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Trend-Surface Analysis of the Structure of the Ste. Genevieve Limestone in the Effingham, Illinois, Area

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TREND-SURFACE ANALYSIS OF THE STRUCTURE OF THE STE. GENEVIEVE LIMESTONE IN THE EFFINGHAM, ILLINOIS, AREA

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ABSTRACT

Recent studies of oil accumulations in the Ste. Genevieve Limestone Formation in Illinois demonstrate the usefulness of fitting third-order trend surfaces to structural data and analyzing the residuals calculated by subtracting the trend surface from the structure surface. Known oil pools are located in areas having positive residual values. This type of investigation, supplemented by conventional structural and stratigraphic studies, was performed on a nine-township (approximately 324 sq. mi.) area in Effingham and Shelby counties, Illinois. The known oil pools in the oolite and sandstone lenses of the Ste. Genevieve Formation lie within positive residuals resulting from the difference between a third-order trend surface and the structural surface on top of the Ste. Genevieve.

A composite map outlining areas where present anticlinal noses, sandstone lenses, and positive residuals lie in close proximity to each other is included in this report to indicate places where future exploration for Ste. Genevieve oil would have the greatest chance for success.

INTRODUCTION

Previous Studies

A study of factors controlling oil accumulations in the Exchange area of Marion County, Illinois, demonstrated the usefulness of fitting low-order trend surfaces to geologic structure and mapping the resulting residual values (Stevenson, 1969). Computer methods were employed to fit first-, second-, and third-order trend surfaces to structural data on top of the Ste. Genevieve Limestone Formation (Mississippian). The purpose of this operation was to pass a surface through control points that would represent the regional tilting undergone by the area since

the time of deposition of the Ste. Genevieve. The resulting residual values, the difference between the structural surface and the trend surface, would represent the configuration of the top of the Ste. Genevieve before the tilting. The Ste. Genevieve oil pools in the Exchange area coincided quite closely with closed residual highs resulting from the use of the third-order trend surface. The conclusion drawn from the coincidence of oil pools and positive residuals was that early structural features, existing during and soon after Ste. Genevieve deposition, exerted a major influence on the location of oil accumulation. The closure on these early structures was greatly reduced or completely removed by the regional tilting that occurred later in the development of the Illinois Basin. Lateral permeability barriers or facies changes prevented the oil from migrating far from its original place of entrapment (Stevenson, 1969, p. 19-23).

Included in the report on the Exchange area is a recommendation that trend-surface analyses be utilized in other areas of the Illinois Basin with similar depositional and tectonic histories. One such area is the Effingham area, which lies to the north of Marion County along the east flank of the Louden Anticline (Stevenson, 1969, p. 23). This present study is the result of an investigation of that area, using the same techniques, with some modifications, as those used in the Exchange area.

Mapping Methods

Computer facilities available to the Illinois State Geological Survey made possible the utilization of several automatic plotting techniques in preparing this report (Swann et al., 1970). The base map grid was plotted by machine methods. The drill hole locations were calculated and plotted automatically and in all cases but one, the contouring was done by machine. The machine-produced maps were redrafted by hand to produce a final copy of publishable quality. The one exception to this procedure is figure 4, which was contoured by hand.

Location of the Effingham Area

The Effingham area, as referred to in this report, consists of nine townships (T. 7, 8, and 9 N.; R. 4, 5, and 6 E. of the third principal meridian) and contains approximately 324 square miles. Most of the area is in Effingham County; however, the three northernmost tiers of sections, comprising the northern half of T. 9 N., lie in Shelby County. Figure 1 shows the location of the area with respect to the major tectonic features associated with the Illinois Basin. It lies in south-central Illinois in the Fairfield Basin in the deeper portion of the Illinois Basin.

Figure 2 locates the area more precisely and shows its relation to local structural features, which are expressed by contours on the base of the Beech Creek (Barlow) Limestone Formation (Bristol, 1968). The most prominent structure shown on this map is the Louden Anticline. The Effingham area can be described as lying on a structural surface that dips rather gently to the southeast from the Louden Anticline toward the deepest part of the Fairfield Basin.

