STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION

# GEOLOGIC SIGNIFICANCE OF THE GRAVITY FIELD IN THE DE WITT-MC LEAN COUNTY AREA, ILLINOIS

Paul C. Heigold
Lyle D. McGinnis
Richard H. Howard

ILLINOIS STATE GEOLOGICAL SURVEY
John C. Frye, *Chief* URBANA

CIRCULAR 369 1964

# GEOLOGIC SIGNIFICANCE OF THE GRAVITY FIELD IN THE DE WITT-MC LEAN COUNTY AREA, ILLINOIS

**Paul C. Heigold, Lyle D. McGinnis, and Richard H. Howard**

ABSTRACT

A least-square method of analysis is applied to a reconnaisance gravity survey of the DeWitt-McLean County area, Illinois. Bouguer anomalies are theoretically divided into components which best correspond with various geologic features. Maps of the Bouguer anomaly and its components are examined and evaluations are made.

In central Illinois, the major trends on the Bouguer anomaly map are primarily of Precambrian origin. Buried bedrock valleys are difficult to map by gravity methods in this area due to the low density contrast between glacial drift and bedrock. Even so, a significantly high percentage of the larger bedrock valleys coincide with lows on the residual gravity map to indicate a direct correlation. Rather good correlation exists between known geologic structures and the differences of regional gravity surfaces in those areas where deep well control on the key structural datum is good.

## INTRODUCTION

During the summer of 1963 a reconnaisance gravity survey of the DeWitt-McLean County area in central Illinois was conducted by the Illinois State Geological Survey (plate 1). The report area (fig. 1) was covered by a gravity network with approximately one mile grid spacing, or more precisely, everywhere that point elevations were given on the 15 minute topographic maps of the area. This area was selected following the discovery of the Wapella East oil pool in late 1962 (Howard, 1963); however, it is only a portion of a larger Survey program that ultimately will cover the state of Illinois with a gravity network of one mile grid spacing.

The instrument employed was a World-Wide Gravity Meter. This meter is of the null reading, temperature compensated variety and has a scale constant of approximately .1 milligal per scale division.

All data reduction beyond the manual correction of the observed gravity for meter drift was performed on the CDC 1604 computer at the University of Illinois. This included the standard calculations of the Bouguer anomalies and also the various degree surfaces that served as least square approximations (regional gravity surfaces) to the Bouguer anomaly surface.

Sections in this paper on "Gravity Data Reduction and Theory," and "Regional Differences and Structures" were prepared by Heigold, who also directed the field work; McGinnis prepared the section on "Bedrock and Present Topography, Structures, and Residuals" while Howard constructed the structural map and wrote the section on "Structural and Stratigraphic Setting". The authors wish to express their appreciation to John W. Mack and Associates of Madison, Wisconsin, who made available their 1604 Fortran Gravity Reduction Program.

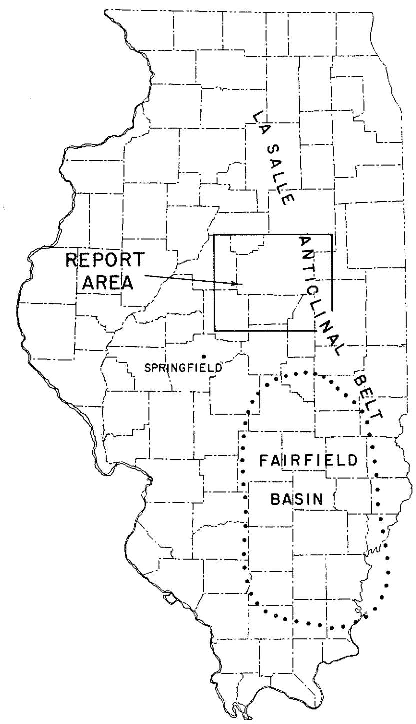


Figure 1 - Location of DeWitt-McLean County area.

## STRUCTURAL AND STRATIGRAPHIC SETTING

The report area is in the northern part of the Illinois Basin just north of the deepest part, which is called the Fairfield Basin (fig. 1). Four-fifths of the area is west of the steepest dips along the western flank of the LaSalle Anticlinal Belt. In the basin, rock strata dip regionally southeastward to southward at an average rate of about 25 feet per mile.

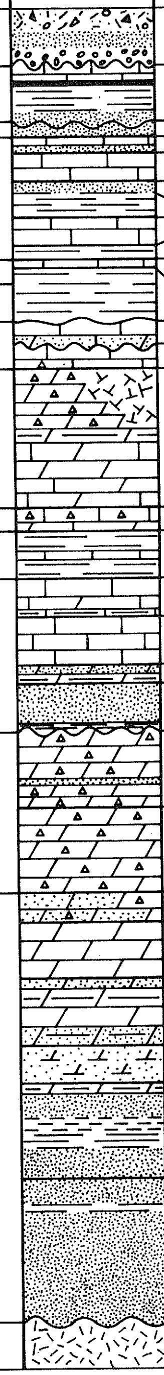
Stratigraphic position, gross lithology, and approximate thickness of sedimentary strata are shown in figure 2. Recent study (Howard, in preparation) shows that Niagaran reef-rock up to 350 feet thick accumulated in many parts of the area. Although reef-rock is somewhat more dense than interreef rock, the effect on the gravity field should be much less than that produced by variations resulting from deformation and truncation of structures by erosion.

Howard shows that the present structural configuration of the Wapella East area is mainly due to tectonic deformation rather than by differential compaction over a Niagaran reef.

Major unconformities exist at the base of the glacial drift, base of the Pennsylvanian, base of the Devonian, base of the Middle Ordovician St. Peter Sandstone, and base of the Cambrian. The geologic structure map (fig. 3) is drawn using the top of the Devonian-Silurian Hunton Limestone Megagroup as a datum, except in the northeastern corner where the unconformity beneath the glacial drift cuts into the Hunton and the base of the Hunton is used as a datum.

The structural grain of the area is dominated by Gibson City and Mahomet Domes on the LaSalle Anticlinal Belt in ranges 7E. and 8E. and by the Downs Anticline and the Parnell and Deland Domes in the middle of the area. The steeply dipping western flanks of both the Downs Anticline and the Mahomet and Gibson City Domes attest to their genetic similarity. Structural control in most of the western half of the area is sparse.

