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STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION

# Oil Production from the Ste. Genevieve Limestone in the Exchange Area, Marion County, Illinois

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CIRCULAR 436 1969

# OIL PRODUCTION FROM THE STE. GENEVIEVE LIMESTONE IN THE EXCHANGE AREA, MARION COUNTY, ILLINOIS

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## ABSTRACT

The four townships making up the southeastern quarter of Marion County, Illinois, contain seven relatively small oil pools. The major portion of the oil produced from these pools was trapped in oolitic limestones and sandstones of the Ste. Genevieve Formation. The oil appears to be accumulated in stratigraphic traps, as no significant structural closure is evident. A reconstruction of the geologic history of the area, aided by the technique of trend-surface fitting, suggests that structural folding was, however, an important factor in trapping the oil. Subsequent tilting of the area has removed the closure of the structures, but the oil did not escape because of permeability pinch outs of the reservoir beds.

## INTRODUCTION

The four townships in the southeastern corner of Marion County, Illinois, contain several relatively small oil pools. Most of the oil has been produced from various zones in the Ste. Genevieve Limestone, with minor amounts being contributed by sandstones in the lower part of the Chesterian Series. The production from some of the most recently completed wells in the area is from the St. Louis Limestone.

The oil pools are located on gently folded plunging anticlines, having little or no closure. These structures tend to be obscured by an eastward regional dip from the crest of the Salem Anticline on the west toward the Fairfield Basin to the east and south. Some of the oil pools form roughly circular patterns, whereas others are markedly elongated. Those pools with an elongated shape are oriented in various ways with respect to the structure. In some cases, the long axis of the pool is parallel to that of the anticline on which it is located. In other instances, the long axis of the pool lies at right angles to the regional dip and parallel to the structural contours. The latter produces a situation that looks very much like a stratigraphic oil trap. The most striking example of this is shown by the Exchange North Consolidated pool in Secs. 1, 12, and 13, T. 1 N., R. 3 E., and Sec. 6, T. 1 N., R. 4 E. The consolidation of this pool is the result of the northward development of the Slapout pool and eventual merger with the Exchange North pool. The holes downdip from production encountered a permeable zone at the producing horizon, but it was water-saturated. The holes updip of production encountered no permeability in the same zone. Other pools in the area display similar circumstances, although in some cases structural folding appears to play a more important role in controlling the oil accumulation.

The purpose of this study is to analyze the controlling factors of these oil accumulations by means of conventional subsurface mapping techniques supplemented by a trend-surface analysis of the geologic data. The stratigraphic and structural features are then placed in their proper order of importance as controlling factors in the trapping of oil thereby aiding further exploration in those areas in the Illinois Basin that have experienced similar geologic histories.

## LOCATION

The four townships chosen for this study are T. 1 and 2 N., R. 3 and 4 E., lying in the southeastern corner of Marion County, Illinois. Figure 1 shows the location of these four townships with respect to the tectonic features associated with the Illinois Basin. The area can be described as lying on the eastern flank of the Salem Anticline, which forms part of the western margin of the Fairfield Basin. Several factors were considered in choosing this particular area (not necessarily in order of importance): (1) Although several pools lie within the boundaries, the area is small enough to be examined in detail; (2) Oil is produced from several zones, yet a fairly short stratigraphic interval is involved; (3) The size and shape of the area conveniently lend themselves to the automatic plotting techniques used in preparing some of the maps in this report; (4) Recent discoveries of oil in the area have aroused interest within the industry; and (5) Many of the pools in this area appear to be the result of stratigraphic traps. This last item by itself is probably sufficient cause for a detailed investigation of this and other areas within the basin.

## STRUCTURAL SETTING

The gross structural framework of the area is shown in figure 1. A more detailed picture of the structures related to this area is seen in figure 2. The contours in figure 2 are drawn on the base of the Beech Creek (Barlow) Limestone. The structure of the top of the Ste. Genevieve Limestone closely parallels the structure of the Beech Creek. The strike is nearly due north-south in the western half of the area and slightly east of north in the eastern half. An eastward regional dip persists over most of the area. Figure 3 is a detailed structure map with contours drawn on the top of the Ste. Genevieve. The 20-foot contour interval shows the smaller structures that are superimposed on this eastward dip. The oil-producing

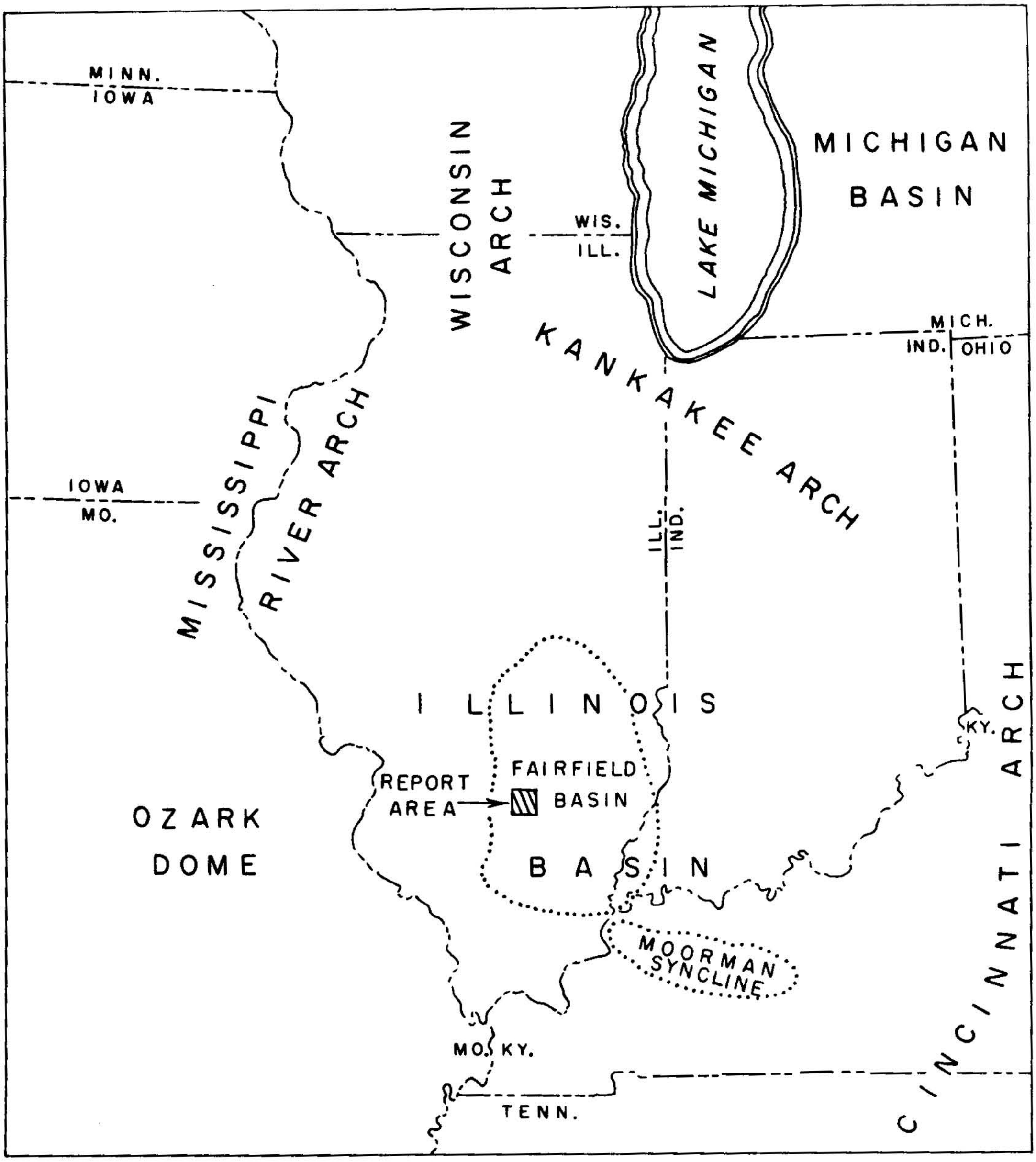



Figure 1 - Index map showing location of report area with respect to major tectonic features.

areas are shown on figure 3. In most cases, the oil is accumulated on positive structural features. However, in most instances, the folding has been minor. The amount of folding ranges from that found at the Iuka pool, located on a relatively strong southward-plunging anticline, to that found at the Exchange West pool, located on a minor structural "wrinkle" having only a slight reversal of dip.

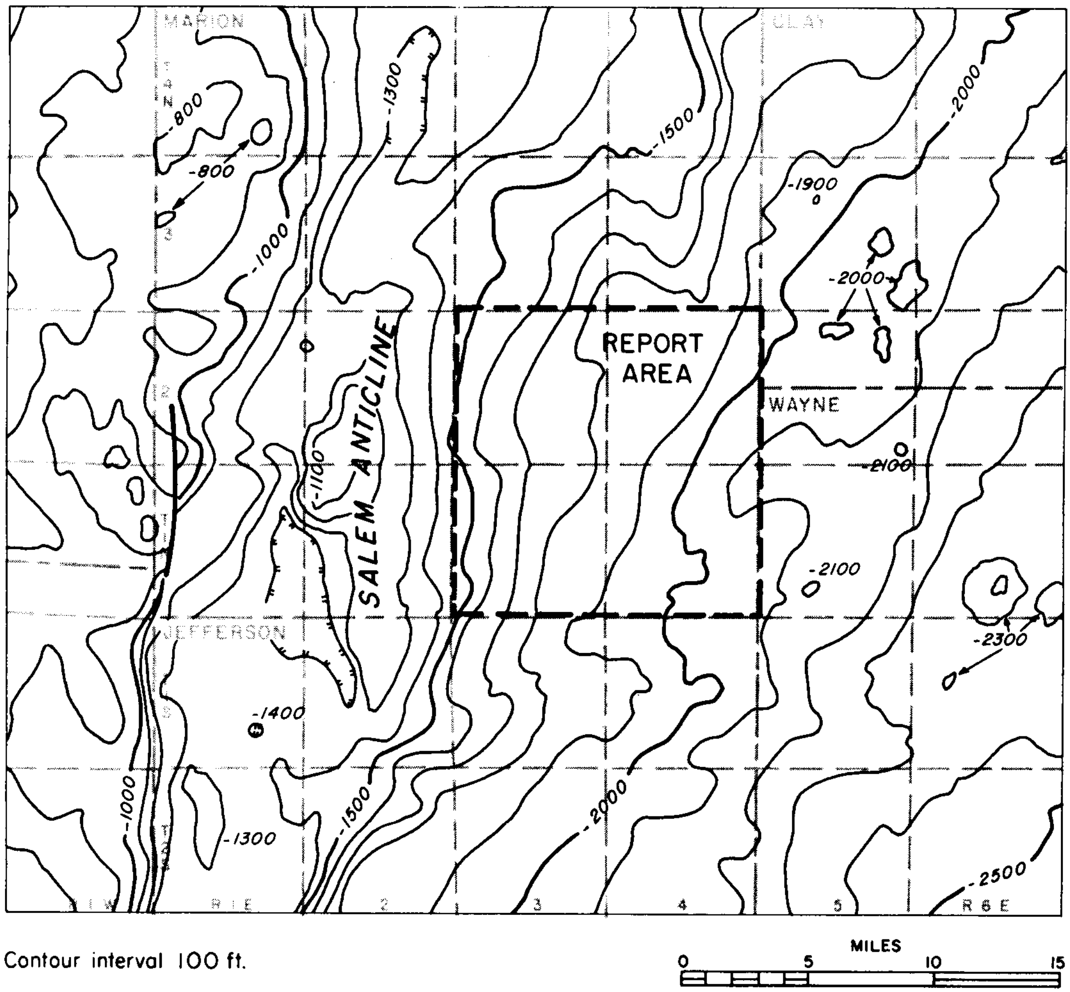



Figure 2 - Structure map on base of Beech Creek (Barlow) Limestone showing location of report area with respect to the the Salem Anticline.

