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SPAR MOUNTAIN SANDSTONE IN COOKS MILLS AREA, COLES AND DOUGLAS COUNTIES, ILLINOIS

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ABSTRACT

Development of significant oil production from erratic sand lenses in the Ste. Genevieve carbonate sequence some 20 miles north of other production in east-central Illinois has generated new interest in oil possibilities along the northern rim of the deep part (Fairfield Basin) of the Illinois Basin.

The Cooks Mills area of northern Coles and southern Douglas County is a rectangular area of about 200 square miles. The first producer was completed in 1941 but important development did not follow until 1954. By the end of 1957 more than 600 holes had been drilled, resulting in 334 producing wells located in five different pools, and more than 3, 000, 000 barrels of oil had been produced from 5, 170 proven acres. Reserves studies indicate that 7.5 million to 8 million more barrels of oil will ultimately be produced from these wells.

The producing sand commonly referred to as "Rosiclare" is older than true Rosiclare and is correlative with the Spar Mountain Sandstone. It is suggested that the environment in which Spar Mountain sediments were deposited resembled that on the Bahama Banks today. Minor but important structural deformation on a low, southeastward dipping slope developed during Chester time, and the present sites of oil concentration are found along structural trends formed at that time. Post-Mississippian folding, resulting in major uplift along the LaSalle Anticlinal Belt just to the east, further modified the Cooks Mills area. Current structure maps on Mississippian horizons show a regional southwestward dip on which the earlier areas of positive deformation are reflected as noses or terraces with little or no closure.

INTRODUCTION

The Cooks Mills area, in northern Coles and southern Douglas Counties, is a rectangular area about 12 miles wide from east to west and 16 miles from north to south. The area includes the towns of Tuscola at the northeast edge, Cooks Mills near the south edge, and Arcola in the east-central part. The area is nearly flat with local relief less than 30 feet. Topographic elevations range from 615 feet above sea level on the Kaskaskia River bottom at the south edge of the map to 690 feet on the highest points in the area.

Structurally the Cooks Mills area (fig. 1) lies north of the center of the Illinois Basin, the major structural depression in the Illinois-Indiana-Kentucky

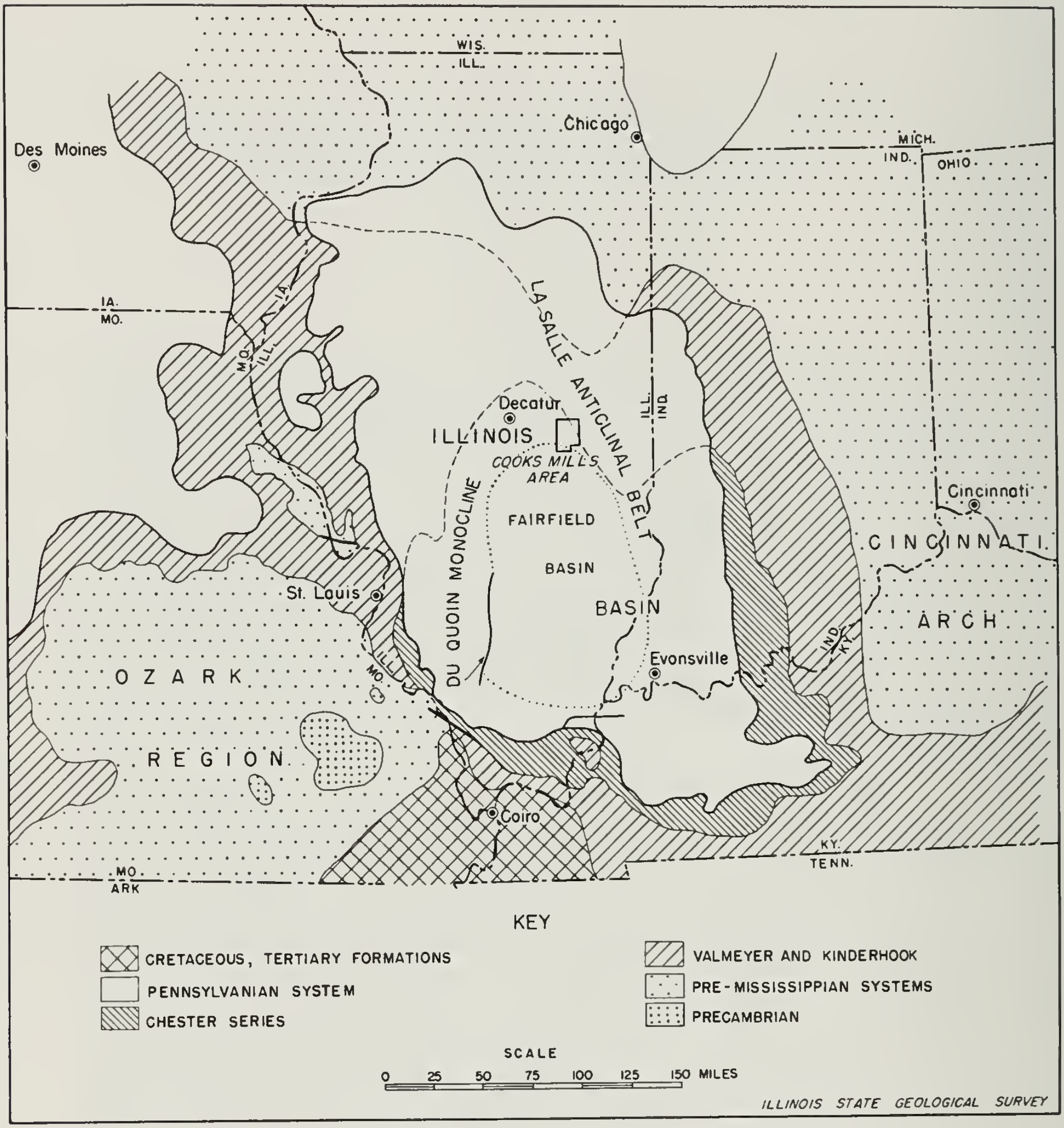

Fig. 1 - Location of the Cooks Mills area as related to regional structure.

region. It is at the northeast edge of the deeper or Fairfield Basin portion of the Illinois Basin and just west of the LaSalle Anticlinal Belt which is the major positive feature within the Illinois Basin.

In May 1953 Clyde Bassett completed the No. 1 Haybrook well in sec. 2, T. 13 N., R. 7 E., Coles County, for an initial production of 24 barrels of oil a day from the Spar Mountain ("Rosiclare") Sandstone. The well revived interest in the old Cooks Mills area where earlier mediocre production had been abondoned in 1950. Subsequent interest in this area resulted in drilling more than 600 holes, 334 of which were completed as producing oil wells and 17 as gas wells. Oil production, with only minor exceptions, is from the Spar Mountain ("Rosiclare") Sandstone of middle Mississippian (Valmeyer) age; the gas is from sandstone in the Cypress Formation of late Mississippian (Chester) age.

The general geologic setting and the stratigraphic sequence in this vicinity are described, but primary emphasis is placed on the lithologic relationships of the Spar Mountain ("Rosiclare") Sandstone, the structural evolution of which has resulted in the accumulation of oil in that zone, and a brief review of the economic results.

Conslusions presented are based on various types of information including reports received from the Illinois Basin Scouts Association, personal discussions with geologists and engineers at the wells, and data on file at the Illinois State Geological Survey. Basic data on the structural and isopach maps are taken from electric or radioactivity logs which are available for about 95 percent of the holes drilled. Sample studies by Survey staff members and independent geologists furnish the basis for lithologic descriptions and correlation.

Acknowledgments

It is a pleasure to acknowledge the assistance provided by other members of the Illinois State Geological Survey staff. Sample studies by and discussions with Elwood Atherton aided materially in establishing correlations shown on the cross section of the Chesterville East pool. The geologic criticism of H. R. Wanless of the University of Illinois, and of A. H. Bell and David Swann of the Survey, have been especially helpful. In addition thanks are due to the several company and independent geologists who provided detailed core descriptions on various holes scattered throughout the area.

GENERAL STRATIGRAPHY

The deepest test within the area, both by actual footage drilled and in terms of the stratigraphy involved, is the Harold Sanders No. 1 Huffman in the SE$\frac{1}{4}$ sec. 19, T. 14 N., R. 8 E., Coles County. This hole is near the center of the area, and the thicknesses given in the stratigraphic column (table 1) below the Beech Creek (Barlow) Limestone are those encountered in this test. The strata thin northward and thicken southward. Chester beds above the Beech Creek were removed in the area of this test during the erosional period that immediately preceded Pennsylvanian deposition, so data on this part of the column are taken from holes drilled in the southern end of the Cooks Mills Consolidated pool at the south end of the area.

Pleistocene

Pleistocene sediments range in thickness from about 50 feet in the southern part of the area to nearly 150 feet in the northern part. They are represented by unconsolidated surface sands, gravels, and boulder clays that were deposited by the various ice sheets which have covered the area in the past. Glacial deposits of Wisconsin, Illinoian, and Kansan age are represented.

