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CIRCULAR NO. 169

FUTURE OIL POSSIBILITIES OF THE EASTERN INTERIOR BASIN

By

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Reprinted from the Eastern Interior Basin Chapter, "Possible Future Petroleum Provinces of North America," A.A.P.G. Bulletin, February, 1951

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URBANA, ILLINOIS
1951

BULLETN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 35, NO. 2 (FEBRUARY, 1951), PP. 486-498, 8 FIGS

EASTERN INTERIOR BASIN

ILLINOIS GEOLOGICAL SOCIETY AND COOPERATING ORGANIZATIONS[1]

The Eastern Interior basin, in Illinois, Indiana, and Kentucky, has produced oil for more than 60 years and has been a major producing province for 45 years. During this time nearly 1⅔ billion barrels of oil have been obtained from the basin. Its reserve producible by current methods is about ⅔ billion barrels, and the use of water flooding and other secondary methods may add another ½ or ⅔ billion barrels to the recoverable reserve. About three-quarters of the current annual withdrawal of 80 million barrels of oil is being replaced by new drilling, largely in extensions to known pools. There are already more than 500 named pools and, as multiple pay zones and isolated lenses in the same zone are very common, there may be 3,000 or more separate reservoirs. About 60 new pools are being found each year, primarily in the same areas and beds as the present production and are therefore of little interest in this appraisal of those neglected beds and areas which may furnish future vertical or horizontal extensions to the province.

The rocks of the Eastern Interior basin are unmetamorphosed Paleozoic sedimentary rocks, except for a glacial veneer over the northwestern half of the basin, a thin wedge of Tertiary and Cretaceous rocks of the Mississippi embayment overlapping the southwestern margin, and quantitatively insignificant post-Paleozoic intrusives. The Permian is the only Paleozoic system not represented.

The basin is usually defined to include the area of 53,000 square miles that is covered by Pennsylvanian rocks (Fig. 146). As nearly all beds in the basin thicken southward or southeastward, the basin is displaced to the southeast in lower formations. The 58,000 square miles within the sea-level contour on the top of the Devonian-Silurian carbonate section (base of the Chattanooga-New Albany shale) provide a better frame of reference for the discussion of oil possibilities than does the Pennsylvanian outcrop which overlaps the structural basin a considerable distance on the northwest. This sea-level contour is repeated on other maps.

The chief features breaking the spoon-shaped basin are the LaSalle anticlinal belt and the Rough Creek-Shawneetown fault zone. The deeper part of the Eastern Interior basin, approximately within the −2,500-foot contour north of the Rough Creek fault zone, is differentiated as the Illinois basin proper.

Within the basin no wells penetrate more than two-thirds of the probable section, and the thicknesses of lower beds shown on the cross section (Fig. 147) are estimated by projection from a deep test on the LaSalle anticline north of the basin and another on the Ozark-Tennessee arch in southeastern Missouri. The thickness of sediments in the basin may reach 13,000 feet, and the volume