Because of the proximity of the Exchange area to the Centralia area of Brownfield (1954), about 13 miles to the west, it is reasonable to assume a similar structural history for both areas. Brownfield (1954) gives evidence for the existence of the Centralia Anticline and other nearby anticlinal features before "Trenton" (Ordovician) deposition. He shows that the Salem Anticline probably formed during Chesterian (Mississippian) time. The DuQuoin Monocline was formed after Chesterian time. The present structure of the Centralia area was developed prior to deposition of the Carbondale (Pennsylvanian) Formation. Slight structural modification has occurred since then, as a result of compaction and faulting (Brownfield, 1954, p. 30). The structures discussed in this paper were probably formed at approximately the same time as the uplift of the Salem Anticline. The entire area has been tilted downward to the east and south by basin subsidence.

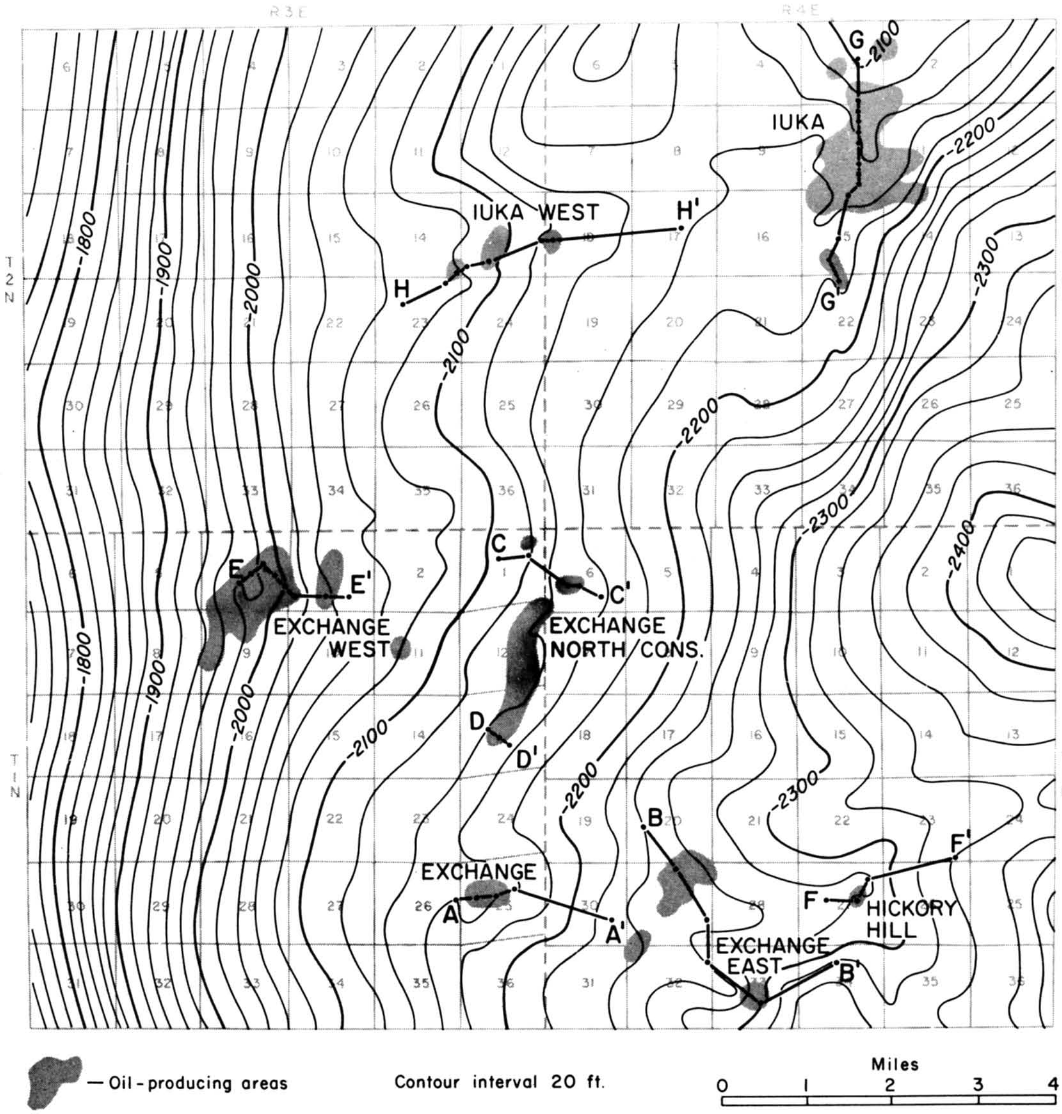



Figure 3 - Structure map on top of Karnak Limestone Member showing oil-producing areas.

## STRATIGRAPHY

Figure 4 is a typical electric log showing the characteristic resistivity and self-potential (S.P.) curves of the strata from the Mississippian-Pennsylvanian contact to a point below the base of the Fredonia Limestone Member of the Ste. Genevieve Formation. All stratigraphic units are not named on the electric log

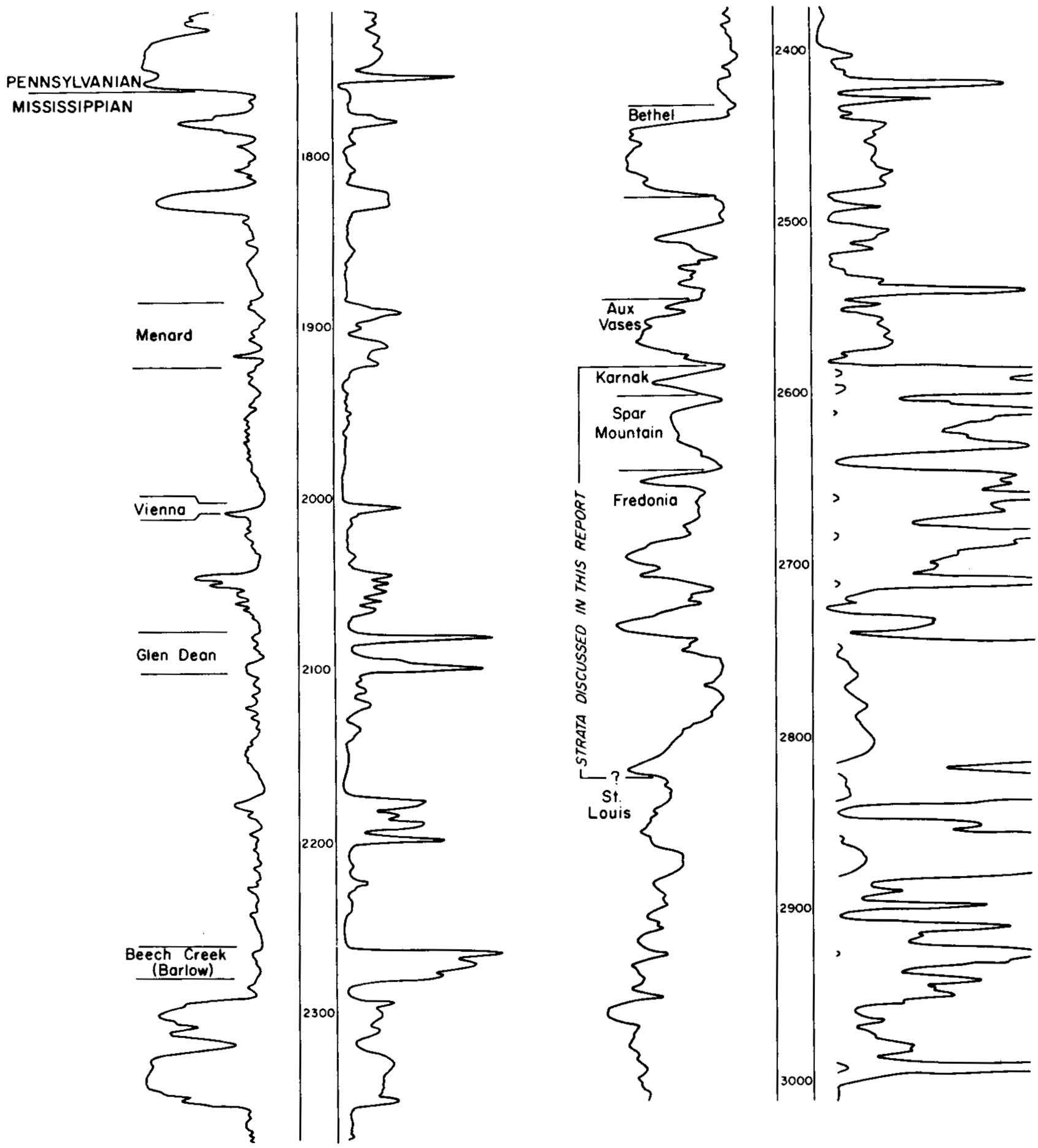



Figure 4 - Typical electric log indicating the strata discussed in this report.

but a sufficient number are identified to aid the reader. The section discussed in this report is indicated on the log. Figure 5 is an idealized representation of this section showing the typical rock types that may be encountered in the area with the potentially productive zones indicated. No hole drilled in the area has found all of these zones to be productive, but they have produced oil at one place or another in one or more of the pools discovered to date.