Pennsylvanian

The Pennsylvanian System is represented by about 1100 feet of sediments in the northern part of the area, but southward the beds thicken to about 1500 feet near Cooks Mills. The greater thickness is due partly to regional thickening toward

Table 1. - Stratigraphic Section

		Thickness in feet
Pleistocene		50-150
Pennsylvanian		1100-1500
Unconformity		
Mississippian		
Chester		0-400
Menard	0-10	
Waltersburg	0-40	
Vienna	0-5	
Tar Springs	0-90	
Glen Dean	0-15	
Hardinsburg	0-40	
Golconda	0-70	
Beech Creek (Barlow)	0-20	
Cypress	80	
Paint Creek, Bethel	45	
Downeys Bluff	5	
Yankeetown, Renault	30	
Aux Vases	20	
Valmeyer		1045
Ste. Genevieve		
"Levias"	26	
Spar Mountain ("Rosiclare")	42	
"Fredonia"	36	
St. Louis	118	
Salem	103	
Warsaw	80	
Borden	640	
Kinderhook		116
Chouteau	7	
New Albany (in part Devonian)	109	
Unconformity		
Devonian		165
Unconformity		
Silurian		496
Ordovician		
Maquoketa	210	
Kimmswick (Trenton)	152 penetrated	

the south and west and partly to the fact that younger beds are present toward the south. Immediately east of the area, over the axis of the LaSalle Anticlinal Belt, beds of Pennsylvanian age are very thin or may be absent.

Rocks of the Pennsylvanian System are predominantly silty or sandy shales with local developments of sandstone. Three thin but persistent and readily identified limestones, the Millersville, Shoal Creek, and West Franklin, are present in the upper 600 to 800 feet of section. Several coal seams, including No. 7 Coal which was mined in the 1880's at Mattoon about five miles to the south, are represented in the area, but there are not enough data at this time to tell whether any are of minable thickness.

Mississippian

Chester

Chester beds range in thickness from about 200 feet at the north edge of the area mapped to about 400 feet at the south. They are absent over the LaSalle Anticlinal Belt, cutting out approximately as indicated on the structure map on the Ste. Genevieve Limestone (see fig. 4). Their variation in thickness over the area and their absence over the LaSalle Anticlinal Belt is due to erosion which preceded Pennsylvanian sedimentation.

The youngest Chester beds preserved in the area are Menard in age. A few feet of limestone representing the base of the Menard Formation is found in subsurface in the southern part of the area.

Where not affected by pre-Pennsylvanian erosion, the Tar Springs Formation ranges in thickness from about 60 feet to more than 90 feet. The thicker sections are invariably associated with local increases in sand development. Over most of the area the section consists of gray to dark gray shale with some red and green shale streaks all interbedded with thin bands of silt and fine sandstone.

The Glen Dean Limestone is present in the southern half of the area, where it is the first good marker bed. It is buff to light brownish gray, cherty, finely crystalline to coarsely granular limestone, and is usually sandy. Its thickness averages 10 to 15 feet and it is characterized electrically by high self potentials and low resistivities.

The Hardinsburg and Golconda strata are represented by a sequence of greenish or greenish gray to reddish shales with a few thin interbedded limestones especially in the Golconda portion. The total sequence including the Beech Creek (Barlow) Limestone at the base of the Golconda averages 80 to 100 feet thick.

The Beech Creek Limestone is the highest Chester marker bed consistently represented. The name Beech Creek Limestone from the Indiana outcrop has priority over the term "Barlow" which is commonly employed by the oil field geologist. In the southern part of the area the Beech Creek is a light to dark brownish gray limestone, very finely to coarsely crystalline, fossiliferous, and in part oolitic. Northward it becomes sandy and more porous. On electric logs in the southern part of the area it is characterized by the relatively low self potential and high resistivity readings expected of a limestone, but northward the self-potential readings increase and resistivities decrease so that some electric log curves can be interpreted as indicating a sandstone. Its thickness remains fairly constant at about 20 feet. (For electric log characteristics of the column from the Beech Creek to the Salem Limestone see cross sections, figs. 5 and 6.)

The Cypress Formation ranges in thickness from a normal of 60 to a maximum of about 90 feet. The thinner sections are predominantly greenish gray or red silty shales with occasional thin sandstone streaks. Locally a well developed sandstone lens is present. Such a lens is the reservoir for the gas wells centering in sections 23 and 26, T. 14 N., R. 7 E.

Ideally the top and bottom of the Paint Creek Formation (including the equivalents of the Bethel Sandstone) are delimited by readily identifiable limestone beds, but in this area the upper part of the formation is represented by a calcareous zone with only locally developed discontinuous thin limestone streaks. The remainder of the formation is primarily gray to greenish or brownish gray, splintery shales which are similar to those of the Cypress Formation above and the Yankeetown and Renault Formations below. The lack of a persistent limestone marker bed at the top makes it difficult to pick the exact upper boundary, especially when correlations over wide areas are based on electric log interpretations. The lower limit is marked by the underlying Downeys Bluff Limestone which is generally present.

Called "Upper Renault" in this area by many geologists, the Downeys Bluff Limestone can usually be identified with reasonable certainty. It is a light gray to brownish gray, fine to medium crystalline, rather dense to sublithographic limestone containing some red or orange chert. As stated above, the shales of the Yankeetown and Renault Formations lithologically are similar to those of the Paint Creek Formation.

The upper part of the Aux Vases Formation is sandy throughout most of this area. These sandstones are light greenish gray, generally fine- or very fine- to medium-grained and quite calcareous. Minor amounts of oil have been produced from the upper part of the Aux Vases in two or three wells in the area. The lower part of the formation is usually a soft grayish or greenish shale, often with some thin white to tan somewhat sucrosic dolomite breaks. This part is sometimes included in the Ste. Genevieve Formation, but in the Cooks Mills area it is not easily identified on either electric logs or sample studies, so the top of the Ste. Genevieve is placed on the dense limestone beneath this unit.

Valmeyer

The Ste. Genevieve Formation is divided into three members, the "Levias" at the top, the Spar Mountain (or "Rosiclare"), and the "Fredonia." The "Levias" Limestone Member is an easily recognized 10- to 30-foot limestone unit, with the greater thicknesses toward the north. It is light tan to brown, sublithographic, finely crystalline limestone. Locally it may become coarser and granular in character, and on occasion may include some dolomitic streaks.

The Ste. Genevieve Formation was originally divided into the three members, Levias, Rosiclare, and Fredonia, in outcrops of the fluorspar district of southeastern Illinois and western Kentucky. However, the type Rosiclare Sandstone Member has been shown (Swann and Atherton, 1948) to be the Aux Vases rather than the lower sandstone generally called "Rosiclare" in the oil areas or in the Indiana outcrop (Pinsak, 1957). As the type Rosiclare is equivalent to the Aux Vases, and probably only the upper half of the Aux Vases as recognized in this paper, it follows that all three divisions of the Ste. Genevieve used here, "Levias", Spar Mountain or "Rosiclare", and "Fredonia" are actually parts of the type Fredonia. Though three divisions of the Fredonia in its type region can be recognized, only the middle one has been named (Tippie, 1945). The upper essentially pure dense limestone member is called "Levias" here despite recognition that it lies below the position of the true Levias.

The name Spar Mountain Sandstone Member (Tippie, 1945, p. 1658) is used here for the middle member recognized in the Ste. Genevieve and commonly called "Rosiclare" in the Cooks Mills area and most other parts of the basin. It is a unit that is extremely erratic in thickness and includes a varied lithology that ranges from dolomite through limestone, sandy limestone, and shale. It is generally easy to establish the top because of a thin, 1- to 2-foot dark greenish gray to brown, fissile, calcareous shale that is identified on electric logs by a narrow reverse kick on the resistivity curve just above an increase in self potential. Where the shale is absent the increase in self potential serves to locate the top.

Where the Spar Mountain Member is best developed it consists of a sandy limestone, or calcareous and often shaly sandstone, up to 8 feet thick, overlying a clean, porous, 10-foot sandstone composed of fine- to medium-sized, angular to subangular sand grains. These beds rest on a dense to sublithographic limestone of the "Fredonia" Limestone Member. In cores from sec. 6, T. 14 N., R. 8 E., examined by the writer, the sandstone exhibits cross bedding averaging about 25° with the vertical axis of the cores. Although the few cores examined from other parts of the area did not exhibit this same phenomenon, it is believed that similar cross bedding may be erratically represented.

The extreme and rapid variation in lithology is well illustrated by core descriptions of a few holes in secs. 16, 17, 18, and 19, T. 14 N., R. 8 E. The Spar Mountain sequence at the producing wells in sec. 19 is from 20 to 30 feet thick, has a 5- to 10-foot calcareous sandstone section at the top, a middle 5- to 10-foot oolitic limestone that may be slightly sandy, and a friable porous sandstone resting on "Fredonia" Limestone at the base. Northeastward in secs. 18 and 17 the total zone thins to an average of about 9 feet although in scattered wells it may still be as much as 20 feet thick. Sand becomes a minor part of the sequence and the dry hole in sec. 16, where the zone is about 26 feet thick, has only 2 feet of tight sandy dolomite, the rest of the zone being dolomite or limestone. The problem is further complicated by the fact that relatively massive dense limestone near the bottom of the "Fredonia" Member may suddenly change laterally to thinner limestone streaks with interbedded dolomites or even to a thick dolomite. At such places it is difficult to ascertain the base of the Spar Mountain, and in the absence of core information it is likely to be picked much too low. In sec. 17 much of the production attributed to the Spar Mountain Sandstone is actually coming from the lower dolomites of the "Fredonia."