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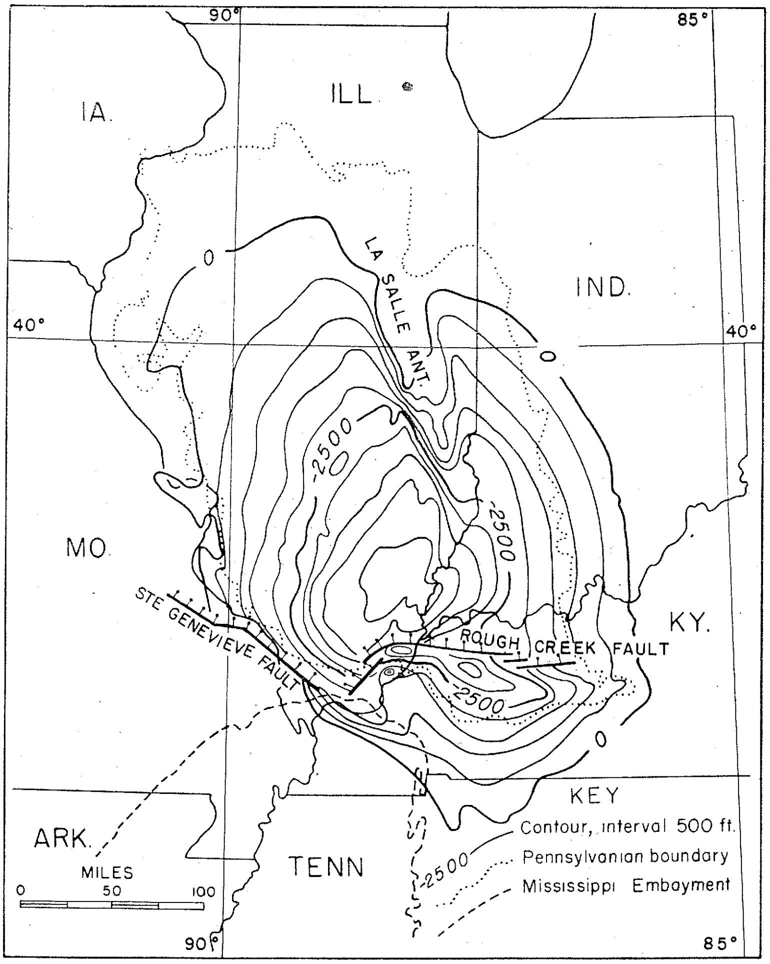

FIG. 146.—Map showing geologic structure of Eastern Interior basin by contours drawn on base of Chattanooga-New Albany black shale (top of Devonian limestone or older beds).

90,000 cubic miles. The stratigraphic terms used here do not conform with the official classification of any organization represented on the committee, but instead were selected as commonly understood names for sequences significant in discussing petroleum possibilities, not necessarily corresponding to conventional units. To avoid unnecessary repetition the report is organized on a stratigraphic rather than a geographic basis. The younger beds are discussed first.

Pennsylvanian.—Seventy-five hundred cubic miles of Pennsylvanian rocks cover an area of about 53,000 square miles to a maximum thickness of 2,500 feet. A fifth of the basin's production has come from the Pennsylvanian, and small pools with reserves of a few thousand to a few hundred thousand barrels are