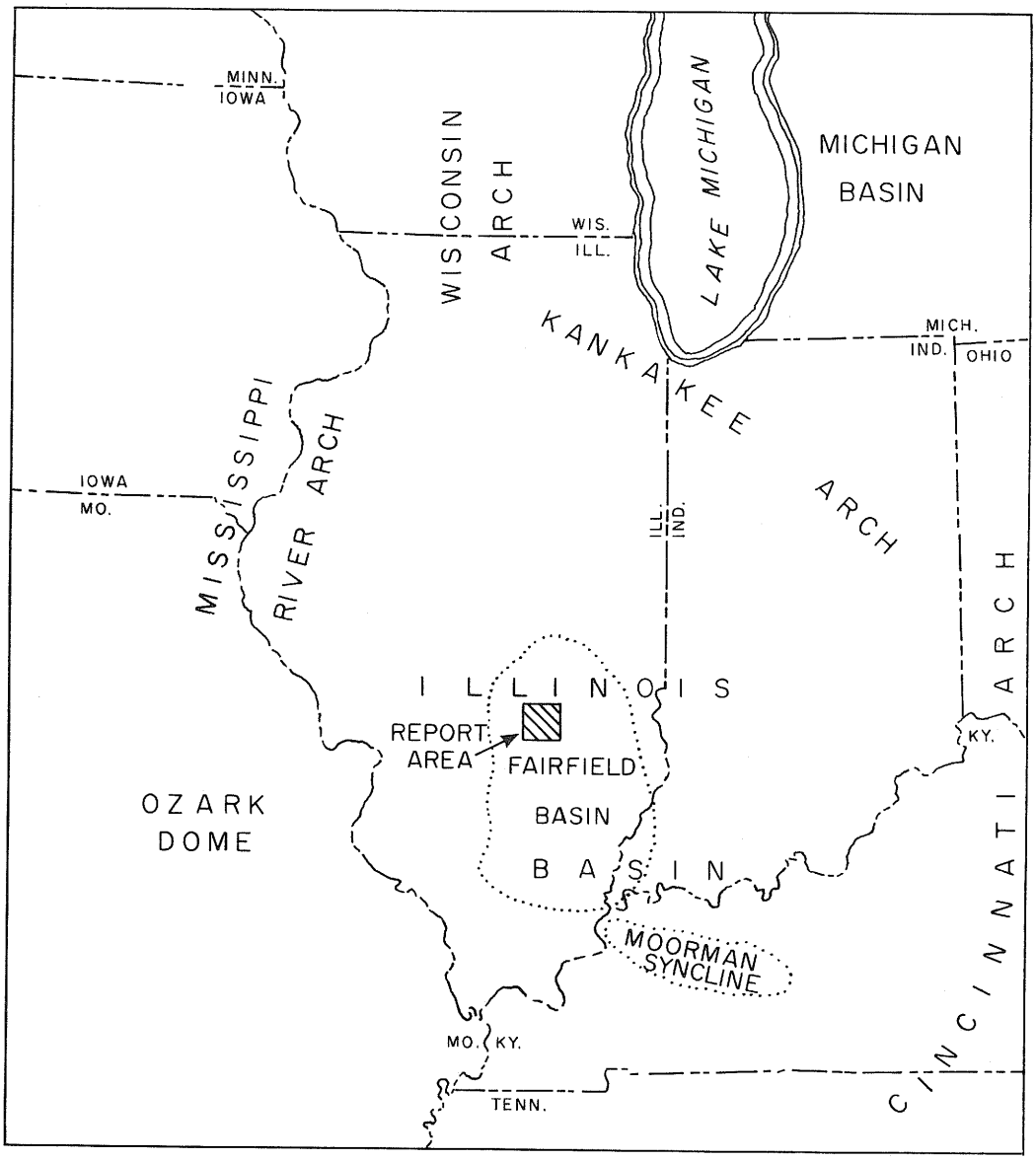

Fig. 1 - Index map showing location of report area with respect to major tectonic features.

GEOLOGY

Stratigraphy

Figure 3 is a portion of a typical electric log taken from one of the holes in the Effingham area (Kaufman No. 1 Haack, sec. 22, T. 8 N., R. 6 E.). The lithology of the rocks penetrated is indicated in the central portion of the graphic log. The rock types and the resulting electric log character are very similar to