The "Fredonia" sequence is not always identified in samples or electric logs. This may be due to inability to recognize these beds at places or to the fact that at some places the sequence may be absent. Where well represented it consists of alternating beds of light brownish gray, dense or sublithographic limestone, sometimes slightly cherty, and gray to brownish gray dolomites. There appears to be little, if any, oolitic limestone in this area typical of the McClosky zones farther south. As stated in the discussion of the Spar Mountain above, the upper contact of the "Fredonia" in subsurface is often uncertain. This is also true of the lower contact with the St. Louis Limestone.

The St. Louis Limestone is light brownish gray, dense to sublithographic, contains blue-gray cherts, and is interbedded with light brownish gray, finely crystalline dolomite. Since the "Fredonia" and St. Louis Limestones are somewhat similar in character, it is often difficult to pick the exact top of the latter. Many people studying samples put the top where the first chert appears in the section. The light blue-gray chert is easily recognized and serves as a useful tool, but there are also cherts in the "Fredonia, " so this criterion must be used with care. The best criterion for identification of the St. Louis is the presence of anhydrite. Only rarely have evaporties been reported in beds higher in the section than the St. Louis and then only as nodules. Both bedded and nodular anhydrite is present just below the Spar Mountain Sandstone in the Chesterville East pool in beds which may be "Fredonia." The St. Louis as identified in this area ranges in thickness from 50 feet to about 180 feet.

The Salem is a gray-tan to brown, medium- to coarse-grained limestone composed in large measure of fossil fragments. At some places it may be oolitic or even somewhat sandy. The presence of the foraminifer *Endothyra baileyi* generally identifies the formation. Its thickness ranges from 100 to 120 feet.

The Warsaw Limestone in this area includes 40 to 80 feet of finely crystalline, silty and cherty gray dolomites and limestones with some interbedded siltstones similar to those in the Borden beneath.

The Borden Group is a sequence of calcareous gray siltstones about 650 feet thick. Fine- to very fine-grained sandstone beds, at places as much as 50 feet thick, may be present in the lower 200 to 250 feet of the sequence. To the southeast these sandstones, known as the Carper, have contained oil, and on occasion oil shows have been reported in this area.

Kinderhook

The Kinderhook Series is represented by 5 to 15 feet of pale bluish gray, finely crystalline dolomite or dolomitic limestone of the Chouteau Formation at the top and about 100 feet of New Albany Shale that is black or brownish black, pyritic, and spore bearing. The lower part of the New Albany sequence is of Devonian rather than of Mississippian age.

Devonian and Older

Several holes have been drilled through the Kinderhook strata and one has penetrated more than 1, 000 feet of older beds. They indicate that the Devonian and Silurian beds are predominately limestones or dolomites, about 600 to 700 feet thick, underlain by about 200 feet of Maquoketa Shale of Ordovician age. The Kimmswick (Trenton) Limestone underlying the Maquoketa was penetrated 152 feet. These beds are not pertinent to this study and are not discussed.

PROBLEMS OF THE SPAR MOUNTAIN FORMATION

Depositional Environment of the Spar Mountain Formation

Inasmuch as the Spar Mountain Formation in this area is a variable sequence composed principally of limestone or dolomite with included well developed sandstone lenses and only minor amounts of shale, and as it is bounded above and below by limestones, it is obvious that the environment of deposition was especially favorable for carbonate development. The formation represents an episode in the long interval of Mississippian carbonate deposition beginning in this area with beds of late Osage or early Salem age and culminating with the immediately overlying "Levias, " after which the environmental conditions changed to those suitable for the Chester type of deposition. What are the physical and climatic factors that could have accounted for this episode?

Rodgers (1957) states that "sea water must be approximately saturated or even slightly supersaturated to permit large-scale carbonate deposition whether chemical or organic. But saturation will be reached first in warm shallow seas in tropical or subtropical climates." He concludes that "the extraordinary spread of limestone deposition over the world at several times in the Paleozoic . . . implies therefore that warm shallow seas and 'subtropical' climates covered much more of the earth than now."

Newell and Rigby (1957), in discussing the Bahamian platforms which are covered by only a few feet of clear water, say "conditions of sedimentation here must closely resemble those of the limestone shelf seas of the Paleozoic and Mesozoic. Nearly three miles of carbonate deposits have been laid down in the Bahamas since the early part of the Cretaceous period, indicating that there has been a high sustained rate of deposition. Doubtless this has contributed to the persistent subsidence of the area."

A review of the literature shows that the most widespread carbonate deposits being formed today lie between the 30th parallels of north and south latitude. This includes many thousand square miles of shallow sea bottom in the Gulf of Mexico-Caribbean Sea area, on the Northwestern Shelf of Australia and over the platform between Mindanao and Borneo, and parts of the shelf areas between Borneo and Java, and along the northwestern edge of the Indian Ocean including the Red Sea. These areas not only serve as sites of carbonate deposition today, but their geologic columns show thick limestone sequences indicating the long existence of similar conditions. All of these areas have three things in common, a tropical or subtropical climate, shallow waters supporting a tremendous organic population, and an absence of major streams dumping large amounts of detritus.

Several aspects of the Illinois limestones that represent Valmeyer time seem to indicate a similar environment of deposition. The abundant fossil fragments in the Warsaw, Salem, and at some places in the St. Louis Limestones indicate a sea teeming with organisms. The presence of evaporites, particularly in the St. Louis, suggests isolated patches of shallow water and a climate warm enough that evaporation materially exceeded rainfall in the area. Such a negative rainfall relationship would imply probable scarcity of moisture which could move detritus from adjacent land areas into the marine environment, thus explaining the paucity of shales and siliceous sandstones.

Pettijohn (1957) is of the opinion that the presence of oolitic calcarenites implies strongly agitated shallow waters, and Illing (1954), in discussing calcareous oolites in the Bahamas, claims they are formed only after fresh oceanic waters sweeping onto the banks have become sufficiently warmed and mixed to be appreciably supersatured with calcium carbonate. Further "oolitic coated sands are formed only where the sediment is subjected to strong marine currents (normally tidal). They do not occur in the marginal areas . . ." The Salem, St. Louis at places, and "Fredonia" (McClosky) all have well developed oolitic zones which are cross bedded, indicating deposition in an agitated environment.

From the above discussion it may be concluded that the climate in the Cooks Mills area during Valmeyer time was tropical or subtropical. The waters in which the limestones were being deposited were generally shallow, being only a few feet deep over wide areas, yet subject to considerable agitation, with selective sorting of materials. This is the over-all situation into which the Spar Mountain episode must fit.