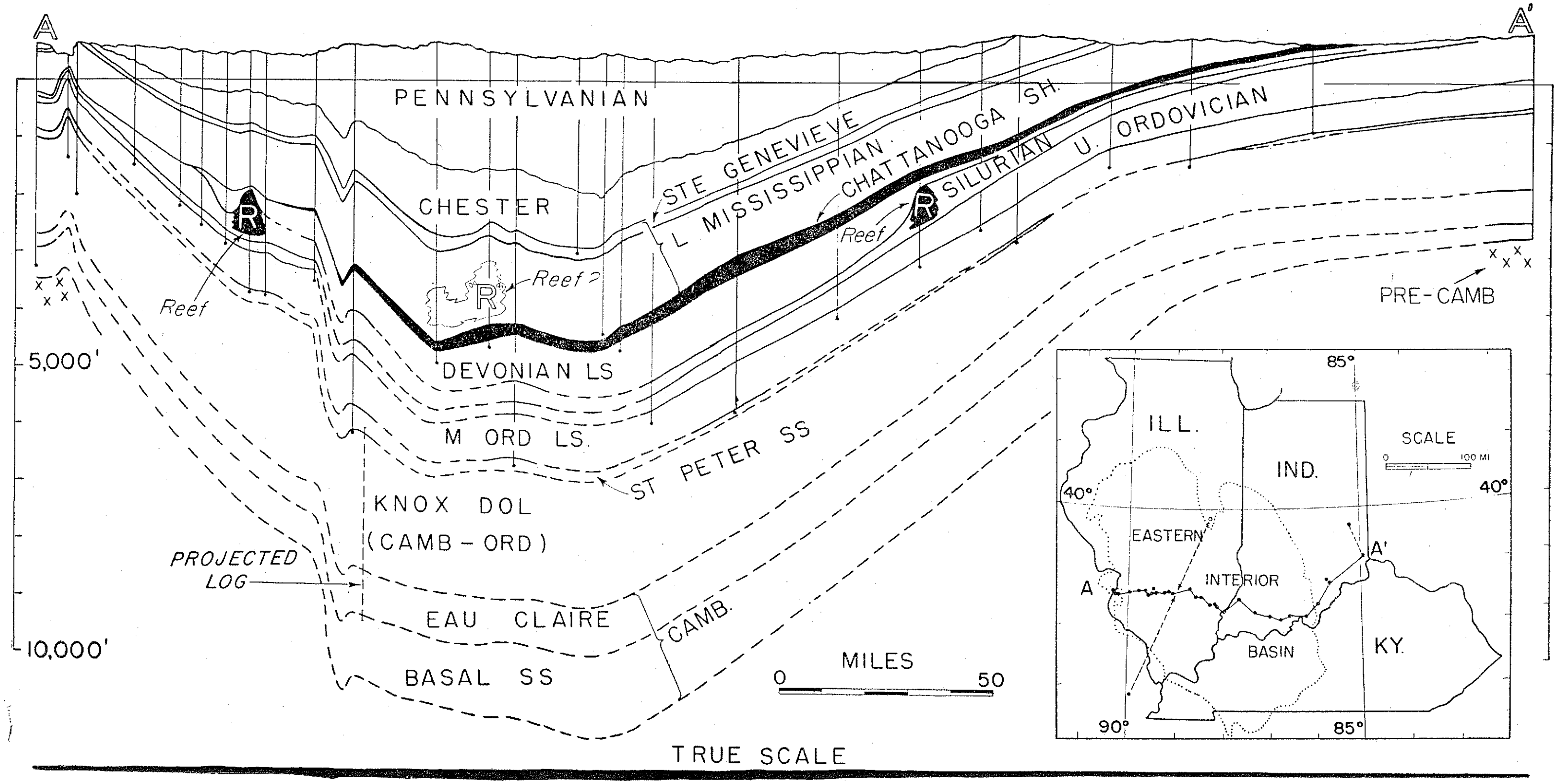

FIG. 147.—Cross section of Eastern Interior basin.

still being found. Very little Pennsylvanian oil is indigenous. Most of the oil has been derived from underlying rocks along fault planes or through the cross-cutting pre-Pennsylvanian unconformity, which is the most important unconformity in the region. About an eighth of the total Pennsylvanian area is productive, and it seems unlikely that appreciable extensions to the producing regions will be found.

Mississippian (*Chester and Ste. Genevieve*).—Nearly three-fourths of the oil

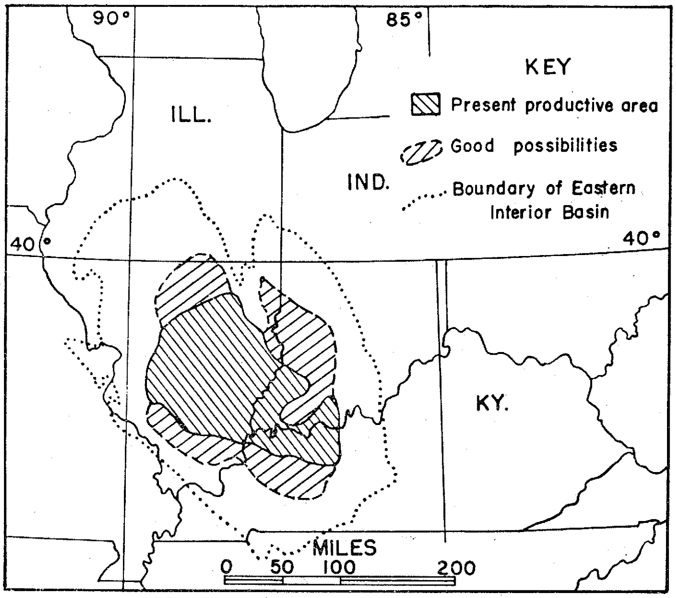

FIG. 148.—Petroleum possibilities in Mississippian, Chester and Ste. Genevieve rocks, Eastern Interior basin.