Although the major development of the LaSalle Anticlinal Belt and associated folds came in early Pennsylvanian time, considerable deformation occurred after Pennsylvanian time.



| SYSTEM | SERIES | GRAPHIC COLUMN | FORMATION OR GROUP | THICKNESS (FEET) |
|---|---|---|---|---|
| QUATERNARY | PLEISTOCENE | | | 0 - 400 |
| PENNSYLVANIAN | | | | 350 - 800 |
| MISSISSIPPIAN | CHESTERIAN | | | 0 - 100 |
| | VALMEYERAN | | Ste. Genevieve | 60 - 100 |
| | | | St. Louis – Salem | 180 - 200 |
| | | | Sonora | 40 - 60 |
| | | | Warsaw | 90 - 180 |
| | | | Keokuk – Burlington | 120 - 220 |
| | | | Fern Glen | 40 - 70 |
| | KINDERHOOKIAN | | Chouteau | 15 - 40 |
| DEVONIAN | UPPER | | New Albany | 80 - 220 |
| | MIDDLE | | Cedar Valley (Hunton Megagroup) | 0 - 50 |
| | | | Wapsipinicon (Hunton Megagroup) | 0 - 40 |
| SILURIAN | NIAGARAN | | (Hunton Megagroup) | 275 - 700 |
| | ALEXANDRIAN | | (Hunton Megagroup) | 25 |
| ORDOVICIAN | CINCINNATIAN | | Maquoketa | 200 |
| | CHAMPLAINIAN | | Galena | 150 - 180 |
| | | | Platteville | 200 - 250 |
| | | | Joachim | 40 |
| | | | St. Peter | 230± |
| | CANADIAN | | Shakopee | 300± |
| | | | Oneota | 425± |
| CAMBRIAN | CROIXAN | | Eminence | 75± |
| | | | Potosi | 250± |
| | | | Franconia | 275± |
| | | | Ironton–Galesville | 150± |
| | | | Eau Claire | 575± |
| | | | Mt. Simon | 2000 est. |
| PRECAMBRIAN | | | | |

EXPLANATION

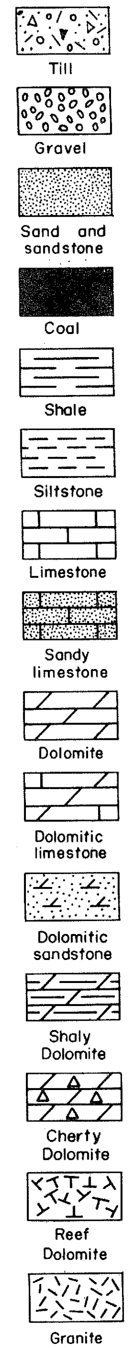
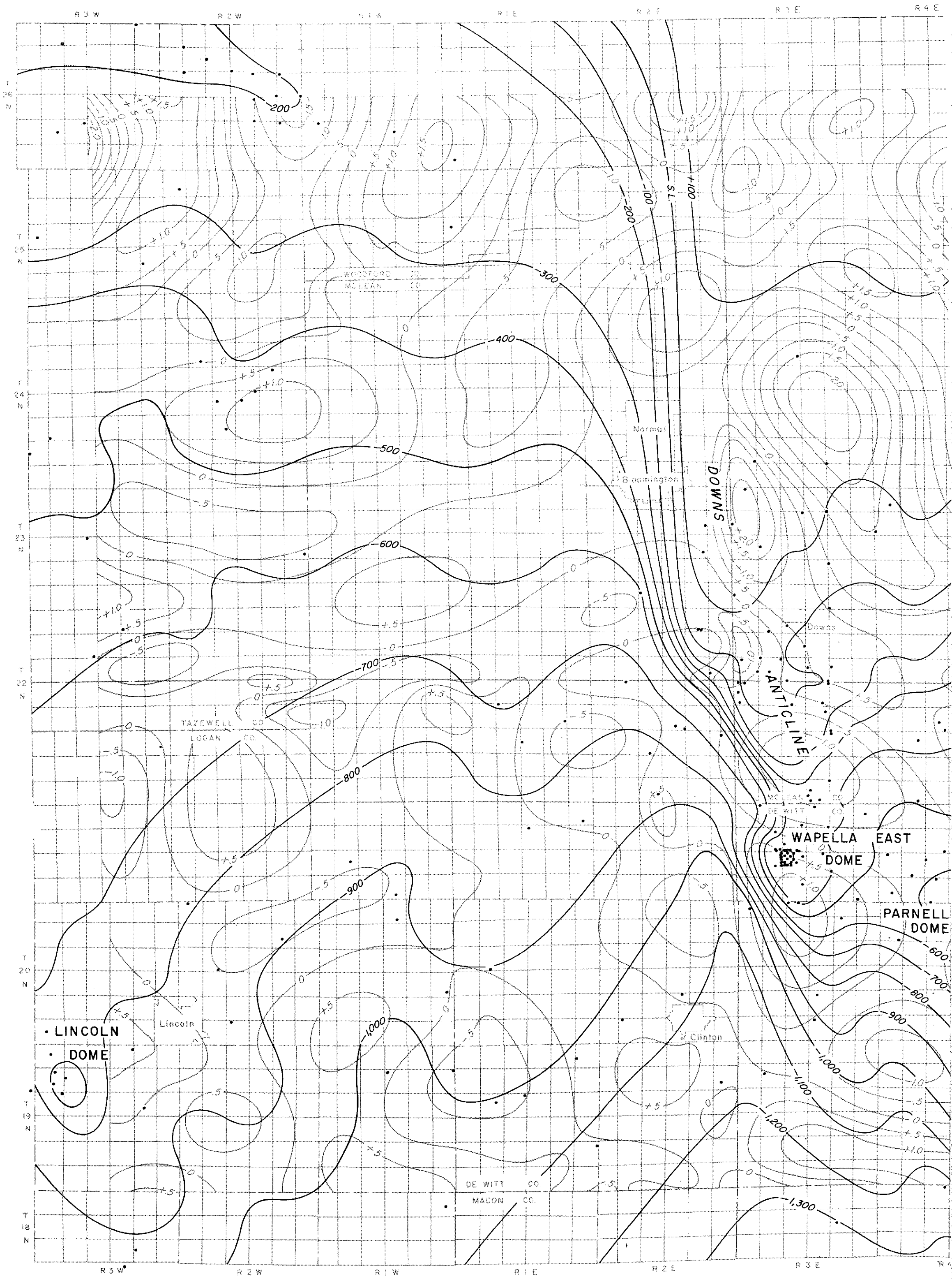
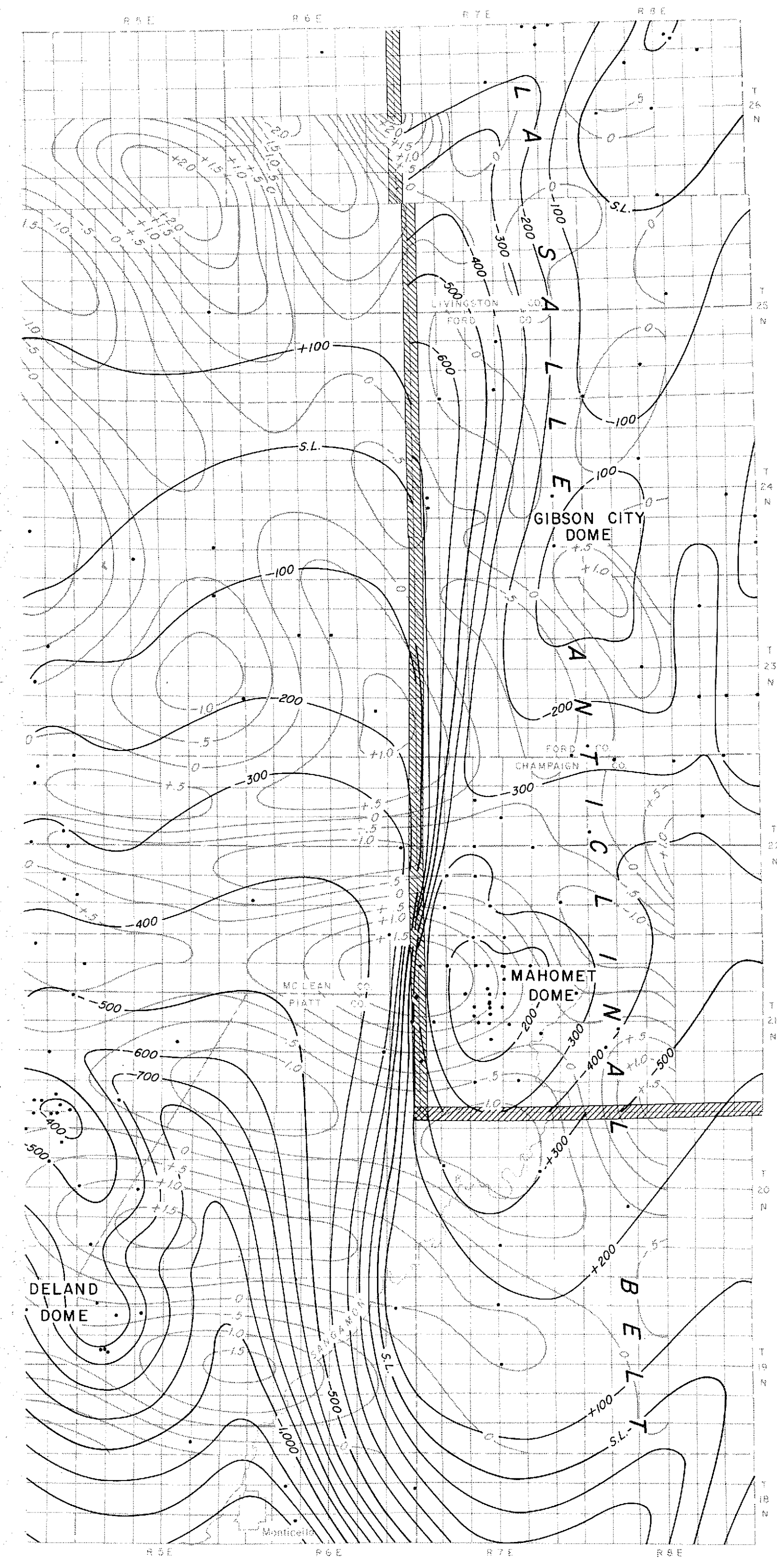