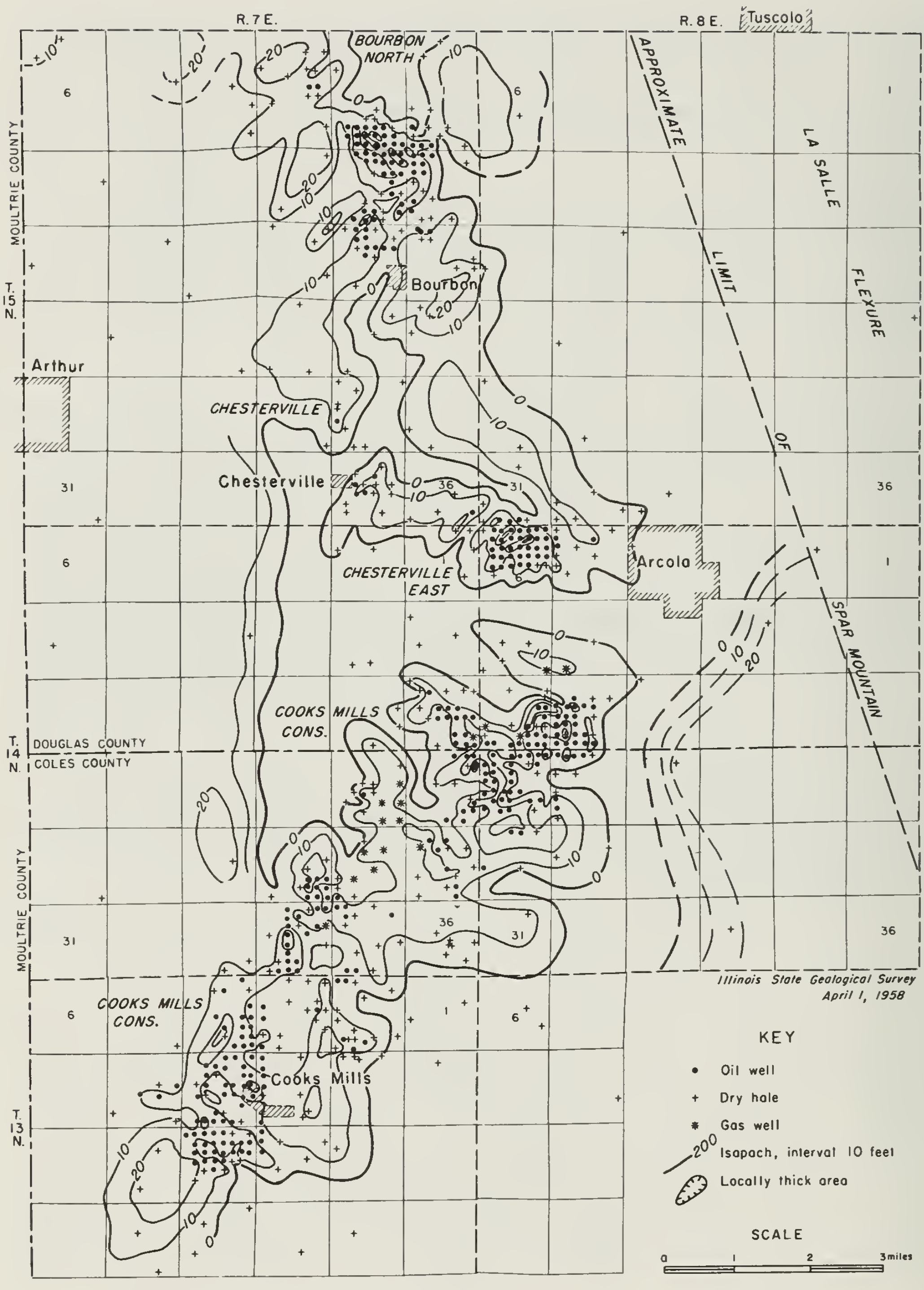

Fig. 2. - Thickness of the Spar Mountain ("Rosiclare") Sandstone.

Two modern day areas of deposition, the Bahama Banks and Florida Bay, fulfill the general requirements set out above. Both have been studied recently and in considerable detail. Each, in addition to having been preceded by a thick sequence of carbonate sediments, seemingly supplies many of the physical elements believed necessary to produce features observed in cores or inferred from the electric characteristics of the Spar Mountain Formation.

According to Illing (1954) the Bahama Banks,covering over 40, 000 square miles, are a huge submarine plateau lying some 50 miles southeast of Florida. The top of the plateau is a remarkably flat surface just below sea level with only a few marginal areas in which the water depths exceed 36 feet and over which the average depths vary from 12 to 20 feet. The plateau is surrounded on all sides by precipitous slopes which drop to oceanic depths. Twice daily the surface of the plateau is alternately partly flooded and partly drained, due to the rhythmic 3-foot tidal variation along its margins. As a result rather strong tidal currents are generated which gradually decrease in intensity and become essentially negligible toward the center of the plateau.

At various places, principally near the margins and covering about a tenth of the total banks, there are islands whose only elevations are long ridges of carbonate dune sands. For a distance of one to four or five miles around these extreme shoal areas or island patches there is a considerable accumulation of various materials such as oolites, rounded fragments of shells, etc., which are sorted and directionally aligned according to the particular agent which predominated in that vicinity. Interspersed between such shoal areas are somewhat deeper channels where little sediment is accumulating at present.

Ginsburg (1956 and 1957) described conditions in the Florida Bay area. Here, as in the Bahama Banks, there are shoal areas a foot or two below water level separated by deeper channels. Occasionally there are very small mangrove islands lying just above water level. Depth to bedrock ranges from about 4 feet in the northeast part of the bay to nearly 12 feet near the keys at the southwest. The deeper areas at any given part of the bay are, therefore, essentially controlled by the bedrock surface and represent those places where water movement, from whatever cause, is sufficient to keep the bottom scoured.

Life in this area is extremely prolific, with the calcareous mud banks composed of the skeletal remains of organisms. The skeletal fragments, however, are digested and redigested by living organisms until a high percentage of the total accumulation is represented by particles less than 1/8 mm in diameter. Here the environment is restricted rather than in the open sea, as in the Bahama Banks. The hinterland is moist,and currents from the land do enter the bay from the north. These waters, however, travel over a limestone terrain before entering the bay and, hence, do not carry debris which can supply shale or quartz sand. Minor daily fluctuations in water level over a good portion of the bay and reversals in current direction near the seaward margin are caused by tidal advances and retreats.

Figure 2 is an isopach map of the Spar Mountain Sandstone in the Cooks Mills area. Thickness values used include, as nearly as can be told from available core and electric log data, only that part of the total Spar Mountain sequence in which quartz sand is present, regardless of whether it be a single body or several lenses.

The map invites some interesting speculation. The arcuate character of the trend is immediately obvious. It should be borne in mind, however, that holes to the east in secs. 10, 21, and 34, T. 14 N., R. 8 E. and nearly all of the holes to the west show appreciable quantities of sand. It is believed that a study of a larger area would indicate a more patchy distribution and belie any important significance that the arcuate trend shown in figure 2 might imply. The Mattoon pool, just off this map to the south, has a definite north-south alignment. Certain details, however, do seem to warrant consideration.

Study of the thicker sand bodies, especially west and northwest of Arcola, reveals a definite two-directional alignment pattern,a general over-all pattern from northwest to southeast,with a more subdued superposed northeast-southwest alignment in local areas. The former may be the result of tidal currents which Shepard (1948) points out are significant at the bottom along the contours of slopes or over flat stretches. He also calls attention to the fact that inland seas having fairly restricted connections with the ocean are often subject to relatively strong tidal currents. The northeast to southwest alignment may be the result either of local variations in current direction or possibly of wind sorting.

The strongest argument for wind action is localized in sec. 6 and to a lesser degree in secs. 17 and 18, T. 14 N., R. 8 E. Several cores through the sand body in sec. 6 are cross bedded, exhibiting an angle with the vertical axis of the core of between 25° and 30°. Cross bedding does not prove wind deposition but when coupled with an abrupt local thickening in the sand body at an angle to the apparent direction of the main mass, it strongly suggests such deposition.

Attention is also called to the area, extending westward from the southwest corner of Arcola, in which no sand is present. This strongly suggests a scoured channel, possibly by tidal currents which prevented any sand deposition. Additional evidence for this probability may be deduced from the westward extension of the good sand body in sec. 6, T. 14 N., R. 8 E. Arguments could be made for the presence of similar though less prominent scoured channels from sec. 2, T. 13 N., R. 7 E. northwestward across sec. 34, T. 14 N., R. 7 E., and across secs. 12 and 14 and sec 24, T. 15 N., R. 7 E.

Features similar to those mentioned above are present and described by Illing (1954) in his discussion of the Bahama Banks area. Especially striking are the similarities in many details between his illustrations of Ragged Island, Nurse Cay and other island tracts with those shown on figure 2. There are, of course, also dissimilarities but they are related primarily to features influenced by wind action which apparently was insignificant in the Cooks Mills area.

There is one other difference not specifically apparent from the foregoing discussion. The Bahama Banks area sediments are all limestone, but the Spar Mountain sediments at places contain appreciable amounts of quartz sandstone that grades laterally into carbonate sediments. It is pointed out, however, that both quartz sand and the material around Ragged Island represent clastic materials and that both would be distributed by currents in the same manner. If a limited supply of quartz sand were available along the Bahama Banks today one would expect it to be incorporated in the sediments in a patchy manner and with the materials distributed by currents.

Similarities between the Cooks Mills area and the Florida Bay picture are considerably less obvious. The distribution pattern of the shallower or bank areas in the bay is similar to the distribution pattern of the areas lying between the accumulations of sand in the Spar Mountain strata. The areas of non-sand deposition contain dense limestones or very fine- to fine-grained dolomites, which one can imagine as having been derived from fine carbonate materials such as are present in the shallow banks of the bay. Waters entering the bay from the land side flow through the deeper channels on their way to the sea. It might be postulated that if these waters were for some reason to obtain a supply of quartz sand, they would tend to drop the sand upon entering the bay, resulting in a progressive filling of the channel areas with the sand. After the channels had been filled, a slight over-all increase in water depth over the entire area with an attendant return to carbonate deposition would complete the picture.

It is apparent that the depositional processes in the two environments are different. If the Bahama Banks situation is pertinent, the emphasis is on processes imposed by direct connection with the open sea, and the distribution of the sand bodies is the result of ocean generated currents, probably mostly tidal in origin. The Florida Bay situation is much more restricted, and, although tidal currents and a connection with the ocean are necessary, the distribution of the sand depends upon current action imposed by runoff from the adjacent land. Probably elements of each were operating in different parts of the Illinois Basin during the Spar Mountain episode, but it is believed that in the Cooks Mills area conditions similar to those around the Bahama Banks were predominant.

Structural Evolution

The Spar Mountain was deposited on a relatively flat surface very close to sea level. At the present time, however, structure contour maps using the base of the Beech Creek (Barlow) Limestone (fig. 3) and the top of the Ste. Genevieve Limestone (fig. 4) as datums show continuous dips toward the southwest averaging between 60 and 80 feet to the mile. This southwestward dip is much steeper along the east side of the mapped area where the beds are rising on the west flank of the LaSalle flexure.