produced in the basin has come from less than 4 per cent of its volume, or from about 3,300 cubic miles of rocks of Chester and Ste. Genevieve age in the main developed area of 15,000 square miles (Fig. 148). Most reservoirs are lenticular sandstones or oölitic limestones, and porosity traps are common in addition to anticlinal and faulted traps.

South of the most developed region is an area of about 5,000 square miles (Fig. 148) containing 1,300 cubic miles of Chester and Ste. Genevieve rocks which differ very little from the rocks in the region on the north, though faulting is more common and many sandstones are more quartzitic than in the main basin region. Oil showings are common; at least half the 330 tests within this region have had showings, and some tests have had showings in as many as ten different zones. Although about ten non-paying pools, largely in the Kentucky part of the area, have cooled exploratory fever, the presence of three good commercial pools—the recently discovered Morganfield South and Slaughters and the older Livermore—along, and south of, the Shawneetown-Rough Creek fault in Kentucky, suggests that the Chester sands will be found porous and permeable enough to be productive at other places.

Directly north of the principal productive region, an area of about 2,800 square miles (Fig. 148) has 200 cubic miles of Chester and Ste. Genevieve rocks, which are thinner and more shaly than on the south. However, several lower Chester sandstones are present and permeable, although thin, and one Ste. Genevieve sandstone bed reaches its greatest development in this part of the basin. Production from the Benoist and Rosiclare sandstones at Assumption North near the center of the area proves that these beds may be oil bearing north practically to their pre-Pennsylvanian bevelled edge. Sixty tests have failed to discover other pools, and even shows of oil are uncommon.

Northeast of the developed region, an area of nearly 6,000 square miles (Fig. 148) with 500 cubic miles of Chester-Ste. Genevieve sedimentary rocks has been relatively neglected despite having produced oil for nearly 50 years. Current exploration of this area is proceeding rapidly, spurred by recent discoveries of Ste. Genevieve dolomitic pay zones at Plainville, Indiana, and Elbridge, Illinois, and by Devonian possibilities in the same region.

Lower Mississippian.—Mississippian beds beneath the Ste. Genevieve formation have produced only a few tenths of a per cent of the basin's oil. The entire 12,000 cubic miles of these rocks in the basin constitute a possible future province, for the few pools developed to date in the lower Mississippian are widely scattered over the entire region. Accumulation is structurally controlled, but the stratigraphic and ecologic factors which localize accumulation on certain structures are not understood. Oölites, very fine-grained highly porous dolomites, coarse-grained dolomitic limestones, coquinites, sandstones, permeable siltstones, and even fractured black shales (in the Mississippian-Devonian New Albany formation) serve as reservoirs.

The Salem formation appears to offer the greatest possibilities. Experience has shown that it is possible to drill several tests through a commercial pool in the Salem without discovering it. Geologists working on Devonian test wells would do well to drill-stem test any showing in the Salem, no matter how slight.

At least one large Ste. Genevieve pool, Johnsonville, near the center of the basin (Fig. 147) overlies a lower Mississippian bioherm, as proved by a Devonian test which penetrated an abnormally thick water-bearing section of organic limestone represented in near-by tests by a lesser thickness of fine-grained silty limestones.