Figure 2 - Generalized columnar section for the DeWitt-McLean County area.


R 3 W
R 2 W
R 1 W
R 1 E
R 2 E
R 3 E
R 4 E
T 26 N
T 25 N
T 24 N
T 23 N
T 22 N
T 20 N
T 19 N
T 18 N
WOODFORD CO.
McLEAN CO.
TAZEWELL CO.
LOGAN CO.
DE WITT CO.
MACON CO.
Normal
Bloomington
Downs
Lincoln
Clinton
DOWNS
ANTICLINE
WAPELLA EAST
DOME
PARNELL
DOME
LINCOLN
DOME
S.L.
-100
-200
-300
-400
-500
-600
-700
-800
-900
-1,000
-1,100
-1,200
-1,300
+100



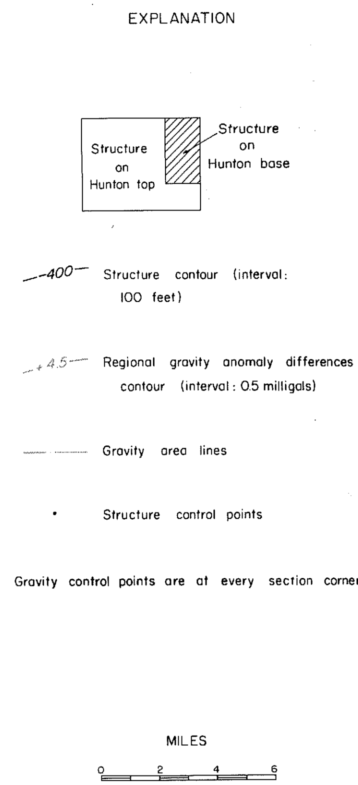




Figure 3 - Geologic structure and regional gravity anomaly differences, DeWitt-McLean County area.

## GRAVITY DATA REDUCTION AND THEORY

The gravity survey was tied to the gravity control network in North America at Springfield, Illinois Station (WA 23) reported by Behrendt and Woollard (1961). Corrections, which were applied to the observed gravity values in order to obtain Bouguer gravity, include meter drift, free air, and Bouguer corrections. Terrain corrections were neglected because of the small variance in topographic elevation throughout the surveyed area. Meter drift was determined by repeated readings at a base station throughout the field day. Free air and Bouguer corrections were combined under the assumption of 2.35 gm/cc density for surficial glacial drift as determined by McGinnis, Kempton, and Heigold (1963). Elevations listed at section corners and bench marks on United States Geological Survey topographic maps have an accuracy of ±1 foot, which is sufficient for regional gravity surveys. Meter drift and the combined free air-Bouguer corrections contributed errors of ±.05 mg and ±.06407 mg, respectively, to the value of Bouguer gravity.

Theoretical gravity was based on the "1930 International Formula"

$$g_o = 978.049\ (1 + .0052884 \sin^2 \phi - .0000059 \sin^2 2\phi) \qquad (1)$$

where $\phi$ = latitude.

