ILLINOIS STATE GEOLOGICAL SURVEY

NATURAL RESOURCES BUILDING
URBANA, ILLINOIS

JOHN C. FRYE, CHIEF

November 13, 1963

Dr. James E. Hackett
Northeast Illinois Field Office
115 South Washington
Naperville, Illinois

Dear Jim:

Enclosed is our report for the Planning Commission on the gravity survey of northeast Illinois. The Bouguer Gravity Map and three illustrations derived from seismic reflection studies are being sent under separate cover. As you will note, a report on the seismic activity is not enclosed. I believe the illustrations speak for themselves and therefore a report would only be saying what is obvious. Unless you and the members of the Planning Commission vehemently and insistently demand such a report, none shall be forthcoming.

Sincerely yours,

Lyle

Lyle D. McGinnis
Assistant Geophysicist
Section of Ground Water Geology
and Geophysical Exploration

Enclosure

STATE GEOLOGICAL SURVEY DIVISION
LOCATED ON THE CAMPUS OF THE UNIVERSITY OF ILLINOIS
JOHN C. FRYE, CHIEF
NATURAL RESOURCES BUILDING
URBANA

GEOPHYSICAL REPORT - NORTHEASTERN ILLINOIS

by

Paul C. Heigold and Lyle D. McGinnis

Report No. IV

Prepared for Water Resources

Management and Development

Study (Illinois P-40)

December 1963

Geophysical Report - Northeastern Illinois

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Introduction

A gravity survey of northeastern Illinois was conducted during the summer of 1962 by members of the Northeastern Illinois Metropolitan Planning Commission under the direction of the Illinois State Geological Survey. A smaller area immediately to the west was surveyed in 1961 by members of the Illinois Geological Survey. The latter survey is included in this report since it has been examined rather thoroughly and illustrates the correlation between geology and the gravity field as it exists in north-central Illinois.

Gravity stations are located wherever elevations and bench marks are given on topographic maps. This provides a uniform grid with spacing of approximately 1 mile. In all, there are 5761 gravity stations in the surveyed area, including 1176 which were surveyed in the summer of 1961. The 1961 work was done using a Worden gravity meter while a World Wide gravity meter was employed in the 1962 work. Both of these meters are the temperature compensated, null-reading type, readable to .01 mg.

Elevations used in the gravity data reduction were obtained from topographic maps and are accurate to $\pm$ 1 foot. This variation in elevation introduces small accountable errors in the free air and Bouguer corrections (c. $\pm$ .1 mg.). Terrain corrections were neglected because of small topographic relief in the surveyed area.

In the Bouguer correction a density of 2.35 gm/cc. was employed. This value was determined from the results of the analysis of numerous core samples from borings obtained for the water resources management study. Drift corrections were based on curves drawn from repeated observations of the same field location each day. Overall, the survey, tied to the Behrendt and Woollard gravity base station in Janesville, Wisconsin, at the Rock County Airport, is accurate to ± .19 mg.

Bouguer Gravity and Regional Geology

Prior to any mention of specific gravity anomalies, a brief discussion of Bouguer gravity anomalies in general, and their analysis, will be given in order to point out the fact that gravity data by its very nature is suggestive rather than definitive.

The Bouguer map (Plate 1), or more accurately the Bouguer gravity anomaly map, represents the difference between the Bouguer gravity and the theoretical gravity, based on the 1930 "International formula." The Bouguer gravity is the result of applying the standard corrections (mentioned above) to the raw observed gravity. The anomalies displayed on the Bouguer map are the algebraic sum of all the anomalies that would cause the Bouguer gravity to deviate from the theoretical gravity. The singular anomalies involved in this natural summation are the result of density contrasts located anywhere from near the surface to sub-crustal depths. In addition to this inherent superposition problem, individual gravity anomalies, by nature, are ambiguous. For example, the anomaly caused by a mass with a certain density contrast at great depth could be the same as that produced by a shallow mass with a different size, shape, or density contrast. Depth, size, shape, and density contrast are all variables on which the Bouguer gravity anomalies depend.