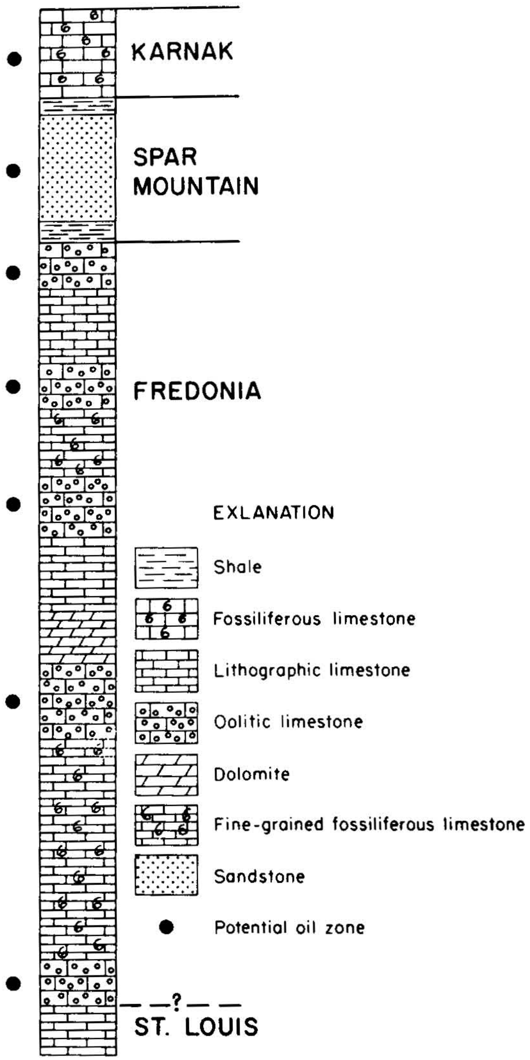



Figure 5 - Idealized Ste. Genevieve section in the Exchange area showing potentially oil-productive zones.

Because most of the oil produced in the area has come from the Ste. Genevieve Limestone, the detailed discussion of stratigraphy is limited to the sequence of rocks lying between the top of the Karnak Limestone Member and the base of the Fredonia Limestone Member.

The Karnak Limestone Member is a light-colored fossiliferous limestone containing abundant fragments of crinoids and other fossil debris. Oolites are quite common in many places. The Karnak is generally quite dense, but in places sufficient permeability has developed to produce fluids. Minor amounts of oil have been produced from this zone. The thickness of the Karnak ranges from 7 to 36 feet in the holes drilled to date. Most commonly it is found to be 20 to 25 feet thick (fig. 6).

Underlying the Karnak is the Spar Mountain Sandstone Member, a clastic unit composed of gray shale interbedded with varying amounts of fine-grained, light gray sandstone. Thin beds of oolitic limestone are present within the Spar Mountain in some holes. The sandstone is cemented with calcite to varying degrees of hardness and ranges from quite compact to very friable. The thickness varies between a maximum of 59 feet and a minimum of 2 feet (fig. 7). In most holes, 20 to 40 feet of Spar Mountain was encountered. The top and bottom of this member are defined as the limits of the uppermost and lowermost clastic units, usually shales, as interpreted from an electric log. The lowest portion of the Karnak commonly contains abundant quartz grains, but because of a predominance of calcite, this portion is included in the Karnak rather than the clastic Spar Mountain.

The Fredonia Limestone Member underlies the Spar Mountain Sandstone Member. The Fredonia, the lowest member of the Ste. Genevieve, is typically made up of beds of dense, fine-grained to lithographic limestone alternating with zones of very oolitic limestone. Some units are more or less dolomitic. The permeability of the oolitic zones ranges from good to poor depending on the amount of interstitial calcite. The two main rock types of this member are readily recognized by characteristic curves on the electric logs. The oolitic zones produce rounded,

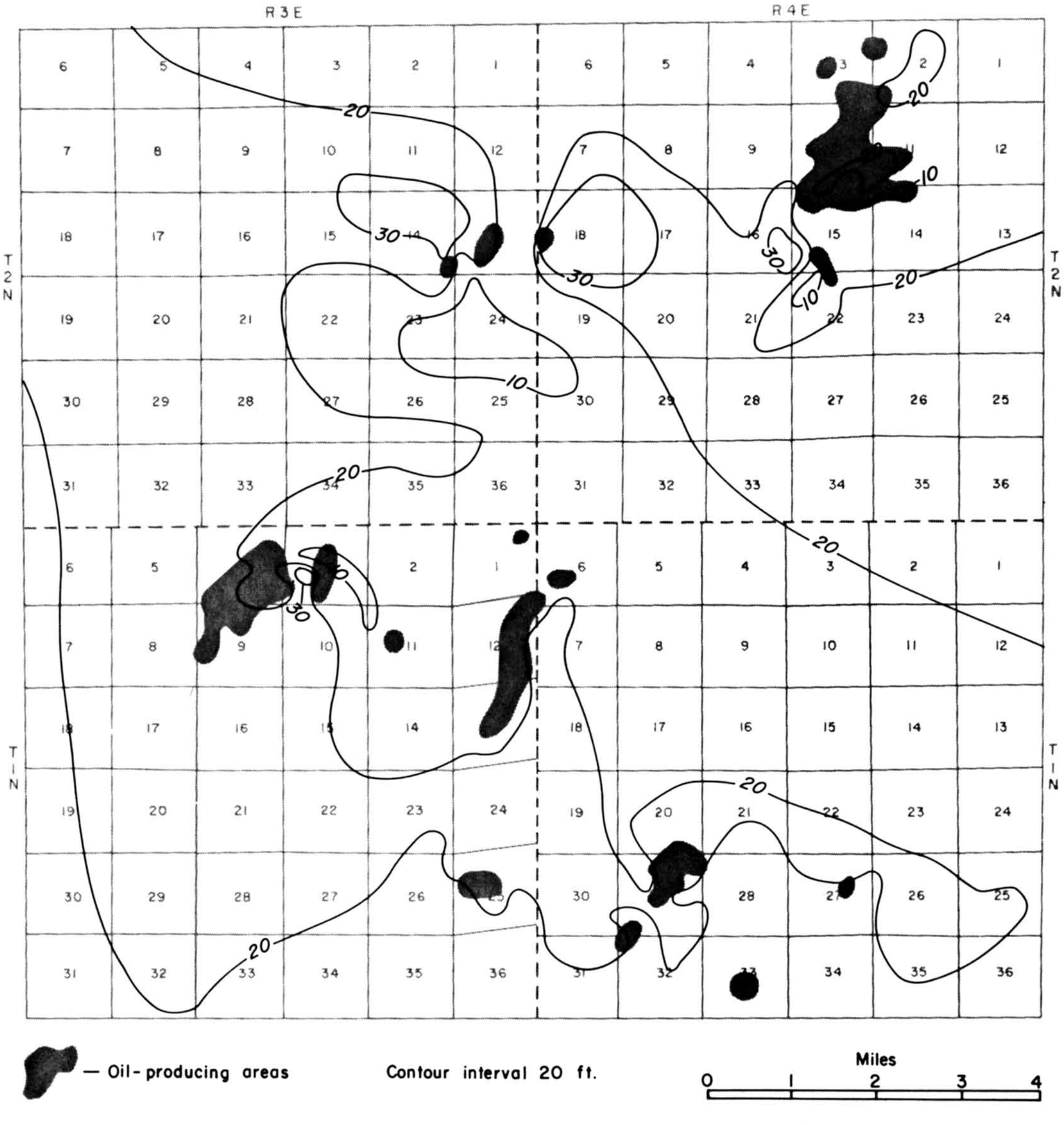



Figure 6 - Thickness of the Karnak Member.

fairly symmetrical S.P. curves. The resistivity curves vary, depending on the amount of interstitial calcite and nature of entrapped fluids. The dense zones cause little or no deflection of the S.P. curve and consistently show a high resitivity.

The oolitic zones are not continuous over long distances. Some can be traced on the basis of their stratigraphic position from hole to hole over a distance of a few miles. Others, however, appear to pinch out or grade laterally into dense units within the distance between holes drilled on 20-acre spacing. The oolitic facies