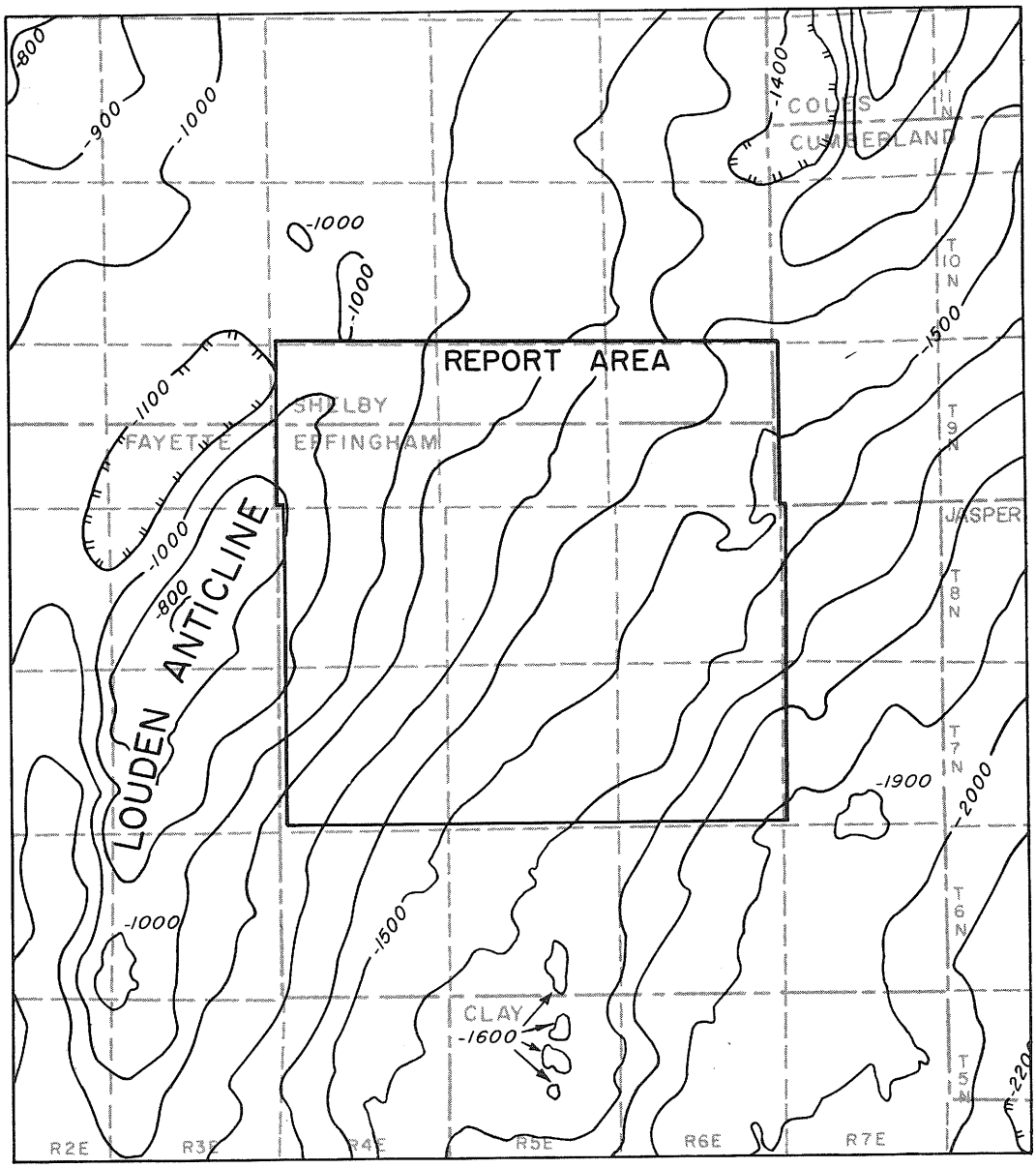

Fig. 2 - Structure map of the base of the Beech Creek (Barlow) Limestone showing outline of study area.

those in the Exchange area (Stevenson, 1969, p. 7). The similarity of rock types suggests that the same shallow, normal marine environment existed in both the Exchange and Effingham areas during deposition of the Ste. Genevieve Limestone (Stevenson, 1969, p. 10). The oolite lenses in the Fredonia Limestone Member are widespread but quite discontinuous and could not be mapped. The sandy facies of the Spar Mountain Sandstone Member is quite persistent and can be found in most of the holes drilled in the area. Where it is absent, it has graded laterally into shale or, less commonly, into sandy limestone. Figure 4 is an isopachous map showing the thickness of sandstone in the Spar Mountain Member. Geologic evidence suggests

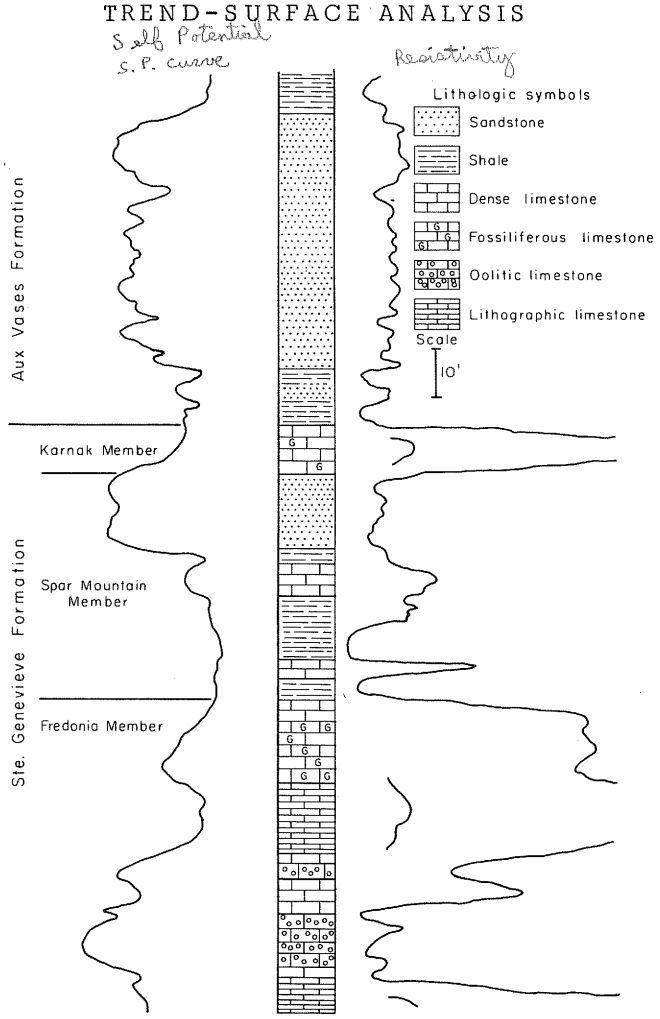

Fig. 3 - Electric log of the Aux Vases and Ste. Genevieve Formations in the Kaufman No. 1 Haack, sec. 22, T. 8 N., R. 6 E., Effingham County, Illinois.

that the sand was deposited in elongate lenses with the long axes of the lenses oriented in a northeast to southwest direction. Figure 4 was contoured by hand because machine contouring methods did not adequately reflect this interpretation.

