1979 Nov 19	4:58:43.40	40:14.86	100:02.77	13.57	1.5
24	1979 Nov 29	22:02:31.21	40:09.80	100:21.64	3.15	1.9
25	1980 Apr 26	14:21:48.50	40:43.99	99:43.91	5.00	2.3
26	1980 Aug 13	5:50:11.83	41:53.59	97:06.01	9.90	2.1
27	1981 Mar 13	12:42:16.68	40:53.44	99:41.67	5.00	2.4
28	1981 Mar 20	5:09:48.17	40:10.31	100:19.60	1.75	1.4
29	1981 Apr 20	18:18:15.28	41:01.02	97:49.49	20.80	2.4
30	1981 Jun 26	18:55:02.07	41:31.75	97:39.06	5.00	2.8

[1] (UTC) Coordinated Universal Time.--Subtract 6 hours for Central Standard Time.
[2] Depth calculated in kilometers or fixed at 5.00 km.
[3] Duration magnitude calculated from equation derived by Oklahoma Geological Observatory.



MICROEARTHQUAKES IN NEBRASKA

Figure 9

GRAVITY AND GROUND MAGNETIC INVESTIGATIONS IN EASTERN NEBRASKA

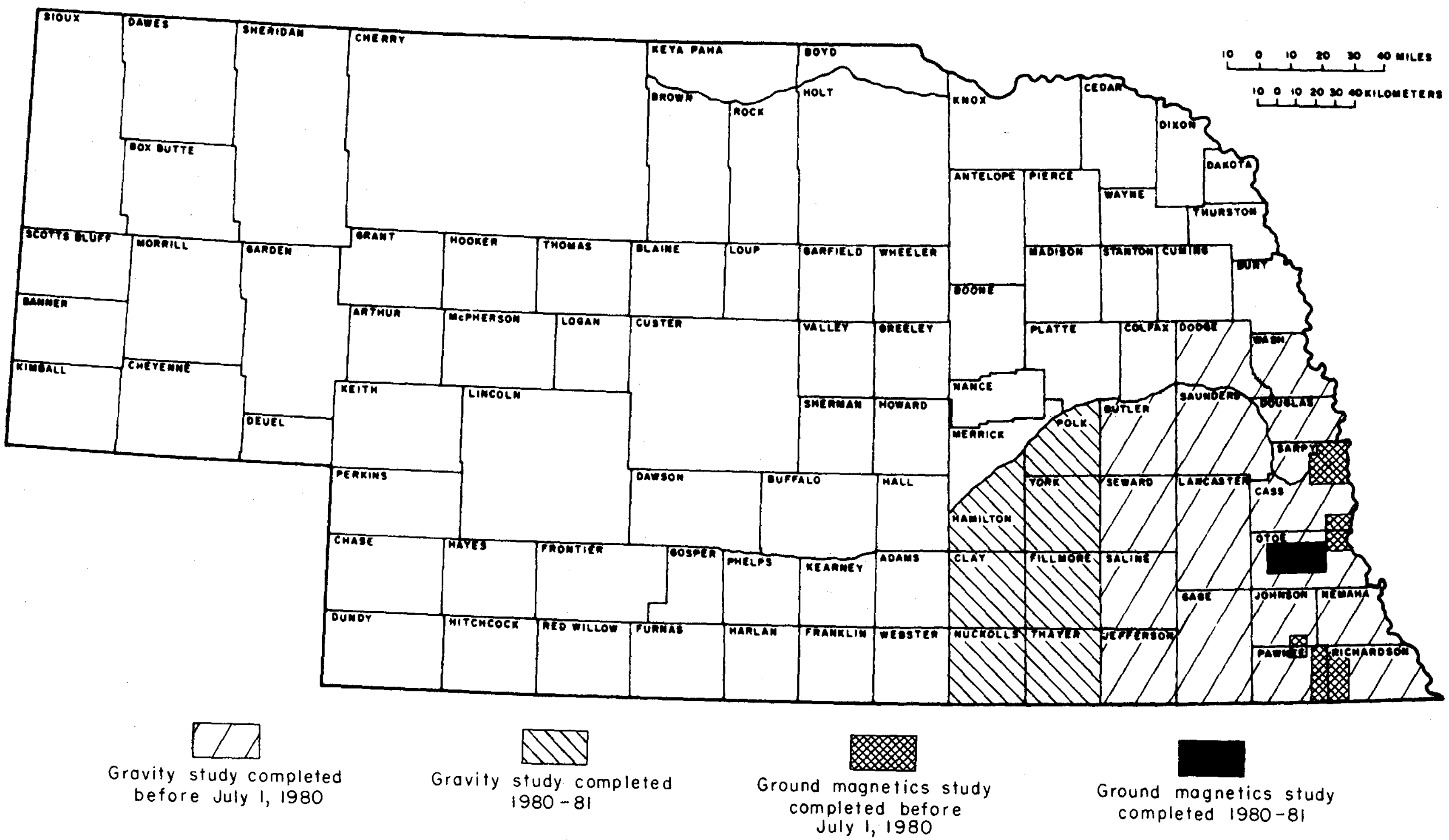
R. F. Diffendal, Jr. and R. R. Burchett

Introduction

The purpose of this investigation was to extend the area covered by gravity and ground magnetic data related to the Nemaha Uplift and associated structures in eastern Nebraska (fig. 10). Gravity data were collected from Clay, Fillmore, Hamilton, Nuckolls, Polk, Thayer, and York counties. Additional ground magnetic data and gravity data were collected for central Otoe County.

Gravity Study

Gravimetric surveying is a geophysical technique that aids in interpretation of subsurface geologic structure. A Worden Master, a very sensitive weighing device which measures differences in gravity intensity (acceleration) at specific points on the earth's surface, is used in this type of surveying. 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.



LOCATIONS OF GRAVITY AND MAGNETIC STUDIES IN EASTERN NEBRASKA

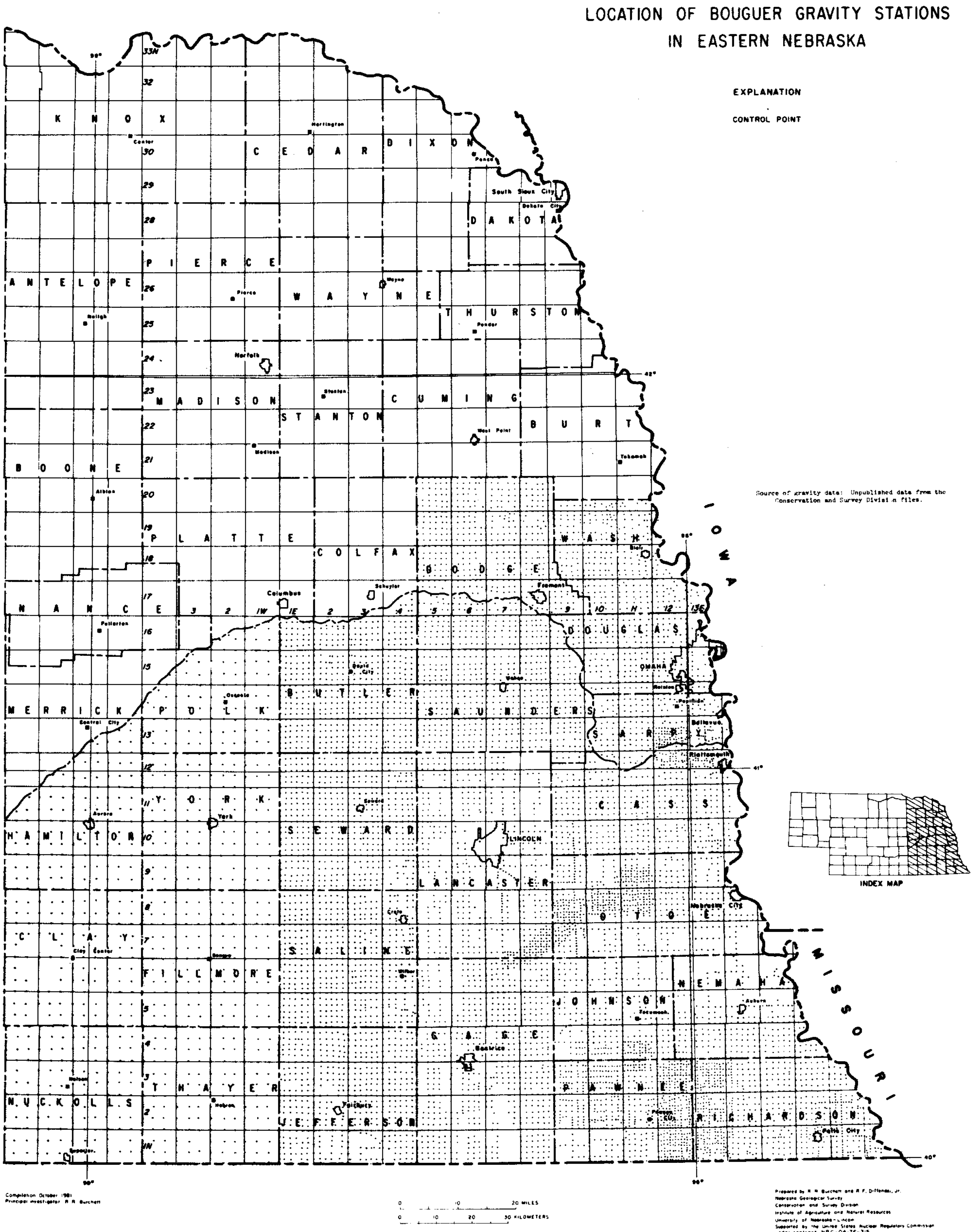
Figure 10

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 in some cases half-mile section lines (fig. 11). Land-surface altitudes at most stations could be determined directly from 7.5-minute topographic quadrangles. For other stations, land-surface altitudes were established 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. These three densities were used to compute the efforts of observed gravity versus theoretical gravity for anomaly interpretation.

In central Otoe County 253 gravity stations, in addition to those previously established, were used to produce a


LOCATION OF BOUGUER GRAVITY STATIONS
IN EASTERN NEBRASKA
EXPLANATION
CONTROL POINT
Source of gravity data: Unpublished data from the Conservation and Survey Division files.
INDEX MAP
IOWA
MISSOURI
KNOX
CEDAR
DIXON
DAKOTA
ANTELOPE
PIERCE
WAYNE
THURSTON
MADISON
STANTON
CUMING
BURT
BOONE
PLATTE
COLFAX
DODGE
WASHINGTON
NANCE
DOUGLAS
MERRICK
POLK
BUTLER
SAUNDERS
SARPY
HAMILTON
YORK
SEWARD
LANCASTER
CASS
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JOHNSON
NEMAHA
GAGE
PAWNEE
RICHARDSON
NUCKOLLS
THAYER
JEFFERSON
LINCOLN
OMAHA
Compilation October 1981
0 10 20 MILES
0 10 20 30 KILOMETERS
Conservation and Survey Division
Supported by the United States Nuclear Regulatory Commission

Figure 11

hand-contoured Bouguer gravity map (fig. 12). In addition about 980 gravity stations were occupied in Clay (fig. 13), Fillmore (fig. 14), Hamilton (fig. 15). Nuckolls (fig. 16), Polk, (fig. 17), Thayer (fig. 18), and York (fig. 19). Data collected at these stations were used to produce Bouguer gravity maps for each of the counties (figs. 20, 21, 22, 23, 24, 25, & 26). These data were also integrated with previously collected data to generate a comprehensive regional Bouguer gravity map of eastern Nebraska (fig. 27).

Ground Magnetic Study

The instrument used in the ground magnetic study was a Geometrics® 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 about 300 magnetic stations were established at 0.5- and 1.0- mile spacings in central Otoe County. 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

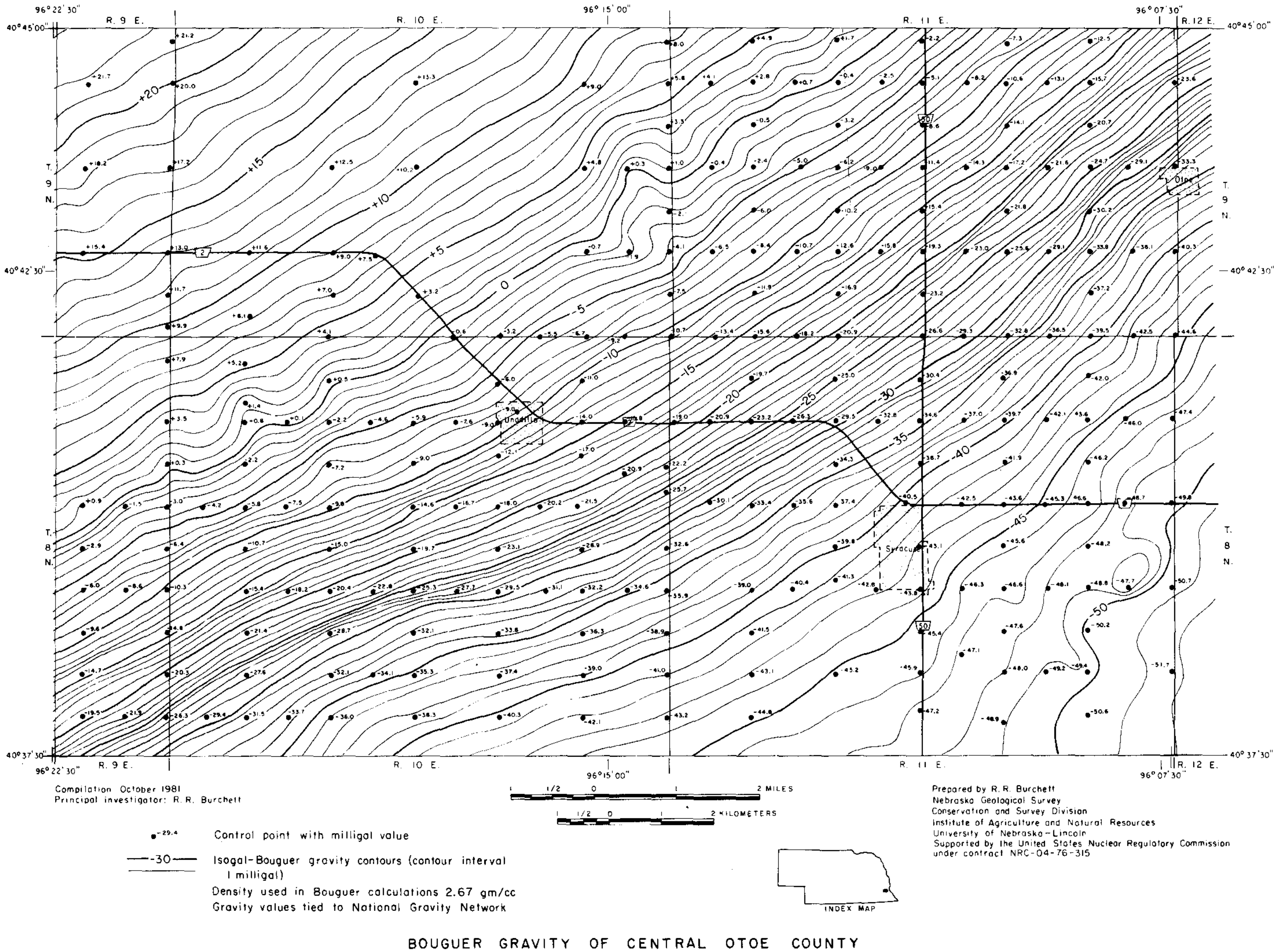
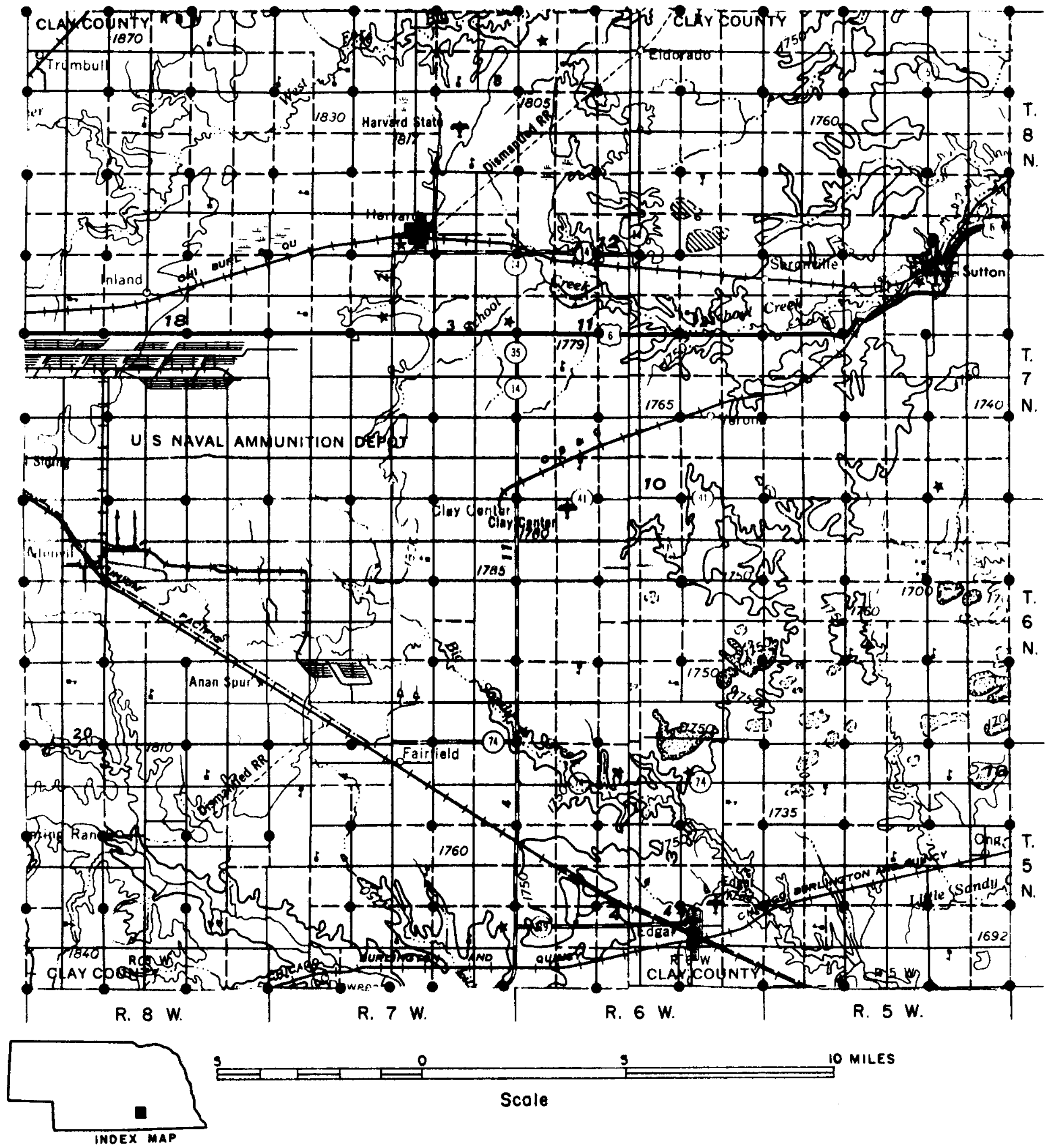
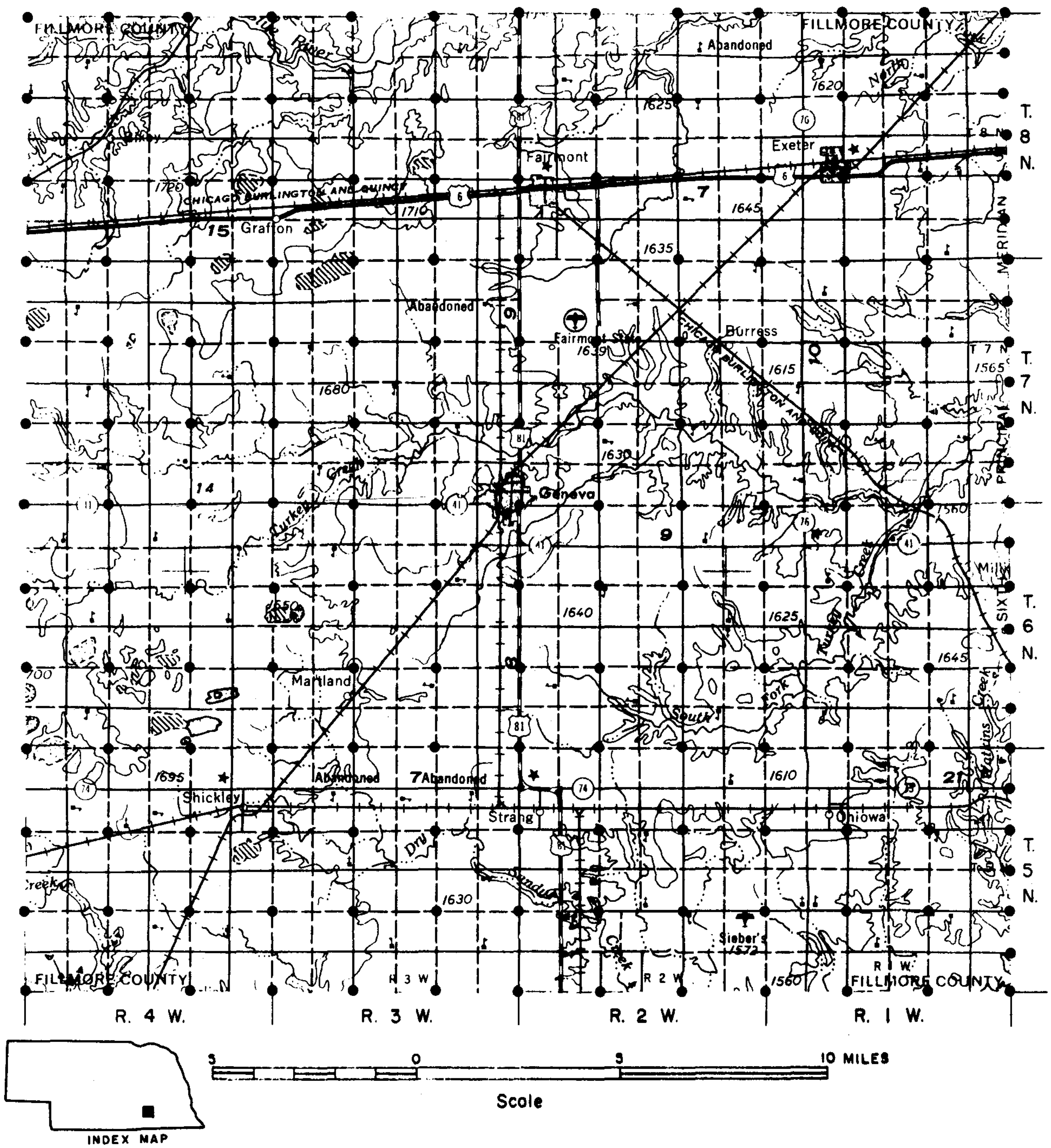