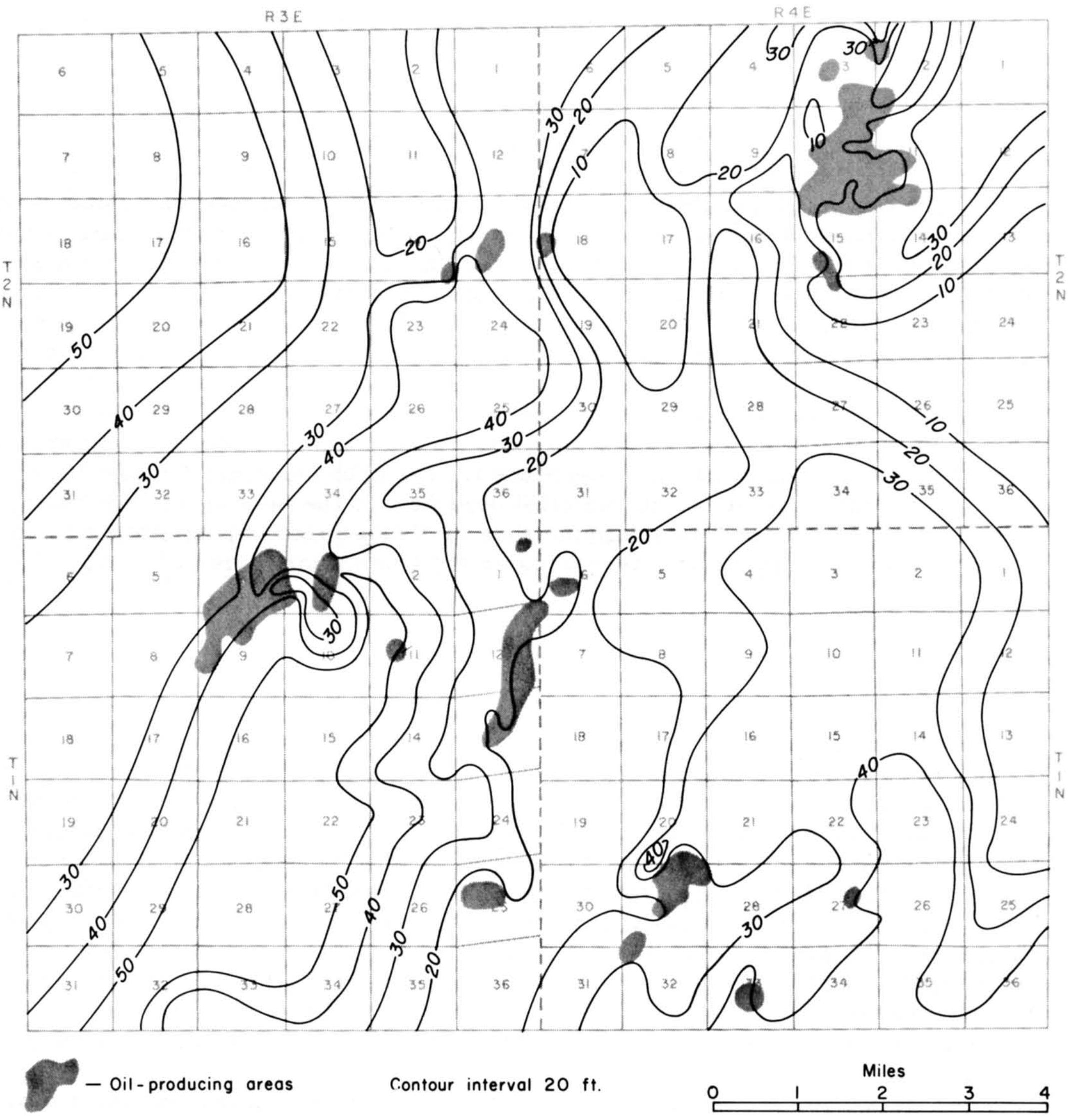



Figure 7 - Thickness of the Spar Mountain Member.

of the Fredonia, although certainly widespread, appear to be quite lenticular in nature. Oil production of the McClosky pay zone is from lenses of oolitic limestone in the Fredonia Member, but, because of the lenticular nature of the oolite zones, the term McClosky may refer to any of several possible pay horizons, shown in the later discussion of the pools in the area.

The contact of the Fredonia with the underlying St. Louis Limestone is difficult to recognize because of a variable transition zone. There is neither a distinct lithologic change nor an electric log "kick" that can be traced over the entire area.

## DEPOSITIONAL ENVIRONMENT

The oil-producing limestones discussed in this report were deposited in a marine environment that existed in the Illinois Basin during the middle part of the Mississippian Period. Prior to and following this time, large amounts of clastic sediments were carried into the basin from the northeast by the Michigan River (Swann, 1963, p. 12-17). The abundance and widespread distribution of oolites throughout the Exchange area indicate frequent periods of shallow water existing during Ste. Genevieve deposition. The more agitated shallow-water areas were interspersed with relatively quiet, deeper water areas that received the fine-grained lime muds that have produced the dense, commonly lithographic limestones with which the oolitic strata are interbedded. The Spar Mountain Member represents the initial surge of clastic material brought into the area by the Michigan River. The remainder of Mississippian time is characterized by an alternation of limestones and clastic sediments making up the Chesterian Series of rocks.

## OIL PRODUCTION

At the time of this writing, eight oil pools had been discovered in this area. Two of these, Exchange North and Slapout, have been consolidated, with the name of the former being retained. Table 1 lists these pools in alphabetical order. The data shown in table 1 are compiled from several sources. Average pay thicknesses, total production, and number of completions are those given by Van Den Berg, Lawry, and Mast (1968). API gravity was determined by Armon et al. (1964) and Armon, Lawry, and Mast (1966). The remaining information is from unpublished data on file at the Illinois State Geological Survey. The table summarizes the history of discovery wells for the pools as well as the various pays. The figures concerning the reservoir properties involve some estimating and averaging and undoubtedly vary considerably from the figures given in specific wells. Probably the most significant figures given in this table are the number of completed wells and the total oil produced.

Figure 8 A - H consists of structural cross sections drawn through the oil pools in the Exchange area. These cross sections are oriented to show the absence of structural closure. In those pools that lie on plunging anticlines, this was accomplished by drawing the cross section along a line roughly coincident with the anticlinal axis. The locations of the cross sections are shown on figure 3. Electric logs were the primary source of information used in the preparation of the cross sections. Lithologies were determined by sample studies of many of the holes.

The oolitic zones as shown on these cross sections were determined by an interpretation of electric logs supplemented by sample studies of selected wells. Correlation of these zones from hole to hole is questionable and is based primarily on the assumption that deposition was rather uniform, producing fairly regular thicknesses of limestone over the small areas covered by each cross section. The primary purpose of the cross sections is to illustrate the lateral discontinuity

TABLE 1 - PRODUCTION DATA ON POOLS IN EXCHANGE AREA AS OF JAN. 1, 1968

| Pool | Pay zone | Discovery well | Location | Completion date | Average thickness of pay | Total production in thousands of bbls | Average Porosity (%) | Average permeability (md)* | API gravity | Initial Production (bbls/day) | Total completions |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Exchange | McClosky | Gulf #1 Floyd | SE SE NW 25-1N-3E | Sept. 1943 | 12' | 68.3 | 16 | 100 | 38° | 152 oil 12 water | 2 |
| Exchange East | McClosky | Union Contracting #1 Hawkins | SE SW SW 29-1N-4E | Jan. 1955 | 10' | | 17 | 150 | 37 | 100 oil | 16 |
| | Spar Mtn. | Gulf #2 Meadors | NW NW NE 29-1N-4E | May 1955 | 10' | 442.2 | 17 | 150 | 37 | 65 oil 25 water | |
| | St. Louis | Union Contracting #1 Vera | 330 NL 500 WL NW NW 32-1N-4E | Apr. 1955 | 8' | | 12 | 20 | 38 | 28 oil | |
| Exchange North Cons. | McClosky | Atlas & Co. #1 Sawyer | SW SE NW 11-1N-3E | July 1951 | 6' | | 17 | 150 | | 152 oil 50 water | 21 |
| | Spar Mtn. | Ego #2 "B" Arnold | 330 NL 380 EL SW SE 12-1N-3E | Aug. 1966 | 6' | 143.3 | 17 | 150 | 37 | 100 oil | |
| | Salem | Ego #1 "A" Harvey | N/2 SW SW 6-1N-4E | July 1966 | 11' | | 14 | 60 | | 17 oil 17 water | |
| Exchange West | McClosky | Fletcher #1 Sawyer | NE SE SW 3-1N-3E | July 1957 | 6' | | 15 | 60 | 37 | 51 oil | 18 |
| | Spar Mtn. | Winn #1 Wyatt | NW SW SW 3-1N-3E | July 1966 | | 48.3 | | | | 75 oil 25 water | |
| | Karnak | Nat. Assoc. #3 "A" Charlton | NW NW SE 4-1N-3E | Oct. 1966 | | | | | | 5 oil 25 water | |
| | St. Louis | Nat. Assoc. #1 "B" Charlton | SE SE SW 4-1N-3E | July 1967 | 8' | | 12 | 20 | 38 | 173 oil 48 water | |
| Hickory Hill | Cypress | Nat. Assoc. #1 Meadors | SE NW NE 27-1N-4E | Dec. 1964 | 10' | | 18 | 100 | 36 | 20 oil 100 water | 4 |
| | Benoist | Nat. Assoc. #1 Halfacre Est. | NW SE NE 27-1N-4E | Dec. 1964 | 7' | 16.7 | 16 | 50 | 37 | 28 oil 90 water | |
| | Spar Mtn. | Nat. Assoc. #1 Lowry-Shelton Comm. | SE SW NE 27-1N-4E | Dec. 1964 | 6' | | 16 | 100 | 37 | 27 oil | |
| Iuka | St. Louis | Gillian #1 Ebe | NE NE NW 14-2N-4E | July 1947 | 5' | | 14 | 25 | 37 | 285 oil 180 water | |
| | Aux Vases-McClosky | Runyon #1 Frye | NW SW NW 2-2N-4E | Oct. 1960 | 10' | 982.5 | 17 | 80 | 37 | 30 oil 60 water | 46 |
| | Karnak-Spar Mtn., McClosky | Welker #1, Fatheree | SE SW SE 10-2N-4E | July 1954 | 11' | | 17 | 150 | 38 | 332 oil | |
| Iuka West | McClosky | Fletcher #1 Blankenship | NE NE SW 13-2N-3E | Oct. 1955 | 5' | 25.9 | 17 | 150 | 37 | 7 oil | 4 |