Devonian and Silurian.—Between 5 and 6 per cent of the Eastern Interior basin's oil production to date has come from Devonian-Silurian limestones and dolomites. In the southeastern corner of the basin in south-central Kentucky (Fig. 149) oil occurs largely at the unconformity between the black shale and the underlying bevelled Devonian and Silurian formations. The Devonian-Silurian limestones decrease in thickness, in part laterally and in part by erosion at the top, from 500 feet along the western edge of this producing area to a feather edge at the eastern border. The 2,500 square miles of the productive area in south-central Kentucky is underlain by only 100 cubic miles or so of Devonian-Silurian strata. Although conditions are superficially similar north of the productive area as far as the Ohio River and even into Indiana, there has been much unsuccessful testing in the last three decades. The possibility of finding

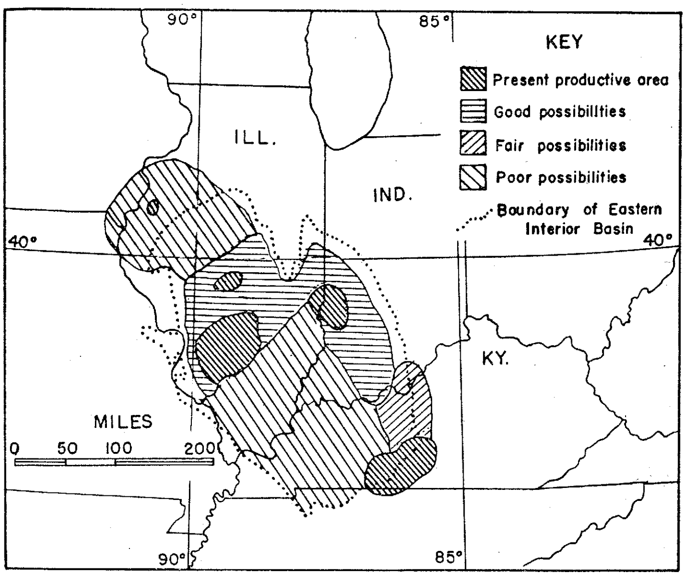

FIG. 149.—Petroleum possibilities in Devonian and Silurian rocks, Eastern Interior basin.

oil toward the north in an area of 4,000 square miles, with 200 cubic miles of these strata, is considered only fair.

The most promising part of the Eastern Interior basin for future discoveries in the Devonian and Silurian formations is the 2,400 cubic miles of sedimentary rocks under a rather broad belt of 17,000 square miles across the north-central part of the basin that is nearly bisected by the LaSalle anticline (Fig. 149). Three areas, in which there are producing fields within this belt, total about 6,000 square miles and 900 cubic miles. The thickness of Devonian and Silurian ranges from less than 500 feet near the northern margin of this crescentic belt to a little more than 1,000 feet at some points along the southern margin.

Commercial oil has been produced under three different conditions in this northern belt. Porous, bedded Devonian dolomites or dolomitic limestones produce at the crests of about ten normal anticlines, and where they overlie about 20 Silurian reefs (Fig. 150); only nine reefs have been drilled and evidence for the other eleven reefs is indirect. Silurian reef rock itself produces in three, or possibly in five, places.

In all occurrences in the northern belt, commercial production appears to be confined to structures with a closure or a reversal of at least 50 feet or more, in contrast to Kentucky where much of the Devonian-Silurian production occurs with no structural closure at all. Four of five non-productive reefs have been found in the northern belt, although it is possible that in some of these instances the wells penetrated the flanks rather than the crest of the reef.