96° 22' 30"
R. 9 E.
R. 10 E.
96° 15' 00"
R. 11 E.
96° 07' 30"
R. 12 E.
40° 45' 00"
40° 42' 30"
40° 37' 30"
T. 9 N.
T. 8 N.
Undadilla
Syracuse
Otoe
Compilation October 1981
Principal investigator: R. R. Burchett
1/2 0 1 2 MILES
1 1/2 0 1 2 KILOMETERS
Control point with milligal value
Isogal-Bouguer gravity contours (contour interval 1 milligal)
Density used in Bouguer calculations 2.67 gm/cc
Gravity values tied to National Gravity Network
INDEX MAP
Prepared by R. R. Burchett
Nebraska Geological Survey
Conservation and Survey Division
Institute of Agriculture and Natural Resources
University of Nebraska-Lincoln
Supported by the United States Nuclear Regulatory Commission under contract NRC-04-76-315
BOUGUER GRAVITY OF CENTRAL OTOE COUNTY

Figure 12



LOCATION OF BOUGUER GRAVITY STATIONS IN CLAY COUNTY

Figure 13



LOCATION OF BOUGUER GRAVITY STATIONS IN FILLMORE COUNTY

Figure 14

LOCATION OF BOUGUER GRAVITY STATIONS IN HAMILTON COUNTY

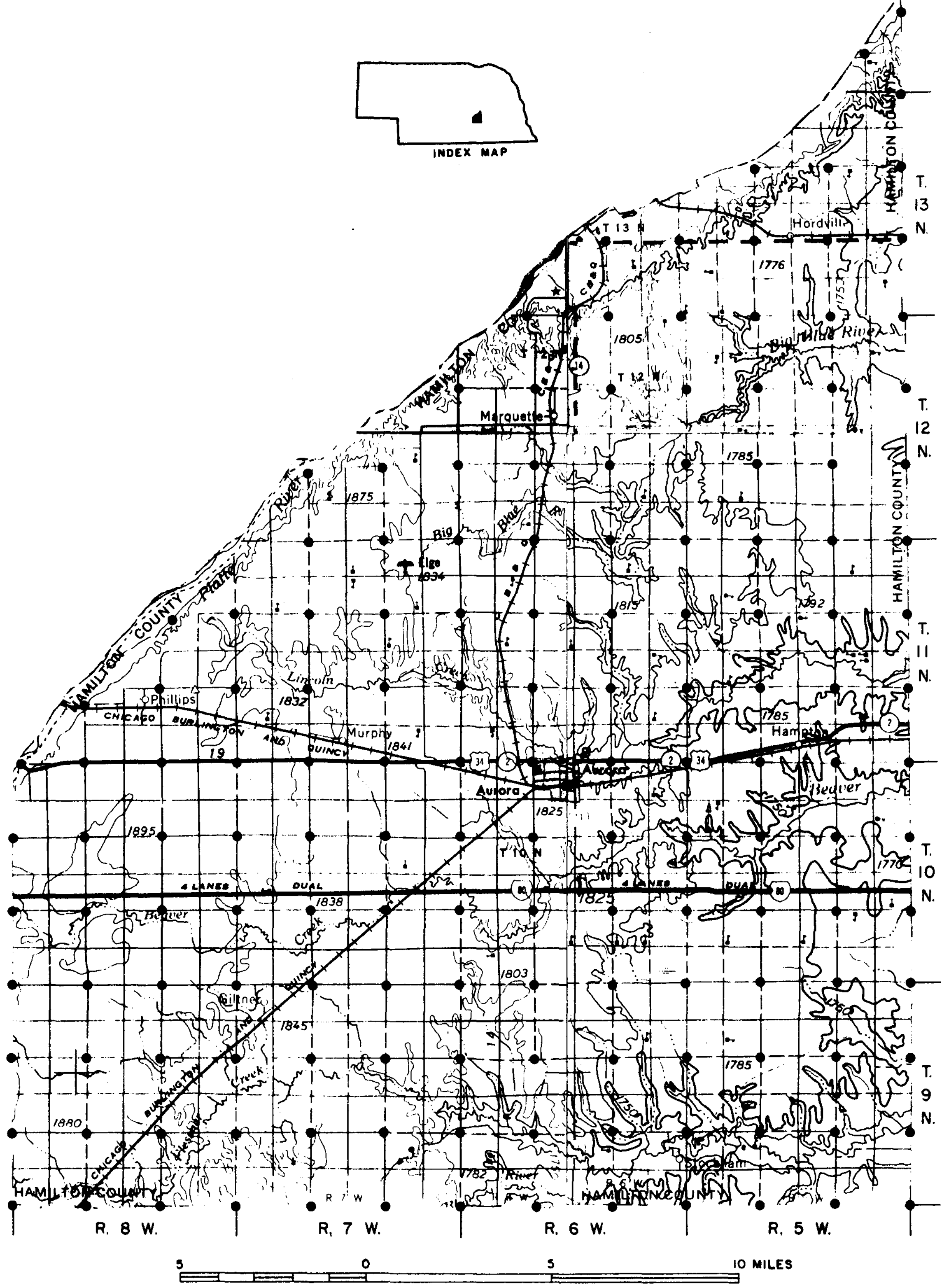
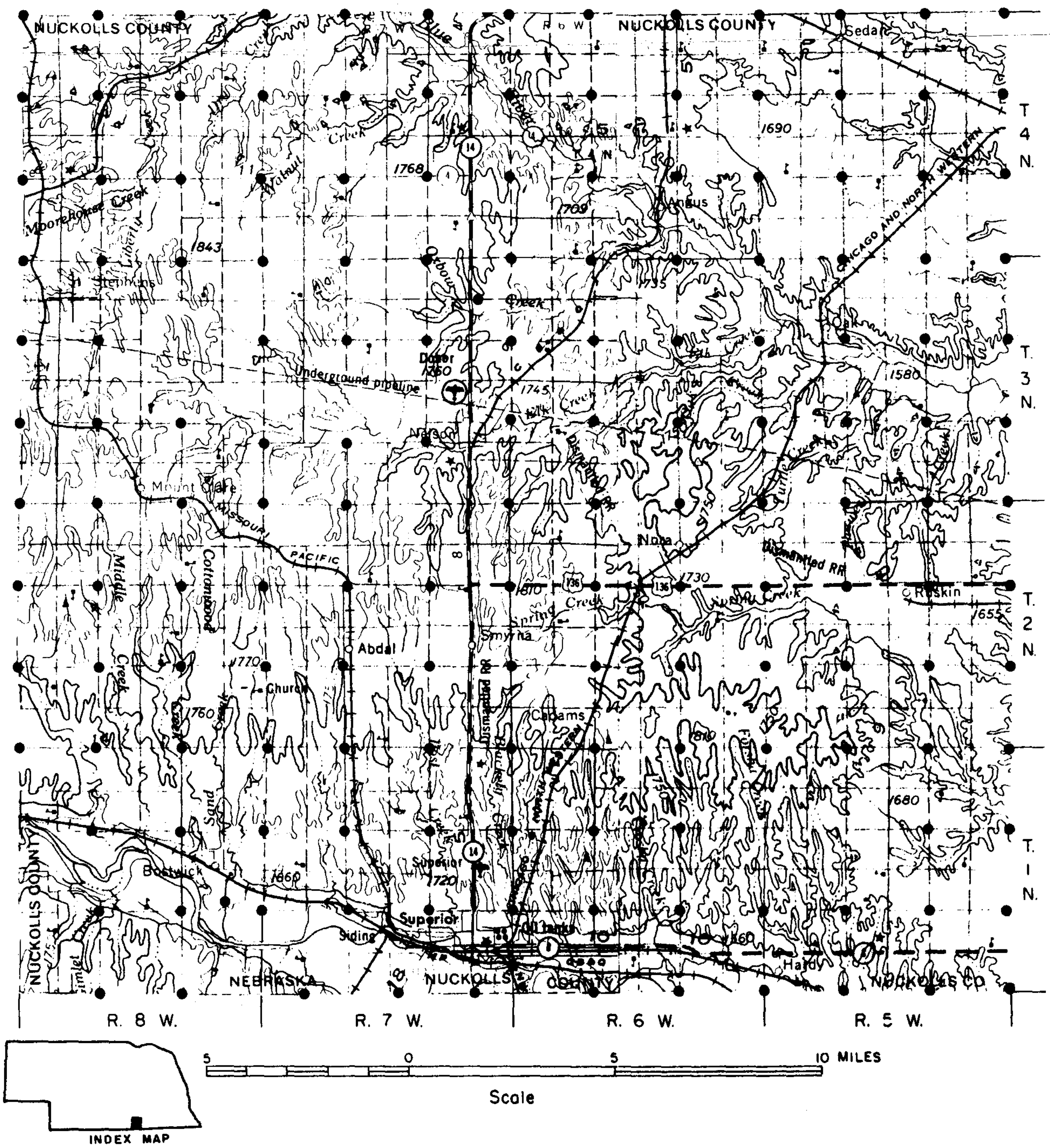
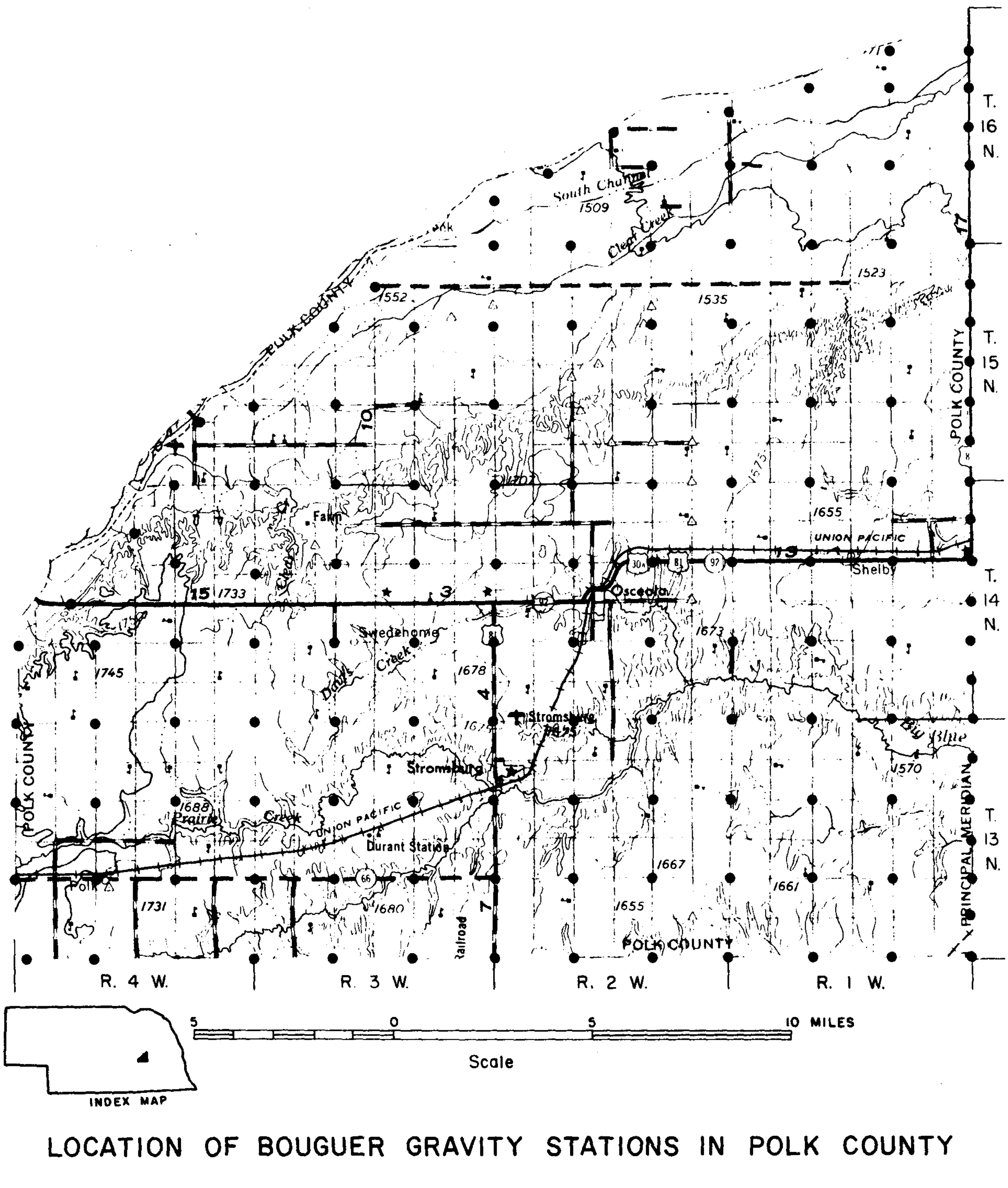


Figure 15



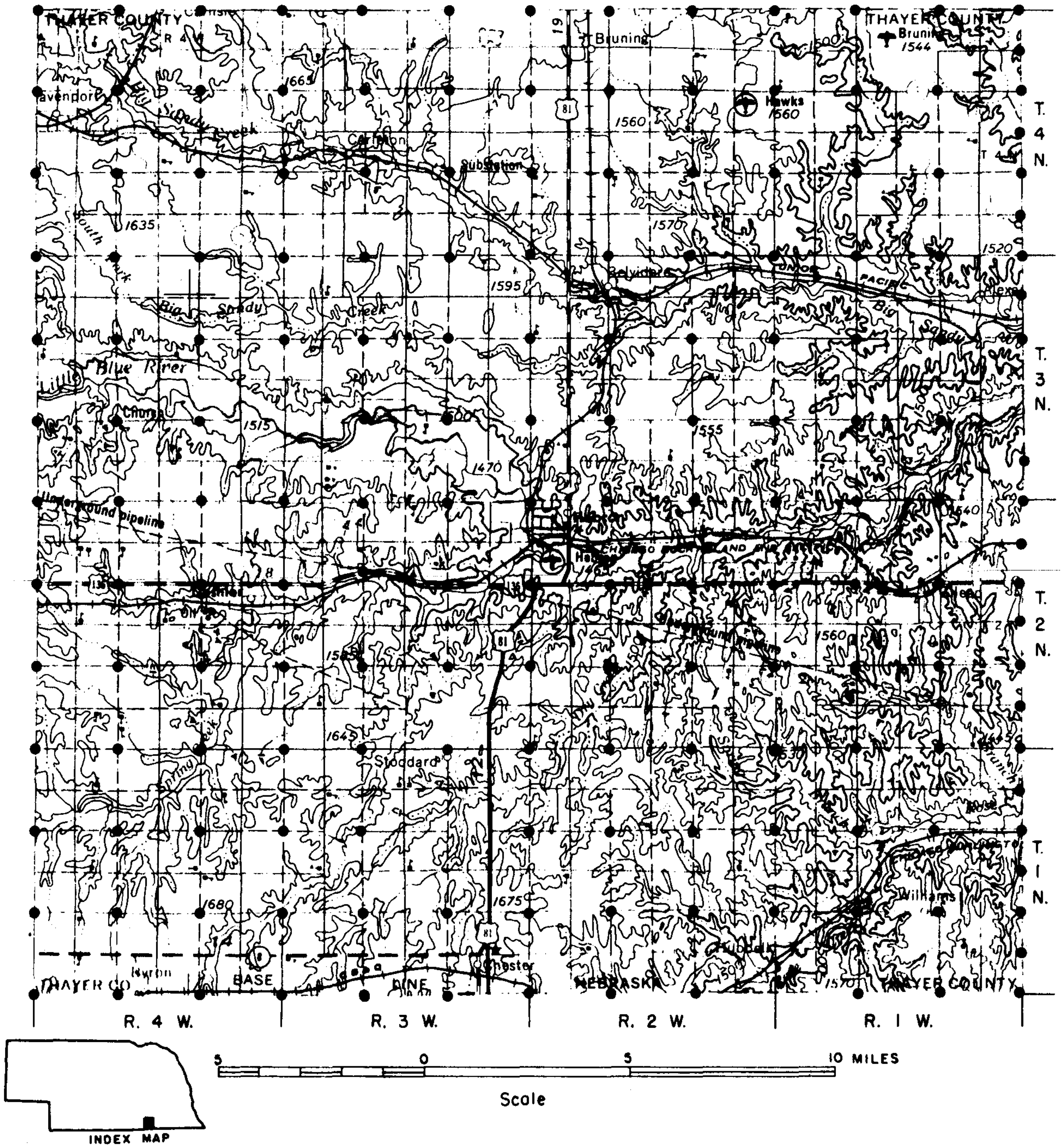
LOCATION OF BOUGUER GRAVITY STATIONS IN NUCKOLLS COUNTY

Figure 16



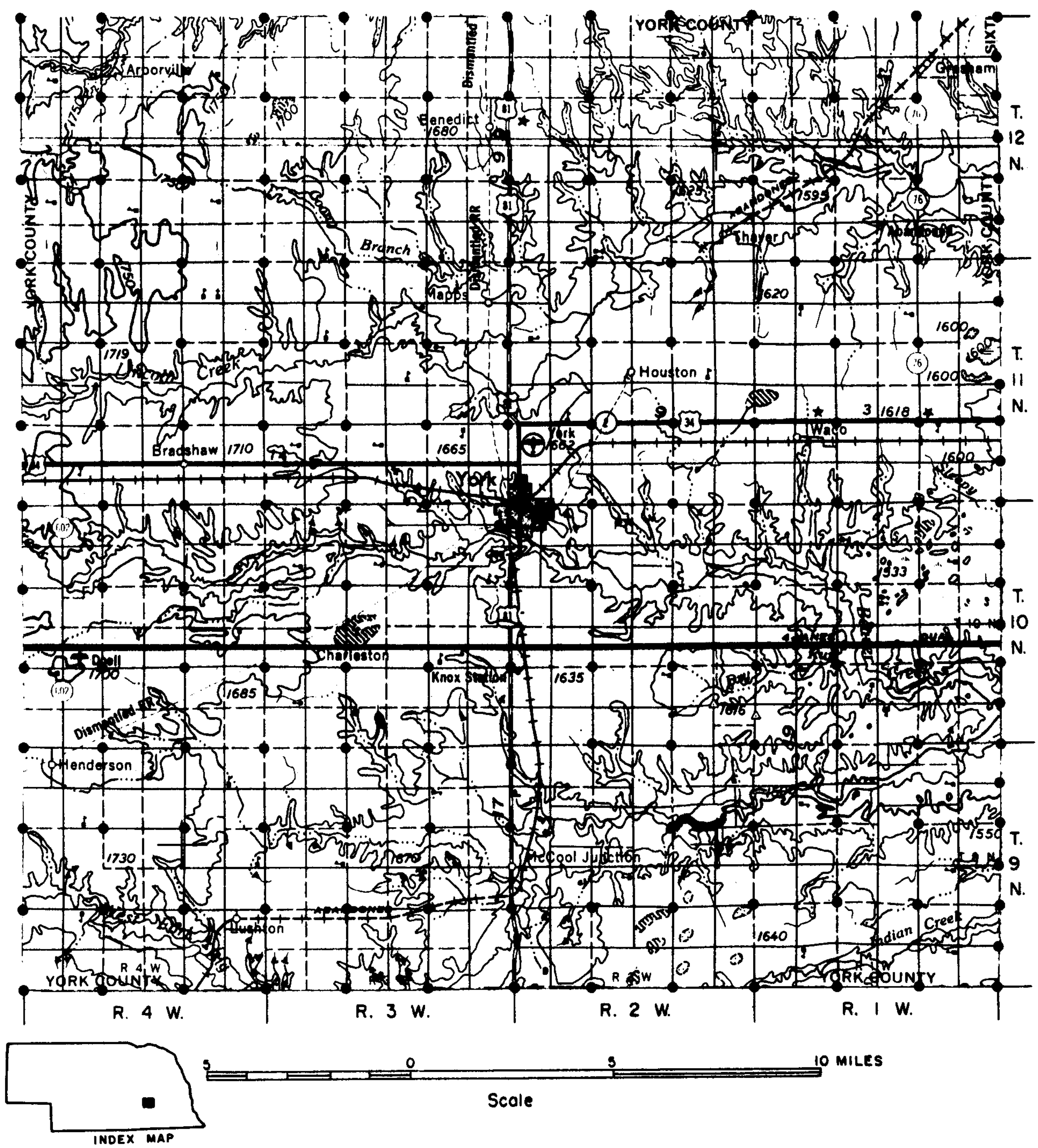
LOCATION OF BOUGUER GRAVITY STATIONS IN POLK COUNTY

Figure 17



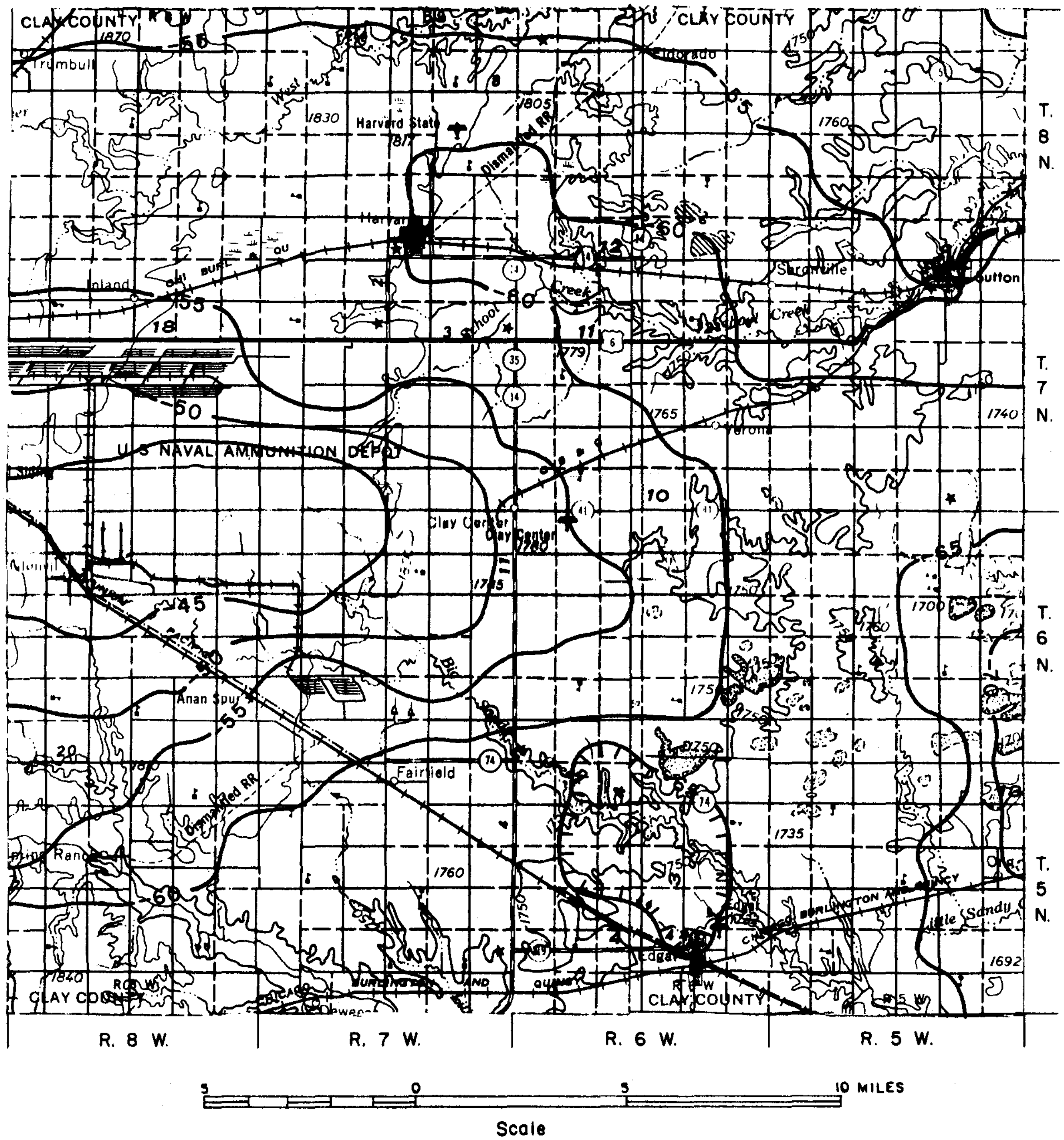
LOCATION OF BOUGUER GRAVITY STATIONS IN THAYER COUNTY