* Millidarcys

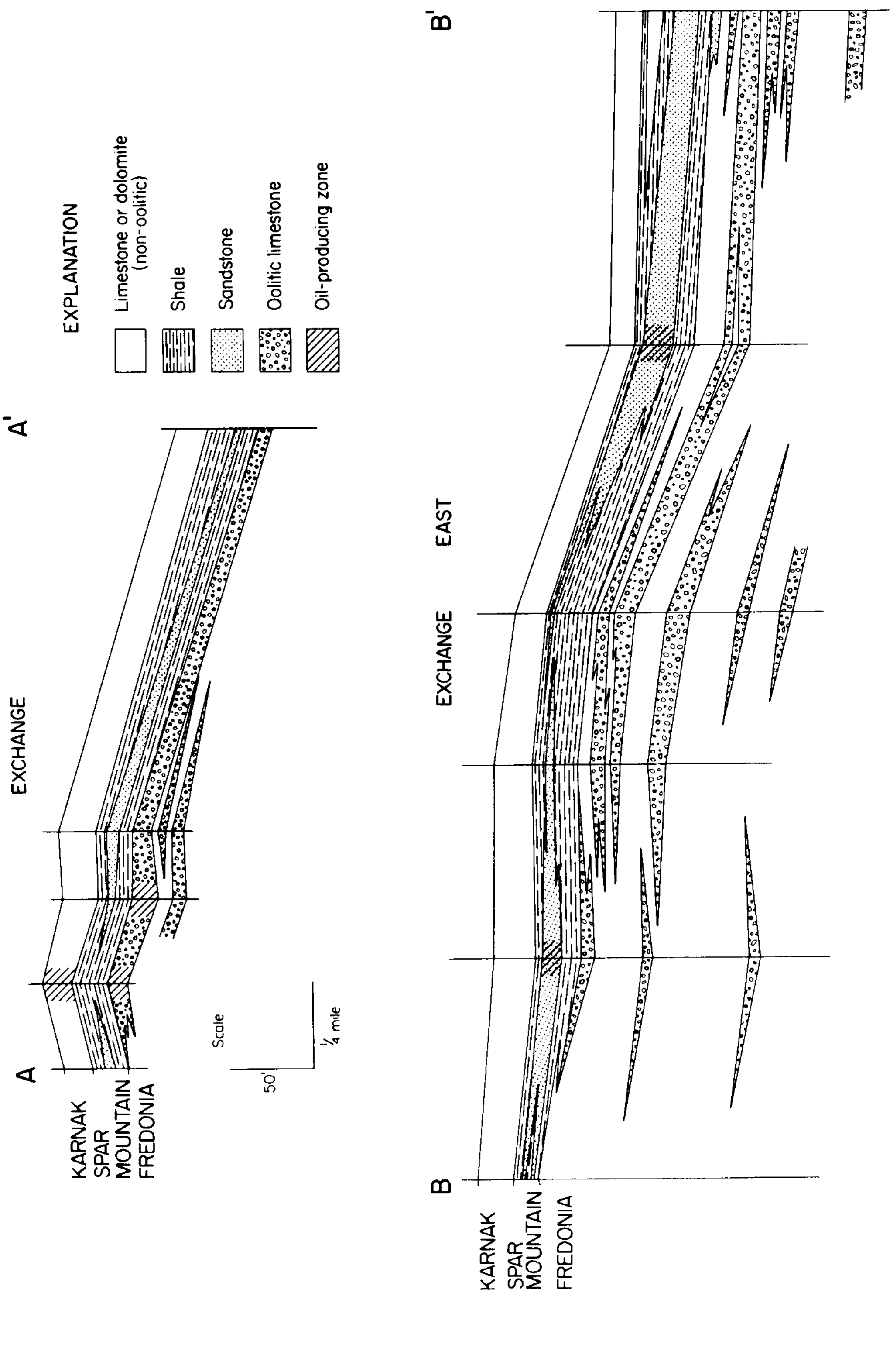



Figure 8 A-H - Structural cross sections showing the lithology of the Ste. Genevieve Formation.

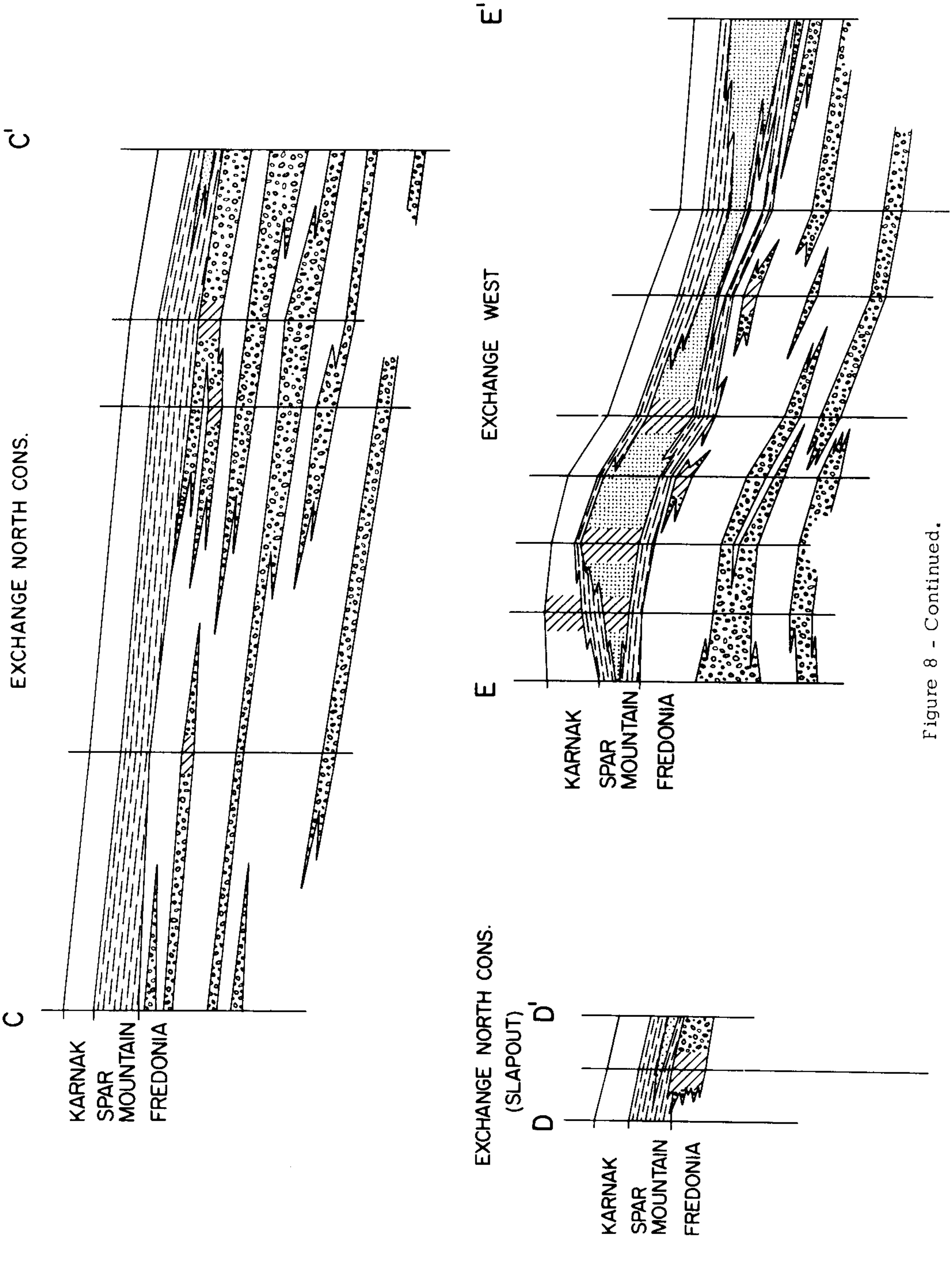
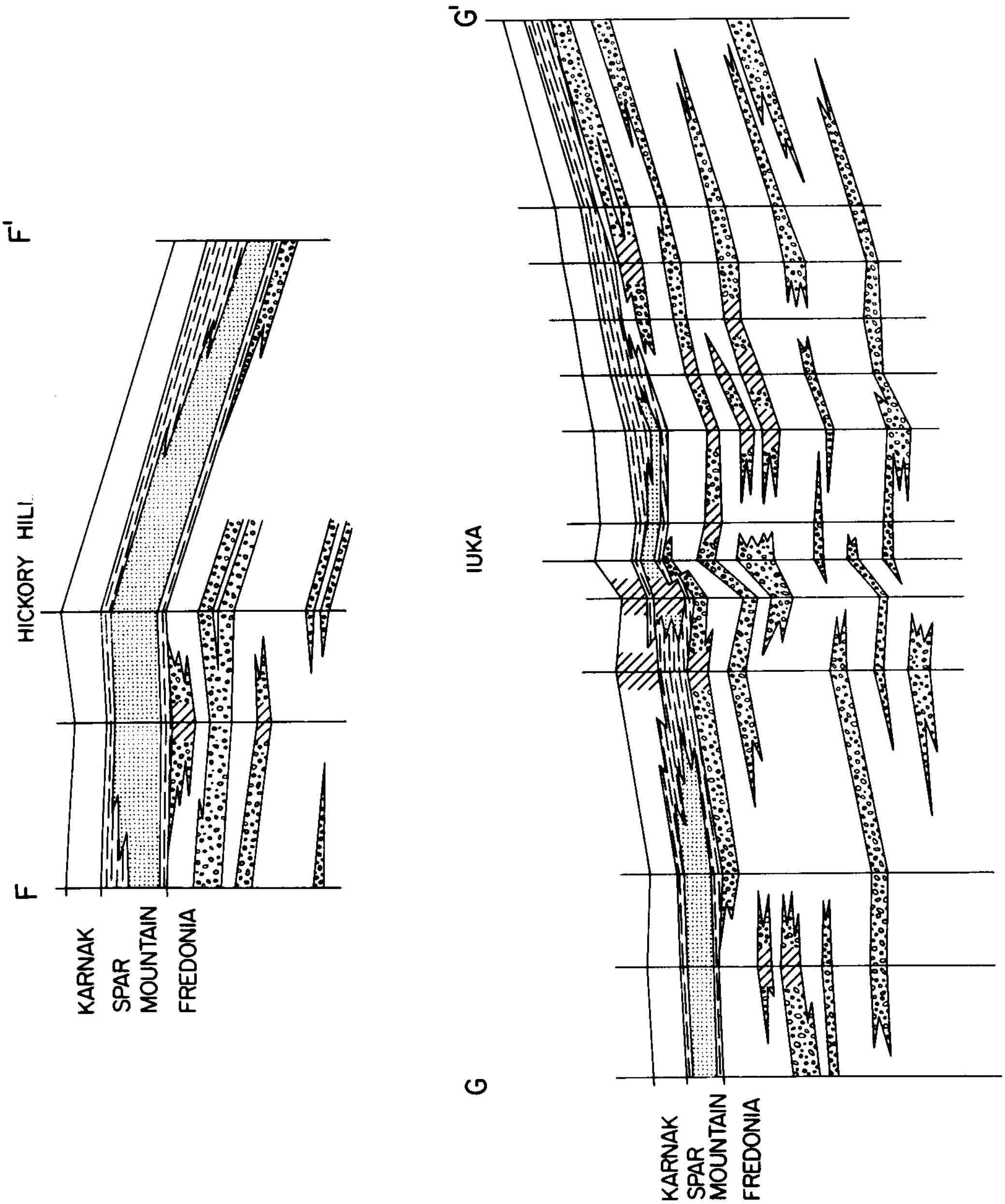



Figure 8 - Continued.