In the early phases of this study several cross sections, some using the base of the Beech Creek (Barlow) and some sea level as datum, were constructed across several of the producing areas. Figures 5 and 6 are east-west cross sections for the Chesterville East pool centering in sec. 6, T. 14 N., R. 8 E.

Examination of the structural cross section (fig. 6) indicates a steady rise toward the east with only a terrace-like flattening near the updip limit of production in the pool. No true reversal typical of structure traps is apparent. Why then should oil be trapped at its present locale?

Cross section (fig. 5) which uses the base of the Beech Creek as a datum plane, portrays the structural relationships at the time of Beech Creek deposition. Careful examination reveals that the sequence of beds between the Beech Creek and the Spar Mountain in the producing wells is thinner by more than 30 feet than in the dry holes that are in the present updip direction toward the east. By constructing sections farther south where the Glen Dean can be used as a datum plane, it can be demonstrated that the thinning was even greater before the end of Chester time.

The obvious conclusion is that structural warping, going on during Chester time, had some effect upon the present location of the oil pools. An isopach map (fig. 7) showing the interval from the base of the Beech Creek to the top of the Spar Mountain gives the plan view of the structure at the beginning of Beech Creek time. The map reveals an arcuate area of thinning extending from the north edge of the map to the south edge. Maximum interval variations at right angles to the area of thinning amount to about 30 feet toward the west and 60 feet toward the east. There is an over-all thickening of about 30 feet in the 16 miles from north

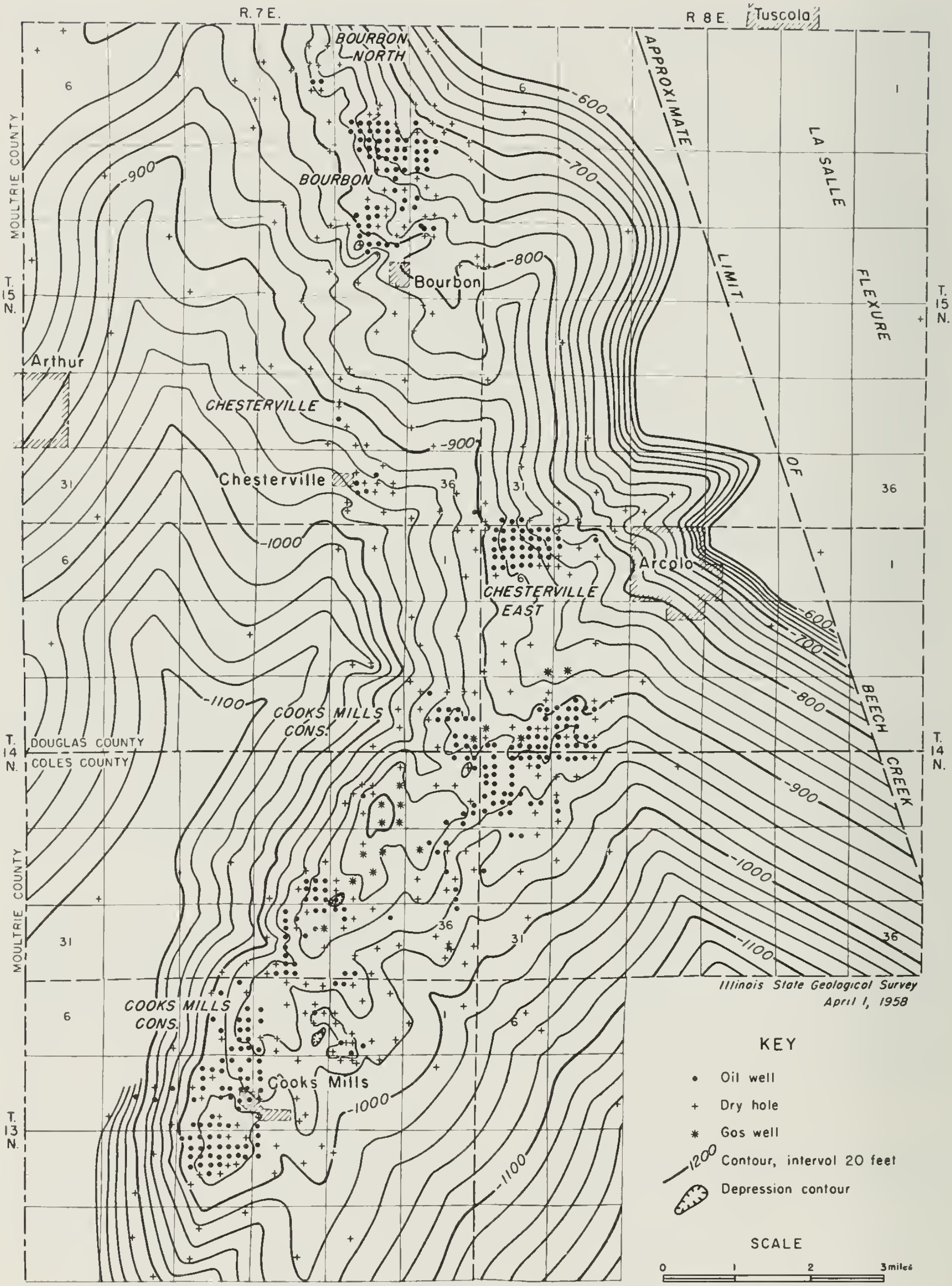

Fig. 3. - Structure on base of the Beech Creek (Barlow) Limestone.

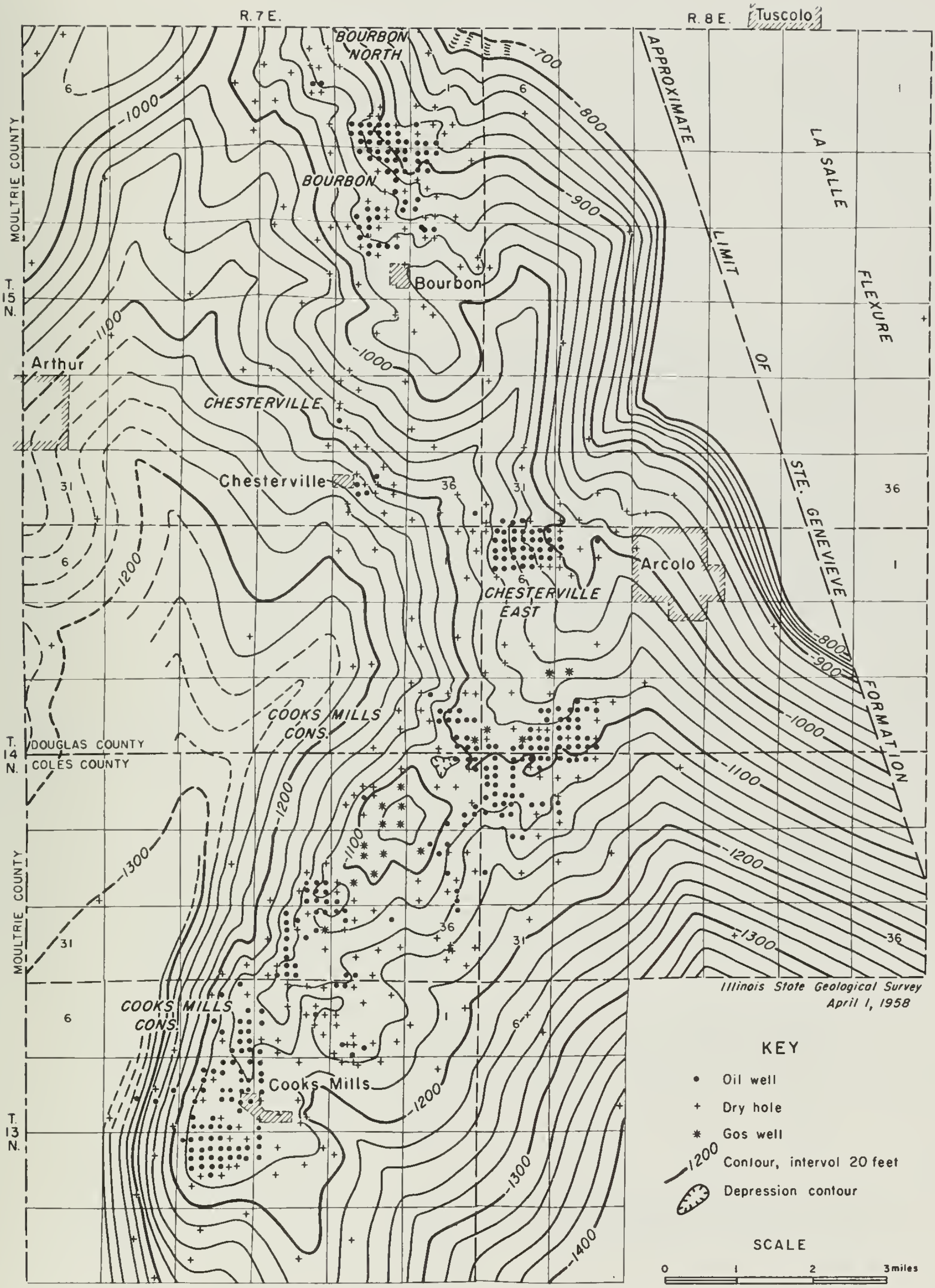

Fig. 4. - Structure on top of the Ste. Genevieve Formation.