The Spar Mountain clastics are overlain by the fossiliferous limestone of the Karnak Limestone Member and underlain by the interbedded fine-grained limestone and coarser fossiliferous limestones and oolites of the Fredonia Member.

Structure

Figure 5 is a structure map contoured on top of the Ste. Genevieve Formation. The regional dip toward the east and southeast is readily apparent from this map. The influence of the Louden Anticline can be seen along the western border. Only two closed contours appear on the entire map when a 25-foot contour interval is used. One of these is near the southern border and the other is near the eastern border of the area. All other positive structures are gently folded, plunging anticlines.

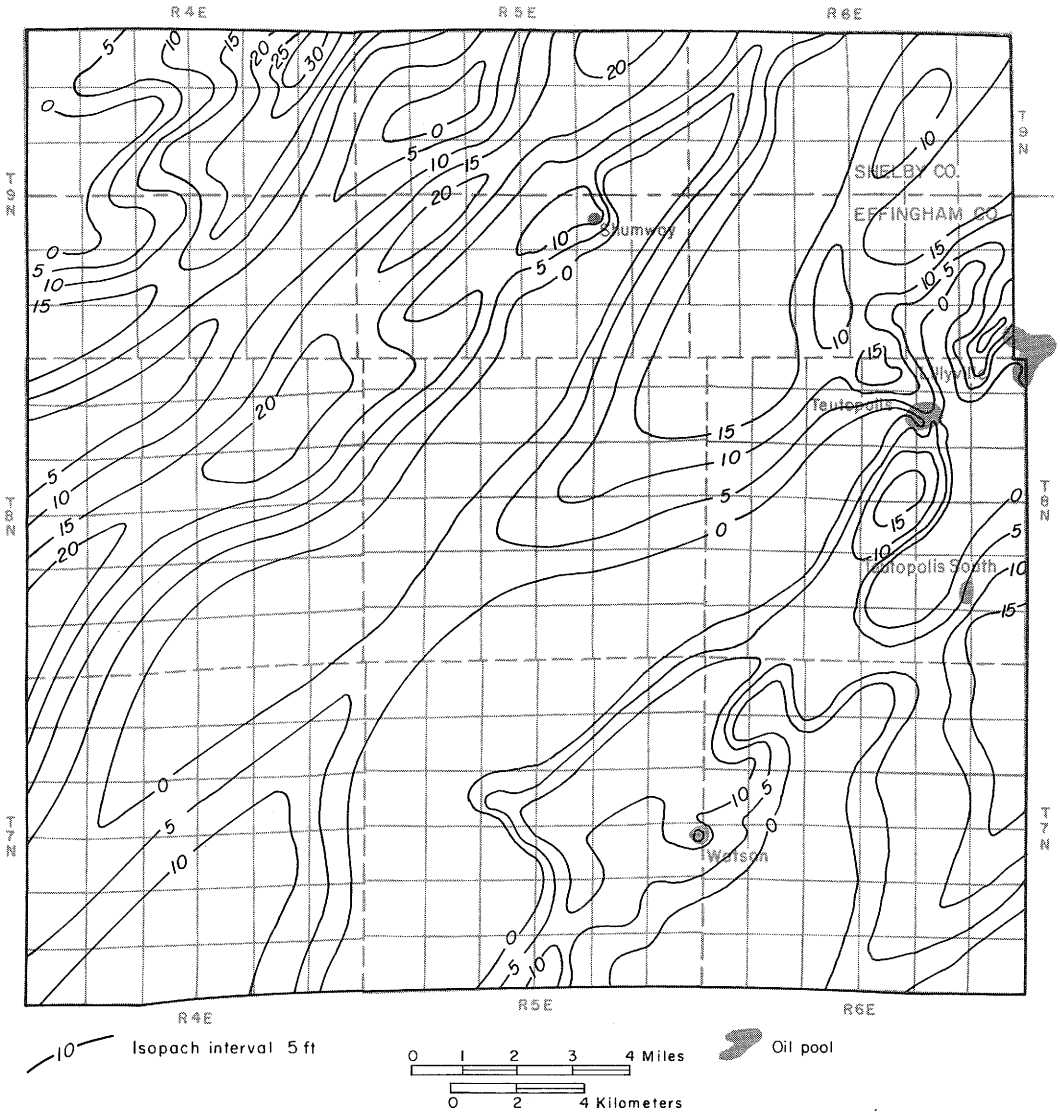

Fig. 4 - Thickness of the Spar Mountain Sandstone Member.

OIL PRODUCTION

Oil entrapped in formations other than the Ste. Genevieve is not discussed in this report because such a discussion would become involved with the Louden Pool. Most of the production from Louden is from shallower Chesterian rocks and the significance of a Ste. Genevieve trend-surface analysis to Cypress production, for example, is questionable.