Despite these apparent shortcomings, there is one fact concerning gravity anomalies that provides grounds for profitable inference to be made from the Bouguer map. Gravity anomalies spread out as the depth of the source increases. Thus, one would expect broad low gradient anomalies to have their cause at greater depth than small high gradient anomalies. As a result of this fact, anomalies associated with shallow masses often appear as small undulations on broad, sweeping contours that owe their configurations to deeper masses.

On examination of the Bouguer map (Plate 1) from a regional point of view, several interesting trends are in evidence. Perhaps the most striking trend on the map is a broad band of relatively high Bouguer gravity extending north and west from the southern border of the surveyed area within the -20 milligal contour line. This band contains a series of closed highs (T.31N., R.1E.; T.33N., R.9 and 10E.; T.36N., R.8E.; T.38N., R.8E.; T.39 and 40N., R.7E.; T.41N., R.6E.; and T.41N., R.4E.) and has a major east-west fork centered between T.38 and 39N., extending to the eastern border of surveyed area. The northern flank of this band possesses a very steep gradient with Bouguer gravity decreasing to the north. This phenomena is very much like that which would be produced by an abrupt change in lithology (lateral change in density contrast), a steep monocline, or a large throw vertical fault. To the northeast the Bouguer map shows a broad low centered in T.46N., R.10E., extending north and east into Wisconsin. In the southeastern part of the surveyed area, the Bouguer map is relatively flat, with a broad, irregularly shaped low being the predominant feature. To the southwest, a large circular gravity low dominates the regional picture.

Regionally comparing the Bouguer anomaly map and known geologic structure, it is apparent that a simple one-to-one correlation of structure and Bouguer gravity does not exist throughout the surveyed area. Perhaps the best example of this occurs in the southwest where the Bouguer map shows a sizeable circular low. This particular area is structurally high. It is bounded on the north by the Sandwich Fault and to the southwest by the LaSalle Anticline. Theoretical calculations show that the absence of part of the section could account for the magnitude of the negative anomaly, whereas a simple density contrast could account for only a small part of the anomaly. The cause of an anomaly of such magnitude could more realistically be a lateral change in density somewhere in the basement complex. This would not be an unreasonable assumption especially in light of the known crustal weakness associated with this area. On the other hand, there is reason to believe that within a region a simple correlation between gravity and the elevation of the basement surface does exist. This is reasonable since a good density contrast exists at the Mt. Simon-Precambrian contact and the relief of the basement is much greater than anywhere in the section.

A seismic reflection profile (Figure 1) mapping the Pre-Cambrian surface in the south-central portion of the surveyed area was recently conducted by members of the Illinois Geological Survey. This profile shows a rather good one-to-one correspondence with a similar gravity profile (Figure 1) and will be reviewed later. The problem resolves itself into determining regional Precambrian lithologic boundaries and the topography of the basement within these regions. A good part of the answer to this phase of the problem can be supplied by strategic seismic reflection profiling, especially across what appears to be boundaries of lithologic (density) provinces on the Bouguer gravity map.

Seismic profiling from one density region to another would provide information in the boundary regions where the gravity values would naturally be experiencing translation. If the density provinces were large enough, the work needed to clarify the basement relief in the boundary zones would be considerably less than say if in addition to large lithologic provinces there were many lithology changes within the larger provinces. The latter event could produce an almost insurmountable problem in determining the topography of the basement surface. Once the basement surface has been determined to the desired degree of confidence, anomalies whose causes are in the sedimentary column can be examined.

At the present time, meaning can be given to the Bouguer gravity map (Plate 1), only in the most general terms. The Bouguer anomaly trends roughly coincide with isopach trends of the deeper sedimentary formations. In the northern half of the area the overall tendency is for Bouguer values to decrease, along with decreasing thicknesses of the deeper formations, as for example, the thickness of rocks between the top of the Glenwood-St. Peter Sandstone and the top of the Ironton-Galesville Sandstone. This is in contrast to what might be expected even though this part of the section is composed mainly of dense limestones and dolomites. The -20 mg. contour line oriented in a west northwest direction on the northern flank of the band of gravity highs is nearly parallel to the line of flexures appearing on the structure contour map of the Galena-Platteville Dolomite. Folding is also apparent here on the structure map of the Mt. Simon aquifer, although it is not as well aligned with the gravity trends as the Galena-Platteville. This lack of agreement may be the result of fewer control wells reaching the Mt. Simon. It is impossible that such folding alone is the reason for the alignment of the gravity contours. Besides some effect due to the folding, there appears to be some large, deep-seated faulting or lithologic variation.