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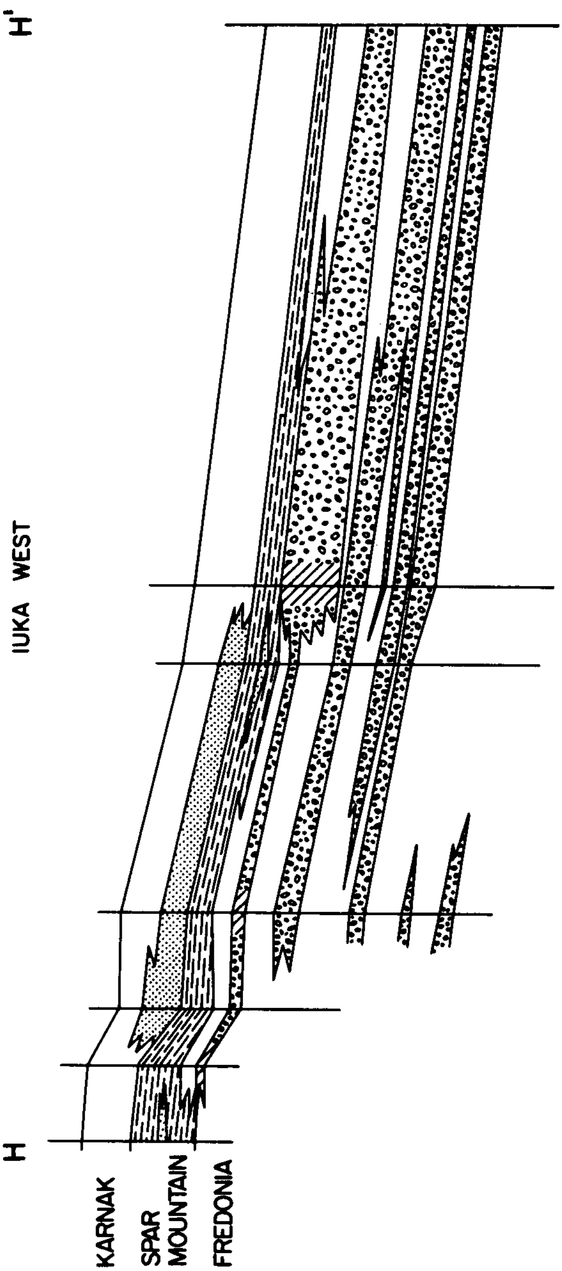


Figure 8 - Continued.

of the oolitic zones. They may actually be less continuous than shown between the more widely spaced holes. This discontinuity is probably the primary factor in preventing the updip migration of the oil.

The oil pools are associated with folding of varying intensity. Iuka lies on the nose of a rather large southward-plunging anticline (fig. 3). This structure is clearly shown by contours drawn on a 100-foot interval on the base of the Beech Creek Limestone (fig. 2). The Exchange, Exchange East, and Hickory Hill pools lie on a series of much smaller eastward-plunging anticlines that are aligned in an east-west direction at the southern margin of the area (fig. 3). In the north-central portion of the area, Iuka West lies on a similar eastward-plunging fold. Exchange North Consolidated and Exchange West pools lie on very minor folds.

The very small amount of closure that exists in some of the structures and the complete absence of closure in others, along with the discontinuous nature of the reservoir beds, suggest that stratigraphy is the more important factor controlling the trapping of oil in these pools. Structure does appear to have played some part in accumulating the oil in commercial quantities, as shown by the fact that each pool found to date lies on a positive structural feature, although in some cases a very slight one. Two possible sequences of oil emplacement are suggested. One is that the updip migration of oil was limited by permeability pinch outs, eliminating the need for structural closure. The plunging anticlines served as a locus toward which this updip migration occurred from several directions, resulting in an oil accumulation of potentially commercial size. The other possibility is that the structures were originally closed with the oil migrating into the structure. Subsequent basinward tilting then removed the closure on the western or northern side of the structures. The discontinuous nature of the permeable beds would have prevented the escape of the oil. We can better evaluate the second of these possibilites by removing the tilted surface and examining the oil-producing structures as residuals. The method of removing this regional dip is referred to as trend-surface analysis.

## TREND-SURFACE ANALYSIS

The practice of fitting trend surfaces to structure data for the purpose of removing regional dip has become quite common in recent years as a result of the increasing availability of electronic computers to geologists. The purpose of this type of analysis is to remove from the presently observed data the effects of certain geological changes (i.e. regional tilting) in order to observe the geological conditions that existed prior to these changes. For example, in this study it was desired to remove the present basinward dip from the present-day structure of the beds being studied in order to determine the existence of structural uplift in this area that may have been altered by later basinward tilt. This type of analysis was accomplished by constructing a mathematically calculated surface (using polynomial equations) that best fit some conception of regional dip. Inasmuch as the formulas force a particular surface, such as a plane, to be calculated from the observed data points, some data points end up above the calculated surface and some below. Depending upon the degree of complexity desired, the calculated (trend) surface may resemble closely, or not at all, the observed data points. The important factor is that the calculated surface resemble as closely as possible the idea of the configuration of the surface to be subtracted from present-day conditions. Because the trend surface is calculated in such a manner that the sum of the squares of the distance between the observed data points and the trend surface is the smallest possible number, the values on the trend surface will always be the best to use for the configuration calculated. The trend surface calculated may be a simple one, such as a plane (first degree), or a complex one, involving high degree formulas. Table 2 includes equations that define first-, second-, and third-order surfaces.

TABLE 2 - TREND-SURFACE EQUATIONS

| Surface | Dependent variable | Linear component | Quadratic component | Cubic component |
|---|---|---|---|---|
| First degree (plane) | Z | $= A + Bx + Cy$ | | |
| Second degree (paraboloid) | Z | $= A + Bx + Cy$ | $+ Dx^2 + Exy + Fy^2$ | |
| Third degree | Z | $= A + Bx + Cy$ | $+ Dx^2 + Exy + Fy^2$ | $+ Gx^3 + Hx^2y + Ixy^2 + Jy^3$ |

In these equations, the dependent variable, Z, represents the value of the observed data (the elevation of a particular contact, for example). The independent variables, X and Y, represent the coordinates that define the location of the point with respect to a point of origin. The letters A through J are constants. Figure 9 is a diagrammatic illustration of a first-order surface fitted to points on a gently folded surface. The vertical lines represent holes drilled through a particular stratum. The observed values (OBS) are elevations on top of this stratum. The trend values (TR) are those on the trend surface at the location of the holes. The residual values (RES) are the differences between observed and trend values. Residuals are positive or negative depending on whether the trend surface lies above or below the observed points.

A cluster of points in any particular area will exert a greater influence on the calculated trend surface than will an area with fewer points but having the same average value. Such clusters are common in pool areas that have a greater density of wells. The undue influence of these pool areas on trend surfaces must be avoided. In this study, the clustering effect was avoided by excluding some of the holes from the data. This results in a more uniform distribution of data points, although some minor clustering may still exist. The irregular spacing of data points is unavoidable when oil test holes are used to obtain the data. A uniform grid spacing of data, such as is obtained in some geophysical studies, lends itself more readily to surface fitting.

A trend surface is calculated in such a manner as to make the sum of the squares of the residual values as small as possible. There is, therefore, only one surface in any degree that produces the best fit to any set of data. The goodness of fit (F) is expressed as the percentage reduction in the total sum of squares that is given by the following expression:

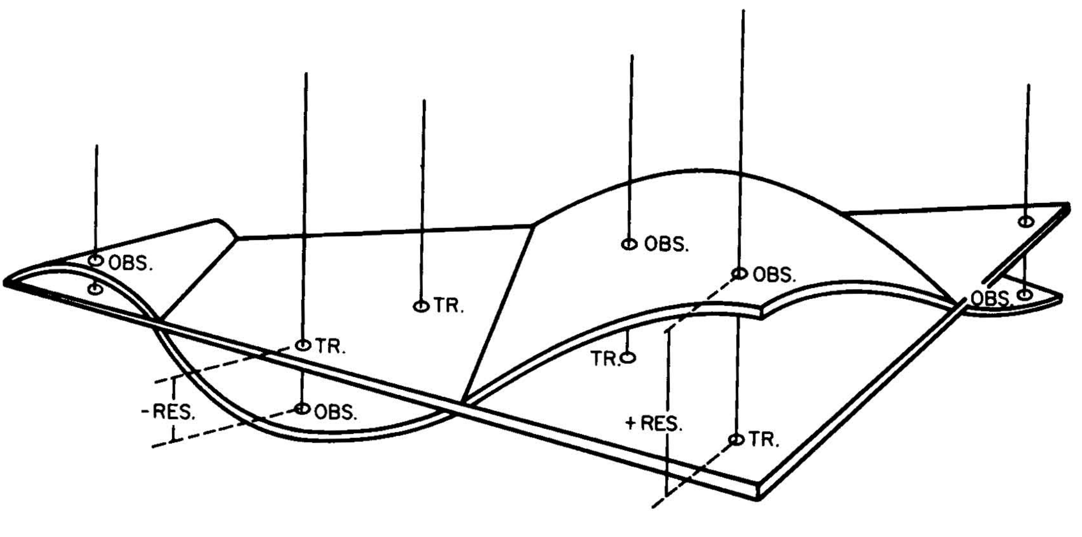


Figure 9 - Diagrammatic illustration of surface fitting. OBS.=observed surface value, TR.=trend-surface value, RES.=residual value (after Sutterlin and Brigham, 1967).

$$F = 100 \times \frac{\Sigma Z^2 \text{ trend} - \frac{(\Sigma Z \text{ trend})^2}{n}}{\Sigma Z^2 \text{ obs} - \frac{(\Sigma Z\text{obs})^2}{n}}$$

where

Z trend = values on trend surface at location of data points,
Zobs = observed data values, and
n = number of data values

(after Merriam and Harbaugh, 1964).

If a calculated surface passed through all of the observed data points, the goodness of fit would be 100 percent. However, goodness of fit should be used only to indicate how well the trend surface fits the observed data points, not as a control over which degree surface to use as the trend. The geologist must decide which surface (degree) best fits his interpretation of the "regional dip."

A first-order surface, or plane, fitted to the Fredonia structural data accounts for 83 percent of the total sum of squares. A fourth-order surface increases this to 98 percent. The close fit of the fourth-order surface results in very small residuals of questionable significance. For this reason, the analysis of the Exchange area was restricted to a study of first-, second-, and third-order trend surfaces and residuals.

The trend-surface maps were produced on a computer printout sheet with the values represented by various letters and numbers. An example of the actual printout is shown in figure 10. A contoured map can easily be made from this by drawing a line down the center of each band of characters. The residual maps were plotted and contoured by hand, as the computer facilities for automatic mapping were not available to the author at the time of this writing.