As shown by the cross section (Fig. 147), the Silurian is thin in the central

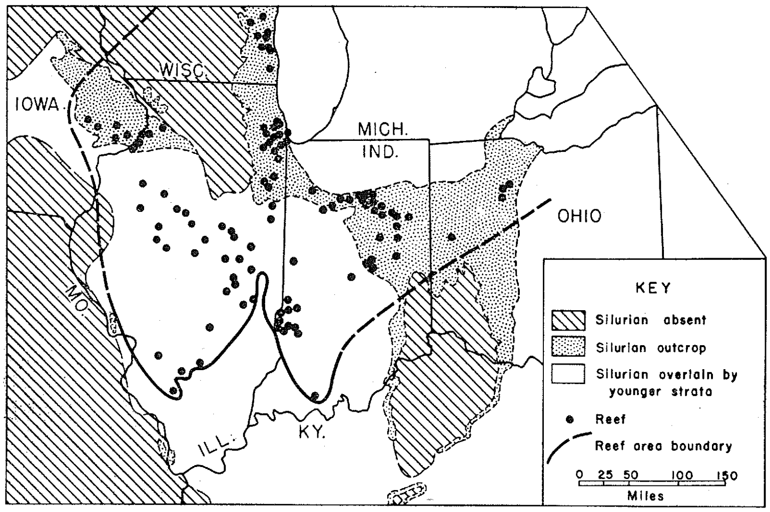

FIG. 150.—Distribution of Silurian strata and location of known reefs, Eastern Interior basin (after Lowenstam, 1949).

part of the basin, where the fine-grained shaly Middle Silurian sedimentary rocks indicate deposition in water too deep for the development of reefs. The southern reefs, located closer to the center of the basin, are the thickest, attaining thicknesses ranging from 600 to nearly 1,000 feet. Although some of the reefs were bevelled by the Devonian seas, it is evident from the shallow-water character of the non-reef sediments that farther from the center of the basin the upward growth of reefs must have been limited during Silurian time by wave base and sea-level.

Deposition during the early Devonian was confined to the deeper part of the basin inside the rim of the encircling Silurian reefs. Some students believe Silurian-Devonian deposition was continuous here. It was not until Middle Devonian time that seas lapped over the reef rim and spread broadly toward the north, west, and east. In the Devonian seas, the shoal conditions over the buried Silurian reef front were most conducive to the development of rocks suitable for reservoirs, though the productive "Geneva" porous dolomitic facies of the Middle Devonian extends a few miles south of the Silurian reef front and covers the edge of the Lower Devonian wedge. Shallow waters apparently kept the Devonian organisms from forming reefs, but there are extensive biostromes in some of the rocks.

The area of 23,000 square miles in the central and southern parts of the basin that is indicated as having poor possibilities (Fig. 149) includes nearly 6,000 cubic miles of Devonian-Silurian sedimentary rocks. These strata are about 500 feet thick along the eastern edge of the area in Kentucky and more than 1,500 feet along the southwestern boundary of the basin. The section of Devonian and Silurian rocks is thicker at the latter locality than in other parts of the basin excepting where it is abruptly bevelled at erosion surfaces. About ninety wells, including tests on most major structures, have reached the top of the Devonian. Four of these tests have been completed as producing wells, but none will pay back drilling costs. The western border of this area seems rather sharply defined with only 4 or 5 miles separating very prolific Devonian zones of the "Geneva" facies in the Salem and Irvington fields from tight non-commercial Devonian at the Woodlawn, Boyd, and Dix fields. The eastern limit is more vague, and some geologists would place the boundary 10 or 15 miles farther west, to extend the area of good possibilities across the LaSalle anticlinal belt.

In western Illinois the Colmar-Plymouth oil field is producing from sandstone lenses at the base of the Upper Devonian sequence of rocks where the Upper Devonian overlaps the Silurian and overlies Ordovician rocks. Three and a half million barrels of oil have been produced at Colmar-Plymouth from a depth of only 400 feet. Although the Upper Devonian is sandy near the base in a rather large area, at least 300 wildcat tests in the area of 13,000 square miles (Fig. 149), with 700 cubic miles of Silurian-Devonian rocks, have failed to find more commercial oil.

Upper and Middle Ordovician.—The Upper Ordovician (Cincinnatian) thickens rather regularly toward the east from 100 to 500 feet across the Eastern Interior basin. The 3,300 cubic miles of Cincinnatian rocks are largely shale, and lesser amounts of limestone and sandstone are too shaly to provide reservoirs in most of the basin, though minor quantities of oil are produced from Upper Ordovician limestones in the Cincinnati Arch province. There have been shows of gas and some slight oil stains in the Thebes sandstone member in southwestern Illinois.