Stations were located accurately to ±.1 minute of latitude, so theoretical gravity was subject to an error of ±.075 mg.

From these considerations, it follows that the Bouguer anomaly, that is, Bouguer gravity minus theoretical gravity, is accurate to ±.19 mg.

In the analysis of gravity data, the problem of interpretation ultimately reduces to dividing the Bouguer anomaly into a regional Bouguer anomaly and a residual Bouguer anomaly.

residual Bouguer anomaly = Bouguer anomaly - regional Bouguer anomaly (2)

The regional Bouguer anomaly surface is usually some sort of approximation to the Bouguer anomaly surface. In this paper, the approximation, like the Bouguer anomaly surface, $g(x, y)$, is based on Bouguer anomaly values at N distinct points and follows from the method and theory as outlined by Mack (1963) and by Coons, Mack, and Strange (1964).

The regional Bouguer anomaly surface, $g^*(x, y)$, has the form of a power series in x and y,

$$g^*(x, y) = a_1 + a_2x + a_3y + a_4x^2 + a_5xy + a_6y^2 + \ldots . \qquad (3)$$

Equation 2 may be written

$$\Delta g = g(x, y) - g^*(x, y). \qquad (4)$$

The regional Bouguer anomaly surface is determined subject to Gauss' principle of least squares,

$$\Delta G = \sum_{i=1}^{N} [g(x_i, y_i) - g^*(x_i, y_i)]^2 = \text{minimum} \qquad (5)$$

The necessary conditions for $\Delta G$ to be minimum are given by

$$\frac{\delta \Delta G}{\delta a_j} = 0 \qquad j = 1 \ldots n. \qquad (6)$$

These conditions provide n linear equations in n unknowns, the $a_j$'s. The solution of these equations provides the $a_j$'s that in turn provide the desired $g^*(x, y)$ surface.

The degree of the power series $g^*(x, y)$ is arbitrary. The higher the degree, the better $g^*(x, y)$ approximates $g(x, y)$. It is interesting to note that the number of $a_j$'s in the power series of degree p, where all terms are present, is given by $n = \frac{1}{2}(p+1)(p+2)$, and if n = N then $g^*(x, y) = g(x, y)$.

The area surveyed was rectangular in shape with a rather even distribution (approximately 1 mile spacing) of almost 4000 points. Because of the limited capacity of the CDC 1604 computer employed to calculate the high degree $g^*(x, y)$ surfaces, the overall area was subdivided into 4 equally sized and shaped overlapping rectangular areas, and the various $g^*(x, y)$ surfaces were computed as in the manner previously described for each quadrant. The result of combining the $g^*(x, y)$ surfaces of the same degree for each quadrant is equivalent to calculating a $g^*(x, y)$ surface of twice that degree for the whole area.

## Bouguer Anomaly Map

The Bouguer anomaly is the deviation of the Bouguer gravity from the theoretical gravity. In central Illinois, the Bouguer anomaly is influenced by three major factors. Not necessarily in order of importance, these factors are:

1. Structures, unconformities, and lithologic changes in the sedimentary column.
2. Relief on the basement surface.
3. Lateral density changes in the crystalline portion of the earth's crust and upper mantle.

Because of the density contrast afforded by Paleozoic sediments overlying crystalline basement rocks, the broad trends in the Bouguer anomaly surface (plate 1) would be expected to correlate directly with basement topography; however, this is not found to be the case in Illinois. Bouguer anomaly values in central Illinois (average elevation of basement is about 5,000 feet below sea level) are not generally lower than Bouguer anomaly values (McGinnis et al., 1963) in north-central Illinois (average elevation of basement about 2,000 feet below sea level). In fact, there are Bouguer anomaly values in north-central Illinois at least 10 mgs. less than any Bouguer anomaly value in central Illinois. This raises the possibility that the dominant factor on the Bouguer anomaly map is lateral variation in density in the crust and upper mantle portions of the earth.

In the report area, several features on the Bouguer anomaly map appear to have no direct correlation with structure. The predominant trend on the Bouguer anomaly map, the broad northwest-southeast trending high extending through the entire area, appears to be associated with the LaSalle Anticlinal Belt, but its offset to the west of the steepest dips indicates that no direct correlation exists between the Bouguer anomaly surface and structure. The sizeable broad low on the eastern side of the area just south of Fisher (T.21N., R.8E.) cannot be correlated with any feature of the Paleozoic section. Also, a feature that most certainly must be of basement origin is the rather sharp high located north of Bloomington between Towanda and Lexington (T.25N., R.3E.). A rough calculation indicates that an anomaly of this size must have its origin somewhere between 2 or 3 miles below the surface of the earth. Woollard (1962) has indicated that such gravity features are prevalent in Paleozoic basins such as the Illinois Basin.

Lateral density variations in the crust and upper mantle are explained by the two currently accepted hypotheses concerning the nature of the Mohorovicic Discontinuity. According to the chemical discontinuity hypothesis (Wyllie, 1963), the M Discontinuity is believed to be caused by a chemical change from basaltic rock (density 2.70 -3.00 gm/cc) of the lower crust to peridotite (density 3.15-3.28 gm/cc) in the upper mantle (mean chemical composition of upper mantle over any extensive region, four parts peridotite to one part basalt). At appropriate depths, the basaltic portion of the peridotite in the upper mantle changes to eclogite (density 3.415 gm/cc) (densities from Birch et al., 1942).

According to the phase change hypothesis (Wyllie, 1963), the Mohorovicic Discontinuity is a phase change from basalt to eclogite. The great attraction of this hypothesis lies in the fact that vertical movements of isogeotherms cause M to move up and down producing local changes in crustal thickness.

In order that basins be gravity highs, it is necessary that the negative gravity anomalies which have been caused by sediments filling the basins in the crystalline rocks of the crust, be overcompensated by positive anomalies resulting from sufficiently large masses with positive density contrast at greater depths. Wyllie (1963) has constructed a model involving a combination of the aforementioned hypotheses concerning the nature of the Mohorovicic Discontinuity where such a situation could possibly exist.