Figure 18



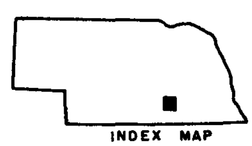
LOCATION OF BOUGUER GRAVITY STATIONS IN YORK COUNTY

Figure 19



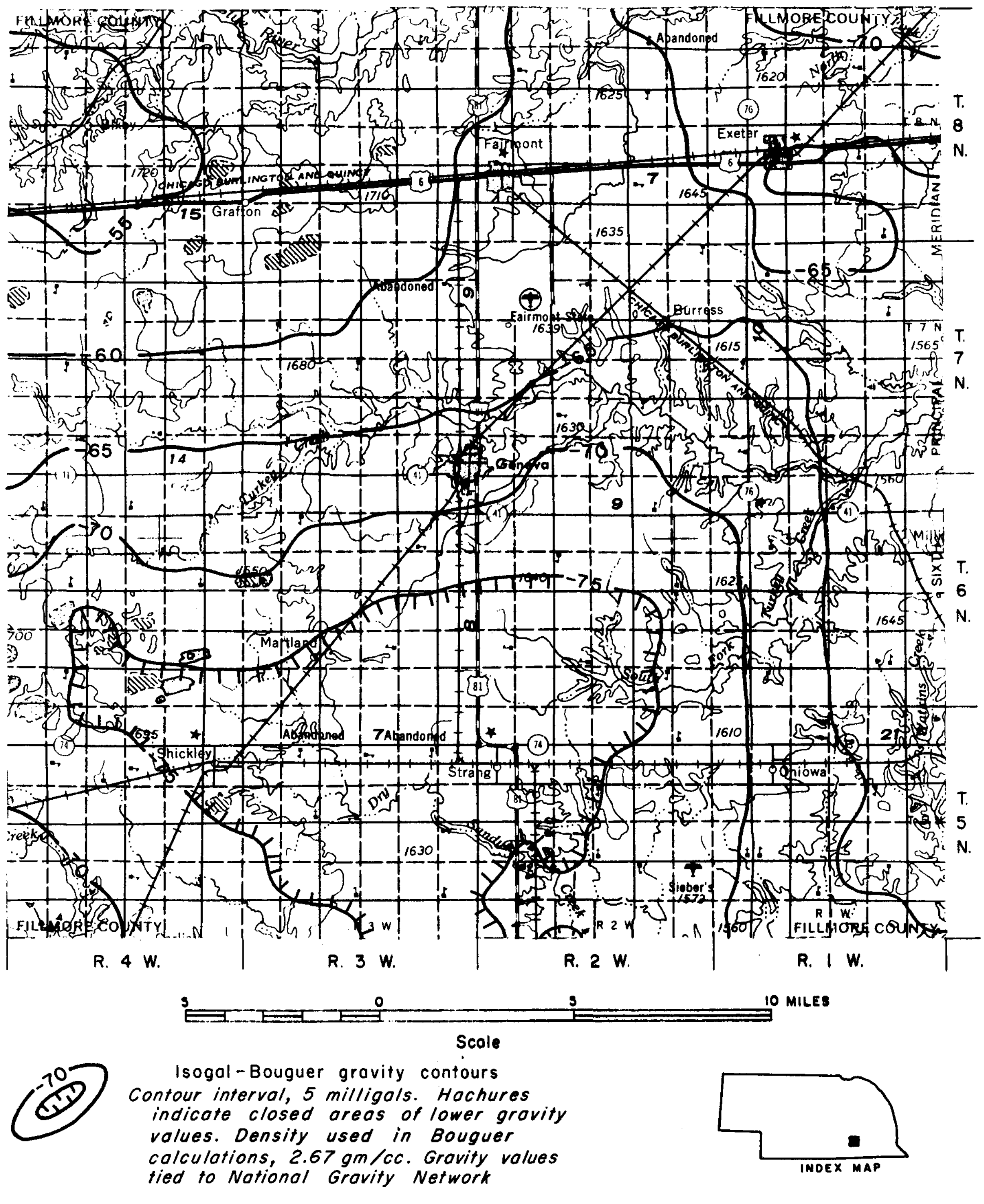
Isogal-Bouguer gravity contours

Contour interval, 5 milligals. Hachures indicate closed areas of lower gravity values. Density used in Bouguer calculations, 2.67 gm/cc. Gravity values tied to National Gravity Network



BOUGUER GRAVITY OF CLAY COUNTY

Figure 20



BOUGUER GRAVITY OF FILLMORE COUNTY

Figure 21

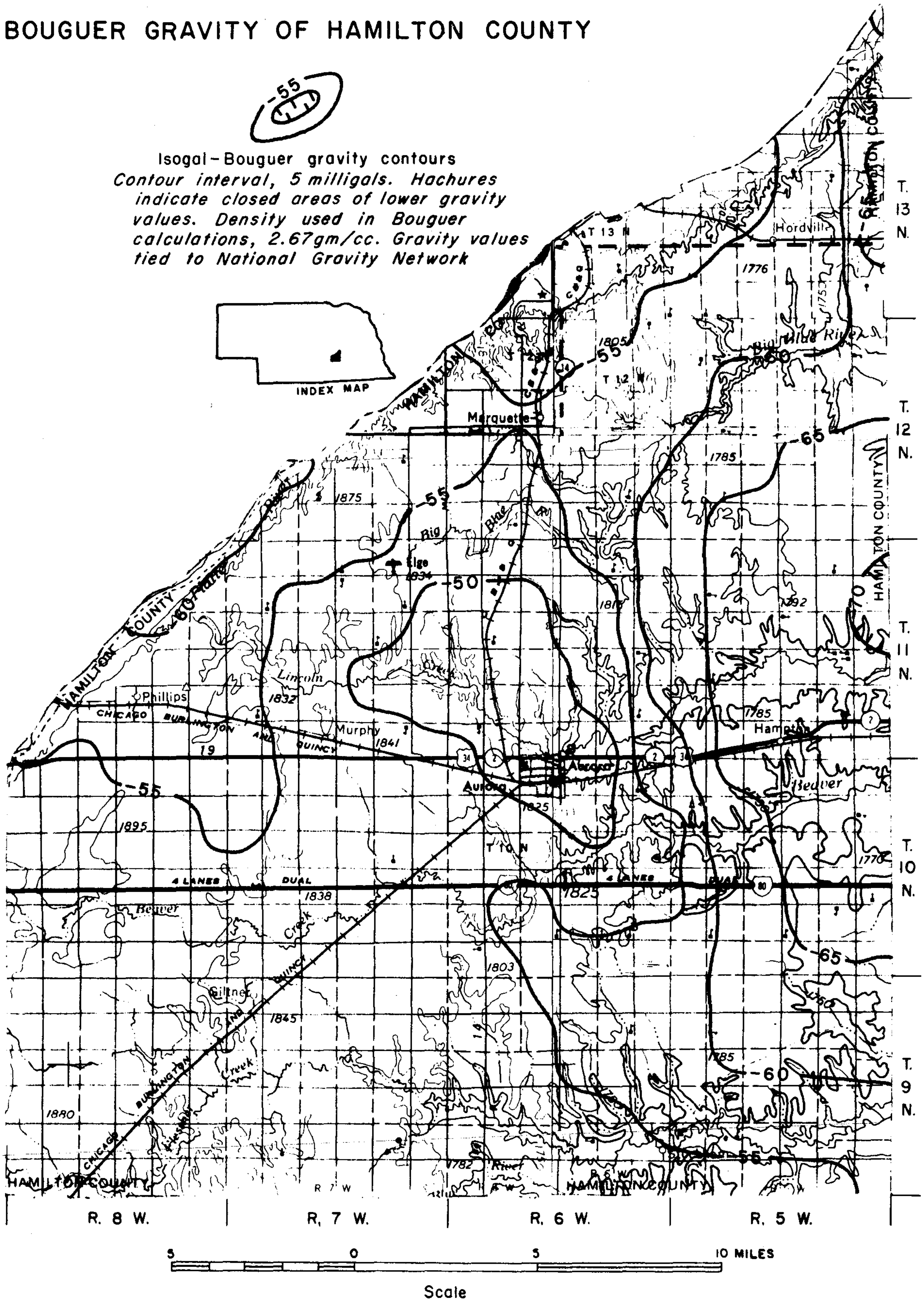
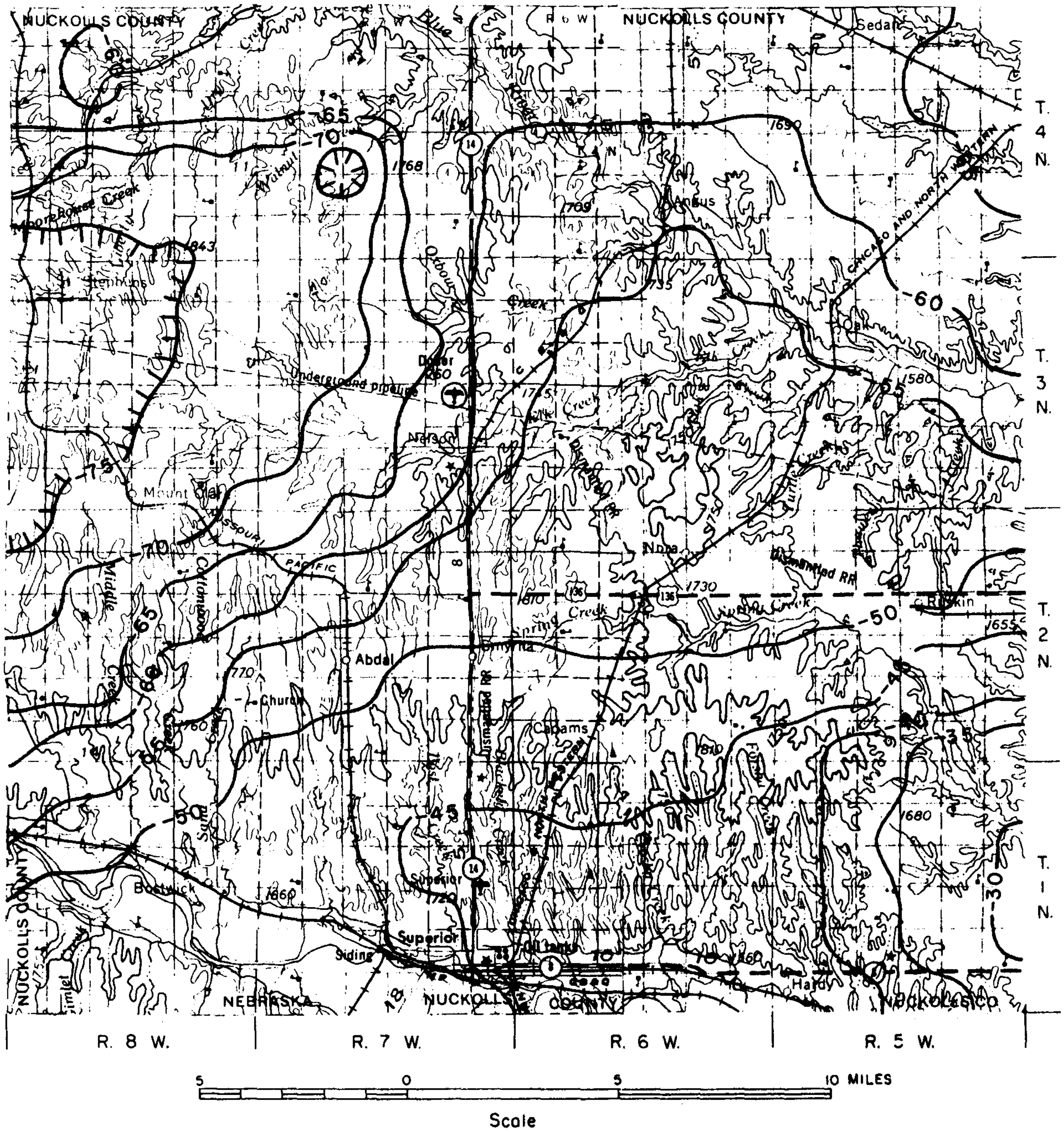
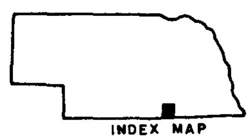

BOUGUER GRAVITY OF HAMILTON COUNTY
-55
Isogal-Bouguer gravity contours
Contour interval, 5 milligals. Hachures indicate closed areas of lower gravity values. Density used in Bouguer calculations, 2.67gm/cc. Gravity values tied to National Gravity Network
INDEX MAP
Hordville
Marquette
Elge
Phillips
Murphy
Aurora
Hampton
Giltner
Lincoln
Big Blue River
Beaver
CHICAGO BURLINGTON AND QUINCY
4 LANES DUAL
HAMILTON COUNTY
T. 13 N.
T. 12 N.
T. 11 N.
T. 10 N.
T. 9 N.
R. 8 W.
R. 7 W.
R. 6 W.
R. 5 W.
-50
-55
-60
-65
-70
5
0
5
10 MILES
Scale

Figure 22



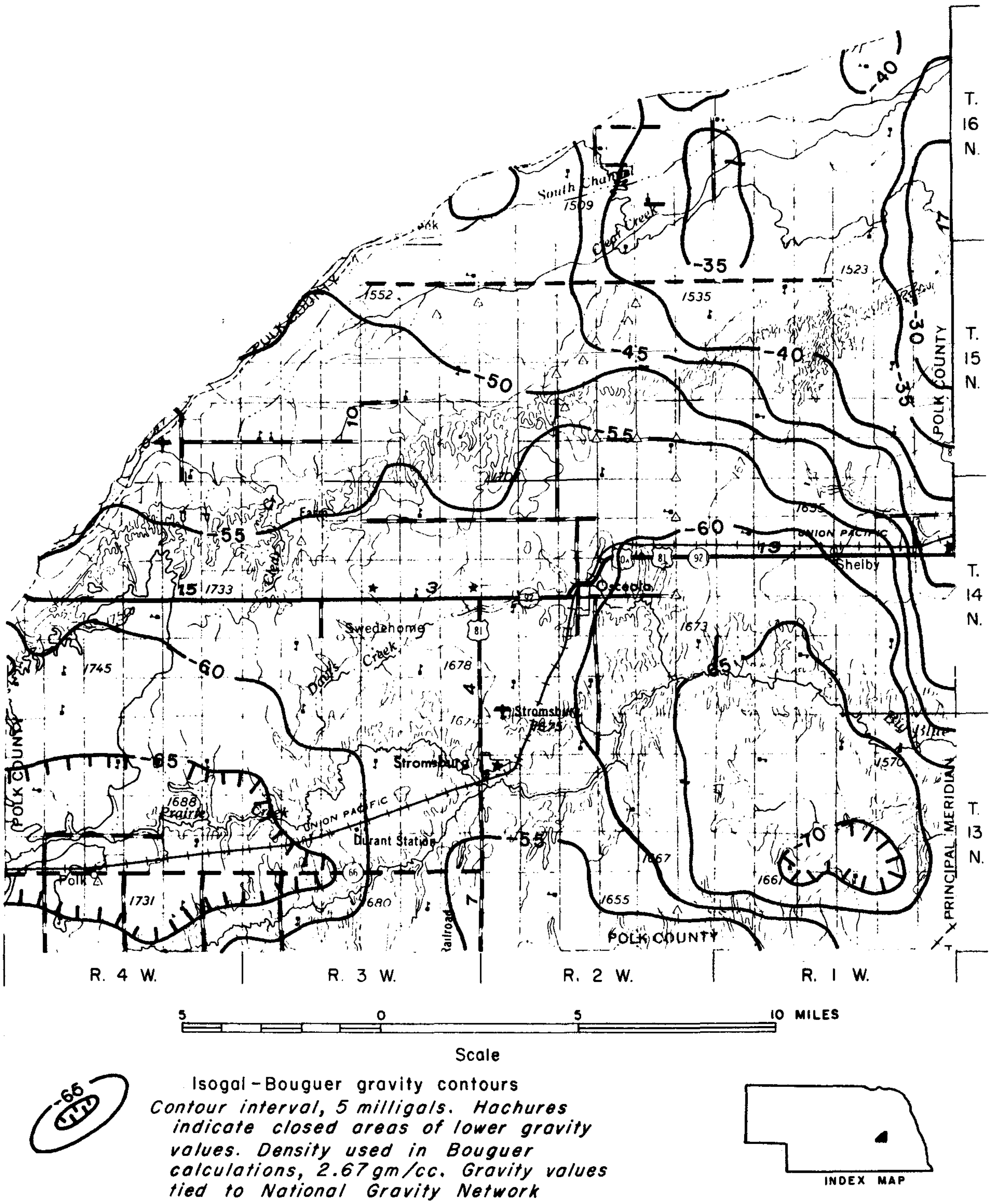
Isogal-Bouguer gravity contours

Contour interval, 5 milligals. Hachures indicate closed areas of lower gravity values. Density used in Bouguer calculations, 2.67gm/cc. Gravity values tied to National Gravity Network



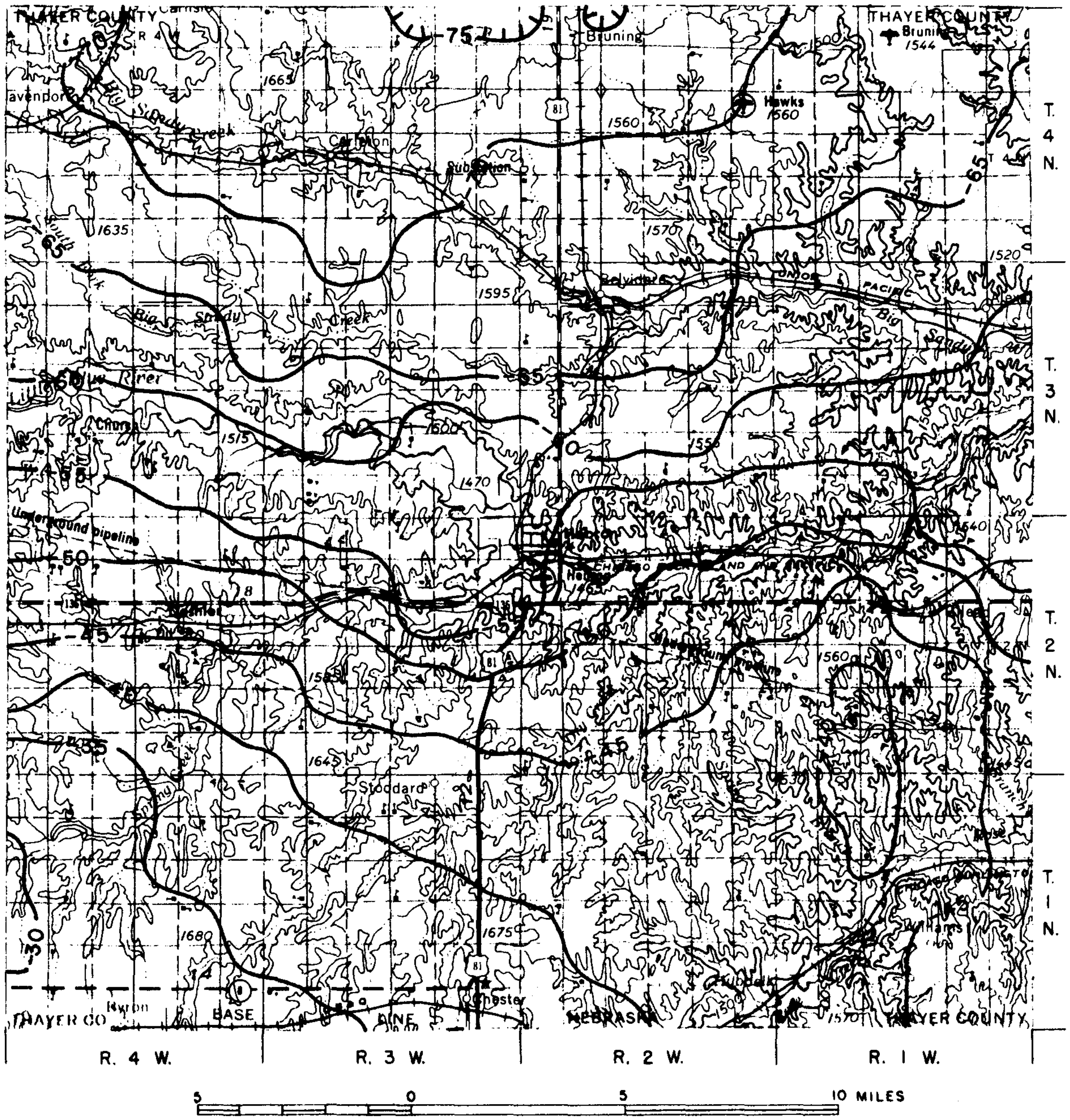
BOUGUER GRAVITY OF NUCKOLLS COUNTY

Figure 23



BOUGUER GRAVITY OF POLK COUNTY

Figure 24



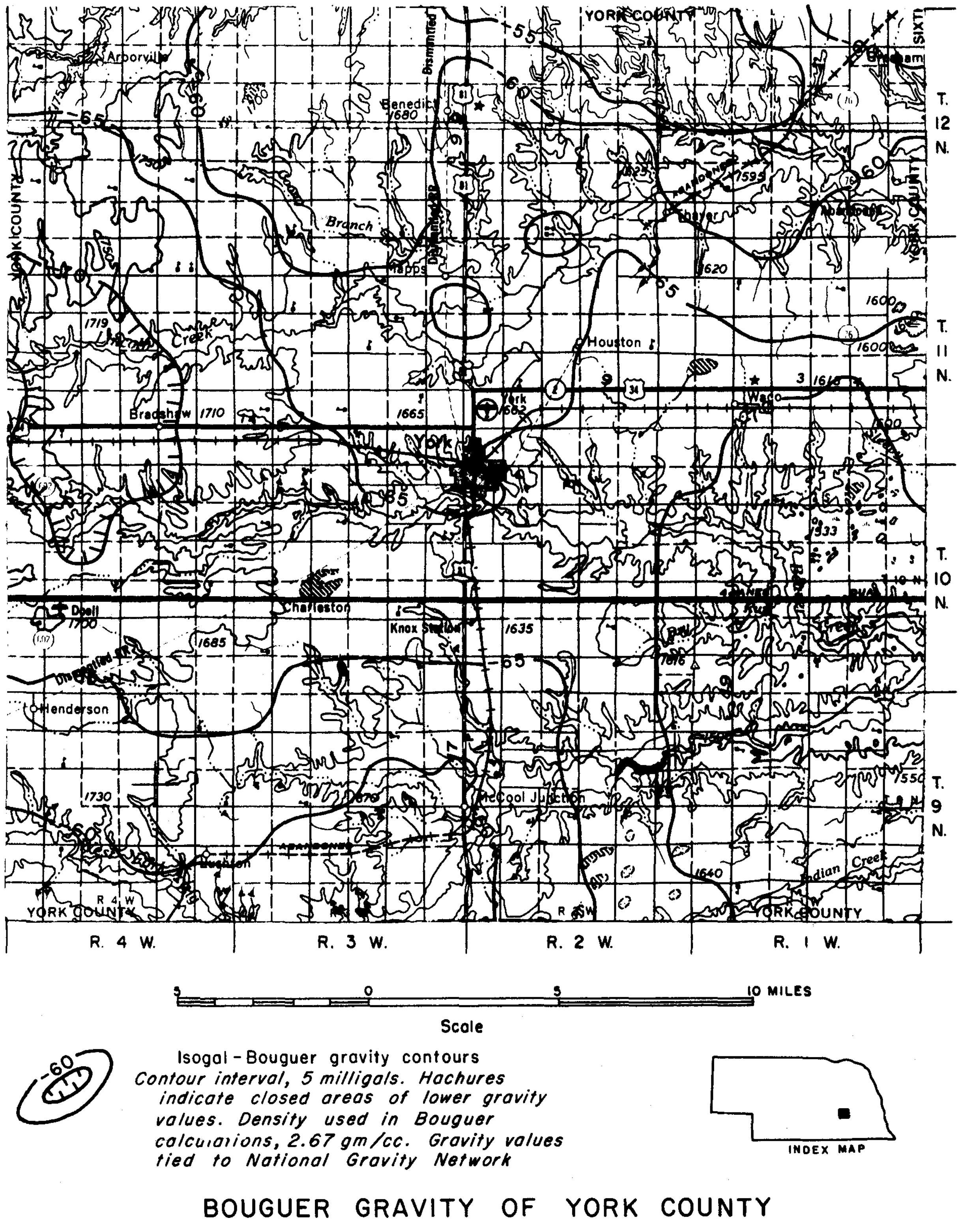
Scale

Isogal-Bouguer gravity contours

Contour interval, 5 milligals. Hachures indicate closed areas of lower gravity values. Density used in Bouguer calculations, 2.67 gm/cc. Gravity values tied to National Gravity Network