To date 5 Ste. Genevieve oil pools that lie at least partly in the Effingham area have been discovered. The Ste. Genevieve oil occurs in sandstone reservoirs in

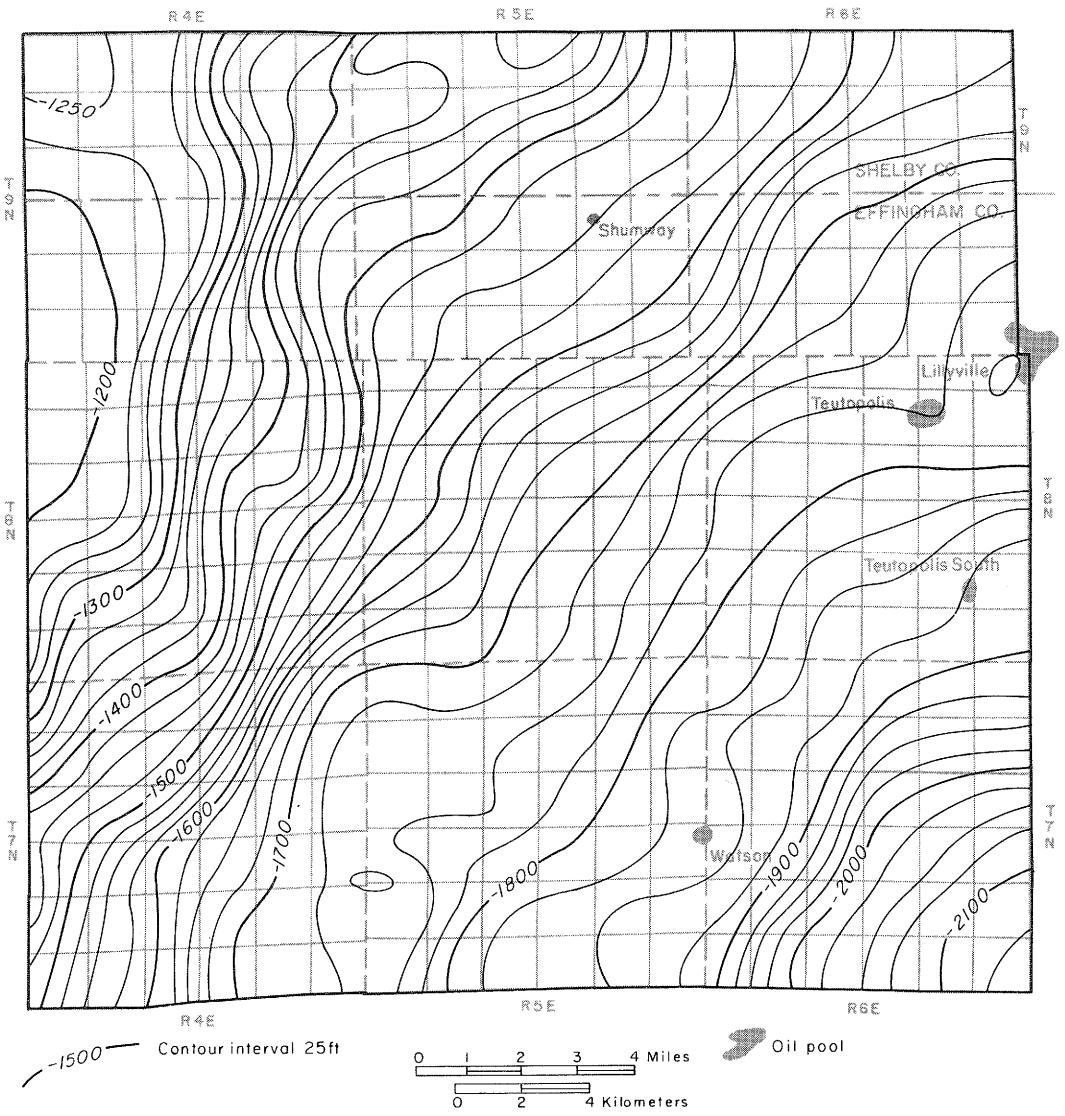

Fig. 5 - Structure of the top of the Ste. Genevieve Formation.

the Spar Mountain Member or in one or more of the porous oolites of the Fredonia Member. In common oil-field terminology, this sandstone is referred to as "Rosiclare" and these oolites are referred to as "McClosky."

Table 1 lists the five pools and shows the total number of wells completed as producers, the pay zones, and total cumulative production as of April 1, 1970. All five pools are relatively small, both in the number of wells completed and in the amount of oil produced. They do, however, demonstrate the presence of Ste. Genevieve oil in the area; therefore, the possibility of larger accumulations existing nearby should not be overlooked.

TABLE 1 – TOTAL NUMBER OF COMPLETED PRODUCING WELLS AND CUMULATIVE PRODUCTION IN THE EFFINGHAM AREA

Pool	Total completed producers	Pay zone	Cumulative production in barrels
Lillyville	13	Fredonia	481,915
Shumway	1	Fredonia	3,418
Teutopolis	10	Fredonia	109,526
Teutopolis So.	3	Fredonia	12,527
Watson	3	Spar Mountain and Fredonia	62,677
Total	30		670,063

TREND-SURFACE ANALYSES

The procedure used in fitting trend surfaces to the structure of the Ste. Genevieve in the Effingham area is the same as that used in the Exchange area (Stevenson, 1969, p. 16-19). Here, as in the Exchange area study, the third-order surface was chosen as the surface most closely representing the regional dip of the area. Figure 6 is a contoured map of the third-order surface.