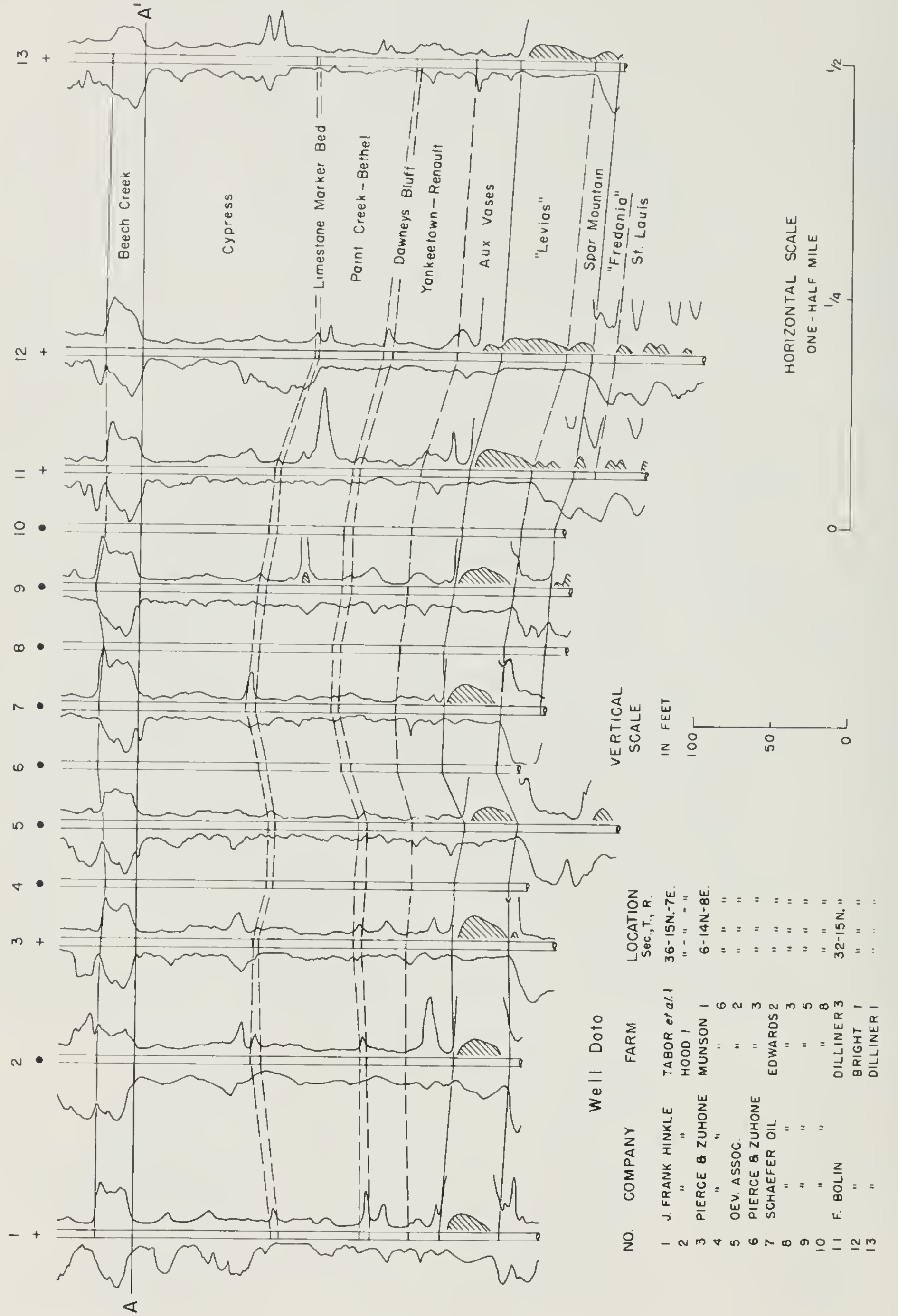

Fig. 5. - Stratigraphic cross section, Chesterville East pool. Datum - base of Beech Creek (Barlow) Limestone. Location shown on figure 7.

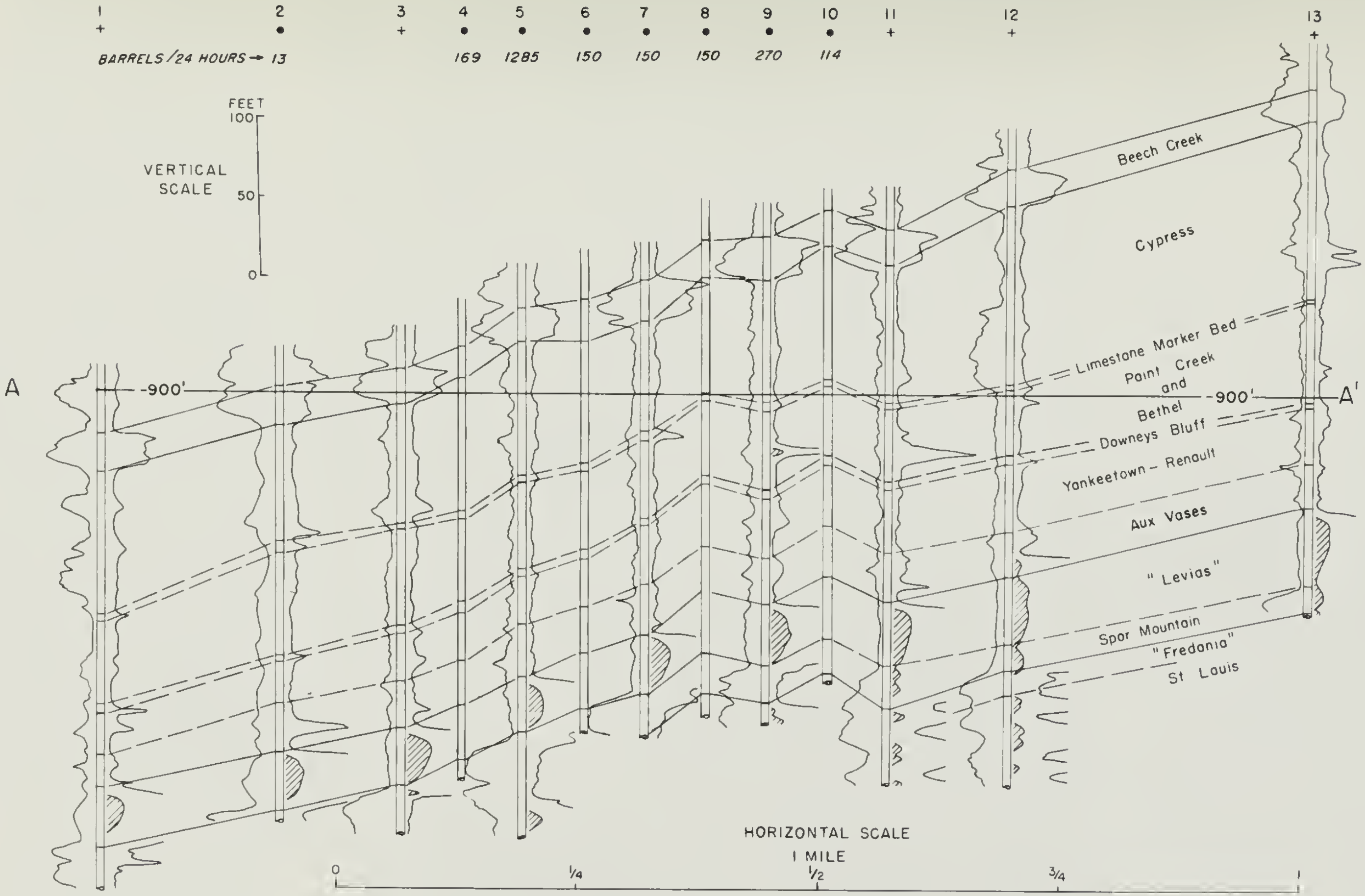

Fig. 6. - Structural cross section, Chesterville East pool, using the same wells as on figure 5. Location shown on figure 7.