BOUGUER GRAVITY OF THAYER COUNTY

Figure 25



BOUGUER GRAVITY OF YORK COUNTY

Figure 26

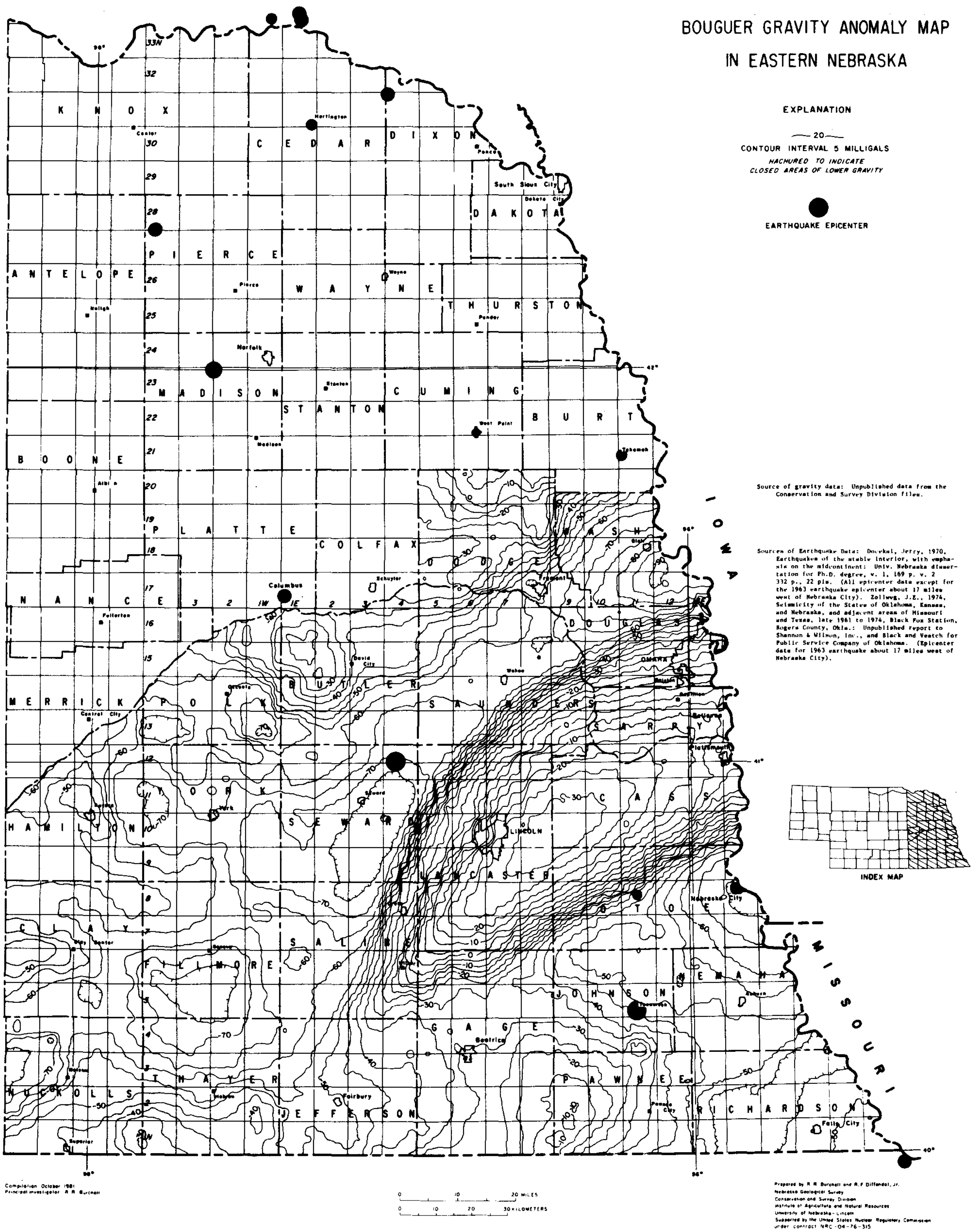
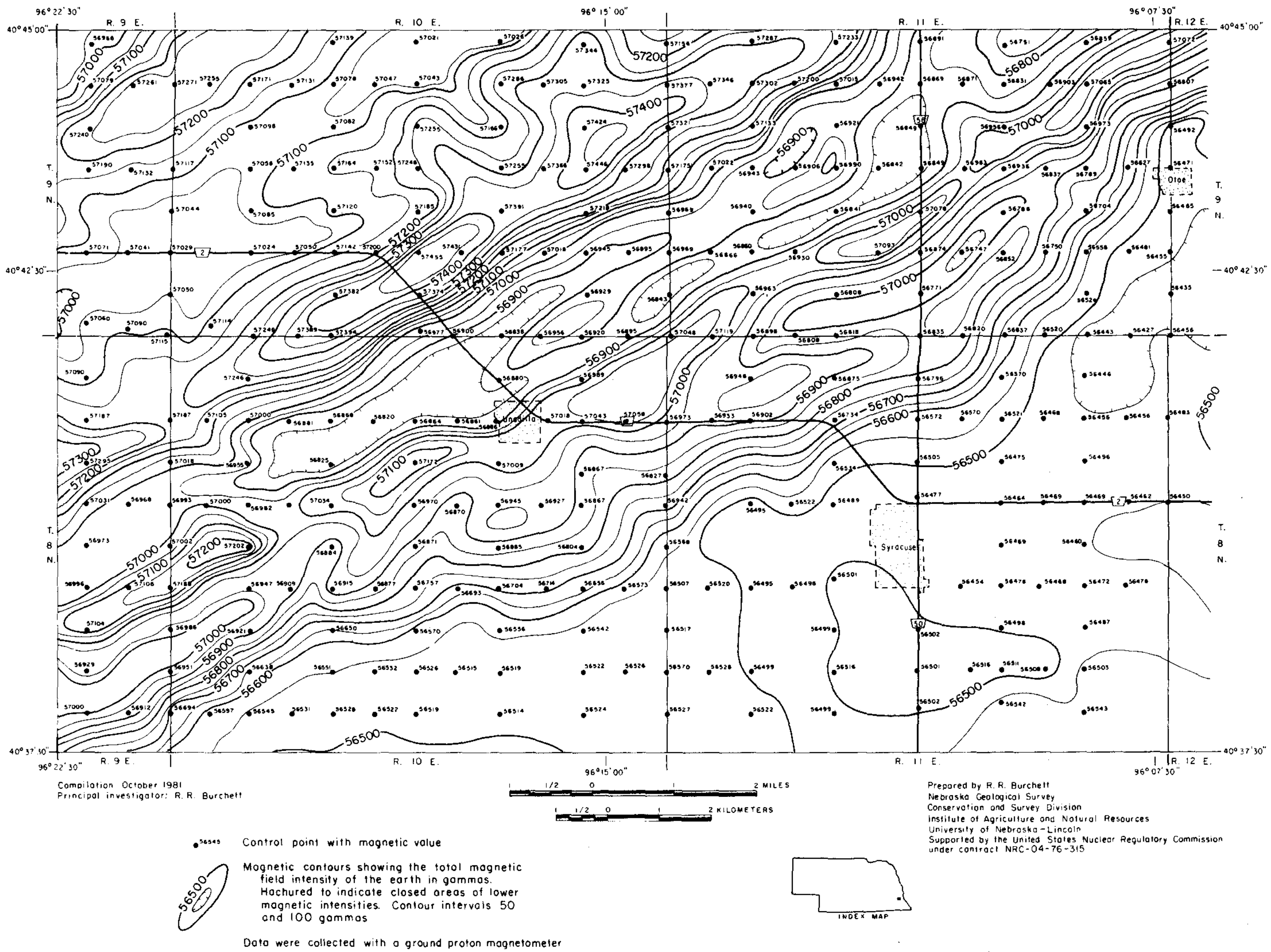

BOUGUER GRAVITY ANOMALY MAP
IN EASTERN NEBRASKA
EXPLANATION
20
CONTOUR INTERVAL 5 MILLIGALS
HACHURED TO INDICATE CLOSED AREAS OF LOWER GRAVITY
EARTHQUAKE EPICENTER
Source of gravity data: Unpublished data from the Conservation and Survey Division files.
Sources of Earthquake Data: Docekal, Jerry, 1970, Earthquakes of the stable interior, with emphasis on the midcontinent: Univ. Nebraska dissertation for Ph.D. degree, v. 1, 169 p, v. 2 332 p., 22 pls. (All epicenter data except for the 1963 earthquake epicenter about 17 miles west of Nebraska City). Zollweg, J.E., 1974, Seismicity of the States of Oklahoma, Kansas, and Nebraska, and adjacent areas of Missouri and Texas, late 1961 to 1974, Black Fox Station, Rogers County, Okla.: Unpublished report to Shannon & Wilson, Inc., and Black and Veatch for Public Service Company of Oklahoma. (Epicenter data for 1963 earthquake about 17 miles west of Nebraska City).
INDEX MAP
KNOX
CEDAR
DIXON
DAKOTA
PIERCE
ANTELOPE
WAYNE
THURSTON
MADISON
STANTON
CUMING
BURT
BOONE
PLATTE
COLFAX
DODGE
WASHINGTON
NANCE
MERRICK
POLK
BUTLER
SAUNDERS
DOUGLAS
SARPY
HAMILTON
YORK
SEWARD
LANCASTER
CASS
OTOE
CLAY
FILLMORE
SALINE
JOHNSON
NEMAHA
GAGE
PAWNEE
NUCKOLLS
THAYER
JEFFERSON
RICHARDSON
IOWA
MISSOURI
Columbus
Norfolk
Fremont
Omaha
LINCOLN
Beatrice
Nebraska City
Falls City
Schuyler
West Point
Tekamah
Pierce
Wayne
Pender
Madison
Stanton
Ponca
South Sioux City
Dakota City
Fullerton
Central City
Osceola
York
Seward
Wahoo
Fairbury
Hebron
Superior
Pawnee City
Tecumseh
Auburn
Plattsmouth
Papillion
Bellevue
Blair
David City
Geneva
Albion
Neligh
Center
Hartington
42°
41°
40°
98°
96°
Compilation October 1981
Principal investigator R. R. Burchett
0 10 20 MILES
0 10 20 30 KILOMETERS
Prepared by R. R. Burchett and R. F. Diffendal, Jr.
Nebraska Geological Survey
Conservation and Survey Division
Institute of Agriculture and Natural Resources
University of Nebraska-Lincoln
Supported by the United States Nuclear Regulatory Commission under contract NRC-04-76-315

Figure 27

were made for latitude. The final magnetic intensity data were contoured by hand (fig. 28) and show very clearly the southern edge of the midcontinent anomaly.



TOTAL MAGNETIC INTENSITY OF CENTRAL OTOE COUNTY

Figure 28

References

Muehlberger, W. R., Denison, R. E., and Lidiak, E. G. 1964. Buried basements rocks of the United States of America and Canada: Final Report, Appendix to vol. II, contract AF49(638)-1115/ARPA Order No. 180-62. Univ. Texas, Austin.

SOME PRECAMBRIAN GABBROIC ROCKS FROM SOUTHEAST NEBRASKA

S. B. Treves

Introduction

Our papers on the Elk Creek carbonatite of southeast Nebraska (1972, 1972b, 1975) produced a flurry of leasing, geophysical surveys and, finally, drilling of the Elk Creek anomaly and some smaller, nearby anomalies. Recently two cores from boreholes that were drilled to basement at the site of the nearby Steinhauer anomaly were released to the Conservation and Survey Division for reference purposes and study. These cores are described in the sections that follow.

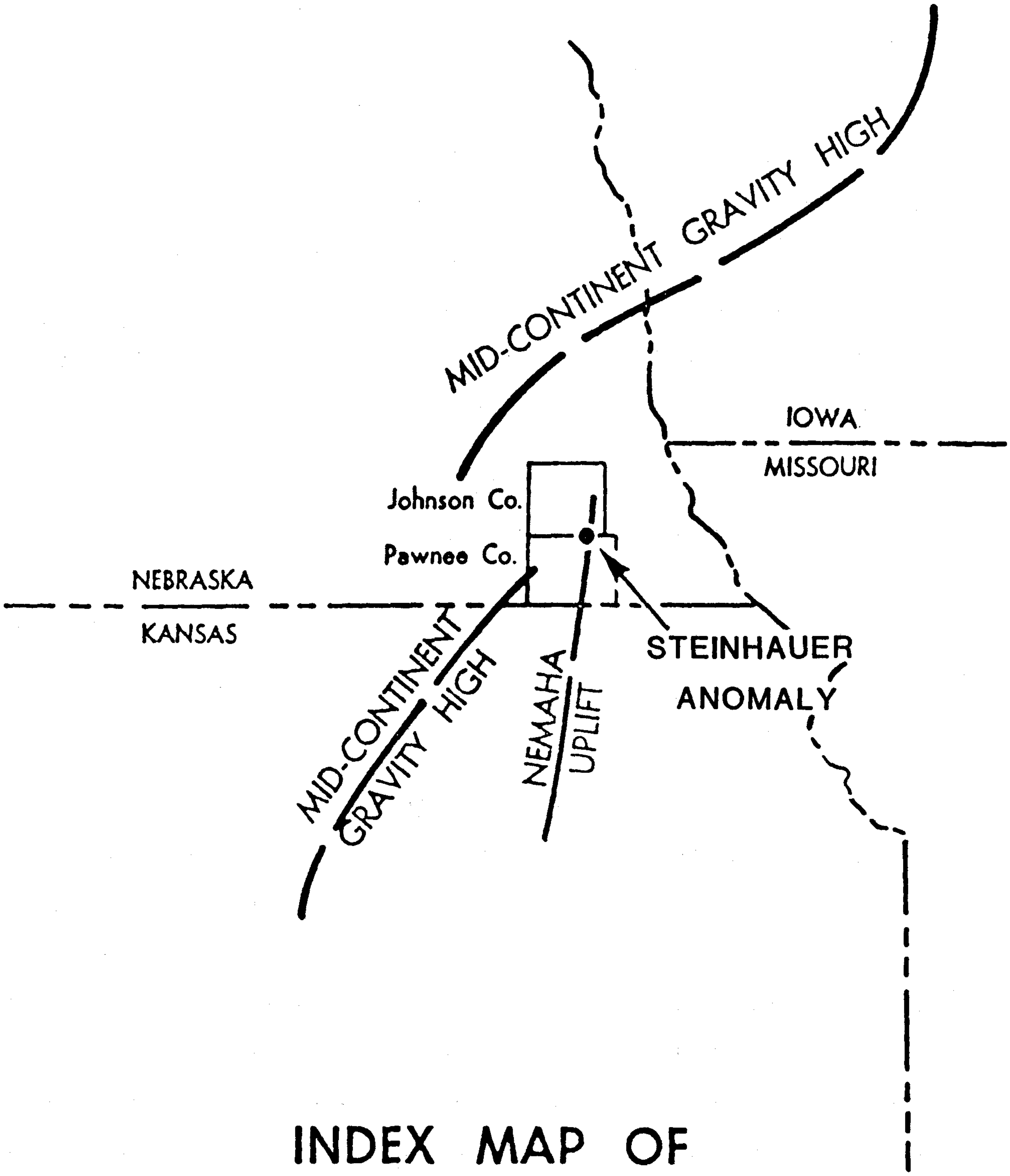
Location

The cores are designated Steinhauer 1 and 2, and are referred to as St - 1 and St - 2 in the rest of the text. St - 1 was drilled (fig. 29) at the center of the north boundary line of the NW 1/4 NE 1/4 NW 1/4 Sec. 19 T.3N. R.11E. St - 2 was drilled at the center of the south boundary line of the SW 1/4 SE 1/4 SW 1/4 Sec. 14 T.3N. R.12E.

Core Description

Analysis of the core of St - 1 shows that basement rocks were encountered at a depth of 800.5 feet and that drilling was continued to a depth of 994 feet, producing 194 feet of core. Analysis of the core from St - 2 shows that basement rocks were encountered at a depth of 971 feet. Additional drilling to a depth of 1072 feet produced 101 feet of core. The contact of the basement rocks with the overlying, younger sedimentary rocks is sharp and nonconformable. It is clearly not an intrusive contact, as fragments of the older rock occur as clasts in the basal unit of the overlying sedimentary unit.

The upper portions of both cores are deeply weathered and stained by iron oxides. The St - 1 core is weathered to a depth of 67 feet; St - 2 core is only



INDEX MAP OF
Southeast Nebraska and Northeast Kansas

50 Miles

Figure 29

weathered to a depth of 5 feet. The rocks of both cores are extensively jointed and cut by veins of secondary calcite and quartz. The orientation of the joints ranges from horizontal to vertical, with most being inclined at angles that range from 30° to 60°. Slickensides are common. The rocks immediately adjacent to the veins and most of the joints are altered, sometimes extensively.

Below the weathered zone the rocks are strikingly fresh and unaltered and are black and dark grey. Hand specimens show abundant plagioclase and lesser amounts of pyroxene, olivine, and opaque minerals. The average grain size ranges from about 2 mm to about 10 mm. Specimens from both holes are identical in hand specimens.

Thin-section analysis of unaltered specimens of core indicate the rocks are gabbroic and that they consist primarily of olivine, plagioclase, pyroxene, opaque minerals, biotite and traces of apatite and alkali feldspar. The olivine is magnesium-rich and is generally about Fo_{80}. Locally, it is altered to serpentine. The plagioclase is generally sodic labradorite. It is complexly twinned and generally unaltered. In plagioclase-rich rocks the fabric shown by the plagioclase suggests that it may be a cumulate phase. Some plagioclase shows slight alteration to sericite. The pyroxenes consist of orthopyroxene and clinopyroxene. The orthopyroxenes are inverted pigeonites and contain lamellae of augite that are parallel to the (001) of the original pigeonite. The clinopyroxene is augite, which contains exsolved blebs of pigeonite. Orthopyroxenes are much more abundant than clinopyroxenes in these rocks. The opaque minerals are primarily ilmenite, but some sulphides are present. In many sections the ilmenite and the mafic minerals are mantled with overgrowths of biotite. Apatite occurs as prismatic, interstitial crystals or as inclusions in the plagioclase. Alkali feldspar occurs in the interstices between plagioclase grains.

Modal analyses of the gabbroic rocks are presented in table 2. The analyses show that the upper reaches of St- 1 consist primarily of anorthositic gabbro,

Elevation	Olivine	Pyroxene	Plagioclase*	Opaque Minerals	Biotite	Apatite	Alkali Feldspar
St-1							
847	9	6	75(57)	5	3	Tr	Tr
839.8	5	6	74(65)	11	2	Tr	Tr
842	9	7	75(52)	7	2	Tr	Tr
944.5	7	23	57(56)	11	2	Tr	Tr
989.5	11	28	52(57)	7	1	Tr	Tr
994.5†	4	21	66(55)	7	1	Tr	Tr
St-2							
974	36	13	32(58)	18	Tr	Tr	Tr
976	39	7	35(50)	16	2	Tr	Tr
978	33	10	40(35)	16	1	Tr	Tr
1000	37	5	35(58)	22	3	Tr	Tr
1032.5	38	5	33(58)	20	3	Tr	Tr
1037	38	5	39(60)	16	2	Tr	Tr
1045	45	4	25(55)	17	2	Tr	Tr
1051	18	5	39(55)	17	2	Tr	Tr
1060	43	4	34(62)	17	1	Tr	Tr
1067.5†	31	20	29(62)	18	2	Tr	Tr
1070.5	30	13	31(50)	22	3	Tr	Tr

†Chemical analysis

*Figure in brackets is anorthite content

Table 2. Modal Analyses of Specimens from St-1 and St-2.

whereas the lower reaches consist of olivine gabbro. The upper and lower reaches of St - 2, in contrast, consist of ilmenite-rich olivine gabbros, whereas the middle reaches consist of troctolitic, ilmenite-rich gabbros. The cores seem to exhibit a coarse lithologic layering. It does not seem possible to correlate units between the holes.

Near the bottom of both holes the core shows several thin, horizontal layers of grey carbonate. Thickness ranges from a few centimeters to about 10 centimeters. These units consist primarily of calcite, phlogophite, apatite(?) and opaque minerals and may be carbonatites. Further work will be necessary before a final determination is possible.