A direct relation between structure and gravity anomalies may be observed in the southeast portion of the area outlined by the -20 mg. contour line. In this region a structural low is associated with the broad gravity low which causes the forked appearance of the band of highs on the gravity map.

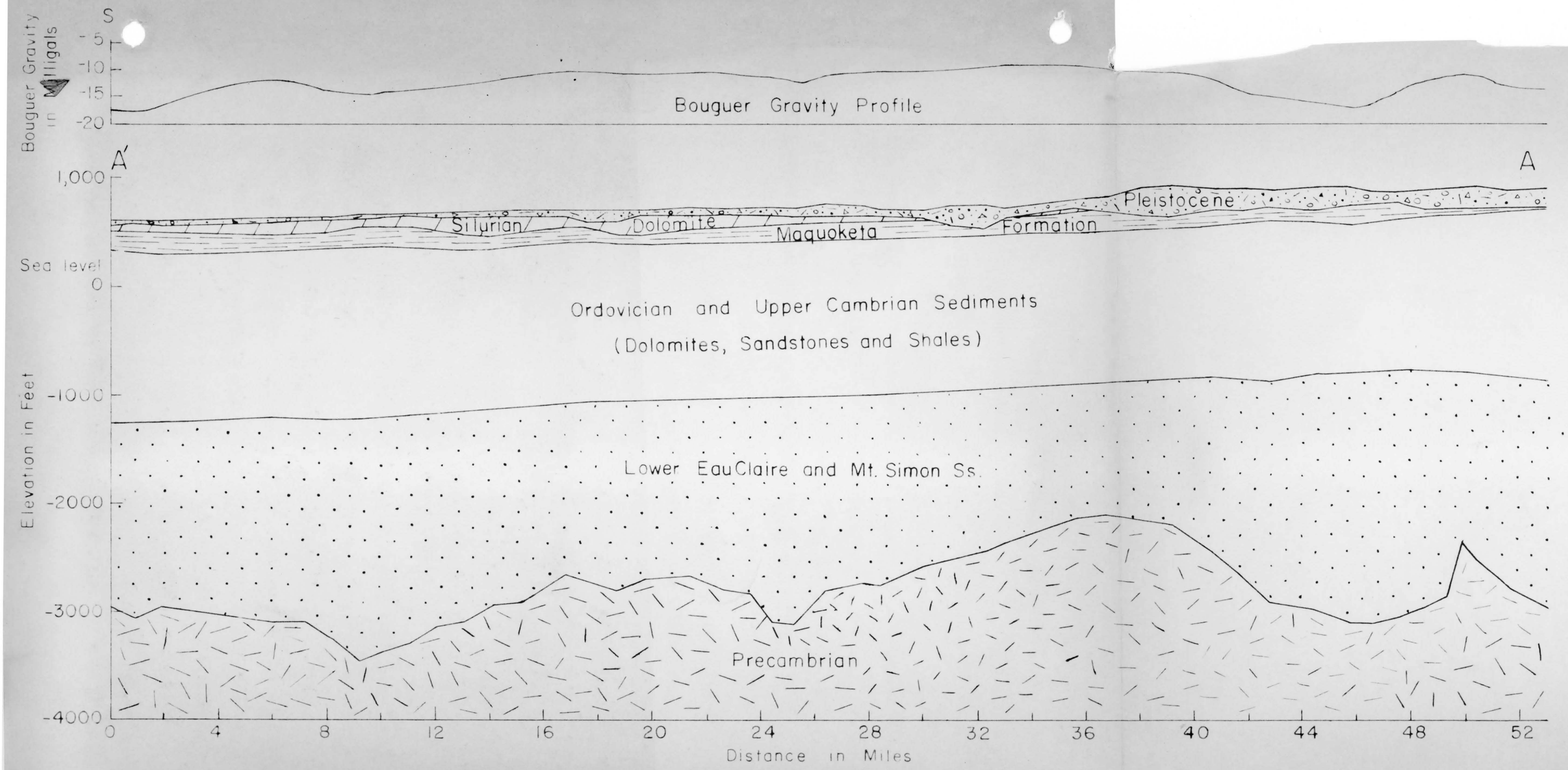
Many other similar relationships are probably present between the gravity data and the geology, but insight on these relationships must wait until further information on the basement surface is known. Of particular interest in this light would be the relationship of the basement surface to the north-east trending low near the Wisconsin border, as well as the relationship of the basement surface to the extended band of highs predominant on the Bouguer map.