### Residual Gravity Map

In an attempt to rid the Bouguer anomaly map of the unwanted regional trends, the 9th (18th when the total area is divided into four parts) degree power series approximation to the Bouguer anomaly surface was used for the regional trend surface. This surface, when subtracted from the Bouguer anomaly surface, eliminates the effects of extremely deep seated density contrasts in the crust and upper mantle. After this subtraction, all that remains in the residual map (plate 1) are anomalies primarily due to the first two factors discussed in the section on the Bouguer anomaly map, and possibly some of the steeper gradient anomalies due to the third factor. Perhaps, the best example of this latter effect is the positive anomaly just north of Bloomington, between Towanda and Lexington. The subtraction of the 9th degree regional decreased the amplitude of the original Bouguer anomaly but did not eliminate it. This indicates that the anomalous mass is in the upper portion of the crystalline crust because the lateral dimensions of the gravity anomaly are small in relation to its amplitude. A large portion of the small but relatively sharp anomalies present on the residual gravity map may originate from the drift-bedrock unconformity.

## BEDROCK AND PRESENT TOPOGRAPHY, STRUCTURES, AND RESIDUALS

Correlating gravity residuals with shallow structures is complicated by bedrock topography, especially where bedrock topographic features and geologic structures more or less coincide. Knowledge of bedrock configuration is useful, therefore, in the analysis of the residual gravity field besides being important from a groundwater standpoint. Buried bedrock valleys often contain large quantities of saturated sand and gravel of high porosity and permeability, which represent some of the most important shallow aquifers in the state.

Interpretation of the bedrock configuration may, therefore, be aided by correlating bedrock valleys with residual gravity lows. In a regional manner, bedrock elevations can be correlated with surficial elevations, but intricate bedrock drainage systems can be correlated with surficial drainage systems only in areas of thin drift.

## Bedrock Topography

The Mahomet bedrock valley system in central Illinois is located in what Horberg (1950) called the Pennsylvanian Lowland Division of the preglacial physiographic divisions in Illinois.

Figure 4 shows the topography of the bedrock surface, at a 25 foot contour interval, based on approximately 700 wells, of which about 30 percent reach bedrock. Residual gravity trends have influenced the authors' positioning of valley trends in areas of sparse well control. The major valley trends are quite similar to those of Horberg (1947). The smaller valleys are defined more clearly on the present map due to the utilization of a smaller contour interval and the accumulation of additional control points during the seventeen years since publication of Horberg's map. The additional data also indicate narrower bedrock channels than shown by Horberg.

## Present Topography

The area included in the gravity survey is in the till plains section of the Central Lowland province and is a region of young till plains and broad, low morainic ridges. The drift ranges from 0 to 400 feet thick but is 200 feet or more in most of the the area. The present drainage system bears little resemblance to the bedrock drainage system.

## Structures and Bedrock Topography

As stated by Horberg (1950), the Mahomet Valley "transgresses regional structural trends"; however, the valley is diverted sharply to the south a distance of about 27 miles when it approaches the east flank of the LaSalle Anticlinal Belt and the Gibson City-Mahomet axis. It then swings back to the north more than 20 miles after passing around the Downs Anticline (fig. 5). In so doing, the major bedrock valley conforms to and roughly outlines ancient structures. The relation of smaller bedrock tributary valleys to structure is not clear because of the paucity of both structural and bedrock control; however, as will be discussed later, inferences can be made from gravity data.

A broad bedrock high is located over Downs Anticline, while a small circular bedrock high coincides exactly with Wapella East Dome. An oval bedrock high is also located directly over Mahomet Dome. The relation between the other structural domes and bedrock topography is not quite so obvious although both Gibson City and Deland Domes are located in broad bedrock uplands. Parnell Dome is located on the northwest flank of Harris Bedrock Valley.

Surface drainage in the central Illinois region is usually interpreted with reference to the glacially constructed topography and without consideration of bedrock structure or topography. The geologic map of Illinois (Weller et al., 1945) shows that in the vicinity of the LaSalle Anticlinal Belt, (with few exceptions) surface drainage does not cross the belt but flows away from it. One exception occurs where the Sangamon River flows southwest through the Champaign moraine. The Mahomet bedrock valley underlies the Sangamon River in this zone and may cause a slight surficial sag. Present drainage patterns are thus in subtle accord with structure in the surveyed area as indicated by drainage away from the Downs Anticline and the LaSalle Anticlinal Belt (fig. 5). Morainic ridges provide the primary control over the pattern of surficial drainage, but structures and bedrock highs also show some influence. This may reflect in a subdued fashion the draping effect of thick drift over bedrock uplands.


Figure 4 - Topography of bedrock surface in DeWitt-McLean County area. Bedrock elevations are in feet above sea level. Contour interval 25 feet.