Two chemical analyses of fresh specimens of the core were made. The results are presented in table 3. It is readily apparent that both rocks are abnormally rich in ilmenite. If allowances are made for this feature, the rocks are not too much unlike Nockolds' average gabbro. Analysis three is of a basalt obtained from a borehole, Radenslaben No. 1, drilled on the midcontinent gravity high near Omaha, Nebraska. More chemical analyses will be required to completely characterize these rocks.

Two $^{39}A/^{40}Ar$ dates (Dalrymple and Lanphere, 1971) were determined on plagioclase separates from St -1 and St - 2 by J. Sutter. The pertinent analytical data and $^{39}Ar/^{40}Ar$ age spectrum diagrams are presented in table 4 and figure 30. Sutter reports that both spectra are indicative of the loss of radiogenic ^{40}Ar since crystallization of the gabbros. Thus, none of the ages indicated by the diagram is the time of crystallization of the gabbros. The spectra further indicate that the gabbros are older than the oldest age measured, which was 1.18 b.y. on the fuse fraction of St - 1 plagioclase. Sutter suggests that both specimens are likely to be the same age and that the age is probably not much in excess of 1.2 b.y., which makes these rocks Keweenawan in age (Goldich et al., 1960).

	(1)	(2)	(3)†	(4)	(5)
SiO_2	49.60	34.30	48.50	50.83	48.36
TiO_2	5.37	12.50	1.48	2.03	1.32
Al_2O_3	15.00	8.52	15.80	14.07	16.84
Fe_2O_3	14.40*	35.00*	2.99	2.88	2.55
FeO	--	--	8.74	9.00	7.92
MnO	0.14	0.22	0.19	0.18	0.18
MgO	3.77	5.14	7.44	6.34	8.06
CaO	5.99	2.98	10.20	10.42	11.07
Na_2O	2.36	1.04	2.37	2.23	2.26
K_2O	0.86	0.57	0.34	0.82	0.56
P_2O_5	0.05	0.05	0.10	0.23	0.24
H_2O+	--	--	1.52	0.91	0.64

*total iron
†composite sample

1. St-1; 994.5 ft.
2. St-2; 1067.5 ft.
3. Radenslaben No. 1, C SW 1/4 SE 1/4 NW 1/4 Sec. 28 T13N R8E
4. Average tholeiitic basalt (Nockolds, 1954)
5. Average gabbro (Nockolds, 1954)

Table 3. Chemical Compositions.

St - 1 Plagioclase 944.5 ft.

Temp. °C.	^{39}Ar % of Total	Radio-genic ^{40}A %	Age in m.y.*
500	1.69	8.65	> 1,000 m.y.
800	11.79	39.11	1053.883 ± 21.336
1000	15.59	40.50	978.892 ± 19.464
1050	32.05	67.75	1053.472 ± 11.847
1100	15.45	48.21	1134.997 ± 18.098
Fuse	23.41	62.02	1178.587 ± 13.789
Total Gas	100.00	49.85	1082.873
St - 2 Plagioclase			
400	0.82	55.97	575.340 ± 52.792
500	1.97	80.07	818.143 ± 17.583
600	5.78	92.00	964.203 ± 10.950
700	5.22	93.26	972.995 ± 10.738
800	8.43	95.62	979.916 ± 9.901
900	7.44	94.88	965.828 ± 9.906
1050	25.85	98.03	929.321 ± 8.847
Fuse	44.50	98.31	1115.876 ± 10.087
Total Gas	100.00	96.55	1021.017

*Post-1977 constant

Table 4. Age Spectrum Analysis Analytical Data.

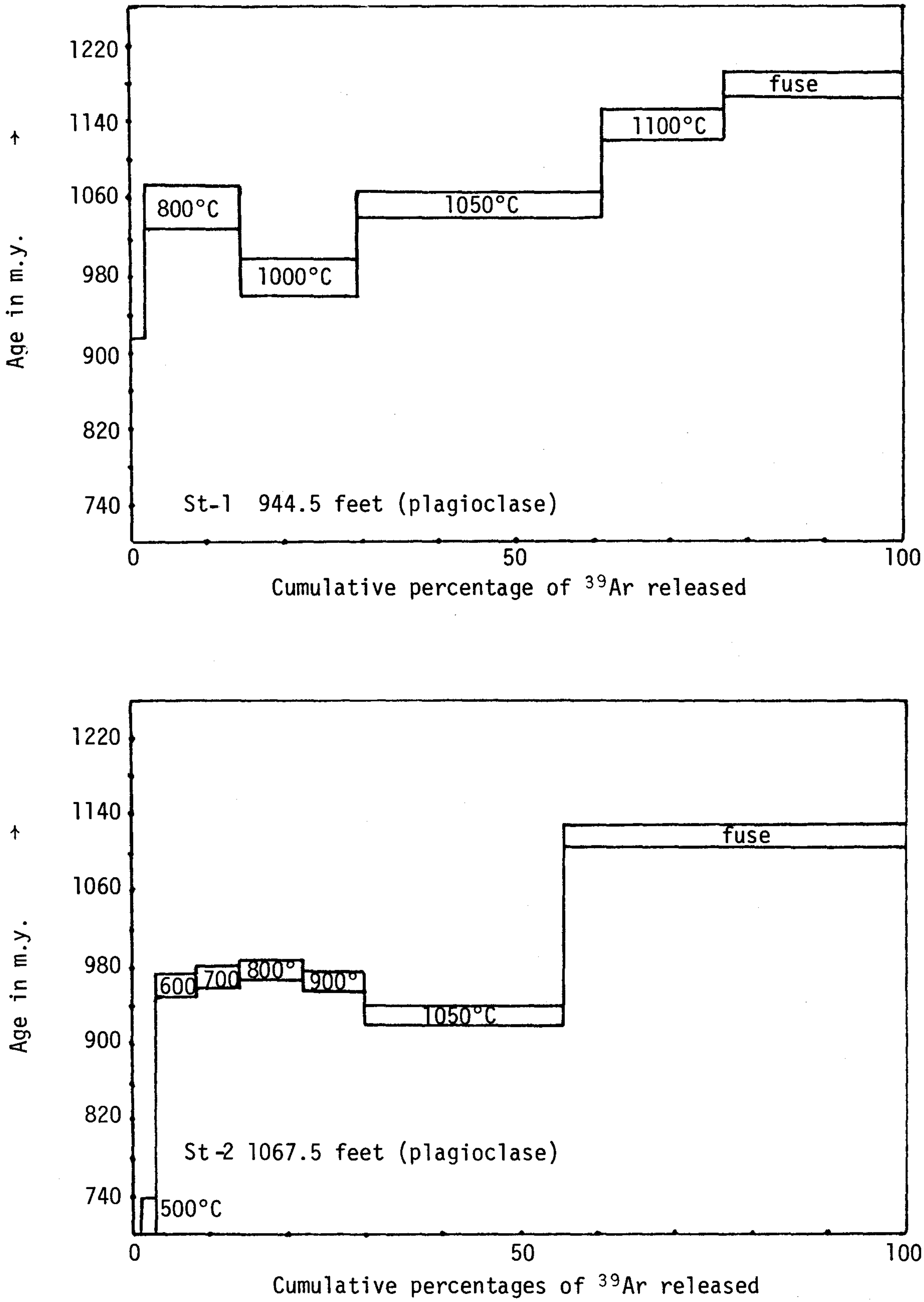


Figure 30. $^{40}Ar/^{39}Ar$ age spectrum diagram for St-1 and St-2.

Summary and Conclusions

The gabbroic rocks associated with the Steinhauer anomaly are intrusive into older granitic rocks. They constitute a plug or plugs that occur on the west flank of the Nemaha uplift to the south and northeast of the midcontinent gravity high. The coarse-grained Steinhauer gabbros do not resemble the ophitic basalts of the midcontinent gravity high in appearance or mineralogy. They also appear to be older than the basalts in Nebraska (Goldich et al., 1966). They do, however, resemble the basalts in terms of their chemistry and, hence, may be products of the same igneous event. Further, the Steinhauer gabbros resemble the Keweenawan rocks of the Duluth gabbro as described by Weiblen and Morey (1980). In light of the above, it seems that the Steinhauer gabbros are probably an early intrusive phase of the igneous activity, in Nebraska, that gave rise to the Keweenawan basaltic rocks of the midcontinent gravity high and the Keweenawan basalts and gabbros of the Lake Superior region.

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APPENDIX A

This appendix consists of descriptions of the twenty-two test holes drilled in central Otoe County. Locations of these test holes 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 1-81

Location: Otoe County, SW SW NW sec. 19, T. 8 N., R. 10 E., approximately 1950 feet south of north section line and 20 feet east of west section line.

Ground-level elevation: 1182.5 feet above mean sea level.

Started: May 7, 1981. Completed: May 7, 1981.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample)	0.0	5.0
Clay, light yellowish brown; moderately silty	5.0	10.0
Clay, light yellowish brown; contains gravel	10.0	23.0
Clay, dark gray, slightly silty	23.0	37.5
Clay, light greenish gray	37.5	48.0
Clay, olive, silty	48.0	52.5
Clay, medium to dark gray, slightly silty	52.5	66.0
Clay, medium to dark gray, slighlty silty; contains black carbonaceous material	66.0	69.0
Clay, medium gray, slightly silty	69.0	83.0
Clay, light gray, slightly silty	83.0	86.0
Clay, medium gray, slightly silty	86.0	88.0
Clay, light gray, slightly silty	88.0	92.0
Clay, light gray, sandy, silty	92.0	96.0
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Willard Formation:		
Shale, light greenish gray	96.0	97.2
Limestone, medium gray, very finely crystalline; contains fusulinids	97.2	97.8
Shale, pale olive	97.8	99.0
Shale, light reddish gray	99.0	100.1
Emporia Formation:		
Elmont Member:		
Limestone, medium gray to tan, finely crystalline, pseudo-oolitic; contains bryozoans, crinoids and *Osagia*	100.1	102.8
Shale, light reddish gray	102.8	103.7
Limestone, very light gray, finely crystalline; contains *Osagia*	103.7	105.4

Description	Depth, in feet From	To
Harveyville Member:		
Shale, light to medium gray	105.4	106.9
Reading Member:		
Limestone, light gray, finely crystalline; contains crinoids, brachiopods, and *Osagia*	106.9	110.0
Shale, light to medium gray	110.0	110.2
Limestone, medium gray, finely crystalline, pseudo-oolitic in part; contains brachiopods and *Osagia*	110.2	113.0
Auburn Formation:		
Shale, light greenish gray	113.0	114.0
Shale, red	114.0	123.2
Shale, red mottled tan	123.2	126.0
Shale, light greenish gray mottled olive	126.0	130.0
Shale, medium to dark gray	130.0	138.2
Wakarusa Formation:		
Limestone, medium to dark gray, finely crystalline; contains fusulinids; interbedded with shale, medium gray	138.2	140.6
Limestone, light gray, finely crystalline	140.6	142.7
Soldier Creek Formation:		
Shale, medium gray	142.7	145.2
Limestone, medium gray, finely crystalline; contains fusulinids, crinoids, *Osagia*, and "black inclusions"; interbedded with shale, medium gray	145.2	145.8
Shale, reddish gray	145.8	147.2
Limestone, light gray, very finely crystalline; contains crinoids	147.2	150.4
Shale, dark gray	150.4	151.5
Limestone, light gray to tan, finely crystalline; contains *Osagia*	151.5	152.1
Shale, medium gray	152.1	155.0
Shale, light gray	155.0	156.2
Shale, medium gray	156.2	160.1
Burlingame Formation:		
Limestone, medium gray, finely crystalline	160.1	161.0
Limestone, medium gray, variably crystalline; contains fusulinids, crinoids, brachiopods, pyrite, and "black inclusions"	161.0	161.6
Shale, light greenish gray	161.6	162.0
Shale, light to medium gray	162.0	163.5
Limestone, light gray, very finely crystalline; contains brachiopods and glauconite	163.5	164.8
Scranton Formation:		
Silver Lake - White Cloud Members:		
Shale, pale olive	164.8	167.0

Description	Depth, in feet From	To
Shale, red mottled green	167.0 -	167.2
Shale, light greenish gray	167.2 -	170.0
Shale, reddish gray	170.0 -	178.3
Shale, reddish gray; interbedded with limestone, light greenish gray	178.3 -	182.9
Shale, light greenish gray	182.9 -	183.0
Limestone, light greenish gray, finely crystalline	183.0 -	183.9
Shale, pale olive	183.9 -	184.5
Shale, light gray	184.5 -	194.0
Coal, black	194.0 -	194.5
Shale, light greenish gray	194.5 -	213.3
Shale, light greenish gray; interbedded with thin limestone streaks	213.3 -	213.5
Shale, medium gray	213.5 -	240.3
Shale, light gray, silty	240.3 -	242.0
Howard Formation:		
Limestone, medium to dark gray, finely crystalline; contains abundant crinoids	242.0 -	243.3
Shale, dark gray	243.3 -	245.2
Limestone, light to medium gray, very finely crystalline; contains crinoids, fusulinids, pyrite, and "black inclusions"	245.2 -	250.8
Severy Formation:		
Shale, medium gray	250.8 -	251.0
Coal, black	251.0 -	251.4
Shale, medium gray	251.4 -	257.0

Test Hole 2-81

Location: Otoe County, NE corner SE sec. 17, T. 8 N., R. 10 E., approximately 2578 feet north of south section line and 22 feet west of east section line.

Ground-level elevation: 1152.0 feet above mean sea level.

Started: May 7, 1981. Completed: May 7, 1981.

Total depth: 227.0 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample)	0.0 -	3.0

Description	Depth, in feet From	To
Clay, yellowish brown; contains gravel.......	3.0 -	7.0
Clay, yellowish brown; contains sand and gravel..................................	7.0 -	10.0
Clay, light brownish gray, slightly silty....	10.0 -	17.0
Sand, coarse; contains gravel................	17.0 -	19.0
Clay, tan, slightly silty....................	19.0 -	23.5
Clay, light brown............................	23.5 -	24.0
Clay, light brown to light gray..............	24.0 -	31.0
Clay, medium gray to tan, silty..............	31.0 -	42.0
Clay, medium gray, silty.....................	42.0 -	47.0
Clay, light to medium gray, silty............	47.0 -	54.5
Clay, light greenish gray, silty.............	54.5 -	59.5
Clay, medium greenish gray, silty............	59.5 -	64.3
Clay, medium to dark gray, silty.............	64.3 -	68.0
Clay, medium gray to greenish gray...........	68.0 -	79.5
Sand, fine to medium; contains gravel........	79.5 -	89.0
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Auburn Formation:		
Shale, pale olive............................	89.0 -	93.0
Shale, light greenish gray...................	93.0 -	94.0
Shale, light to medium gray..................	94.0 -	103.5
Wakarusa Formation:		
Limestone, medium gray, finely crystalline; contains crinoids, fusulinids, brachiopods, and <u>Osagia</u>..........................	103.5 -	107.4
Soldier Creek Formation:		
Shale, medium gray...........................	107.4 -	108.5
Limestone, medium gray to tan, finely crystalline...............................	108.5 -	110.2
Limestone, light gray, finely crystalline, pseudo-oolitic; contains <u>Osagia</u> and glauconite................................	110.2 -	114.2
Shale, light gray............................	114.2 -	117.0
Shale, medium gray...........................	117.0 -	120.1
Shale, light gray............................	120.1 -	126.2
Burlingame Formation:		
Limestone, medium gray to tan, finely crystalline; contains fusulinids and <u>Osagia</u>...	126.2 -	127.5
Shale, light gray............................	127.5 -	128.6
Limestone, tan, finely crystalline; contains fusulinids, <u>Osagia</u>, glauconite, and stylolites................................	128.6 -	131.0
Scranton Formation:		
Silver Lake - White Cloud Members:		
Shale, light greenish gray mottled olive.....	131.0 -	132.8
Shale, light gray............................	132.8 -	150.5
Shale, light gray; contains brown sandstone streaks and pyrite........................	150.5 -	151.0

Description	Depth, in feet From	To
Shale, light gray; contains brown sandstone streaks and black carbonaceous material...	151.0 -	163.4
Shale, light gray; contains brown sandstone streaks.................................	163.4 -	179.3
Sandstone, medium to dark gray..............	179.3 -	180.1
Shale, light gray, silty....................	180.1 -	192.0
Shale, medium gray mottled tan; contains brown sandstone streaks..................	192.0 -	198.4
Shale, light gray; contains brown sandstone streaks and trace of coal at 209.0........	198.4 -	212.0
Limestone, medium gray, very finely crystalline; contains brachiopods, crinoids, and pyrite..............................	212.0 -	212.2
Shale, light gray; contains brown sandstone streaks.................................	212.2 -	214.3
Howard Formation:		
Limestone, medium gray, very finely crystalline; contains crinoids and abundant fusulinids..............................	214.3 -	216.2
Limestone, light gray, very finely crystalline; contains crinoids, fusulinids, *Osagia*, and pyrite.......................	216.2 -	222.4
Severy Formation:		
Shale, black, carbonaceous..................	222.4 -	222.7
Shale, light gray...........................	222.7 -	227.0

Test Hole 3-81

Location: Otoe County, NW corner sec. 21, T. 8 N. R. 10 E., approximately 138 feet south of north section line and 18 feet east of west section line.

Ground-level elevation: 1170.0 feet above mean sea level.

Started: May 8, 1981. Completed: May 8, 1981.

Total Depth: 182.0 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample)............................	0.0 -	6.0
Clay, brown.................................	6.0 -	18.0
Clay, light brown to tan, sandy.............	18.0 -	22.0
Clay, gray to tan, sandy....................	22.0 -	25.0

Description	Depth, in feet From		To
Clay, tan, very sandy........................	25.0	-	32.0
Clay, brown, very sandy......................	32.0	-	44.0
Clay, light brown, sandy.....................	44.0	-	51.0
Sand, fine...................................	51.0	-	54.5
Clay, light brown, very sandy................	54.5	-	59.0
Clay, light gray, silty......................	59.0	-	62.5
Clay, medium gray, very sandy................	62.5	-	71.0
Clay, dark gray..............................	71.0	-	76.5
Clay, light gray, silty, sandy...............	76.5	-	88.0
Clay, greenish gray, sandy...................	88.0	-	95.5
Pennsylvanian System - Virgil Series - Wabaunsee Group:			
Auburn Formation:			
Shale, red...................................	95.5	-	98.5
Shale, olive, mottled yellow and red.........	98.5	-	100.3
Shale, olive.................................	100.3	-	103.0
Shale, medium gray...........................	103.0	-	112.8
Wakarusa Formation:			
Limestone, medium gray, finely crystalline; contains crinoids, fusulinids, brachiopods, and pyrite..........................	112.8	-	115.0
Limestone, medium gray, finely crystalline; contains fusulinids, pyrite, and "black inclusions".............................	115.0	-	117.2
Soldier Creek Formation:			
Shale, medium gray...........................	117.2	-	118.3
Limestone, light gray to tan, very finely crystalline; interbedded with shale, light greenish gray......................	118.3	-	120.0
Shale, reddish gray..........................	120.0	-	121.1
Shale, light greenish gray mottled red.......	121.1	-	121.8
Limestone, light gray, very finely crystalline; contains _Osagia_ and glauconite......	121.8	-	123.8
Shale, light greenish gray...................	123.8	-	127.0
Shale, light gray............................	127.0	-	130.0
Shale, medium gray...........................	130.0	-	135.1
Burlingame Formation:			
Limestone, medium gray, finely crystalline...	135.1	-	135.6
Shale, light gray............................	135.6	-	136.8
Limestone, light gray, very finely crystalline; contains glauconite.................	136.8	-	137.5
Limestone, light greenish gray, finely crystalline; contains abundant glauconite.....	137.5	-	139.3
Scranton Formation:			
Silver Lake - White Cloud Members:			
Sandstone, tan; interbedded with shale, greenish gray............................	139.3	-	141.8
Shale, black, carbonaceous...................	141.8	-	142.2
Shale, light greenish gray...................	142.2	-	145.0
Shale, red...................................	145.0	-	149.5

Description	Depth, in feet From	To
Shale, green mottled red	149.5	151.0
Shale, red mottled green	151.0	155.3
Shale, green mottled red	155.3	155.9
Shale, red mottled green	155.9	158.5
Shale, olive mottled red	158.5	159.5
Shale, medium gray	159.5	167.2
Coal, black	167.2	167.5
Shale, medium gray	167.5	182.0

Test Hole 4-81

Location: Otoe County, SE corner NE NE SE sec. 5, T. 8 N., R. 10 E., approximately 2012 feet north of south section line and 30 feet west of east section line.

Ground-level Elevation: 1149.0 feet above mean sea level.

Started: May 8, 1981. Completed: May 8, 1981.

Total Depth: 137.0 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample)	0.0	3.0
Clay, brown, silty	3.0	6.5
Clay, light tan, very silty	6.5	20.0
Clay, light tan, sandy	20.0	38.5
Clay, tan, silty	38.5	43.0
Clay, gray, sandy, silty	43.0	47.0
Clay, medium gray, sandy	47.0	51.0
Clay, light gray, sandy	51.0	62.0
Clay, medium gray, sandy	62.0	69.0
Clay, medium gray; contains gravel	69.0	74.5
Pennsylvanian Series - Virgil Series - Wabaunsee Group:		
Auburn Formation:		
Shale, olive	74.5	76.8
Wakarusa Formation:		
Limestone, medium gray, finely crystalline; interbedded with shale, medium gray	76.8	79.6
Shale, black; contains carbonaceous material	79.6	80.0

Description	Depth, in feet From	To
Limestone, medium gray, finely to very finely crystalline; contains brachiopods and pyrite..................................	80.0 -	80.4
Soldier Creek Formation:		
Shale, medium gray...........................	80.4 -	82.0
Shale, reddish gray..........................	82.0 -	84.2
Limestone, light gray, very finely crystalline................................	84.2 -	86.1
Shale, gray to tan...........................	86.1 -	87.8
Shale, medium gray...........................	87.8 -	92.0
Shale, dark gray.............................	92.0 -	98.3
Burlingame Formation:		
Limestone, medium gray, finely crystalline; contains gastropods and pyrite............	98.3 -	100.4
Limestone, medium gray, variably crystalline; contains Osagia.....................	100.4 -	101.4
Scranton Formation:		
Silver Lake - White Cloud Members:		
Shale, medium greenish gray..................	101.4 -	102.6
Shale, medium olive gray.....................	102.6 -	104.3
Shale, grayish red...........................	104.3 -	105.0
Shale, light green...........................	105.0 -	108.0
Shale, dark red..............................	108.0 -	111.5
Shale, red...................................	111.5 -	115.0
Shale, red; interbedded with limestone, gray...	115.0 -	115.5
Shale, dark red..............................	115.5 -	118.0
Shale, olive.................................	118.0 -	118.8
Shale, medium gray...........................	118.8 -	126.7
Shale, light gray............................	126.7 -	128.0
Coal, black..................................	128.0 -	128.4
Shale, light gray............................	128.4 -	130.0
Shale, medium gray...........................	130.0 -	137.0

Test Hole 5-81

Location: Otoe County, SE corner sec. 4, T. 8 N., R. 10 E., approximately 94 feet north of south section line and 15 feet west of east section line.