Woollard, in his analysis of the gravitational field of several geologic provinces throughout the United States, has recognized the lack of correlation between Paleozoic structure, and Bouguer Gravity anomalies, especially in and around medium to large sedimentary basins. He has noted that the basins, though filled with a thickened section of sedimentary rocks, show a positive rather than negative gravity anomaly, and concludes that the density deficiency of the sediments may be offset by a compensating mass distribution at depth. Northeastern Illinois is one of these areas where no simple correlation between the gravity field and the geologic structures can be made.

Related Seismic, Gravity and Geologic Interpretation

Seismic reflections and six wells reaching basement rocks in northeastern Illinois were utilized in the construction of Plate 2. Seismic records of sufficient quality to select a reflection, presumably of the basement surface, were obtained at twenty scattered reflection stations and at forty-eight stations along a northwest-southeast profile. Stations were spaced roughly one mile apart along the profile (Figure 1) which extends from T.35N., R.9E.; north to T.39N., R.9E.; and northwest to T.41N., R.5 E. The profile was tied to a basement well on the northwest end. Reflection quality ranged from poor to good with about 1/3 of all stations being of sufficient quality to pick identifiable reflections. With this understanding, it is evident that some basement well control is necessary in the vicinity of all reflection stations to consistently predict accurate depths to the top of the crystalline rocks. The Precambrian-Mount Simon contact was the only boundary from which reflections could be identified.

Scattered reflection stations, far removed from basement wells, must be viewed with discretion since the selection of a certain reflection cycle at these stations is highly subjective. The reliability of accurate depth predictions along the profile in Figure 1 is enhanced by the proximity of one station to another; however, depth accuracy decreases as distance from the control well on the northwest end of the profile increases. Evidence of the subjective nature of the


S
Bouguer Gravity in Milligals
-5
-10
-15
-20
Bouguer Gravity Profile
A′
A
1,000
Sea level
0
-1000
-2000
-3000
-4000
Elevation in Feet
Pleistocene
Silurian Dolomite Formation
Maquoketa
Ordovician and Upper Cambrian Sediments
(Dolomites, Sandstones and Shales)
Lower EauClaire and Mt. Simon Ss.
Precambrian
0
4
8
12
16
20
24
28
32
36
40
44
48
52
Distance in Miles

selection of a particular cycle on a reflection record was recently brought to light by the drilling of a Precambrian well about two miles from the south end of the seismic profile. The drill encountered Precambrian crystallines at a depth of about 600 feet below that as extrapolated from the seismic data. With the knowledge obtained from this recent well, the profile can be reinterpreted and the accuracy of depth predictions along the profile can be significantly increased. It is interesting to note that decreasing Bouguer values on the southern end of the gravity profile in Figure 1 are suggestive of an increasing depth to basement which would substantiate the fact that within a particular region a one-to-one correlation exists between the basement surface and Bouguer gravity.

Plate 2 is a contour map of the top of the Precambrian crystalline rocks based on all available evidence at the time of its construction. With the addition of new data based on the well mentioned above, the interpretation in the southern part of the map can be modified so as to connect the lows north and south of the fault zone. Plate 3 is an isopach contour map of the Mount Simon Aquifer and is based on elevations obtained from Plate 1 and from the structure contours on the top of the Mount Simon Aquifer. Additional information obtained from the new well will not significantly alter the isopach contours since the contoured area does not extend as far south as the new data.

The direct correlation between the gravity profile and the Precambrian surface (Figure 1) is striking. The only real divergence is on the southern end where it has now been shown that elevations of basement rocks do decrease. This correlation can not be expected when crossing from one density region to another as described in the discussion on gravity. At the present time and from all the available information, it appears that broad gravity lows correspond to Precambrian regional structural highs and conversely, broad gravity highs correspond to regional structural lows. The significance of this relationship is now under study at the Illinois State Geological Survey. Locally, as shown in Figure 1, a direct relationship between gravity anomalies and the Precambrian surface may be expected. The contents of this report ~~are~~ not intended for publication. A continuing more comprehensive program of study is now in progress. Publication of this more comprehensive examination will be within the next two years.