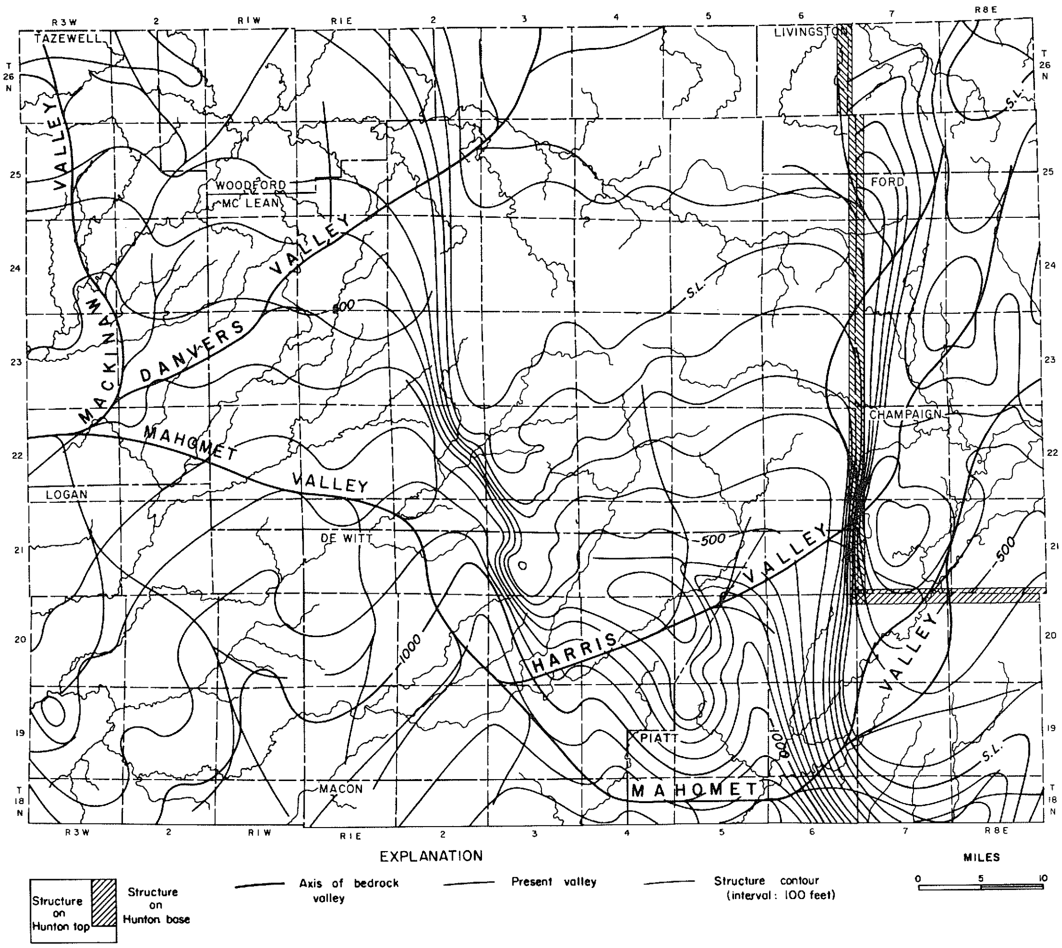



Figure 5 - Present drainage system, bedrock valley system, and major structures of DeWitt-McLean County area.

## Residuals

McGinnis, Kempton, and Heigold (1963) illustrated a close correlation between gravity residuals and bedrock valleys in northern Illinois where the valleys are, for the most part, cut into high density ($2.70^{+}$ gm/cc) Ordovician carbonate rocks and are filled with glacial drift that ranges in density from about 2.0 to 2.5 gm/cc. Smaller residual anomalies should be associated with bedrock valleys in central Illinois where bedrock consists mainly of thinly bedded shales interbedded with sandstones, limestones, underclays, and coals of Pennsylvanian age, which have relatively low density. Mack (1963) reported that average Pennsylvanian densities are in the order of 2.5 gm/cc. In a recent study (Gipson, 1963), Pennsylvanian shales were shown to have porosities ranging from 3 to 15 percent. If particle densities of shales can be assumed to be in the order of 2.67 gm/cc, the saturated bulk densities of these shales would range from about 2.40 to 2.63 gm/cc. Shale densities near the bedrock surface might be expected to be somewhat lower due to weathering, causing a density contrast, if any, to be very small; however, if the bedrock valley were filled with low density sands and gravels, the density contrast would be increased. A density contrast of .1 gm/cc would require bedrock relief of 400 feet in order to produce an anomaly of .5 milligals. Since maximum relief of the bedrock surface in this area is about 400 feet (fig. 4), correspondence of valley and anomaly trends could be due to reasons other than drift-bedrock density contrasts or to valley fill of lower density than 2.35 gm/cc.

The following indicates the total length of each major valley in the contoured area and the percent of the valley that falls in residual gravity lows.

| Valley | Total Length (miles) | Length in Residual Low (miles) | Percent in Residual Low |
|---|---|---|---|
| Mahomet | 109 | 73 | 67 |
| Harris | 76 | 49 | 65 |
| Danvers | 39 | 36 | 92 |
| Mackinaw | 28 | 20 | 71 |
| Total | 252 | 178 | 71 |

The Harris Bedrock Valley, as shown on figure 6, is named in this report after the village of Harris in section 36, T.21N., R.5E. The total length as listed above includes both northern branches of the valley because of insufficient data to select the major valley. A reversed seismic refraction spread (fig. 7), one half mile south of Harris, was completed after construction of the bedrock valley map. Interpretation of the spread yields a drift thickness of about 353 feet, which results in a bedrock elevation of about 362 feet. This elevation is within 25 feet of that shown on figure 4 and confirms the existence of Harris Valley. The other valleys were named by Horberg (1950). The valleys listed above have been contoured solely on the basis of wells; whereas, residual gravity trends have influenced the authors positioning of the other valleys where bedrock control is sparse. Valleys contoured on the basis of one or two wells are subject to major revision and are not named.

The percentages shown above may be altered somewhat in the future depending on the interpretation of valley trends and on additional well control. Since the gravity lows comprise about 50 percent of the total area (due to the method of least square fitting and as confirmed by planimeter measurements), the consistently greater percent of the valleys landing in residual gravity lows must indicate a density contrast between the glacial drift and bedrock or the location of bedrock valleys along structurally disturbed zones. Both alternatives probably are involved, to a greater or less degree, depending on the various characteristics of the valley such as the type of sediment in the valley and its age and origin.

In order to get a better look at the factors that might cause residual anomalies below the bedrock-drift interface and on or above the basement surface, some method must be employed to eliminate those anomalies that are caused by factors outside of this vertical range. The method used in this paper is that suggested by Mack (1963) and involves the differences between two regional surfaces.

## REGIONAL DIFFERENCES MAP

The Bouguer anomaly surface is approximated first by a power series of high enough degree, $g^*_H$, so that when the power series approximation is subtracted from the Bouguer anomaly surface ($g-g^*_H$) only the very small period anomalies are left. Ideally, this subtraction would yield only the anomalies caused by density contrasts close to the surface of the earth.

Next, the Bouguer anomaly surface is approximated by a power series of adequately low degree, $g^*_L$, so that, when the power series approximation is subtracted from the Bouguer anomaly surface ($g-g^*_L$), all anomalies except those caused by very deep density contrasts remain.

The former difference is then subtracted from the latter, that is, $(g-g^*_L) - (g-g^*_H)$. Carrying out the subtraction one arrives at $g^*_H - g^*_L$. The map of this quantity is in essence a map of anomalies that are not of bedrock-drift or of crystalline rock origin.

As explained in the section on the residual gravity map, the 9th degree power series was used to eliminate the very large anomalies caused by very deep lateral variations in density. In this phase of the study, this would correspond to the $g^*_L$ surface. As witnessed from the residual map (plate 1), this surface did remove the gross trends from the Bouguer anomaly map. So this $g^*_L$, or $g^*_9$, serves its purpose, not perfectly, but well.

The best $g^*_H$ available from the program employed is that of the 13th degree power series approximation to the Bouguer anomaly surface. Actually, $g^*_H = g^*_{13}$, or more correctly $g-g^*_{13}$, probably yields not only the anomalies due to the drift-bedrock contact but also anomalies of slightly larger period, whose origins are situated in the Paleozoic section.

It follows then that the regional difference, $g^*_{13}-g^*_9$, represents anomalies owing their origin to density contrasts fairly deep in the sedimentary column and possibly even as deep as the Precambrian surface. Such a regional difference map (fig. 3) should compare favorably with a detailed geologic structure map of a deep rock formation in the surveyed area.