Ground-level elevation: 1159.5 feet above mean sea level.

Started: May 11, 1981. Completed: May 11, 1981.

Total Depth: 136.0 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample)	0.0 -	3.0
Clay, brown, silty, sandy	3.0 -	6.5
Clay, light brown, silty, sandy	6.5 -	11.0
Clay, medium gray to brown, silty, sandy	11.0 -	14.5
Clay, brown, sandy	14.5 -	17.0
Clay, brown, very sandy	17.0 -	24.5
Clay, medium gray to brown, sandy	24.5 -	38.0
Clay, medium gray, slightly sandy	38.0 -	43.4
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Emporia Formation:		
Reading Member:		
Limestone, light gray, finely crystalline	43.4 -	44.9
Shale, medium gray	44.9 -	46.2
Limestone, tan, weathered, finely crystalline; contains fusulinids, crinoids, _Osagia_ and manganese staining	46.2 -	48.1
Auburn Formation:		
Shale, olive	48.1 -	50.1
Shale, red	50.1 -	58.0
Shale, red mottled green	58.0 -	59.0
Shale, red	59.0 -	63.7
Shale, red; interbedded with limestone, medium gray	63.7 -	66.5
Shale, green mottled red	66.5 -	70.8
Shale, medium gray	70.8 -	79.3
Wakarusa Formation:		
Limestone, medium gray, finely crystalline; interbedded with shale, medium gray	79.3 -	80.3
Limestone, medium gray, finely crystalline; contains fusulinids and brachiopods	80.3 -	83.2
Limestone, light to medium gray, finely crystalline; contains fusulinids	83.2 -	84.0
Soldier Creek Formation:		
Shale, medium gray mottled red	84.0 -	85.3
Limestone, medium gray, very finely crystalline	85.3 -	86.2
Shale, medium reddish gray	86.2 -	87.2
Shale, medium gray	87.2 -	88.6
Limestone, light gray, finely crystalline; contains _Osagia_	88.6 -	89.6
Limestone, light gray, very finely crystalline; contains glauconite	89.6 -	91.8
Shale, medium gray	91.8 -	101.2
Burlingame Formation:		
Limestone, medium gray, finely crystalline; contains "black inclusions"	101.2 -	103.1
Shale, medium greenish gray	103.1 -	104.2
Limestone, light gray, very finely crystalline; interbedded with shale, red	104.2 -	106.5

Description	Depth, in feet From	To
Scranton Formation:		
Silver Lake - White Cloud Members:		
Shale, red	106.5 -	107.0
Shale, red mottled gray	107.0 -	109.2
Shale, green	109.2 -	110.2
Shale, red	110.2 -	117.2
Shale, red; interbedded with limestone, medium gray	117.2 -	120.1
Shale, light gray	120.1 -	122.3
Shale, medium gray	122.3 -	123.1
Limestone, medium gray, very finely crystalline; contains _Osagia_; interbedded with shale, dark gray	123.1 -	123.3
Shale, light gray	123.3 -	129.8
Coal, black	129.8 -	130.2
Shale, medium gray	130.2 -	136.0

Test Hole 6-81

Location: Otoe County, SW corner sec. 1, T. 8 N., R. 10 E., approximately 207 feet north of south section line and 103 feet east of west section line.

Ground-level elevation: 1133.5 feet above mean sea level.

Started: May 11, 1981. Completed: May 11, 1981.

Total Depth: 205.0 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample)	0.0 -	4.5
Clay, gray to tan, sandy	4.5 -	10.0
Clay, gray, silty, sandy	10.0 -	19.0
Clay, gray to brown, silty, sandy	19.0 -	25.0
Clay, gray, sandy	25.0 -	32.0
Clay, brown to gray, sandy	32.0 -	38.5
Clay, gray, sandy	38.5 -	47.0
Clay, gray, very silty, sandy	47.0 -	105.5
Clay, dark gray, very silty, sandy	105.5 -	108.9

Description	Depth, in feet From	To
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Burlingame Formation:		
Shale, gray to dark gray	108.9	109.3
Shale, olive	109.3	110.2
Shale, olive, interbedded with limestone, gray	110.2	111.4
Shale, medium gray	111.4	112.1
Limestone, gray to tan, variably crystalline; contains glauconite; interbedded with shale, olive	112.1	113.0
Scranton Formation:		
Silver Lake - White Cloud Members:		
Shale, light green	113.0	114.8
Shale, black	114.8	115.4
Shale, medium greenish gray	115.4	123.5
Shale, red mottled green	123.5	134.2
Shale, light gray	134.2	139.5
Coal, black	139.5	139.9
Shale, light gray	139.9	167.0
Shale, medium gray	167.0	188.3
Howard Formation:		
Limestone, light gray, finely crystalline; contains brachiopods; interbedded with shale, medium gray	188.3	190.4
Limestone, medium gray, very finely crystalline; interbedded with shale, medium gray	190.4	190.7
Shale, medium gray	190.7	193.4
Limestone medium gray, very finely crystalline; contains fusulinids, *Osagia*, and "black inclusions"	193.4	194.7
Limestone, light gray to tan, very finely crystalline; contains fusulinids, *Osagia*, and coarsely crystalline calcite streaks	194.7	198.6
Severy Formation:		
Coal, black	198.6	199.4
Siltstone, light gray	199.4	205.0

Test Hole 7-81

Location: Otoe County, NE corner SE NE sec. 14, T. 8 N., R. 10 E., approximately 1920 feet south of north section line and 19 feet west of east section line.

Ground-level elevation: 1124.5 feet above mean sea level.

Started: May 11, 1981. Completed: May 11, 1981.

Total Depth: 130.0 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample)	0.0 -	6.0
Clay, medium gray, very sandy	6.0 -	10.0
Clay, tan to medium gray, sandy	10.0 -	15.0
Clay, tan, sandy	15.0 -	17.0
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Willard Formation:		
Shale, medium gray; contains sandstone streaks	17.0 -	23.0
Shale, light gray; contains sandstone streaks	23.0 -	32.0
Shale, medium gray	32.0 -	44.5
Shale, medium gray, sandy	44.5 -	48.5
Shale, medium greenish gray	48.5 -	51.0
Shale, green mottled red	51.0 -	52.0
Shale, red and green	52.0 -	53.4
Emporia Formation:		
Elmont - Reading Members:		
Limestone, medium gray, finely crystalline, pseudo-oolitic; contains glauconite and pyrite	53.4 -	54.2
Shale, red	54.2 -	56.4
Shale, medium gray; interbedded with limestone, medium gray	56.4 -	56.8
Limestone, light gray, very finely crystalline; contains <u>Osagia</u> and coarsely crystalline calcite streaks	56.8 -	58.5
Shale, medium gray	58.5 -	59.8
Limestone, light gray to tan, very finely crystalline; contains brachiopods, fusulinids, <u>Osagia</u>, and glauconite	59.8 -	62.2
Auburn Formation:		
Shale, light green	62.2 -	63.5
Shale, red	63.5 -	71.2
Shale, red mottled green	71.2 -	71.6
Shale, red	71.6 -	77.5
Shale, red, very sandy	77.5 -	81.0
Shale, olive	81.0 -	83.6
Shale, grayish green	83.6 -	85.2
Shale, medium gray	85.2 -	93.3
Wakarusa Formation:		
Limestone, medium gray, finely crystalline; contains brachiopods, fusulinids, and pyrite	93.3 -	93.9

Description	Depth, in feet From	To
Limestone, medium gray, finely crystalline; contains brachiopods, *Osagia*, "black inclusions," and abundant fusulinids; interbedded with shale, green.............	93.9 -	98.2
Soldier Creek Formation:		
Shale, medium gray...........................	98.2 -	100.7
Shale, light grayish green...................	100.7 -	103.2
Limestone, light gray to tan, finely crystalline; contains *Osagia*..............	103.2 -	105.1
Shale, medium gray...........................	105.1 -	107.8
Shale, medium olive gray.....................	107.8 -	110.5
Shale, medium gray...........................	110.5 -	116.1
Burlingame Formation:		
Limestone, light greenish gray, finely crystalline; contains glauconite, pyrite, and "black inclusions"...................	116.1 -	119.9
Scranton Formation:		
Silver Lake - White Cloud Members:		
Shale, medium greenish gray..................	119.9 -	121.2
Shale, black.................................	121.2 -	122.7
Shale, grayish green.........................	122.7 -	127.5
Shale, light green...........................	127.5 -	130.0

Test Hole 8-81

Location: Otoe County, SW NW SW sec. 7, T. 8 N., R. 11 E., approximately 1700 feet north of south section line and 20 feet east of west section line.

Ground-level elevation: 1093.0 feet above mean sea level.

Started: May 13, 1981. Completed: May 13, 1981.

Total Depth: 122.0 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample).............................	0.0 -	4.0
Clay, light brown, sandy.....................	4.0 -	11.5
Clay, light brown, very sandy................	11.5 -	15.5
Clay, brown, sandy, silty....................	15.5 -	21.0
Clay, brown, sandy...........................	21.0 -	26.0

Description	Depth, in feet From	To
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Auburn Formation:		
Shale, red, very sandy	26.0 -	27.2
Shale, red, and siltstone, red	27.2 -	32.7
Shale, olive	32.7 -	35.0
Shale, greenish gray	35.0 -	36.8
Shale, medium gray	36.8 -	41.2
Shale, medium gray; contains abundant pyrite	41.2 -	47.2
Wakarusa Formation:		
Shale, medium gray; interbedded with limestone, gray	47.2 -	48.1
Limestone, medium gray, finely crystalline; contains brachiopods	48.1 -	49.4
Shale, black	49.4 -	49.5
Limestone, medium gray, finely crystalline; contains brachiopods	49.5 -	50.6
Shale, black	50.6 -	50.8
Limestone, medium gray, finely crystalline; contains fusulinids and brachiopods	50.8 -	51.9
Soldier Creek Formation:		
Shale, light gray	51.9 -	53.4
Limestone, light gray to tan, very finely crystalline; contains fusulinids	53.4 -	53.9
Shale, red	53.9 -	55.0
Shale, red mottled green	55.0 -	56.1
Limestone, light gray, very finely crystalline; contains _Osagia_	56.1 -	57.0
Limestone, light greenish gray, very finely crystalline; contains fusulinids, _Osagia_, and glauconite	57.0 -	59.6
Shale, light green	59.6 -	60.2
Shale, light gray	60.2 -	62.3
Shale, olive gray	62.3 -	63.0
Shale, medium gray	63.0 -	71.2
Shale, medium to very dark gray	71.2 -	71.4
Burlingame Formation:		
Limestone, medium to dark gray, finely crystalline; contains _Osagia_	71.4 -	71.6
Limestone, medium gray, very finely crystalline; contains "black inclusions" and pyrite	71.6 -	73.0
Limestone, medium gray, finely crystalline; contains fusulinids, _Osagia_, glauconite, pyrite, and "black inclusions"	73.0 -	74.2
Limestone, light greenish gray, very finely crystalline; contains _Osagia_ and glauconite	74.2 -	75.1

Description	Depth, in feet From	To
Scranton Formation:		
Silver Lake - White Cloud Members:		
Shale, light grayish green..................	75.1 -	75.6
Shale, dark gray............................	75.6 -	77.5
Shale, medium gray..........................	77.5 -	79.0
Shale, light green..........................	79.0 -	84.4
Shale, red..................................	84.4 -	87.8
Shale, red; interbedded with limestone, gray..................................	87.8 -	90.1
Shale, red mottled green....................	90.1 -	90.3
Shale, red..................................	90.3 -	92.0
Shale, red mottled green....................	92.0 -	93.5
Shale, light gray...........................	93.5 -	95.1
Limestone, medium greenish gray, medium crystalline; contains abundant brachiopods..............................	95.1 -	95.4
Shale, medium gray..........................	95.4 -	96.5
Coal, black.................................	96.5 -	97.0
Shale, light greenish gray..................	97.0 -	102.4
Shale, black................................	102.4 -	102.6
Shale, light gray...........................	102.6 -	122.0

Test Hole 9-81

Location: Otoe County, NW NE NW sec. 19, T. 8 N., R. 11 E., approximately 19 feet south of north section line and 1775 feet east of west section line.

Ground-level elevation: 1160.0 feet above mean sea level.

Started: May 13, 1981. Completed: May 13, 1981.

Total Depth: 120.0 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample)............................	0.0 -	3.0
Clay, brown, sandy..........................	3.0 -	4.5
Clay, medium gray to brown, sandy...........	4.5 -	6.0
Clay, light brown, very sandy...............	6.0 -	8.0
Clay, olive, sandy..........................	8.0 -	10.0
Clay, tan, sandy............................	10.0 -	10.5

Description	Depth, in feet From	To
Permian System - Big Blue Series - Council Grove Group:		
Red Eagle Formation:		
Bennett Member:		
(no sample)................................	10.5 -	15.5
Glenrock Member:		
(no sample)................................	15.5 -	17.0
Johnson Formation:		
(no sample)................................	17.0 -	20.0
Limestone, olive to medium gray, very finely crystalline..............................	20.0 -	21.0
Limestone, light gray, very finely crystalline..............................	21.0 -	23.0
Shale, grayish green.........................	23.0 -	23.5
Limestone, medium greenish gray, very finely crystalline..............................	23.5 -	24.0
Limestone, gray to pale red, very finely crystalline..............................	24.0 -	27.4
Shale, green.................................	27.4 -	27.5
Shale, tan, limy.............................	27.5 -	28.5
Foraker Formation:		
Long Creek Member:		
Limestone, tan, very finely crystalline......	28.5 -	30.0
Limestone, medium gray, very finely crystalline..............................	30.0 -	30.4
Limestone, tan, very finely crystalline......	30.4 -	32.5
Limestone, medium gray, finely crystalline...	32.5 -	34.0
Hughes Creek Member:		
Shale, dark gray; interbedded with limestone, medium gray........................	34.0 -	38.8
Limestone, medium gray, medium to finely crystalline; contains fusulinids, brachiopods, crinoids, and <u>Osagia</u>.........	38.8 -	41.1
Shale, light gray............................	41.1 -	41.8
Shale, medium gray; interbedded with limestone, medium gray........................	41.8 -	45.0
Shale, medium to dark gray...................	45.0 -	47.5
Limestone, light gray to medium gray, finely crystalline; contains brachiopods, fusulinids, and pyrite....................	47.5 -	48.4
Shale, light gray............................	48.4 -	50.0
Limestone, light gray, finely crystalline; contains brachiopods and crinoids; interbedded with shale, light gray........	50.0 -	51.6
Shale, light gray............................	51.6 -	52.0
Shale, light grayish green...................	52.0 -	53.9
Limestone, medium gray, finely crystalline...	53.9 -	55.1
Shale, very dark gray........................	55.1 -	56.8
Limestone, medium gray, finely crystalline; contains <u>Osagia</u> and "black inclusions"....	56.8 -	58.4
Shale, medium gray...........................	58.4 -	59.0

Description	Depth, in feet From	To
Limestone, dark gray, finely crystalline; contains *Osagia*	59.0 -	59.2
Shale, medium gray	59.2 -	60.7
Limestone, medium gray, finely crystalline	60.7 -	61.1
Shale, medium gray	61.1 -	61.6
Limestone, medium gray, medium crystalline; contains brachiopods, crinoids, fusulinids, and *Osagia*	61.6 -	63.3
Limestone, medium gray, finely crystalline; contains crinoids, fusulinids, brachiopods, and "black inclusions"	63.3 -	64.0
Limestone, light gray, finely crystalline; contains abundant crinoids; interbedded with shale, medium gray	64.0 -	64.5
Shale, medium to very dark gray	64.5 -	65.0
Limestone, medium gray, very finely crystalline	65.0 -	65.6
Shale, medium to dark gray	65.6 -	65.9
Limestone, medium gray, finely crystalline	65.9 -	67.1
Shale, medium greenish gray	67.1 -	68.1
Shale, medium gray	68.1 -	69.0
Limestone, medium gray, finely crystalline; contains brachiopods, *Osagia*, and "black inclusions"	69.0 -	71.4
Shale, medium gray	71.4 -	74.1
Shale, black	74.1 -	74.3
Americus Member:		
Limestone, medium gray, very finely crystalline; contains brachiopods, bryozoans, and black carbonaceous material	74.3 -	75.8
Shale, dark gray	75.8 -	76.8
Limestone, light gray, finely crystalline; contains crinoids; interbedded with shale, dark gray	76.8 -	77.0
Limestone, medium gray, finely crystalline; contains brachiopods and fusulinids	77.0 -	77.3
Shale, medium to dark gray	77.3 -	77.7
Limestone, light gray, very finely crystalline; contains brachiopods and crinoids	77.7 -	78.1
Admire Group:		
West Branch - Hamlin Formations:		
Shale, light gray	78.1 -	82.3
Limestone, medium gray, very finely crystalline	82.3 -	82.6
Shale, medium gray	82.6 -	88.1
Limestone, medium gray, very finely crystalline; contains pyrite	88.1 -	88.3
Shale, medium gray	88.3 -	88.9

Description	Depth, in feet From	To
Limestone, medium gray, finely crystalline; contains brachiopods, Osagia, and pyrite..	88.9 -	90.1
Shale, green..................................	90.1 -	92.0
Shale, reddish green..........................	92.0 -	93.8
Shale, green..................................	93.8 -	94.7
Limestone, cream, very finely crystalline....	94.7 -	95.8
Shale, green..................................	95.8 -	96.0
Shale, red....................................	96.0 -	97.0
Shale, medium gray............................	97.0 -	97.4
Limestone, light gray, very finely crystalline..............................	97.4 -	98.0
Shale, grayish green..........................	98.0 -	98.4
Shale, red....................................	98.4 -	99.0
Shale, olive..................................	99.0 -	99.5
Shale, red mottled green......................	99.5 -	100.0
Shale, olive..................................	100.0 -	100.3
Limestone, very light gray, very finely crystalline; contains glauconite..........	100.3 -	102.5
Shale, red; interbedded with limestone, gray....................................	102.5 -	104.0
Shale, olive..................................	104.0 -	104.4
Shale, green; interbedded with limestone, gray....................................	104.4 -	106.2
Shale, red....................................	106.2 -	108.2
Shale, green..................................	108.2 -	109.0
Shale, olive..................................	109.0 -	109.8
Shale, medium gray............................	109.8 -	111.0
Shale, green..................................	111.0 -	112.1
Shale, light gray.............................	112.1 -	113.8
Shale, dark green.............................	113.8 -	114.5
Shale, green; interbedded with limestone, gray....................................	114.5 -	115.8
Shale, red mottled green......................	115.8 -	116.9
Limestone, light greenish gray, very finely crystalline; contains glauconite..........	116.9 -	120.0

Test Hole 10-81

Location: Otoe County, NE corner SE sec. 30, T. 8 N., R. 11 E., approximately 2463 feet north of south section line and 20 feet west of east section line.

Ground-level elevation: 1136.5 feet above mean sea level.

Started: May 14, 1981. Completed: May 14, 1981.

Total Depth: 130.0 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample)	0.0 -	3.0
Clay, tan, sandy	3.0 -	8.2
Sand, medium	8.2 -	8.5
Clay, tan, sandy	8.5 -	21.0
Clay, brown, sandy	21.0 -	26.0
Clay, tan	26.0 -	28.0
Clay, brown	28.0 -	32.0
Permian System - Big Blue Series - Council Grove Group:		
Foraker Formation:		
Hughes Creek Member:		
Shale, olive; interbedded with limestone, gray	32.0 -	34.3
Shale, olive gray; interbedded with limestone, gray	34.3 -	37.5
Limestone, medium gray, finely crystalline	37.5 -	37.9
Shale, olive	37.9 -	38.6
Limestone, tan, finely crystalline; contains brachiopods and "black inclusions"	38.6 -	39.0
Limestone, medium gray to tan, finely crystalline; contains brachiopods and "black inclusions"	39.0 -	40.1
Shale, olive; interbedded with limestone, gray	40.1 -	41.0
Shale, dark gray	41.0 -	42.4
Limestone, medium gray, finely crystalline, pseudo-oolitic; contains brachiopods	42.4 -	43.0
Shale, medium gray	43.0 -	43.1
Limestone, medium gray, finely crystalline; contains *Osagia*	43.1 -	44.8
Shale, medium gray	44.8 -	47.8
Shale, black	47.8 -	48.2
Americus Member:		
Limestone, medium to dark gray, very finely crystalline; contains fusulinids and brachiopods	48.2 -	49.2
Shale, dark gray	49.2 -	50.1
Limestone, medium gray, very finely crystalline; contains fusulinids and brachiopods	50.1 -	50.2
Shale, dark gray	50.2 -	50.7
Limestone, medium gray, very finely crystalline	50.7 -	51.3
Shale, dark gray	51.3 -	51.5
Limestone, medium gray, finely crystalline; contains brachiopods	51.5 -	52.0

Description	Depth, in feet From	To
Admire Group:		
Hamlin Formation:		
Oaks Member:		
Shale, medium gray	52.0	57.1
Limestone, medium gray, very finely crystalline; contains crinoids	57.1	57.8
Shale, medium gray	57.8	58.5
Limestone, medium gray, very finely crystalline; contains fusulinids	58.5	59.6
Shale, light green	59.6	62.0
Limestone, very light gray, lithographic; interbedded with shale, green	62.0	63.5
Shale, green to gray	63.5	65.0
Shale, red mottled green	65.0	66.8
Shale, green	66.8	67.5
Shale, dark gray	67.5	69.3
Houchens Creek Member:		
Limestone, light gray, finely crystalline	69.3	70.1
Stine Member:		
Shale, olive gray	70.1	72.0
Shale, green	72.0	72.7
Limestone, medium gray, finely crystalline	72.7	73.8
Shale, red mottled green	73.8	74.7
Shale, light gray	74.7	75.9
Limestone, light greenish gray, finely crystalline; contains _Osagia_ and abundant glauconite	75.9	77.2
Shale, medium olive gray	77.2	78.8
Shale, olive	78.8	79.8
Shale, medium gray	79.8	81.5
Shale, dark gray	81.5	85.0
Five Point Formation:		
Limestone, light gray, finely crystalline; contains crinoids, brachiopods, _Osagia_, and glauconite	85.0	86.2
West Branch Formation:		
Shale, light gray	86.2	88.1
Shale, green	88.1	89.3
Shale, reddish gray	89.3	91.0
Limestone, light gray, very finely crystalline	91.0	92.1
Shale, light green	92.1	93.4
Shale, light gray	93.4	100.0
Shale, black	100.0	100.5
Shale, light gray	100.5	102.1
Falls City Formation:		
Lehmer Member:		
Limestone, light gray, very finely crystalline	102.1	104.0

Description	Depth, in feet From	To
Limestone, medium gray, very finely crystalline; contains pyrite and "black inclusions"	104.0 -	107.0
Shale, light grayish green; interbedded with limestone, light gray	107.0 -	108.9
Reserve Member:		
Shale, medium gray	108.9 -	110.2
Miles Member:		
Limestone, medium gray, very finely crystalline	110.2 -	111.0
Onaga Formation:		
Shale, medium gray	111.0 -	111.4
Shale, green; interbedded with limestone, gray	111.4 -	112.0
Shale, light green	112.0 -	113.0
Shale, very light green	113.0 -	115.0
Shale, green	115.0 -	117.4
Shale, red	117.4 -	119.7
Shale, olive	119.7 -	119.9
Limestone, light greenish gray, very finely crystalline	119.9 -	120.7
Shale, red	120.7 -	124.5
Shale, light gray	124.5 -	127.7
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Wood Siding Formation:		
Brownville Member:		
Limestone, light gray, finely crystalline; contains *Osagia*	127.7 -	129.4
Shale, light gray	129.4 -	130.0

Test Hole 11-81

Location: Otoe County, SW corner sec. 25, T. 9 N., R. 11 E., approximately 205 feet north of south section line and 21 feet east of west section line.