Figure 7 is the residual map resulting from a subtraction of the third-order trend surface (fig. 6) from the structural surface (fig. 5). The known Ste. Genevieve oil pools are shown on this map and all are located within positive residual areas. These positive residual areas are the result of the third-order trend surface passing under the datum points on the present-day positive structural anomalies. The residual highs probably approximate the appearance of these structures before regional tilting modified them. The coincidence of Ste. Genevieve pools and residual highs implies that the structures that existed during and soon after deposition of the Ste. Genevieve played an important role in the location of the oil accumulations.

There are four pronounced residual highs shown in figure 7. They lie on each of the four borders of the map. Three of them contain at least one Ste. Genevieve oil pool. To date, the fourth, the one on the west edge of the map, has not produced any Ste. Genevieve oil. (This western residual high may reflect the influence of the increased rate of dip as the Louden Anticline is approached.) While these highs are not the only places in the area that could contain Ste. Genevieve oil pools, they do indicate the more likely sites of oil accumulation. At best, this type of map is just one more tool to help in interpreting the geologic development of an area and the complexities of the factors influencing the occurrence of oil.

EVALUATION OF STE. GENEVIEVE OIL PROSPECTS

Few oil traps can be easily classified as purely structural or purely stratigraphic traps. In the most obvious structural domes, stratigraphic factors often influence the location of the oil deposit. Also, in classic examples of stratigraphic traps, folding has played a more or less important role in the accumulation of oil in its final resting place.

In the Effingham area, stratigraphy and structures existing soon after deposition of the Ste. Genevieve appear to have exerted nearly equal influence on the location of the known oil accumulations in that formation. Because of basinward

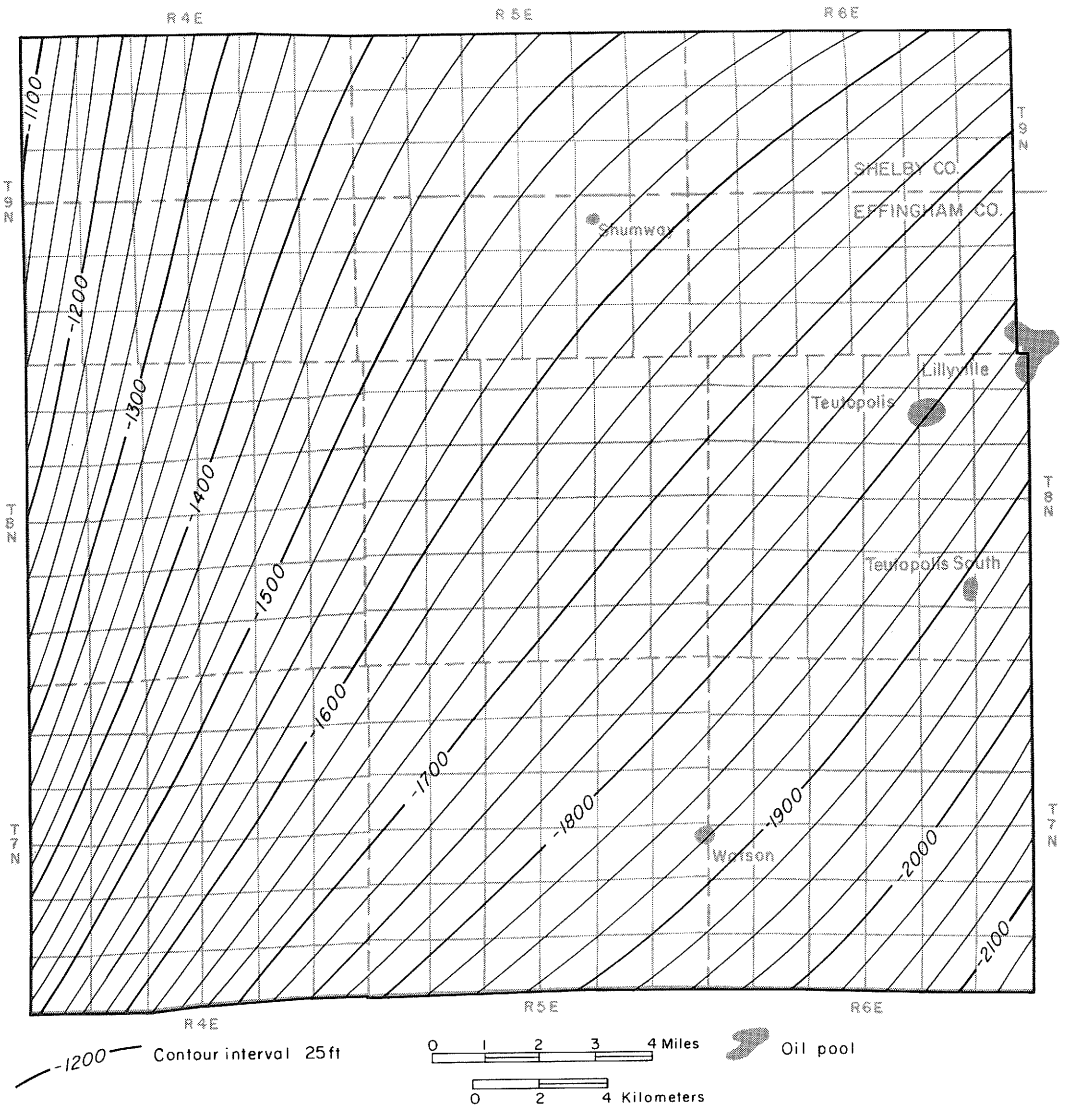

Fig. 6 - Third-order trend surface calculated from Ste. Genevieve structural data.

tilting of the entire area, present-day structural highs have little or no closure to the north and west; therefore, the structure, as it exists today, was probably not a strong controlling factor in the accumulation of Ste. Genevieve oil. However, early structures that existed during and shortly after Ste. Genevieve deposition, as interpreted from trend-surface analysis, were quite influential in controlling oil accumulations. The known oil deposits in the Effingham area all lie within positive third-order residuals (fig. 7).