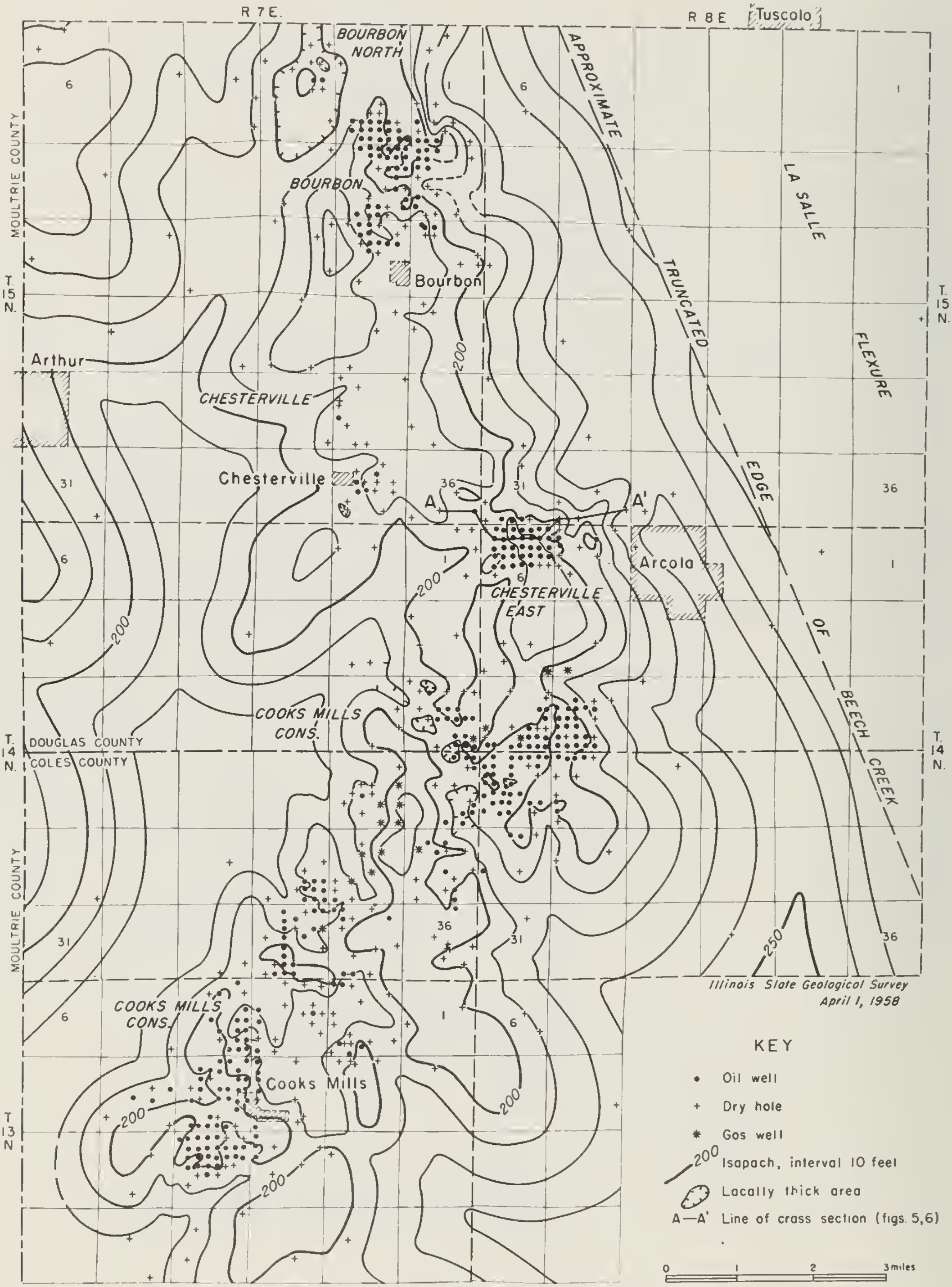

Fig. 7. - Thickness of interval from base of Beech Creek Limestone to top of Spar Mountain Sandstone.

to south along the axis of the arcuate feature and a maximum thickening of 75 feet between the thinnest areas at the northwest and the thickest areas at the southeast. All of the oil pools are located along the arcuate axis although not necessarily at the thinnest places.

Three conclusions may be drawn from these observations:

1) The over-all thickening in Chester sediments from northwest to southeast indicates that the sedimentary basin in southern Illinois was slowly subsiding during this time. By the beginning of Beech Creek (Barlow) deposition the resultant dip toward the southeast over this area on the top of the Ste. Genevieve was about 2 feet to the mile and may have been as much as 5 feet by the close of Chester time.

2) Minor warping was going on during Chester time. By the beginning of Beech Creek time, warping had developed enough relief to give the Spar Mountain Sandstone a structural reversal of about 30 feet against the regional dip.

3) The accumulation of oil at the present sites of production is probably related to the Chester warping, and the migration of oil to these sites may very well have been completed by the end of Mississippian time.

Siever (1951) shows that Mississippian sedimentation in Illinois ended with a withdrawal of the Chester seas and was followed by a long period of erosion, resulting in peneplanation. The area was then uplifted and warped, and the rejuvenated streams cut deep channels into the peneplain. It was during this period of uplift, which probably continued at least throughout Pennsylvanian time, that the LaSalle Anticlinal Belt was given major definition.

The Cooks Mills area, lying along the west edge of the LaSalle structure, was profoundly affected by these events. A strong southwestward dip was imposed on the former very low southeastward dip of the Mississippian strata, and former areas of warping became only minor terraces or local nosing features along the flanks of the larger uplift. This is the present picture shown on the structure maps (figs. 3 and 4).

Information based on subsurface data shows that total erosion, before Pennsylvanian sediments covered the LaSalle structure, was enough to remove 1200 to 1500 feet of Mississippian sediments. At present there is a structural rise on the top of the eroded surface of nearly 1,000 feet between the southeast corner sec. 2, T. 14 N., R. 8 E., and sec. 24, T. 15 N., R. 8 E., a distance of about four miles. The vertical component of the total uplift, therefore, amounted to at least 2,500 feet.

OIL PRODUCTION

Bourbon Pool

The C. B. Earnst No. 1 H. Pflum well in SW$\frac{1}{4}$ SW$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 11, T. 15 N., R. 7 E., Douglas County, was completed in April 1956 for an initial production of 155 barrels of oil a day. Production was from Spar Mountain Sandstone, the top of which was reached at 1654 feet. This was the discovery well for the Bourbon pool, development of which rapidly followed. By the end of 1957 drilling records showed 45 dry holes, 64 producing wells, and one abandoned producer in the pool area. Proven production covered 680 acres, and 763,000 barrels of oil had been produced. This represents more than a third of the total oil expected from the pool by present wells and present methods of operation. December 1957 production was slightly more than 11,000 barrels.

Production is located on a nosing feature that extends south-southwest off the LaSalle structure. Contours based on the Ste. Genevieve indicate a flattening in dip over the nose at the site of production. This terracing, together with an updip facies change of the reservoir beds from sandstone to tight limestone, accounts for the oil accumulation.

Bourbon North Pool

The first production in the Bourbon North pool was obtained when M. H. Richardson completed the No. 1 W. C. Taylor well in the NE$\frac{1}{4}$ sec. 3, T. 15 N., R. 7 E., in May 1956. The well was completed for 58 barrels of oil and 42 barrels of water a day after fracturing the Spar Mountain Sandstone which is the producing zone. The top of the Spar Mountain is at 1, 651 feet. One additional producer, the east offset, and 13 dry holes have been completed in the pool. Production to January 1, 1958, amounted to slightly more than 15, 000 barrels of oil, and daily production was still 12 barrels per well. It is estimated that approximately 20, 000 barrels of recoverable oil remain.

The producing wells are on the regional dip slope with no indication of updip reversal or terracing. The sandstone section has adequate thickness in all the dry holes that have been completed but in general it is tight and very calcareous. It is likely that cleaner and possibly somewhat coarser sandstone is present in the two producers. Additional drilling might add another well or two to the producing area but it is doubtful whether the probable economic return justifies such drilling.

Chesterville Pool

The discovery well of the Chesterville pool was drilled by the Arnett Drilling Company in the NW$\frac{1}{4}$ NE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 35, T. 15 N., R. 7 E., on the M. Miller farm. It was completed August 7, 1956 for an initial production of 70 barrels of oil a day from the Spar Mountain Sandstone, reached at 1806 feet. Before completion the pay zone was fracture-treated at the depth between 1808 and 1813 feet. The subsequent drilling of 29 additional holes resulted in a total of five producers, three of which are still on pump. Production to January 1, 1958, has amounted to 20, 500 barrels of oil, and it is estimated that about twice this amount remains to be produced. Total proven productive area appears to be about 100 acres.

The scattered producers are on the regional southwest dip slope where there is no indication of closure or terracing. Local sand conditions apparently determine the presence or absence of commercial production at any given location.

Chesterville East Pool

New interest in the possibilities for additional production in the Cooks Mills area was aroused when Pierce and Zuhone completed the No. 2 S. L. Munson in NW$\frac{1}{4}$ NE$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 6, T. 14 N., R. 8 E., on July 23, 1957, for a flowing well that made initially 787 barrels of oil a day. Pay formation was the Spar Mountain Sandstone which had indicated production possibilities when a flow of oil was obtained on a drill stem test from 1723 to 1746 feet, the total depth for the hole. Casing was set at 1737 feet and the section below that depth was subjected to a fracture treatment before the well was completed.

As of January 1, 1958, a total of 68 holes had resulted in 40 producers for the pool. The wells had proved a productive area covering 400 acres and had produced more than 464, 000 barrels of oil. Production during December 1957 amounted to 44, 600 barrels. Total production from the pool should approximate 2, 000, 000 barrels.