Ground-level elevation: 1239.0 feet above mean sea level.

Started: May 14, 1981. Completed: May 14, 1981.

Total Depth: 302.0 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample)	0.0 -	3.0
Clay, tan, silty	3.0 -	5.0
Clay, tan, silty, sandy	5.0 -	12.0
Clay, red, sandy	12.0 -	17.5
Clay, tan, sandy	17.5 -	25.5
Clay, light greenish gray	25.5 -	32.0
Clay, medium gray, very sandy	32.0 -	37.0
Clay, gray to brown, sandy	37.0 -	45.0
Clay, light grayish green to brown, sandy	45.0 -	47.5
Clay, gray to olive brown, sandy	47.5 -	55.0
Clay, olive, sandy	55.0 -	70.4
Sand, very fine	70.4 -	77.0
Sand, fine	77.0 -	107.0
Sand, very fine	107.0 -	115.5
Sand, fine	115.5 -	131.0
Sand, fine, very silty	131.0 -	137.5
Clay, medium gray, sandy, silty	137.5 -	173.0
Clay, medium gray	173.0 -	182.0
Sand, coarse	182.0 -	185.0
Sand, coarse; contains gravel	185.0 -	195.2
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Willard Formation:		
Limestone, medium to dark gray, finely crystalline	195.2 -	197.0
Shale, light gray	197.0 -	200.6
Shale, medium gray	200.6 -	201.1
Shale, light greenish gray	201.1 -	203.0
Shale, dark red	203.0 -	204.4
Shale, grayish green	204.4 -	205.4
Emporia Formation:		
Elmont - Reading Members:		
Limestone, light gray to pale red, very finely crystalline; contains crinoids	205.4 -	208.3
Shale, olive	208.3 -	209.6
Limestone, light gray to tan, very finely crystalline; contains *Osagia*	209.6 -	211.0
Shale, light gray	211.0 -	211.8
Limestone, very light gray, very finely crystalline, pseudo-oolitic; contains brachiopods, crinoids, *Osagia*, and glauconite	211.8 -	214.4
Limestone, light gray, finely crystalline; contains crinoids, bryozoans, and *Osagia*	214.4 -	215.5
Auburn Formation:		
Shale, light grayish green mottled red	215.5 -	218.0
Shale, red	218.0 -	234.0
Shale, olive	234.0 -	235.6

Description	Depth, in feet From	To
Shale, medium gray	235.6	239.8
Sandstone, tan	239.8	240.0
Shale, medium gray	240.0	248.1
Wakarusa Formation:		
Limestone, medium gray, finely crystalline; contains crinoids	248.1	248.9
Shale, medium gray	248.9	252.1
Shale, black	252.1	252.2
Limestone, medium gray, finely crystalline; contains brachiopods, pyrite, and "black inclusions"	252.2	253.0
Soldier Creek Formations:		
Shale, light gray	253.0	257.0
Shale, red	257.0	258.9
Shale, medium gray	258.9	259.3
Limestone, very light gray, finely crystalline; contains *Osagia* and glauconite	259.3	261.6
Shale, light grayish green	261.6	262.4
Shale, red	262.4	266.0
Shale, light gray	266.0	275.3
Burlingame Formation:		
Limestone, medium to dark gray, finely crystalline, pseudo-oolitic; contains brachiopods and *Osagia*	275.3	277.0
Shale, medium gray	277.0	278.2
Limestone, medium gray, finely crystalline, pseudo-oolitic; contains fusulinids and *Osagia*	278.2	279.3
Scranton Formation:		
Silver Lake - White Cloud Members:		
Shale, green	279.3	280.3
Shale, light gray	280.3	284.8
Shale, black	284.8	286.5
Shale, light greenish gray	286.5	287.0
Shale, green	287.0	295.5
Shale, red mottled green	295.5	299.0
Shale, red mottled green; interbedded with limestone, medium gray	299.0	302.0

Test Hole 12-81

Location: Otoe County, SW corner sec. 13, T. 9 N., R. 11 E., approximately 212 feet north of south section line and 22 feet east of west section line.

Ground-level elevation: 1132.5 feet above mean sea level.

Started: May 14, 1981. Completed: May 14, 1981.

Total Depth: 92.0 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample)	0.0 -	8.0
Clay, tan, very sandy	8.0 -	14.5
Sand, medium to coarse	14.5 -	15.0
Clay, tan, sandy	15.0 -	16.0
Clay, medium gray, sandy	16.0 -	17.0
Pennsylvanian System - Virgil Series - Shawnee Group:		
Topeka Formation:		
Curzon Member:		
(no sample)	17.0 -	22.0
Iowa Point Member:		
Shale, light gray	22.0 -	22.6
Hartford Member:		
Limestone, tan to light gray, very finely crystalline; contains _Osagia_ and manganese staining	22.6 -	23.0
Shale, black	23.0 -	23.1
Limestone, medium gray, finely crystalline	23.1 -	24.2
Calhoun Formation:		
Shale, medium gray	24.2 -	25.0
Tecumseh - Deer Creek Formations:		
Ervine Creek Member:		
Limestone, light bluish gray, medium to coarsely crystalline; contains crinoids, brachiopods, and _Osagia_	25.0 -	28.0
Limestone, light bluish gray, finely crystalline; contains _Osagia_ and glauconite	28.0 -	30.1
Limestone, light gray, very finely crystalline; contains _Osagia_ and fusulinids	30.1 -	32.2
Limestone, medium to dark gray, finely crystalline; contains pyrite, abundant fusulinids, and abundant black carbonaceous material	32.2 -	34.0
Limestone, dark gray, finely crystalline; contains pyrite, black carbonaceous material, and fusulinids	34.0 -	36.3
Shale, black	36.3 -	36.4
Limestone, medium gray, finely crystalline; contains _Osagia_ and abundant fusulinids	36.4 -	38.6
Shale, medium gray	38.6 -	39.5
Limestone, light gray, finely crystalline; contains crinoids, fusulinids, pyrite, and _Osagia_	39.5 -	40.4
Larsh Member:		
Shale, medium gray	40.4 -	41.0

Description	Depth, in feet From	To
Shale, black	41.0	42.4
Rock Bluff Member:		
Limestone, light gray to tan, very finely crystalline; contains _Osagia_ and pyrite	42.4	44.3
Oskaloosa - Rakes Creek Members:		
Shale, medium gray	44.3	45.2
Shale, medium greenish gray	45.2	47.6
Siltstone, light greenish gray, sandy	47.6	55.0
Shale, green	55.0	69.5
Shale, red	69.5	72.9
Ost Member:		
Limestone, light gray, very finely crystalline, silty; contains _Osagia_	72.9	75.8
Limestone, very light grayish green to white, very finely crystalline to lithographic; contains _Osagia_ and glauconite	75.8	79.1
Kenosha Member:		
Shale, red mottled green	79.1	80.8
Lecompton Formation:		
Avoca Member:		
Limestone, light gray, very finely crystalline; contains _Osagia_ and brachiopods	80.8	81.2
Limestone, light to medium gray, finely crystalline; pseudo-oolitic in part; contains crinoids and _Osagia_	81.2	82.7
King Hill Member:		
Shale, red	82.7	87.5
Shale, medium greenish gray	87.5	89.6
Beil Member:		
Limestone, very light gray to white, very finely crystalline; contains pyrite, glauconite, coral, and _Osagia_	89.6	92.0

Test Hole 13-81

Location: Otoe County, SW corner sec. 24, T. 9 N., R. 11 E., approximately 85 feet north of south section line and 73 feet east of west section line.

Ground-level elvation: 1148.5 feet above mean sea level.

Started: May 20, 1981. Completed: May 20, 1981.

Total Depth: 197.0 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample)	0.0 -	6.0
Clay, medium gray, sandy	6.0 -	14.0
Clay, tan, sandy	14.0 -	25.0
Clay, olive gray, sandy	25.0 -	32.0
(no sample)	32.0 -	40.0
Clay, medium gray, sandy, silty	40.0 -	49.0
Clay, medium gray, silty, very sandy	49.0 -	55.0
Clay, medium gray, sandy, silty	55.0 -	100.5
Sand, coarse; contains gravel	100.5 -	107.0
Clay, medium gray, sandy	107.0 -	111.5
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Scranton Formation:		
Silver Lake - White Cloud Members:		
Shale, medium gray	111.5 -	120.0
Coal, black	120.0 -	120.2
Shale, medium gray	120.2 -	137.0
Shale, medium gray; contains brown sandstone streaks	137.0 -	162.9
Howard Formation:		
Limestone, dark gray, finely crystalline; contains crinoids	162.9 -	163.3
Shale, medium greenish gray	163.3 -	164.4
Limestone, dark gray, finely crystalline; contains brachiopods, pyrite, and "black inclusions"	164.4 -	165.0
Shale, light greenish gray	165.0 -	168.1
Limestone, medium gray, finely crystalline; contains _Osagia_, coral, brachiopods, pyrite, "black inclusions", and abundant fusulinids	168.1 -	170.0
Limestone, light gray, very finely crystalline; contains _Osagia_ and pyrite	170.0 -	171.7
Severy Formation:		
Shale, light gray	171.7 -	172.2
Shale, black	172.2 -	173.0
Shale, medium grayish green	173.0 -	176.0
Coal, black	176.0 -	177.0
Shale, medium grayish green	177.0 -	183.0
Shawnee Group:		
Topeka Formation:		
Coal Creek Member:		
Limestone, dark gray, finely crystalline; contains pyrite	183.0 -	185.0

Description	Depth, in feet From	To
Shale, medium gray	185.0	185.8
Limestone, medium gray, very finely crystalline; contains brachiopods, coral, and pyrite	185.8	187.2
Shale, medium gray	187.2	188.0
Limestone, medium to dark gray, very finely crystalline; contains fusulinids, crinoids, and pyrite	188.0	189.6
Limestone, light gray, finely crystalline; contains fusulinids, crinoids, pyrite, and abundant brachiopods	189.6	190.0
Holt Member:		
Shale, medium gray	190.0	191.0
Shale, black	191.0	192.1
DuBois Member:		
Limestone, light to very dark gray, finely crystalline; contains brachiopods, pyrite, "black inclusions", and abundant crinoids	192.1	193.4
Turner Creek Member:		
Shale, medium greenish gray	193.4	196.1
Sheldon Member:		
Limestone, light to medium gray, very finely crystalline, pseudo-oolitic in part; contains crinoids, pyrite, and abundant fusulinids	196.1	197.0

Test Hole 14-81

Location: Otoe County, NW corner sec. 2, T. 8 N., R. 11 E., approximately 19 feet south of north section line and 177 feet east of west section line.

Ground-level elevation: 1190.0 feet above mean sea level.

Started: May 20, 1981. Completed: May 20, 1981.

Total Depth: 182.0 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample)	0.0	3.0
Clay, tan, sandy	3.0	8.5
Clay, medium olive gray, sandy	8.5	16.0

Description	Depth, in feet From	To
Clay, tan to brown, sandy....................	16.0 -	27.0
Clay, tan, sandy.............................	27.0 -	29.0
Clay, olive, sandy...........................	29.0 -	39.0
Clay, dark gray, sandy.......................	39.0 -	42.0
Clay, reddish gray, sandy....................	42.0 -	47.5
Clay, dark reddish gray, sandy...............	47.5 -	50.0
Clay, medium gray, sandy.....................	50.0 -	53.0
Clay, light grayish green, sandy.............	53.0 -	70.0
Clay, light grayish green, very sandy........	70.0 -	71.0
Clay, tan, sandy.............................	71.0 -	77.0
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Willard Formation:		
Shale, olive.................................	77.0 -	82.0
Shale, medium gray...........................	82.0 -	84.7
Shale, medium gray, limy.....................	84.7 -	89.0
Shale, medium gray...........................	89.0 -	93.3
Emporia Formation:		
Elmont - Reading Members:		
Limestone, light gray, very finely crystalline...............................	93.3 -	96.0
Shale, red...................................	96.0 -	97.1
Limestone, light gray, finely crystalline; contains *Osagia*...........................	97.1 -	99.2
Shale, medium gray...........................	99.2 -	100.0
Limestone, light gray to tan, very finely crystalline, weathered; contains crinoids, *Osagia*, and glauconite..........	100.0 -	102.8
Auburn Formation:		
Shale, dark gray.............................	102.8 -	103.8
Shale, medium grayish green..................	103.8 -	104.8
Shale, red...................................	104.8 -	118.6
Shale, red mottled olive.....................	118.6 -	120.0
Shale, medium gray...........................	120.0 -	124.5
Coal, black..................................	124.5 -	124.6
Shale, medium gray...........................	124.6 -	133.6
Wakarusa Formation:		
Limestone, medium gray, finely crystalline; contains brachiopods and black carbonaceous material.....................	133.6 -	134.8
Shale, medium gray...........................	134.8 -	135.0
Limestone, medium to dark gray, finely crystalline; contains brachiopods and "black inclusions"..............................	135.0 -	138.0
Soldier Creek Formation:		
Shale, medium gray...........................	138.0 -	140.8
Limestone, light gray, very finely crystalline, pseudo-oolitic; contains brachiopods...............................	140.8 -	141.0
Shale, red...................................	141.0 -	144.0

Description	Depth, in feet From	To
Shale, gray mottled red	144.0	145.0
Limestone, light gray, finely crystalline, pseudo-oolitic in part; contains glauconite and abundant *Osagia*	145.0	147.0
Limestone, light gray, very finely crystalline; contains *Osagia*	147.0	147.6
Shale, green	147.6	148.1
Shale, red	148.1	150.8
Shale, medium gray	150.8	160.1
Burlingame Formation:		
Limestone, medium gray, medium crystalline; contains coral, brachiopods, bryozoans, gastropods, and pyrite	160.1	161.4
Shale, medium gray	161.4	162.8
Limestone, medium to dark gray, medium crystalline, pseudo-oolitic; contains crinoids and *Osagia*	162.8	163.0
Scranton Formation:		
Silver Lake - White Cloud Members:		
Shale, light green	163.0	163.8
Shale, light gray	163.8	164.8
Shale, light gray; interbedded with limestone, light gray	164.8	167.5
Coal, black	167.5	169.0
Shale, light gray	169.0	170.5
Shale, light gray; interbedded with limestone, medium gray	170.5	171.5
Shale, light greenish gray	171.5	175.4
Shale, red	175.4	180.7
Limestone, light tan to gray, lithographic; interbedded with shale, red	180.7	182.0

Test Hole 15-81

Loctation: Otoe Conty, NE NW NW sec. 10, T. 8 N., R. 11 E., approximately 28 feet south of north section line and 1036 feet east of west section line.

Ground-level elevation: 1109.0 feet above mean sea level.

Started: May 21, 1981. Completed: May 21, 1981.

Total Depth: 212.0 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample)	0.0	5.0
Clay, black, sandy	5.0	13.0
Clay, dark greenish gray, sandy	13.0	22.0
Clay, green, sandy	22.0	32.5
Clay, medium gray, sandy	32.5	37.0
Clay, dark gray	37.0	48.0
Clay, light gray	48.0	68.5
Clay, light gray, sandy	68.5	96.0
Clay, light gray; contains sand, coarse, and gravel	96.0	106.0
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Stotler Formation:		
Dry Member:		
Shale, light greenish gray	106.0	107.3
Dover Member:		
Limestone, dark gray, finely crystalline, pseudo-oolitic in part; contains crinoids and "black inclusions"	107.3	108.0
Pillsbury Formation:		
Shale, light gray	108.0	129.2
Zeandale Formation:		
Maple Hill Member:		
Limestone, dark gray, finely crystalline; contains crinoids, brachiopods, black carbonaceous material, and pyrite	129.2	130.8
Wamego Member:		
Shale, medium gray	130.8	134.9
Tarkio Member:		
Limestone, tan, lithographic	134.9	135.1
Shale, medium gray	135.1	136.1
Limestone, light gray, finely crystalline; contains *Osagia*	136.1	138.6
Willard Formation:		
Siltstone, green, very sandy	138.6	146.4
Sandstone, grayish green	146.4	147.5
Shale, medium gray	147.5	169.2
Limestone, medium gray, finely crystalline; contains brachiopods and coral	169.2	174.8
Coal, black	174.8	175.0
Limestone, medium gray, finely crystalline; contains pyrite	175.0	175.2
Shale, light grayish green	175.2	179.0
Emporia Formation:		
Elmont - Reading Members:		
Limestone, light gray to tan, very finely crystalline; contains *Osagia* and abundant pyrite	179.0	180.0

Description	Depth, in feet From	To
Shale, medium gray; interbedded with limestone, grayish green	180.0	181.0
Shale, reddish gray	181.0	181.6
Shale, medium gray	181.6	182.0
Limestone, light gray to tan, very finely crystalline; contains <u>Osagia</u>	182.0	183.7
Shale, medium gray	183.7	185.1
Limestone, light gray, very finely crystalline; contains brachiopods, <u>Osagia</u>, and glauconite	185.1	187.7
Auburn Formation:		
Shale, green mottled red	187.7	188.0
Shale, red mottled green	188.0	192.0
Shale, red	192.0	197.0
Shale, red mottled olive	197.0	204.3
Shale, olive	204.3	205.0
Shale, light gray	205.0	206.0
Shale, medium gray	206.0	212.0

Test Hole 16-81

Location: Otoe County, NW corner SW sec. 18, T. 8 N., R. 11 E., approximately 2551 feet north of south section line and 20 feet east of west section line.

Ground-level elevation: 1087.0 feet above mean sea level.

Started: May 21, 1981. Completed: May 21, 1981.

Total Depth: 317.0 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample)	0.0	3.0
Clay, brown, sandy	3.0	9.5
Clay, dark brown, very sandy	9.5	14.5
Clay, tan, sandy	14.5	33.0
Sand, medium to coarse; contains gravel	33.0	37.0
Clay, olive gray	37.0	48.5
Clay, olive gray, very sandy	48.5	58.0
Sand, coarse; contains gravel	58.0	67.7

Description	Depth, in feet From	To
Permian System - Big Blue Series - Admire Group:		
Onaga Formation:		
Shale, tan, weathered	67.7	68.2
Shale, light bluish green	68.2	69.5
Shale, dark red	69.5	69.7
Limestone, light gray, very finely crystalline	69.7	71.2
Shale, red	71.2	73.0
Shale, red mottled olive	73.0	77.5
Shale, medium gray	77.5	80.3
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Wood Siding Formation:		
Brownville Member:		
Limestone, light gray, finely crystalline	80.3	83.5
Pony Creek - Plumb Members:		
Shale, light gray	83.5	84.0
Shale, light green	84.0	85.0
Shale, red mottled green	85.0	86.7
Shale, light green mottled red	86.7	88.4
Sandstone, medium greenish gray	88.4	90.0
Shale, red	90.0	93.4
Shale, green	93.4	96.5
Shale, medium gray	96.5	100.4
Nebraska City Member:		
Limestone, medium gray, medium crystalline; contains brachiopods	100.4	102.6
Pillsbury - Root Formations:		
Coal, black	102.6	103.4
Shale, green	103.4	112.1
Shale, red mottled green	112.1	113.1
Limestone, medium gray, medium crystalline; contains _Osagia_	113.1	113.6
Shale, green	113.6	114.6
Shale, red	114.6	121.3
Shale, olive	121.3	124.0
Shale, medium greenish gray	124.0	145.0
Shale, medium gray	145.0	173.2
Zeandale Formation:		
Maple Hill Member:		
Limestone, dark gray, finely crystalline; contains brachiopods and fusulinids	173.2	174.4
Willard Formation:		
Shale, medium gray	174.4	176.3
Sandstone, medium gray, very limy	176.3	177.6
Shale, light greenish gray	177.6	191.0
Sandstone, light gray; contains black carbonaceous material	191.0	202.3
Shale, medium gray	202.3	218.8

Description	Depth, in feet From	To
Shale, medium gray; contains limy sandstone streaks throughout and limestone streaks near bottom	218.8	223.3
Shale, medium gray; interbedded with limestone, medium gray	223.3	225.0
Shale, olive	225.0	227.0
Shale, red mottled gray	227.0	231.4
Emporia Formation:		
Elmont - Reading Members:		
Limestone, light grayish green, very finely crystalline; contains crinoids and glauconite	231.4	232.0
Limestone, very light gray, very finely crystalline, pseudo-oolitic; contains *Osagia* and pyrite	232.0	234.6
Shale, light greenish gray	234.6	235.1
Limestone, very light gray, very finely crystalline, pseudo-oolitic; contains brachiopods, crinoids, *Osagia*, and glauconite	235.1	240.3
Auburn Formation:		
Shale, green	240.3	240.8
Shale, red	240.8	251.3
Sandstone, light grayish green	251.3	258.5
Shale, medium gray	258.5	268.9
Wakarusa Formation:		
Limestone, medium gray, finely crystalline; contains brachiopods and pyrite	268.9	272.3
Soldier Creek Formation:		
Shale, medium gray	272.3	273.0
Limestone, light greenish gray, lithographic; interbedded with shale, medium gray	273.0	275.0
Shale, green mottled red	275.0	277.4
Limestone, very light gray, very finely crystalline; contains *Osagia*	277.4	280.4
Shale, olive	280.4	281.4
Shale, medium gray	281.4	290.9
Burlingame Formation:		
Limestone, light gray, finely crystalline; contains black carbonaceous material	290.9	295.7
Scranton Formation:		
Silver Lake - White Cloud Members:		
Shale, medium gray	295.7	296.7
Shale, black	296.7	298.7
Shale, medium gray	298.7	301.6
Limestone, medium gray, finely crystalline; contains fusulinids and pyrite; interbedded with shale, medium gray	301.6	303.0
Shale, black	303.0	303.2

Description	Depth, in feet From	To
Limestone, light grayish green, very finely crystalline; interbedded with shale, green	303.2 -	312.0
Shale, red	312.0 -	313.0
Shale, red; contains limestone streaks	313.0 -	317.0

Test Hole 17-81

Location: Otoe County, SE SW SW sec. 8, T. 8 N., R. 11 E., approximately 26 feet north of south section line and 1150 feet east of west section line.