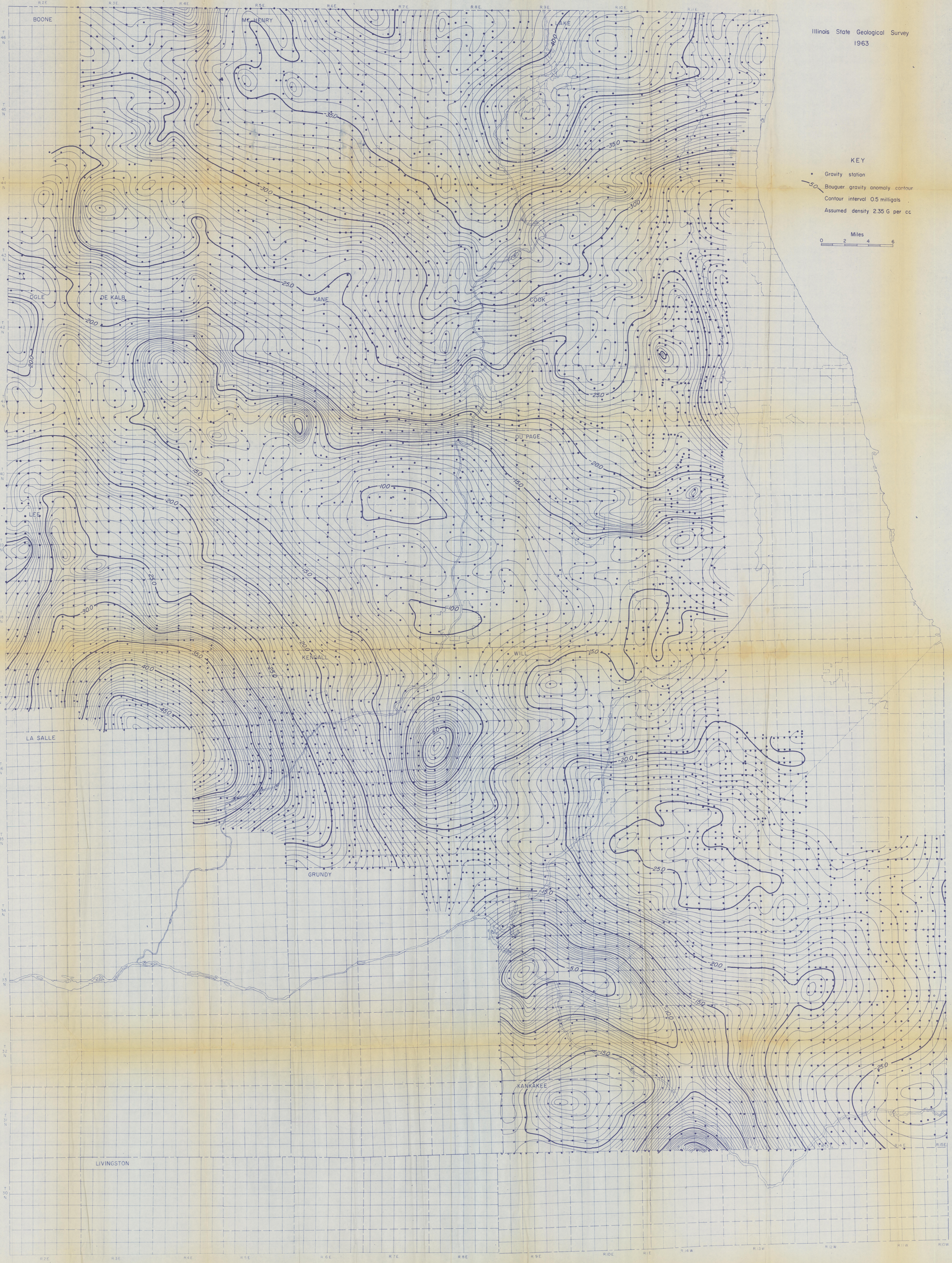