The use of trend-surface fitting and residual mapping has been demonstrated to be a useful tool in explaining Ste. Genevieve oil accumulations in both the Exchange and Effingham areas. In an attempt to use this tool in conjunction with

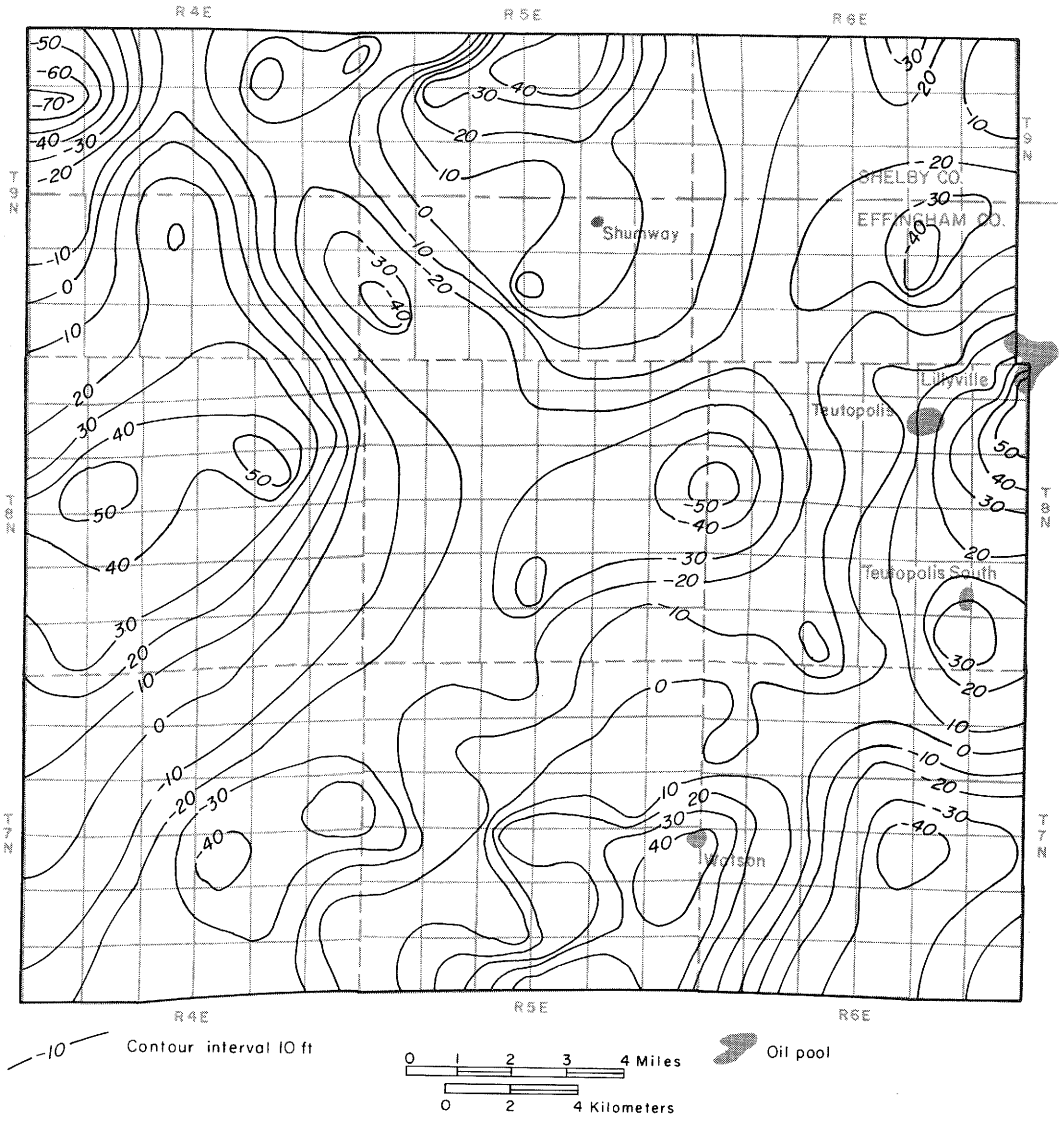

Fig. 7 - Third-order residual map representing the difference between Ste. Genevieve structural surface and third-order trend surface (fig. 5 minus fig. 6).

conventional geologic mapping, a composite map was prepared showing residual highs, present-day structural axes, and stratigraphically favorable areas (fig. 8). Areas above the +10 residual value are enclosed by dashed lines. Axes of anticlinal noses are shown by solid lines terminating in an arrow indicating direction of plunge. The thickness of sandstone lenses in the Spar Mountain Sandstone Member within the residual highs is shown by contrasting patterns. It would be desirable to show also the location and thickness of oolite lenses, but because of their discontinuous nature this could not be done. The oolite lenses are scattered over the entire area and in many places two or more lenses overlap; therefore, any exploratory hole may encouter several oolitic zones. Because of this wide-