Ground-level elevation: 1063.0 feet above mean sea level.

Started: May 22, 1981. Completed: May 22, 1981.

Total Depth: 137.0 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample)	0.0 -	6.0
Clay, brown, sandy	6.0 -	15.0
Clay, olive gray, sandy	15.0 -	17.5
Clay, tan to gray, sandy	17.5 -	23.0
Clay, olive, very sandy	23.0 -	26.0
Clay, medium gray, sandy	26.0 -	26.5
Sand, medium to coarse	26.5 -	29.0
Clay, medium gray, very sandy	29.0 -	34.5
Sand, medium to coarse	34.5 -	35.0
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Soldier Creek Formation:		
Shale, red	35.0 -	37.2
Limestone, yellow to tan, finely crystalline, weathered; contains manganese staining	37.2 -	37.4
Shale, medium gray to tan	37.4 -	39.0
Shale, red	39.0 -	44.5
Shale, medium gray	44.5 -	47.4
Burlingame Formation:		
Limestone, light gray, finely crystalline, pseudo-oolitic; contains bryozoans and *Osagia*	47.4 -	50.2

Description	Depth, in feet From	To
Scranton Formation:		
Silver Lake Member:		
Shale, medium gray	50.2	51.0
Shale, green	51.0	51.6
Shale, red	51.6	60.5
Shale, green mottled red	60.5	61.5
Shale, medium gray	61.5	65.4
Rulo Member:		
Limestone, medium gray, finely crystalline	65.4	66.3
Cedarvale Member:		
Shale, medium gray	66.3	67.0
Shale, black	67.0	68.1
Shale, medium gray	68.1	73.3
Shale, green	73.3	74.3
Shale, red	74.3	75.1
Shale, green mottled red	75.1	77.1
Happy Hollow Member:		
Limestone, light greenish gray, finely crystalline, silty; contains fusulinids, bryozoans, _Osagia_ and glauconite	77.1	79.3
Limestone, tan to light greenish gray, finely crystalline; contains crinoids and _Osagia_	79.3	80.4
White Cloud Member:		
Shale, red mottled olive	80.4	82.5
Shale, olive	82.5	83.5
Shale, light greenish gray	83.5	86.5
Shale, medium greenish gray	86.5	88.0
Shale, medium gray, sandy	88.0	102.0
Shale, medium gray	102.0	122.0
Shale, medium gray; contains brown sandstone streaks	122.0	137.0

Test Hole 18-81

Location: Otoe County, SW corner sec. 13, T. 8 N., R. 10 E., approximately 93 feet north of south section line and 19 feet east of west section line.

Ground-level elevation: 1165.0 feet above mean sea level.

Started: May 22, 1981. Completed: May 22, 1981.

Total Depth: 122.0 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample)	0.0	4.5
Clay, tan, sandy	4.5	9.0
Clay, dark brown, sandy	9.0	13.5
Clay, tan, sandy	13.5	14.5
Permian System - Big Blue Series - Council Grove Group:		
Red Eagle Formation:		
Bennett Member:		
Shale, very light green to tan, weathered	14.5	19.4
Glenrock Member:		
Limestone, tan to light gray, finely crystalline, weathered; contains fusulinids	19.4	20.5
Limestone, tan, very finely crystalline, weathered; contains abundant Osagia and manganese staining	20.5	21.2
Limestone, tan to medium gray, finely crystalline; contains manganese staining	21.2	22.5
Johnson Formation:		
Shale, green	22.5	24.0
Shale, medium gray	24.0	28.4
Shale, dark green	28.4	29.0
Shale, red mottled gray	29.0	29.7
Shale, medium gray	29.7	30.6
Foraker Formation:		
Long Creek Member:		
Limestone, light greenish gray, very finely crystalline, argillaceous	30.6	33.0
Limestone, light greenish gray to medium gray, very finely crystalline	33.0	35.0
Shale, green	35.0	35.2
Limestone, medium gray, very finely crystalline to lithographic	35.2	37.1
Hughes Creek Member:		
Shale, medium gray	37.1	38.1
Shale, light gray	38.1	39.0
Shale, dark gray	39.0	43.2
Limestone, very dark gray, medium crystalline, pseudo-oolitic; contains abundant Osagia	43.2	45.1
Limestone, medium gray, finely crystalline; contains brachiopods, Osagia, and "black inclusions"	45.1	46.3
Shale, medium gray	46.3	52.8
Limestone, medium gray, finely crystalline; contains abundant brachiopods; interbedded with shale, medium gray	52.8	53.0
Shale, medium gray	53.0	53.5

Description	Depth, in feet From	To
Limestone, light gray, finely crystalline; contains abundant brachiopods; interbedded with shale, medium gray.......	53.5 -	54.5
Shale, light greenish gray..................	54.5 -	59.2
Limestone, dark gray, finely crystalline; contains brachiopods and pyrite...........	59.2 -	60.0
Shale, very dark gray........................	60.0 -	61.7
Limestone, medium gray, variably crystalline; contains _Osagia_, coral, "black inclusions", and pyrite...................	61.7 -	63.2
Shale, medium gray...........................	63.2 -	63.6
Limestone, medium to dark gray, finely crystalline; contains fusulinids, crinoids, _Osagia_, and pyrite.............	63.6 -	63.8
Shale, medium gray...........................	63.8 -	66.5
Limestone, medium to dark gray, finely crystalline; contains brachiopods, crinoids, and _Osagia_; interbedded with with shale, medium gray..................	66.5 -	70.2
Shale, black.................................	70.2 -	71.0
Limestone, medium gray, very finely crystalline; contains coral, crinoids, and _Osagia_..................................	71.0 -	72.2
Shale, medium gray...........................	72.2 -	74.0
Limestone, medium to dark gray, finely crystalline, pseudo-oolitic; contains crinoids and _Osagia_.....................	74.0 -	76.0
Shale, medium gray...........................	76.0 -	76.5
Limestone, medium gray, medium crystalline; contains abundant _Osagia_.................	76.5 -	76.7
Shale, medium gray...........................	76.7 -	78.2
Shale, black.................................	78.2 -	78.6
Americus Member:		
Limestone, medium gray, finely crystalline; contains crinoids and pyrite..............	78.6 -	79.8
Shale, medium gray...........................	79.8 -	81.5
Limestone, light gray, very finely crystalline; contains crinoids..................	81.5 -	82.0
Limestone, medium gray, very finely crystalline..............................	82.0 -	82.9
Admire Group:		
West Branch - Hamlin Formations:		
Shale, medium gray...........................	82.9 -	86.4
Limestone, medium gray, very finely crystalline..............................	86.4 -	86.7
Shale, medium gray...........................	86.7 -	88.3
Limestone, light gray, lithographic; interbedded with shale, green.............	88.3 -	89.0

Description	Depth, in feet From	To
Limestone, very light grayish green, very finely crystalline; contains glauconite; interbedded with shale, green, at 91.0-92.4	89.0	92.4
Shale, red	92.4	95.0
Shale, red; interbedded with limestone, light gray	95.0	98.3
Limestone, very light grayish green, very finely crystalline; contains glauconite; interbedded with shale, green	98.3	101.0
Shale, red	101.0	104.2
Limestone, medium gray, very finely crystalline; contains brachiopods and crinoids	104.2	104.8
Shale, medium gray	104.8	107.0
Shale, red	107.0	109.5
Shale, grayish green	109.5	110.5
Shale, pale red; interbedded with limestone, light gray	110.5	114.0
Shale, medium gray; interbedded with limestone, light gray	114.0	115.0
Shale, olive	115.0	117.0
Shale, green	117.0	118.0
Shale, olive	118.0	119.5
Shale, gray mottled olive	119.5	120.5
Limestone, dark gray, finely crystalline; contains _Osagia_, pyrite, and black carbonaceous material	120.5	120.8
Shale, medium gray	120.8	122.0

Test Hole 19-81

Location: Otoe County, SW corner sec. 11, T. 10 N., R. 8 E., approximately 23 feet north of south section line and 103 feet east of west section line.

Ground-level elevation: 1143.0 feet above mean sea level.

Started: May 22, 1981. Completed: May 22, 1981.

Total Depth: 152.0 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample)	0.0	4.0
Silt, brown, sandy	4.0	9.0
Clay, brown, very sandy	9.0	14.0
Clay, brown, sandy	14.0	22.0
Clay, light brown, sandy	22.0	28.5
Clay, medium gray	28.5	29.0
Clay, dark gray	29.0	35.0
Clay, black	35.0	38.0
Clay, dark gray	38.0	39.0
Clay, medium gray	39.0	41.5
Clay, tan	41.5	48.0
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Willard Formation:		
Shale, olive	48.0	50.0
Limestone, medium gray, finely crystalline, pseudo-oolitic; contains brachiopods, crinoids, and _Osagia_	50.0	50.6
Shale, light gray	50.6	55.0
Shale, red	55.0	55.7
Shale, medium gray	55.7	56.5
Emporia Formation:		
Elmont - Reading Members:		
Limestone, light grayish green, very finely crystalline, pseudo-oolitic in part; contains crinoids and _Osagia_	56.5	57.1
Shale, medium gray; interbedded with limestone, gray	57.1	59.0
Shale, medium gray	59.0	59.6
Limestone, light gray, very finely crystalline; contains _Osagia_	59.6	61.2
Shale, medium gray	61.2	62.2
Limestone, light gray, very finely crystalline; contains _Osagia_	62.2	65.5
Auburn Formation:		
Shale, medium greenish gray	65.5	67.0
Shale, red	67.0	80.0
Shale, olive	80.0	82.0
Shale, light gray	82.0	84.5
Shale, medium gray	84.5	92.0
Shale, medium gray; contains thin sandstone streaks	92.0	94.5
Wakarusa Formation:		
Limestone, light gray, finely crystalline; interbedded with shale, medium gray	94.5	98.5
Soldier Creek Formation:		
Shale, medium gray	98.5	100.5
Shale, medium gray; interbedded with limestone, light gray	100.5	103.6

Description	Depth, in feet From	To
Limestone, light gray, irregularly crystalline; contains *Osagia* and glauconite......	103.6 -	106.5
Shale, medium gray..........................	106.5 -	107.0
Shale, medium gray; contains brown sandstone streaks................................	107.0 -	117.1
Burlingame Formation:		
Limestone, light to medium gray, finely crystalline; contains *Osagia*..............	117.1 -	119.0
Limestone, light gray, finely crystalline; contains glauconite......................	119.0 -	120.2
Limestone, light gray, finely crystalline; contains crinoids; interbedded with shale, medium gray.......................	120.2 -	120.6
Scranton Formation:		
Silver Lake - White Cloud Members:		
Shale, black................................	120.6 -	121.0
Shale, green................................	121.0 -	127.5
Shale, red..................................	127.5 -	139.0
Shale, medium gray..........................	139.0 -	142.3
Coal, black.................................	142.3 -	142.6
Shale, medium gray..........................	142.6 -	152.0

Test Hole 20-81

Location: Otoe County, NW NE NW sec. 21, T. 8 N., R. 10 E., approximately 12 feet south of north section line and 1362 feet east of west section line.

Ground-level elevation: 1213.0 feet above mean sea level.

Started: May 26, 1981. Completed: May 26, 1981.

Total Depth: 197.0 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample)............................	0.0 -	4.0
Clay, tan, sandy............................	4.0 -	8.5
Clay, olive, sandy..........................	8.5 -	19.0
Clay, medium gray, sandy....................	19.0 -	22.0
Clay, brown, sandy..........................	22.0 -	34.0
Sand, medium, clayey........................	34.0 -	41.0
Sand, coarse, and gravel....................	41.0 -	43.0
Gravel, clayey..............................	43.0 -	47.0

Description	Depth, in feet From	To
Clay, medium gray, sandy, very silty.........	47.0	- 62.0
Clay, light gray, sandy......................	62.0	- 71.0
Clay, reddish gray, sandy....................	71.0	- 77.0
Clay, reddish gray, very sandy...............	77.0	- 85.8
Permian System - Big Blue Series - Council Grove Group:		
Grenola Formation:		
Burr Member:		
Limestone, light gray, very finely cyrstalline, pseudo-oolitic; contains brachiopods.....................................	85.8	- 88.7
Roca Formation:		
Shale, light grayish green...................	88.7	- 92.5
Shale, very light gray.......................	92.5	- 94.0
Shale, medium grayish green..................	94.0	- 97.6
Shale, red mottled green.....................	97.6	- 101.0
Shale, red mottley gray......................	101.0	- 101.8
Shale, medium gray; contains thin limestone steaks......................................	101.8	- 104.0
Shale, light gray............................	104.0	- 106.5
Shale, red...................................	106.5	- 107.4
Shale, medium gray...........................	107.4	- 108.8
Limestone, very light gray, lithographic.....	108.8	- 109.0
Shale, reddish gray..........................	109.0	- 110.5
Shale, grayish green.........................	110.5	- 112.7
Red Eagle Formation:		
Howe Member:		
Shale, medium gray, limy.....................	112.7	- 113.3
Shale, grayish tan...........................	113.3	- 115.2
Limestone, medium gray to tan, variably crystalline, pseudo-oolitic; contains <u>Osagia</u>......................................	115.2	- 118.4
Bennett Member:		
Shale, light gray............................	118.4	- 121.0
Shale, gray mottled olive....................	121.0	- 124.0
Shale, black.................................	124.0	- 124.7
Shale, medium gray...........................	124.7	- 125.5
Shale, black.................................	125.5	- 126.5
Glenrock Member:		
Limestone, medium to dark gray, very finely crystalline; contains abundant black carbonaceous material.....................	126.5	- 128.4
Johnson Formation:		
Shale, light grayish green...................	128.4	- 129.4
Shale, medium gray...........................	129.4	- 130.1
Limestone, medium gray, finely crystalline; interbedded with shale, medium gray.......	130.1	- 131.1
Shale, medium greenish gray..................	131.1	- 137.2
Shale, red...................................	137.2	- 138.2
Shale, medium gray...........................	138.2	- 139.0

Description	Depth, in feet From	To
Foraker Formation:		
Long Creek Member:		
Limestone, light gray, very finely crystalline	139.0	141.5
Limestone, medium gray, very finely crystalline; contains glauconite	141.5	142.5
Hughes Creek Member:		
Shale, light gray	142.5	145.0
Shale, medium gray	145.0	152.0
Limestone, medium to dark gray, variably crystalline, pseudo-oolitic; contains brachiopods, *Osagia*, and "black inclusions"	152.0	154.5
Shale, medium gray	154.5	162.0
Shale, light gray	162.0	167.8
Limestone, medium gray, finely crystalline	167.8	168.5
Shale, black	168.5	170.1
Limestone, medium gray, finely crystalline; contains fusulinids, brachiopods, *Osagia*, and "black inclusions"	170.1	171.9
Shale, dark gray	171.9	176.5
Shale, medium gray	176.5	178.8
Shale, medium gray; interbedded with limestone, light gray	178.8	180.0
Shale, dark gray	180.0	180.4
Limestone, medium gray, finely crystalline; contains brachiopods, *Osagia*, and "black inclusions"	180.4	181.5
Shale, medium gray	181.5	183.0
Limestone, medium gray, finely crystalline, pseudo-oolitic; contains brachiopods, bryozoans, crinoids, fusulinids, and *Osagia*	183.0	185.0
Shale, medium gray	185.0	188.0
Shale, black	188.0	188.4
Americus Member:		
Limestone, dark gray, very finely crystalline	188.4	189.7
Shale, dark gray	189.7	191.3
Limestone, medium gray, finely crystalline; contains coral, crinoids, and brachiopods	191.3	192.4
Admire Group:		
Hamlin Formation:		
Shale, medium gray	192.4	196.0
Limestone, medium gray, finely crystalline; pseudo-oolitic; contains brachiopods and glauconite	196.0	197.0

Test Hole 21-81

Location: Otoe County, SW corner NW sec. 21, T. 8 N., R. 10 E., approximately 2604 feet south of north section line and 30 feet east of west section line.

Ground-level elevation: 1236.0 feet above mean sea level.

Started: May 26, 1981. Completed: May 26, 1981.

Total Depth: 287.0 feet.

Description	Depth, in feet From	To
Quaternary System:		
Soil (no sample)	0.0 -	5.0
Clay, red, silty	5.0 -	9.5
Clay, tan, sandy	9.5 -	13.0
Clay, tan, very sandy	13.0 -	22.0
Clay, olive gray, sandy	22.0 -	29.5
Clay, brown to gray, sandy	29.5 -	41.0
Clay, olive gray, sandy	41.0 -	49.0
Sand, fine, silty	49.0 -	61.5
Clay, gray, very sandy; contains gravel	61.5 -	72.0
Clay, dark gray, very sandy; contains gravel	72.0 -	85.0
Clay, light gray, very sandy	85.0 -	92.0
Clay, light brown to gray, sandy	92.0 -	108.0
Clay, light gray, sandy	108.0 -	112.0
Clay, medium gray, sandy	112.0 -	128.0
Clay, dark gray, sandy	128.0 -	143.0
Clay, medium gray	143.0 -	148.0
Clay, dark gray	148.0 -	152.5
Clay, medium gray, sandy	152.5 -	158.0
Clay, medium gray	158.0 -	169.0
Clay, dark gray	169.0 -	175.0
Clay, light gray, sandy	175.0 -	181.4
Sand, coarse; contains gravel	181.4 -	183.0
Clay, greenish gray	183.0 -	190.0
Permian System - Big Blue Series - Admire Group:		
West Branch Formation:		
Shale, light green	190.0 -	191.6
Limestone, light gray to green, very finely crystalline; contains bryozoans, brachiopods, and crinoids	191.6 -	192.1
Shale, light gray	192.1 -	199.0
Shale, medium gray	199.0 -	200.0
Shale, dark gray	200.0 -	202.6
Falls City Formation:		
Limestone, light gray, finely crystalline	202.6 -	203.5

Description	Depth, in feet From	To
Shale, medium gray	203.5 -	203.7
Limestone, light gray, very finely crystalline	203.7 -	207.2
Shale, medium gray	207.2 -	210.4
Limestone, medium to dark gray, finely crystalline	210.4 -	212.0
Limestone, light gray, very finely crystalline; contains *Osagia* and "black inclusions"	212.0 -	213.5
Onaga Formation:		
Hauxby - Towle Members:		
Shale, medium greenish gray	213.5 -	215.5
Shale, light grayish green	215.5 -	218.5
Shale, medium gray	218.5 -	220.5
Shale, red mottled green	220.5 -	223.0
Limestone, bluish gray to very light gray, very finely crystalline; interbedded with shale, red	223.0 -	224.0
Shale, red	224.0 -	229.0
Shale, olive	229.0 -	231.5
Pennsylvanian System - Virgil Series - Wabaunsee Group:		
Wood Siding Formation:		
Brownville Member:		
Limestone, very light gray, variably crystalline; contains fusulinids	231.5 -	233.6
Pony Creek - Plumb Members:		
Shale, medium gray	233.6 -	236.2
Shale, red	236.2 -	241.2
Limestone, light gray, finely crystalline; interbedded with shale, red	241.2 -	241.5
Shale, red	241.5 -	244.5
Shale, light grayish green	244.5 -	245.5
Shale, dark gray	245.5 -	250.4
Nebraska City Member:		
Limestone, dark gray, very finely crystalline; contains brachiopods, fusulinids, black carbonaceous material, and pyrite	250.4 -	251.0
Stoler - Root Formations:		
Shale, black	251.0 -	252.5
Coal, black	252.5 -	252.6
Shale, medium gray	252.6 -	259.0
Shale, red mottled green	259.0 -	261.5
Limestone, very light gray to white, very finely crystalline to lithographic; contains fusulinids and crinoids	261.5 -	265.8
Shale, red	265.8 -	267.0
Shale, olive	267.0 -	272.5
Shale, medium gray	272.5 -	287.0

Test Hole 22-81

Location: Otoe County, SE corner sec. 8, T. 8 N., R. 11 E., approximately 136 feet north of south section line and 20 feet west of east section line.

Ground-level elevation: 1071.5 feet above mean sea level.

Started: May 27, 1981. Completed: May 27, 1981.

Total Depth: 171.0 feet.

Description	Depth, in feet From		To
Quaternary System:			
Soil (no sample)	0.0	-	5.0
Silt, black	5.0	-	8.0
Clay, medium gray	8.0	-	13.0
Clay, green	13.0	-	23.0
Clay, medium gray	23.0	-	30.5
Clay, greenish gray, silty	30.5	-	73.5
Sand, medium to coarse, and gravel, medium	73.5	-	78.6
Pennsylvanian System - Virgil Series - Wabaunsee Group:			
Wood Siding Formation:			
Nebraska City Member:			
Limestone, medium greenish gray, finely crystalline; contains brachiopods and glauconite	78.6	-	79.5
Pillsbury - Root Formations:			
Shale, black	79.5	-	81.2
Shale, medium greenish gray	81.2	-	87.4
Shale, red	87.4	-	90.3
Shale, red; interbedded with limestone, gray	90.3	-	93.7
Limestone, light gray, very finely crystalline; contains fusulinids	93.7	-	94.2
Shale, light greenish gray	94.2	-	96.4
Limestone, medium gray, finely crystalline; interbedded with shale, medium gray	96.4	-	98.5
Shale, grayish olive	98.5	-	100.7
Shale, medium gray	100.7	-	128.9
Sandstone, gray; contains black carbonaceous material	128.9	-	129.9
Shale, medium gray	129.9	-	147.0
Shale, medium gray; contains pyrite	147.0	-	152.0
Shale, medium gray	152.0	-	158.6
Zeandale Formation:			
Maple Hill Member:			
Limestone, medium gray, very finely crystalline; contains brachiopods	158.6	-	160.2

Description	Depth, in feet From	To
Wamego Member:		
Shale, medium gray	160.2	163.8
Tarkio Member:		
Limestone, medium gray, very finely crystalline; contains brachiopods	163.8	164.5
Shale, medium greenish gray	164.5	167.0
Shale, dark gray	167.0	167.2
Limestone, medium gray, very finely crystalline	167.2	168.6
Limestone, light gray, finely crystalline; contains abundant brachiopods; interbedded with shale, green	168.6	168.9
Willard Formation:		
Shale, very dark gray	168.9	170.1
Shale, medium gray	170.1	171.0

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16. ABSTRACT (200 words or less)

This annual report presents and interprets the information obtained by the Conservation Survey Division (Nebraska Geological Survey) during contract year July 1, 1980 to June 30, 1981, under contract NRC 04 76 315 with the USNRC. The information pertains to the geology, structure, tectonics, and seismicity of eastern Nebraska with emphasis on central Otoe County. Some of the information presented here result 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 Otoe County were reexamined and reevaluated, and 22 test holes were drilled to determine the altitude of the upper surface of the Elmont Limestone of Pennsylvanian age;
2. One new seismograph was installed in eastern Nebraska;
3. Gravity surveys in eastern Nebraska were extended;
4. Ground magnetic surveys in Otoe County were made and evaluated.
5. Age dating of two Precambrian cores.

Discussion of the results of these studies constitute the remainder of this report.

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