Because of the reasonable appearance of the difference of one pair of regional surfaces or another and also because of the heuristic value, various combinations of regional differences were employed throughout the area. Mack (1963) employed similar regional differences to examine structures in the sedimentary column. The areas and difference values are mapped as follows:

| | | | |
|---|---|---|---|
| Area #1 (SE Quad.) | $g^*_{13}-g^*_{11}$ | Area #3 (SW Quad.) | $g^*_{13}-g^*_9$ |
| Area #2 (NE Quad.) | $g^*_{11}-g^*_9$ | Area #4 (NW Quad.) | $g^*_{13}-g^*_9$ |

The four areas into which the surveyed area has been divided overlap several miles. Thus, the power series surfaces transcend the area division lines rather smoothly. In the indicated areas, the power series surfaces actually have been determined so that they fit points from the other areas. When surfaces are reduced to the areal extent indicated (fig. 3), smoothness is present in the contours at their abuttment. This is not the case along the outside borders of the surveyed area. Here, the power series surfaces are fitted up or down contingent on whether the last inflection of the Bouguer anomaly surface was up or down. For this reason, a three mile band surrounding the surveyed area has been deleted, enhancing both the appearance and, more importantly, the significance of the regional differences map.

The structure map, which was chosen for the purpose of correlating the regional gravity differences with geologic structure, was prepared for the most part well in advance of the residual differences map (fig. 3). Thus, there was no effort at forced correlation. In comparing the two maps, there are a few simple rules of thumb that should be followed. First, comparisons should be initiated in areas where good control is indicated on the structure map. Secondly, lack of good correlation, especially in areas of good control in the structure map, should be an indication of density contrasts that are not involved with structure, such as unconformities in the sedimentary column. It may indicate failure of the method employed in obtaining the regional differences map to exclude all unwanted regional effects.

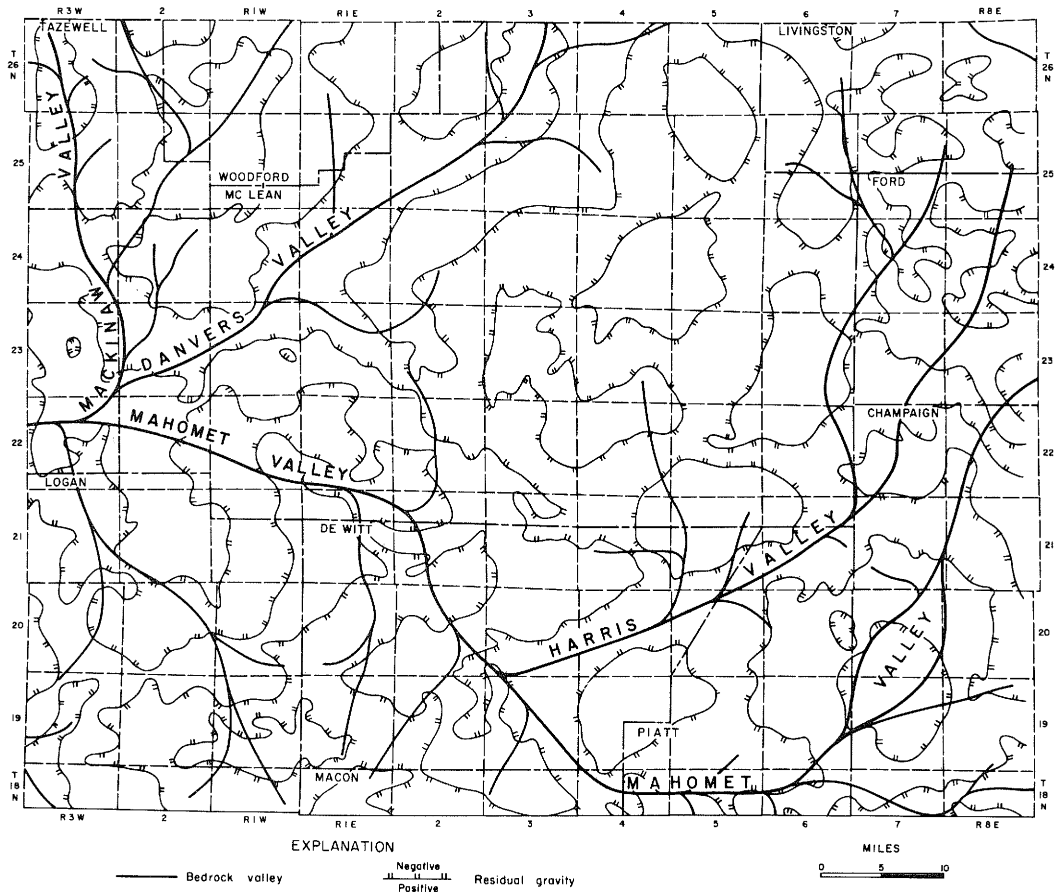



Figure 6 - Bedrock valley system and residual gravity anomalies, DeWitt-McLean County area.

Of considerable interest in this survey is the gravity field around the Wapella East Dome on which oil occurs in Silurian reef-rock (T.21N., R.3E). On the Bouguer anomaly map (plate 1), this shows as a slight nose on a steep gravity gradient decreasing to the west; whereas the residual surface $(g-g^*_9)$ (plate 1) shows it as an east-west trending closed high. The closed high is probably the result of a combination of geologic factors such as structure, bedrock topography, and reef-rock accumulation. Ferris (1964) has "microgravimetrically" profiled the area and shows a residual anomaly of .07 mg directly over the oil pool. The present survey, due to its accuracy of only ±.19 mg and its station spacing, could not be expected to show a residual anomaly as small as this. In order to compare the geologic structure of the Downs Anticline area with gravity data, it is necessary to consult also the regional differences map (fig. 3).