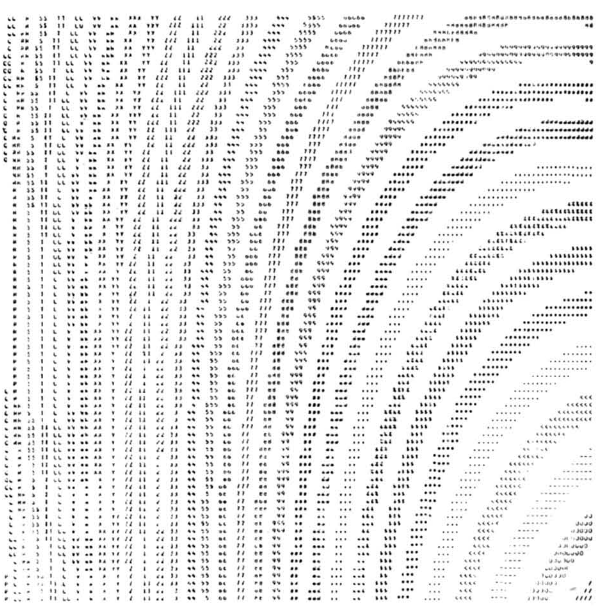

Figure 10 - Photograph of a computer printout of a second-order trend surface.

Trend surfaces were fitted to the tops of the Karnak, Spar Mountain, and Fredonia Members. Very little variation can be seen in any one set of maps when compared to the other two. A third-order trend surface on the top of the Karnak looks very much like a third-order surface on either the Spar Mountain or the Fredonia. The same holds

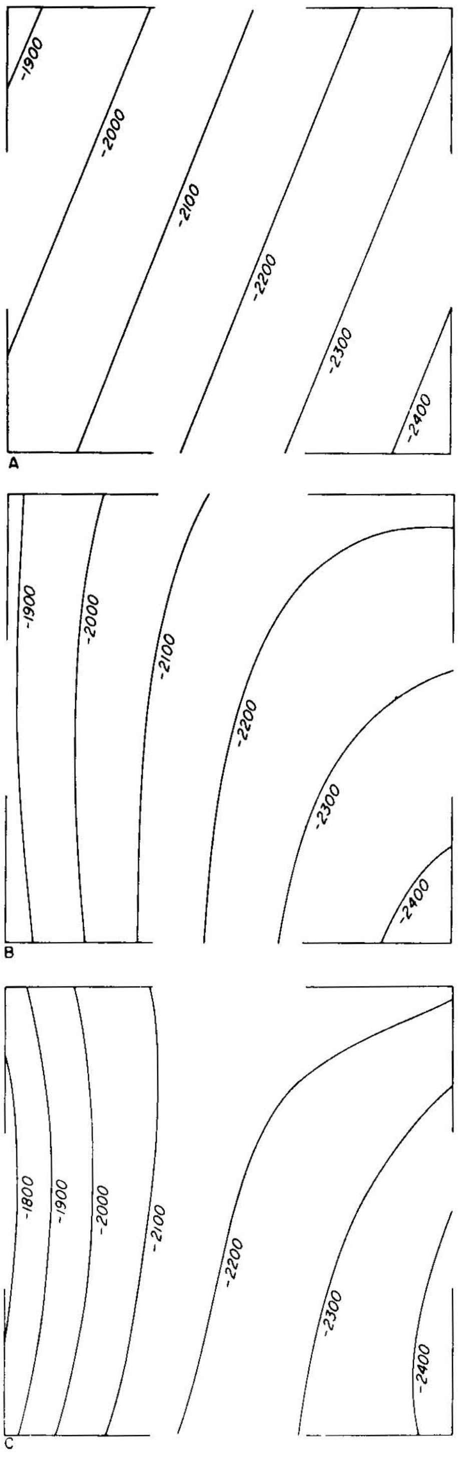


Figure 11 - Top of Fredonia Member first-, second-, and third-order trend surfaces.

true for the residual maps. Because of this, only a single set of trend surfaces and residuals are illustrated in this report.

The maps pertaining to the top of the Fredonia were selected for display because most of the oil produced in the area of study is trapped within the upper 200 feet of the Fredonia.

Figure 11 shows the first-, second-, and third-order trend surfaces fitted to structural data on the Fredonia. The corresponding residual maps are shown by figures 12, 13, and 14 as well as the locations of known oil pools. In the case of all three residual maps, the oil pools are associated with positive residuals.

This association is most clearly shown by the third-order residual map. Five of the seven pools lie on or very near closed positive residuals. These are Iuka, Iuka West, Exchange North Consolidated, Exchange, and Hickory Hill. The other two, Exchange West and Exchange East, lie on positive noses to the west of closed highs.

If we assume that the third-order trend surface (fig. 11C) represents the structural deformation of the area resulting from the Salem uplift and basin subsidence, the third-order residuals may approximate the structures present before this deformation.

This would indicate a strong influence of structural closure as the trapping mechanism that caused the oil to accumulate in its present location. The lateral discontinuity of the permeability in the reservoirs would have prevented the escape of the oil updip after the southeastward tilting of the area. Some updip migration of the oil may have occurred, accounting for the Exchange West and Exchange East pools lying to the west of the residual highs with which they are associated.

## SUMMARY

When oil is located on structures other than closed anticlines, stratigraphy is immediately suspected of being the primary trapping mechanism. It is possible, however, that closed structures existed while the oil was being trapped, but subsequent tilting has removed the closure. In this case,

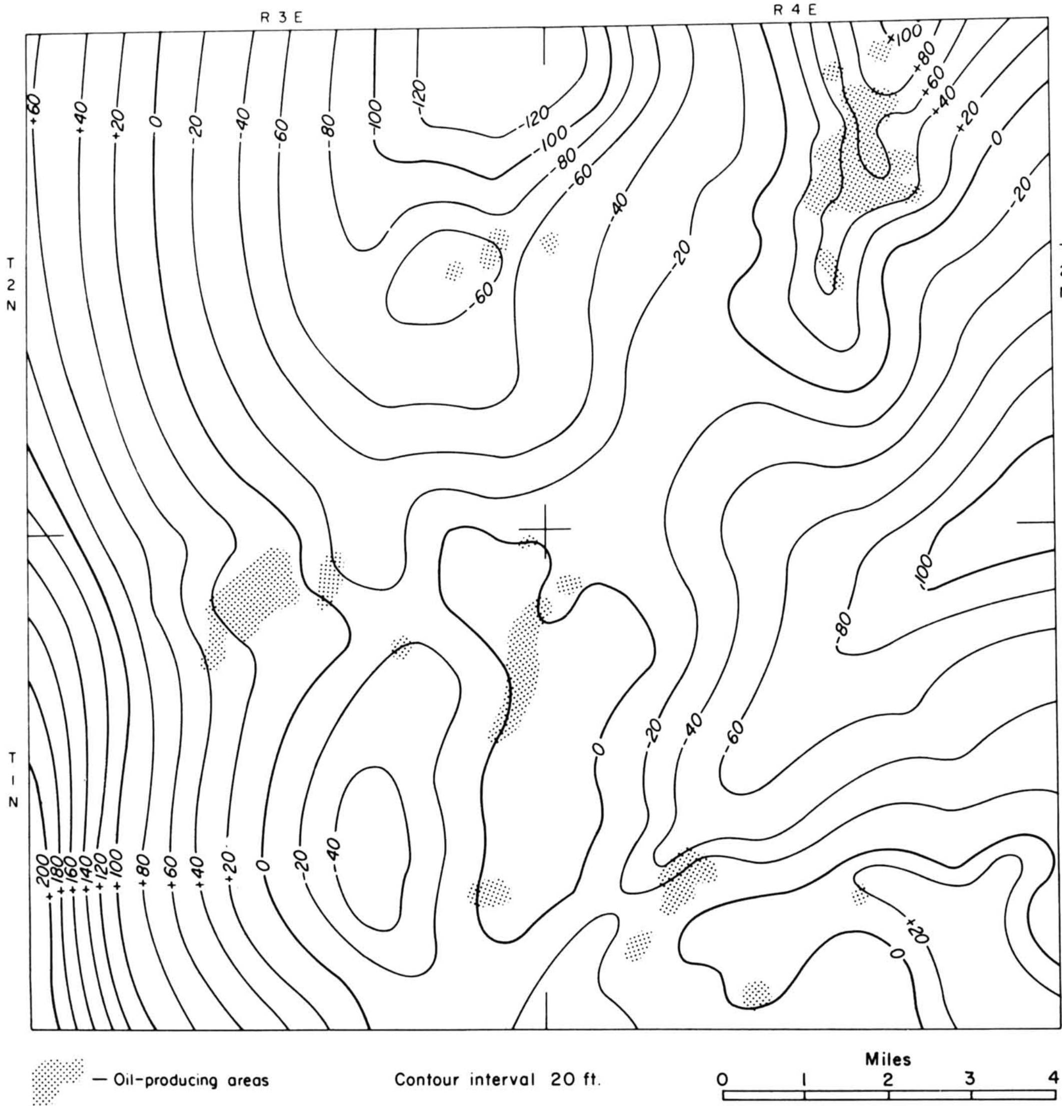


Figure 12 - Top of Fredonia Member first-order residual.

stratigraphy would play the secondary role of preventing the oil from escaping from these tilted structures.

In the study of the Exchange area, it can be demonstrated that the lateral variations of the strata containing the oil are of the type that would restrict migration of oil. Permeable oolitic limestones and sandstones interfingering with dense, fine-grained limestones and shales form the reservoirs. Evidence also exists that closed structures may very well have been present during, as well as before and after, the deposition of these reservoir rocks.