Accumulation of oil in this vicinity is controlled toward the northeast by 1) a flattening in dip over a nosing feature which farther south develops into the Cooks Mills structure, and 2) a change in the sand which becomes tighter and calcareous; the nonpermeable carbonates prevent migration of oil northward along the strike.

Cooks Mills Pool

In 1939 a small oil well completed on the Mattoon structure in sec. 1, T. 11 N., R. 7 E., Coles County, began a period of exploration in the general area. In December 1941 the Carter Oil Company completed the No. 1 Haybrook in C E$\frac{1}{2}$ SE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 2, T. 13 N., R. 7 E., Coles County, for 30 barrels of oil a day from the Spar Mountain Sandstone. This was the discovery well of the Cooks Mills pool. Unfortunately drilling in the immediate vicinity resulted in only one additional well. These two holes produced a total of 6, 000 barrels of oil before the pool was abandoned in 1947.

Although the results discouraged any drilling campaign, the eventual development of an important pool at Mattoon did cause sporadic drilling in the general Cooks Mills area. In 1946 Vincent Nolan opened the Cooks Mills North pool with the No. 1 Coombs Estate well in NE$\frac{1}{4}$ NE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 23, T. 14 N., R. 7 E. Initial production was 12 barrels a day from the Spar Mountain Sandstone. Offsets were dry and the hole produced only 219 barrels of oil before it was abandoned in 1950.

In May 1953 Clyde Bassett completed the No. 1 Haybrook in SW$\frac{1}{4}$ SE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 2, T. 13 N., R. 7 E., for a 20-barrel well from Spar Mountain Sandstone to renew production in the pool and revive interest in the area. The next producer was drilled by H. C. Sanders on the Bessie Parker lease in the SW$\frac{1}{4}$ NW$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 25, T. 14 N., R. 7 E. The well was completed initially for 54 barrels of oil from the Spar Mountain Sandstone and is credited as the discovery well of the Cooks Mills East pool. Development spreading outward from these two wells eventually proved the total area to be one pool which now is officially designated as the Cooks Mills Consolidated pool. Some holes were completed for very little oil whereas others made nearly 1, 000 barrels a day, although an average of 100 to 200 barrels was more common. Considerable volumes of gas were produced with the oil at many of the wells.

Between May 1953 and January 1, 1958, more than 390 holes were drilled in and adjacent to the pool resulting in 222 oil producers, 17 gas wells, and 155 dry holes. An area encompassing 2, 950 acres proved to be productive and approximately 1.8 million barrels of oil was produced. The 212 wells still producing made 28, 000 barrels of oil in December 1957, and it is estimated that 4.5 million barrels remain to be produced from this pool by present wells and current methods of operation.

Producing wells are located for seven miles along the axis of a southward-plunging asymmetric fold which has a vertical component of about 300 feet but a critical closure of less than 30 feet centering in secs. 23, 24, 25, and 26, T. 14 N., R. 7 E. Oil producing wells lie on the north, south, and east sides of, but not over, the area of closure. The Spar Mountain Sandstone under the area of closure was apparently too tight to be productive, but fortunately a good sandstone body containing large volumes of gas was present in the Cypress Formation. This sandstone body is now being developed as a gas storage reservoir.

SUMMARY

1) The sandstone member of the Ste. Genevieve Formation, called "Rosiclare" in the Cooks Mills area by the oil industry, occupies a lower stratigraphic position than the type locality Rosiclare and is probably equivalent to the zone called Spar Mountain by Tippie (1945).

2) Lithologic descriptions of the Spar Mountain Sandstone show it to be quite variable, in both character and composition, over short distances.

3) Reconstruction of the environment in which the Spar Mountain sediments were deposited suggest that it was most nearly parallel to conditions on the Bahama Banks today, although some of the elements present in Florida Bay may also be implied. An isopach map of the quartz sand portion of the Spar Mountain shows some striking similarities with Ragged Island, Nurse Cay, and other island tracts in the Bahama Banks area.

4) An isopach map of the interval from the base of the Beech Creek (Barlow) Limestone to the top of the Spar Mountain Sandstone shows that structural deformation and regional tilting was going on during Chester time. The regional dip developed during Chester time was toward the southeast. It is likely that the oil had migrated to present sites by the end of Chester time.

5) It is shown that post-Mississippian folding to the east along the LaSalle Anticlinal Belt reversed the regional dip and tilted existing structures until their present appearance, as shown by structure contouring on the base of the Beech Creek and on the Ste. Genevieve Limestone, is little more than a slight flattening or terracing on the westward regional dip. The vertical component of this uplift was in the order of 2,500 feet. It is believed that the post-Mississippian folding did not materially affect the present location of oil production in the area.

Maps for figures 2, 3, 4, and 7, on a scale of 1 inch = 1 mile, are available at the Illinois State Geological Survey, Urbana, Illinois

BIBLIOGRAPHY

Bartleson, B. L., 1958, Studies of the Rosiclare Member in Coles and Douglas Counties, Illinois: Master's Thesis, Univ. of Illinois, 37 p.

Ginsburg, R. N., 1956, Environmental relationships of grain size and constituent particles in some south Florida carbonate sediments: Am. Assoc. Petroleum Geologists Bull., v. 40, p. 2384-2427.

Ginsburg, R. N., 1957, Early diagenesis and lithification of shallow-water carbonate sediments in south Florida: Soc. Econ. Pal. & Min. Sp. Bull. 5, p. 80-100.

Illing, L. V., 1954, Bahaman calcareous sands: Am. Assoc. Petroleum Geologists Bull., v. 38, p. 1-95.

Mylius, L. A., 1927, Oil and gas development and possibilities in east-central Illinois: Illinois Geol. Survey Bull. 54.

Newell, N. D., and Rigby, J. K., 1957, Geological studies on the Great Bahama Bank: Regional Aspects of Carbonate Deposition: Soc. Econ. Pal. & Min. Sp. Bull. 5, p. 15-79.

Payne, J. N., 1940, Subsurface geology of Iowa (lower Mississippian) Series in Illinois: Am. Assoc. Petroleum Geologists Bull., v. 24, p. 225-236.

Pettijohn, F. J., 1957, Sedimentary Rocks: Harper & Bros., New York.

Pinsak, A. P., 1957, Subsurface stratigraphy of the Salem Limestone and associated formations in Indiana: Indiana Dept. Conserv. Geol. Survey Bull. 11.

Rich, J. L., 1948, Submarine sedimentary features on Bahama Banks and their bearing on distribution patterns of lenticular oil sands: Am. Assoc. Petroleum Geologists Bull., v. 32, p. 767-779.

Rodgers, John, 1957, Distribution of marine carbonate sediments: Regional Aspects of Carbonate Deposition: Soc. Econ. Pal. & Min. Sp. Bull. 5, p. 1-14.

Shepard, F. P., 1948, Submarine geology: Harper & Bros., New York.

Siever, Raymond, 1951, The Mississippian-Pennsylvanian unconformity in southern Illinois: Am. Assoc. Petroleum Geologists Bull., v. 35, p. 542-581.

Sutton, A. H., 1951, Ste. Genevieve-Chester contact in the Illinois-Kentucky fluorspar district: Am. Assoc. Petroleum Geologists Bull., v. 35, p. 1661-1668.

Sutton, A. H., and Weller, J. M., 1932, Lower Chester correlations in western Kentucky and Illinois: Jour. Geology, v. 40, p. 430-442.

Swann, D. H., and Atherton, Elwood, 1948, Subsurface correlations of the lower Chester strata of the Eastern Interior Basin: Jour. Geology, v. 56, p. 269-287.

Swann, D. H., Atherton, Elwood, and Workman, L. E., 1950, Summary of stratigraphy shown on geologic cross-sections of the Illinois Basin: Illinois Geol. Survey Circ. 160, p. 6-7.

Swann, D. H., et al., 1951, Eastern Interior Basin: Am. Assoc. Petroleum Geologists Bull., v. 35, p. 486-498.

Tippie, F. E., 1945, Rosiclare-Fredonia contact in and adjacent to Hardin and Pope Counties, Illinois: Am. Assoc. Petroleum Geologists Bull., v. 29, p. 1654-1663.

Weller, Stuart, 1920, Geology of Hardin County and the adjoining part of Pope County, Illinois: Illinois Geol. Survey Bull. 41, p. 106-121.

Weller, Stuart, 1928, Geology of Ste. Genevieve County, Missouri: Missouri Survey Geol. and Mines, 2d ser., v. 22, p. 217-226.

Weller, J. M., and Bell, A. H., 1937, Illinois Basin: Am. Assoc. Petroleum Geologists Bull., v. 21, p. 771-788.

Weller, J. M., and Sutton, A. H., 1940, Mississippian border of the Eastern Interior Basin: Am. Assoc. Petroleum Geologists Bull., v. 24, p. 765-857.

Workman, L. E., and Bell, A. H., 1937, Correlation problems in the new Illinois Basin fields: Illinois Geol. Survey Circ. 22, 4 p.

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