The regional differences map shows rather clearly that most of the gravity features possessing steep gradients occur in the eastern half of the area. These features are bounded on the south by an east-west trend that turns gradually until it assumes almost north-south direction in R.2 and 3E. Of particular interest is the series of highs in T.20N., R.5E.; T.21N., R.3E.; T.23N., R.3E.; T.25N., R.2E.; and T.26N., R.2E. These highs correspond to the high side of the strong westerly

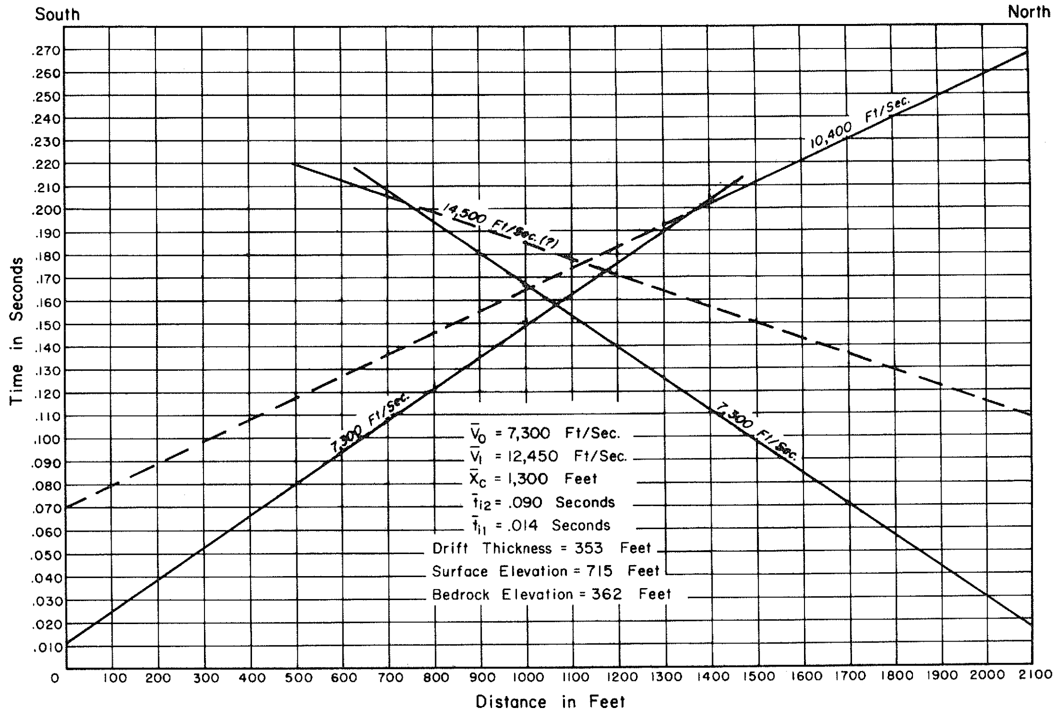



Figure 7 - Reversed time-distance curve, one-half mile south of Harris.

dip on the top of the Hunton. The gravity highs in T.21N., R.3E., and T.23N., R. 3E., correspond quite well with the structural highs. The leveling off on the Hunton top between these two structural and gravity highs is accompanied by a gravity low separating the highs. Another well-defined structural high, the Parnell Dome, in the northeast corner of T.20N., R.4E., just southwest of Farmer City seems to link the gravity highs in T.20N., R.5E., and T.21N., R.3E.

On the eastern side of the map the correlation is not as good. The structural high, Mahomet Dome, in T.21N., R.7E., appears to be related to the gravity high in T.21N., R.6 and 7E., but the gravity high appears to be translated across the strong north-south structural trend indicated there. This may be a failure of the regional approximation technique to remove all unwanted effects. Further credence is given this explanation by the gravity high in T.23N., R.6E., situated on the down dip side of the same north-south structural trend.

Besides those areas already mentioned, there are other areas where correlations can be made or inferred, but most of these are conjectural since control on the structure map is sparse in these areas.

## CONCLUSION

The least square polynomial fitting of gravity data from the DeWitt-McLean County area provided a consistent and economical method of analysis of gravity data free of preconceived ideas on the part of the interpreters. Because of the great amount of information afforded the interpreters in the way of numerous least square polynomial approximations to the Bouguer anomaly surface, this method of analysis had a very desirable flexibility. It was this flexibility that allowed the authors the ability to focus gravity information on several important geologic factors. At the present time, this method of analysis is regarded as quite satisfactory.

## REFERENCES

Behrendt, J. S., and Woollard, G. P., 1961, An evaluation of the gravity control network in North America: Geophysics, v. 26, no. 1, p. 57-76.

Bell, A. H., Atherton, Elwood, Buschbach, T. C., and Swann, D. H., 1964, Deep oil possibilities of the Illinois Basin: Illinois Geol. Survey Circ. 368, 38 p.

Birch, Francis, Schairer, R. J., and Spicer, H. C., 1942, Handbook of physical constants: Geol. Soc. of America, Spec. Paper no. 36, 325 p.

Coons, R. L., Mack, J. W., and Strange, W., 1964, Least-square polynomial fitting of gravity data and case histories: Computers in the Mineral Industries, School of Earth Sci., Stanford Univ., p. 498-519.

Ferris, Craig, 1964, Finding one reef is like finding one ant — look for more reefs in East Wapella: Oil and Gas Jour., v. 62, no. 21.

Gipson, Mack, Jr., 1963, A study of the relations of depth, porosity, and clay mineral orientation in Pennsylvanian shales: Univ. of Chicago Ph.D. theses, 104 p.

Horberg, Leland, 1947, Map of bedrock surface of Illinois: Illinois Geol. Survey

Horberg, Leland, 1950, Bedrock Topography of Illinois: Illinois Geol. Survey Bull. 73, 111 p.

Howard, R. H., 1963, Wapella east oil pool, DeWitt County, Illinois-a Silurian reef: Illinois Geol. Survey Circ. 349, 15 p.

Jakosky, J. J., 1950, Exploration geophysics: Trija Publishing Co., Los Angeles, Californis, 1195 p.

Mack, J. W., 1963, A least-square method of gravity analysis and its application in the study of sub-surface geology: Univ. of Wisconsin Ph.D. thesis, 122 p.

McGinnis, L. D., Kempton, J. P., and Heigold, P. C., 1963, Relationship of gravity anomalies to a drift-filled bedrock valley system in northern Illinois: Illinois Geol. Survey Circ. 354, 23 p.

Meents, W. F., 1954, Preliminary structure map of the "Trenton" in Illinois: Illinois Geol. Survey Map 4103 L-31.

Nettleton, L. L., 1940, Geophysical prospecting for oil: McGraw-Hill Book Co., Inc., New York, 440 p.

Thomas, G. B., Jr., 1956, Calculus and analytic geometry: Addison-Wesley Publishing Co., Inc., Reading, Mass., 822 p.

Weller, J. M., et al., 1945, Geologic Map of Illinois: Illinois Geol. Survey.

Woollard, G. P., 1962, The determination of gravity from elevation and geologic data: Contract AF 23 (601)-3455, Research Rept. no. 62-9, 292 p.

Wyllie, P. J., 1963, The Mohorovicic discontinuity and the orogenic cycle: Natl. Acad. Sci., Internat. Geophysics Bull. 76, p. 12.

Illinois State Geological Survey Circular 369
16 p., 1 plate, 7 figs., 1964

Printed by Authority of State of Illinois, Ch. 127, IRS, Par. 58.25.