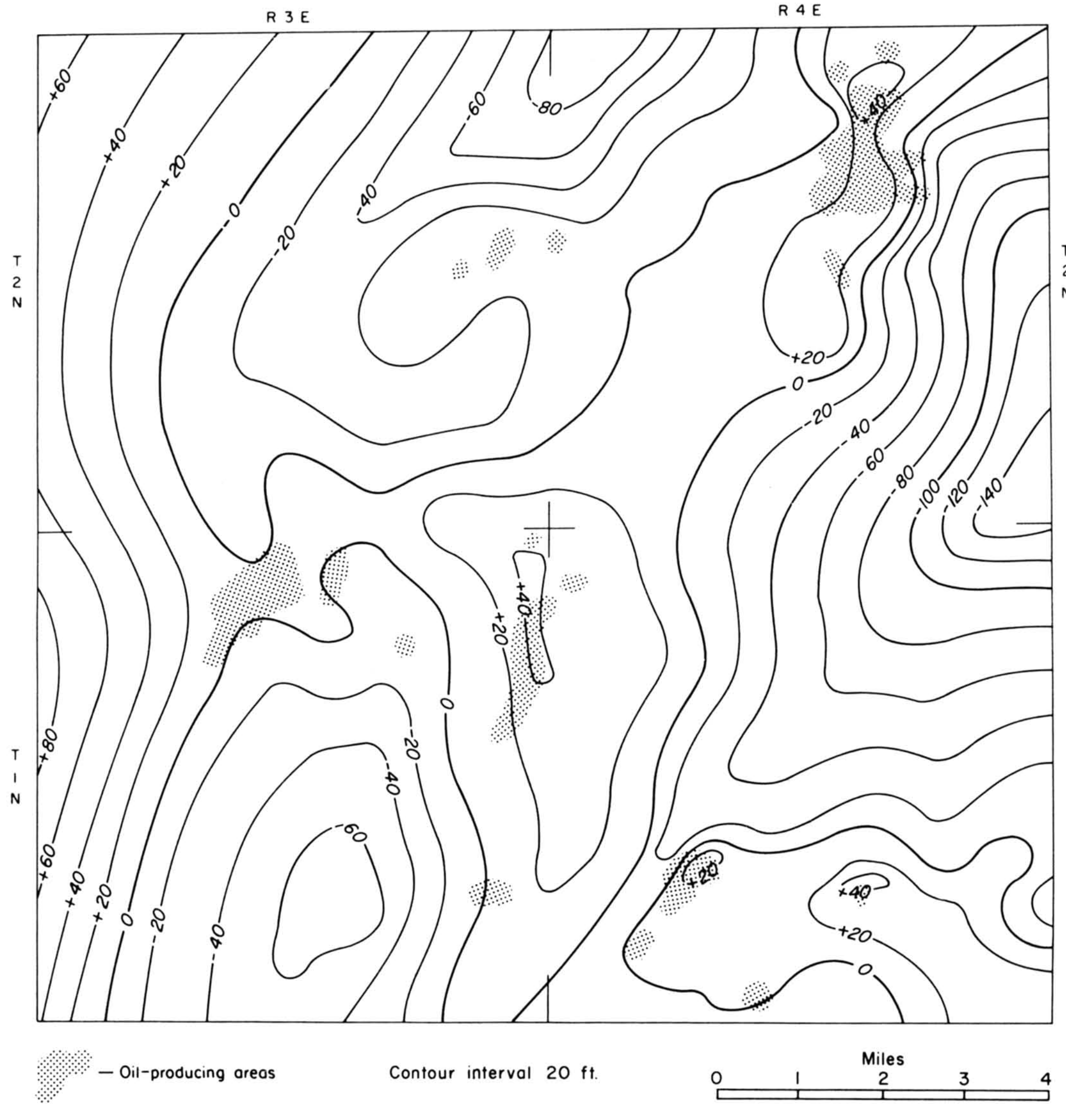


Figure 13 - Top of Fredonia Member second-order residual.

The thickness of the Spar Mountain Member (fig. 7) and the Karnak Member (fig. 6) suggests the presence of some relief on the ocean bottom during their deposition. The Spar Mountain, being a clastic deposit, tends to be thicker in the lower, deeper water areas than it is on top of the structures where the water was shallower. The Karnak, however, tends to be thickest in the areas where the Spar Mountain is thinnest. Being a fossiliferous limestone, the Karnak could have developed its greatest thickness in the shallower areas most favorable for the growth of the fauna comprising the bulk of the rock. These areas could very well

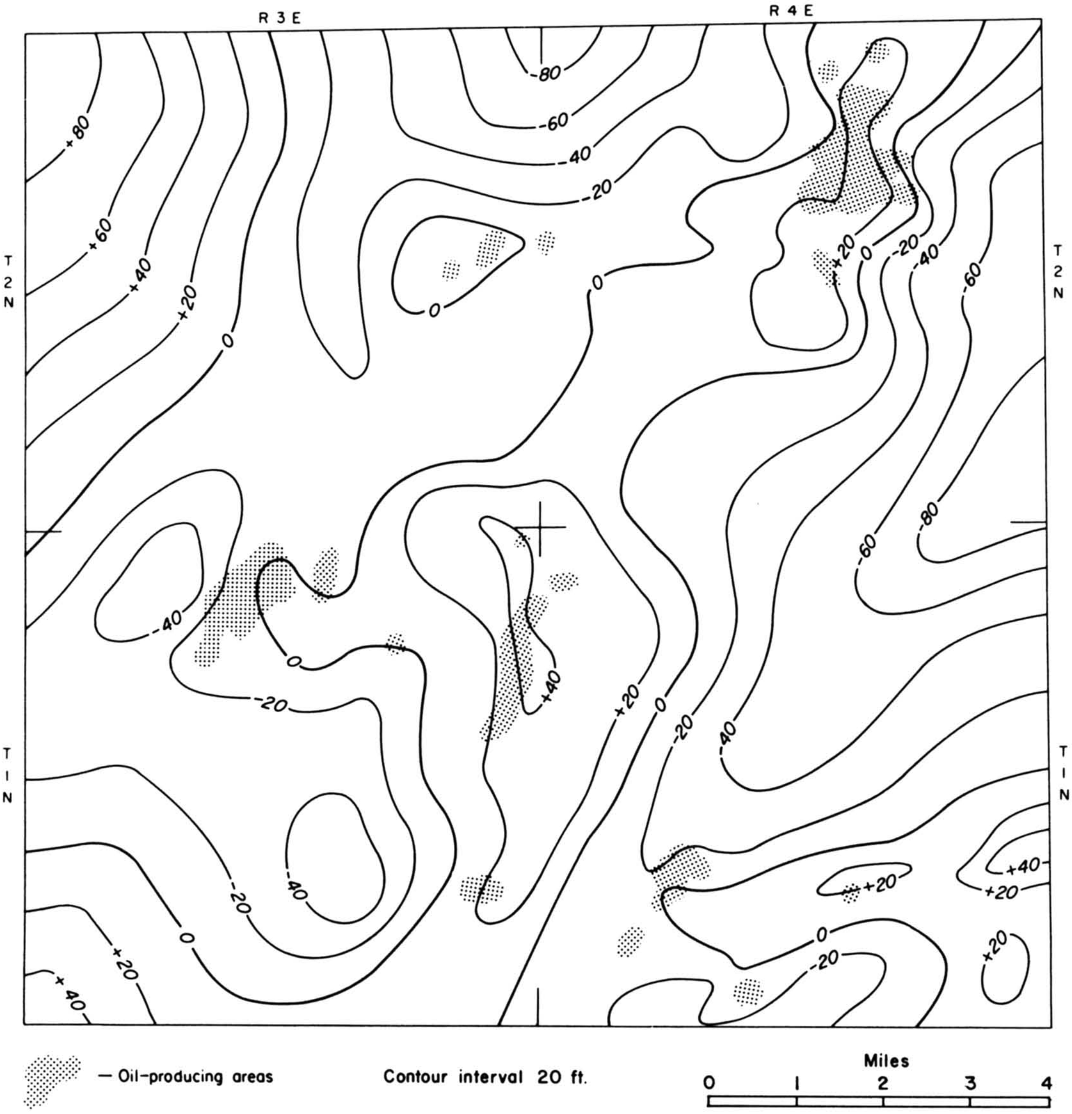


Figure 14 - Top of Fredonia Member third-order residual.

have been the same sea-bottom highs that prevented the clastics of the Spar Mountain from accumulating their greatest thickness. Because these thickness anomalies—thin in the Spar Mountain and thick in the Karnak—are closely associated with areas where oil is now located, it is possible that structural highs may have been present while these members were being deposited. These highs also would have provided favorable areas for the formation of oolitic lenses because the ocean floor would more likely have been above wave base where the sediments would have been periodically agitated.

There is, however, no evidence for the existence of a sloping sea floor during Ste. Genevieve sedimentation that even approaches the magnitude of the present regional dip. This suggests the following sequence of events: the formation of small closed structures before the reservoirs of the Ste. Genevieve were deposited, the migration of oil into these structures, and finally a long period of tilting between a tectonically positive area to the west and a basin to the southeast. The oil did not migrate far as a result of this tilting because of the lateral discontinuity of the permeability of the reservoirs.

A trend-surface analysis supports this sequence of events. It allows a removal of the effects of the regional tilting in the form of a low-order trend surface. The best surface to use for this appears to be that of the third order (fig. 11C). This surface produces closed positive residuals that have a rather striking relationship to the known oil pools.

It seems likely that areas similar to the Exchange area exist in Illinois. Fairly large areas that are not fully explored lie to the north between the Salem-Louden anticlinal trend and the Fairfield Basin. These areas should have experienced geologic history similar to that of the Exchange area. A trend-surface study of the type discussed in this report is impractical without the availability of electronic computers. It is important to recognize, however, that the possibility exists that structural folding may have been a more important factor in trapping oil in the Ste. Genevieve than is immediately apparent. Because of this, structural noses with little or no closure might deserve closer examination by the petroleum geologist.

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## REFERENCES

Armon, W. J., A. A. Coburn, R. F. Mast, and C. W. Sherman, 1964, Physical properties of Illinois crude oil, Part I: Illinois Geol. Survey Ill. Pet. 78, 53 p.

Armon, W. J., T. F. Lawry, and R. F. Mast, 1966, Physical properties of Illinois crude oil, Part II: Illinois Geol. Survey Ill. Pet. 81, 44 p.

Brownfield, R. L., 1954, Structural history of the Centralia area: Illinois Geol. Survey Rept. Inv. 172, 31 p.

Merriam, D. F., and J. W. Harbaugh, 1964, Trend surface analysis of regional and residual components of geologic structure in Kansas: State Geol. Survey of Kansas Spec. Distrib. Publ. 11, 27 p.

Sutterlin, P. G., and R. J. Brigham, 1967, Trend surface analysis—A new look at old data: Contribution of the Dept. of Geology, Univ. Western Ontario, Canada, no. 119, 25 p.

Swann, D. H., 1963, Classification of Genevievian and Chesterian (Late Mississippian) rocks of Illinois: Illinois Geol. Survey Rept. Inv. 216, 91 p.

Van Den Berg, Jacob, T. F. Lawry, and R. F. Mast, 1968, Petroleum industry in Illinois, 1967: Illinois Geol. Survey Ill. Pet. 89, 118 p.

Illinois State Geological Survey Circular 436
23 p., 14 figs., 2 tables, 2200 cop., 1969
Urbana, Illinois 61801

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

CIRCULAR 436

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