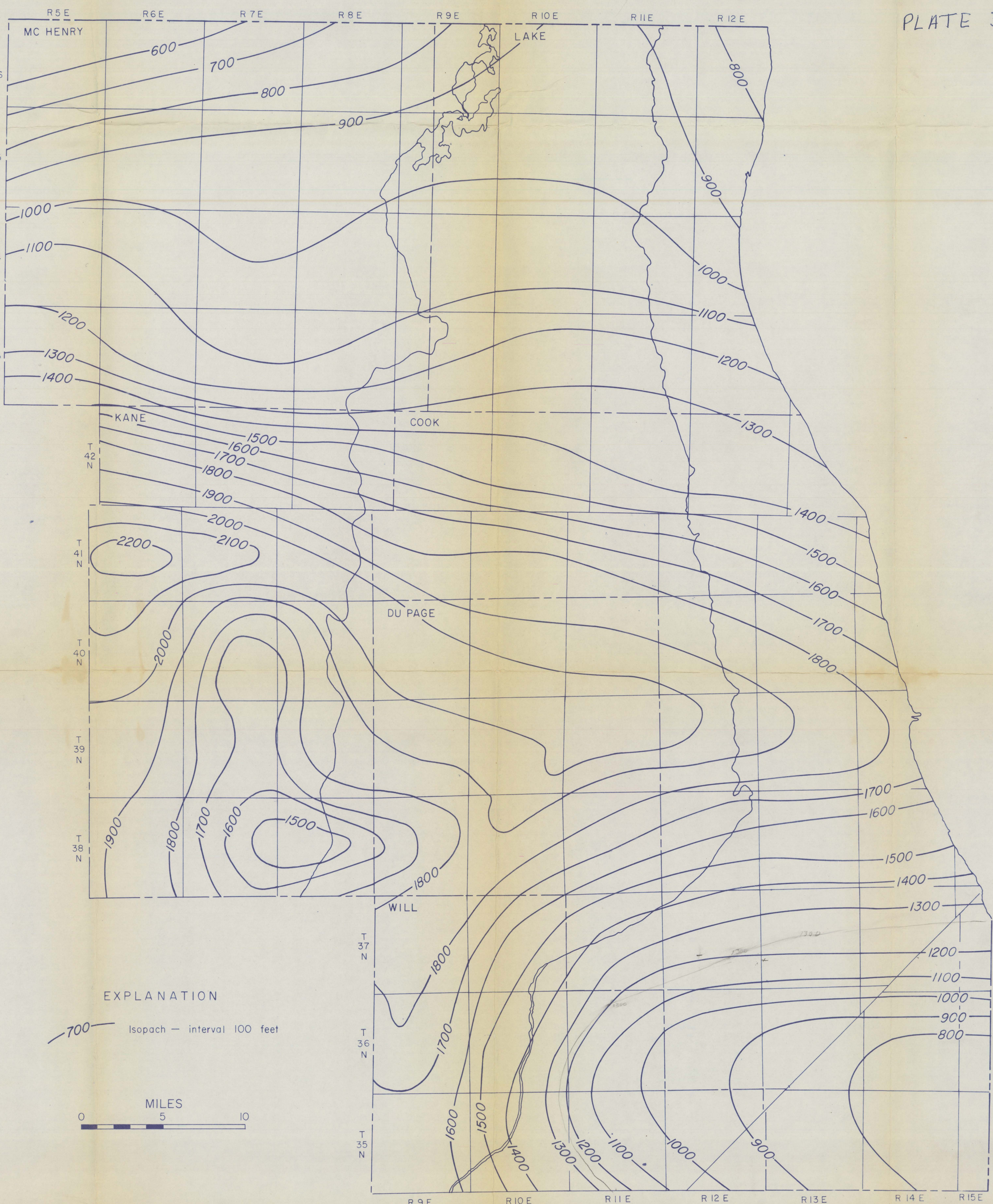