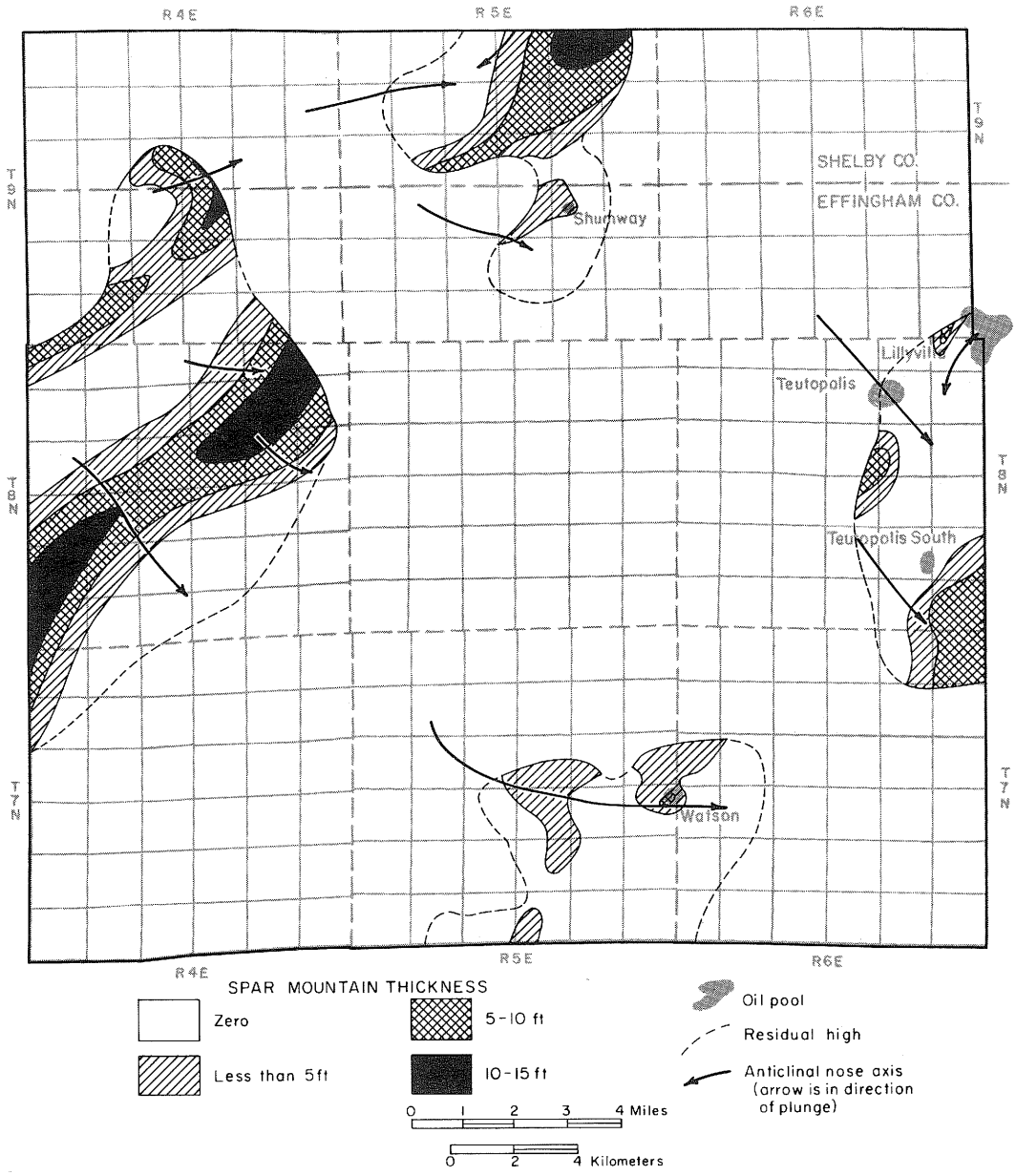

Fig. 8 - Composite map showing known Ste. Genevieve oil pools and areas where positive third-order residuals, Ste. Genevieve anticline noses, and Spar Mountain lenses coincide.

spread distribution, holes drilled in areas underlain by Spar Mountain Sandstone and located on structural noses in residual highs may very well penetrate one or more oolite zones with some reservoir capacity.

CONCLUSIONS

The trend-surface analysis of the Effingham area leads to the same type of conclusions as those resulting from the study of the Exchange area. Residual highs in the vicinity of small structural noses quite likely approximate the small closed highs that were present in the area shortly after deposition of the Ste. Genevieve rocks and before regional tilting to the southeast. These highs served as the original traps for oil; because of lateral facies changes and permeability barriers, the oil was prevented from escaping updip after the subsequent tilting.

The Ste. Genevieve pools found to date in the Effingham area are quite small, and production, in terms of barrels per well, is relatively minor. Future exploration conducted in areas where present-day anticlinal noses coincide with favorable stratigraphy and positive residuals would appear to have the best chance for success in finding Ste. Genevieve oil.

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