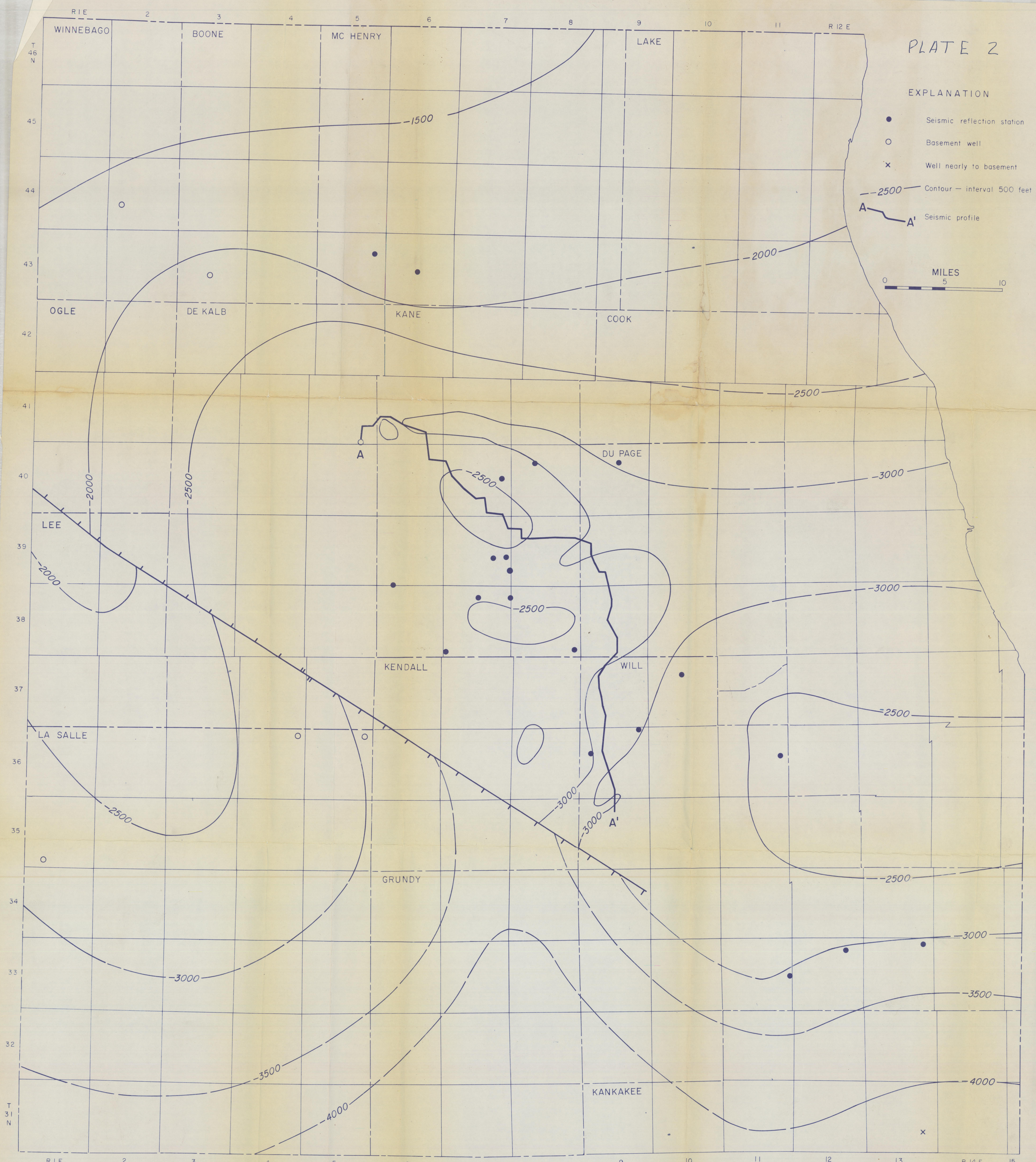
PLATE 1. SIMPLE BOUGUER GRAVITY MAP OF NORTHEASTERN ILLINOIS

by PAUL C HEIGOLD and LYLE D McGINNIS

PLATE 3



PRELIMINARY MOUNT SIMON AQUIFER ISOPACH OF NORTHEASTERN ILLINOIS FROM GEOLOGIC AND SEISMIC REFLECTION STUDIES



PRELIMINARY CONTOUR MAP OF THE TOP OF THE PRECAMBRIAN CRYSTALLINE ROCKS IN NORTHEASTERN ILLINOIS FROM SEISMIC REFLECTION STUDIES AND SIX DEEP WELLS