Considerable amounts of oil have come from Middle Ordovician limestones of the Cincinnati Arch province, but less than 0.5 per cent of the oil of the basin comes from these beds. The basin contains 8,000 cubic miles of Middle Ordovician limestones, the "Trenton" and Black River, which are 1,500 feet thick at the western corner of Kentucky and thin to 600 feet on the Cincinnati arch and 300 feet in northern Illinois. "Trenton" production is controlled by porosity, which was developed on the tops and flanks of the major regional arches but is not present within the structural basins. The producing zones of the Lima-Indiana and the central Kentucky "Trenton" are replaced by tight rock on the eastern flank of the Eastern Interior basin and it is only on the western or Ozark flank (Fig. 151) that permeability extends far down into the basin. The area with the best future possibilities corresponds with the present producing region. Minor "Trenton" oil is produced on the LaSalle anticlinal belt, but eleven or

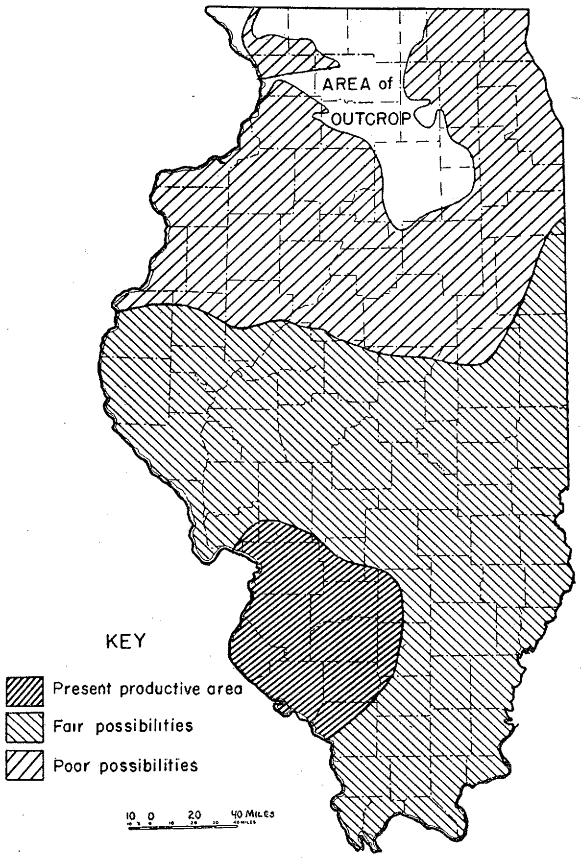

FIG. 151.—"Trenton" petroleum possibilities, Eastern Interior basin (after DuBois and Bays, 1945).

twelve tests in the deeper part of the basin have failed to find porosity in the "Trenton"-Black River.

Beneath the Middle Ordovician limestone sequence and overlying the eroded Lower Ordovician rocks is a very irregular mantle of St. Peter sandstone (Figs. 147 and 152), which is 100–300 feet thick. It is continuous in the north and west parts of the basin but is reduced to discontinuous thin lenses on the eastern flank. The dotted salinity lines in Figure 152 indicate that the blanket sand is flushed along the northwest edge. Only one oil stain at Mattoon (the northern 4,000-foot dome in Fig. 152), has been recorded in the tests on the major structures of the central basin area. Possibilities seem better in the lenticular sands on the east flank, and a little St. Peter oil has been produced in the Cincinnati Arch province.

Lower Ordovician and Cambrian.—It is estimated that the volume of Lower Ordovician and Cambrian sediments beneath the pre-St. Peter unconformity within the Eastern Interior basin is about 45,000 cubic miles. Control wells are absent in the Eastern Interior basin area (Fig. 153) and few of the wells

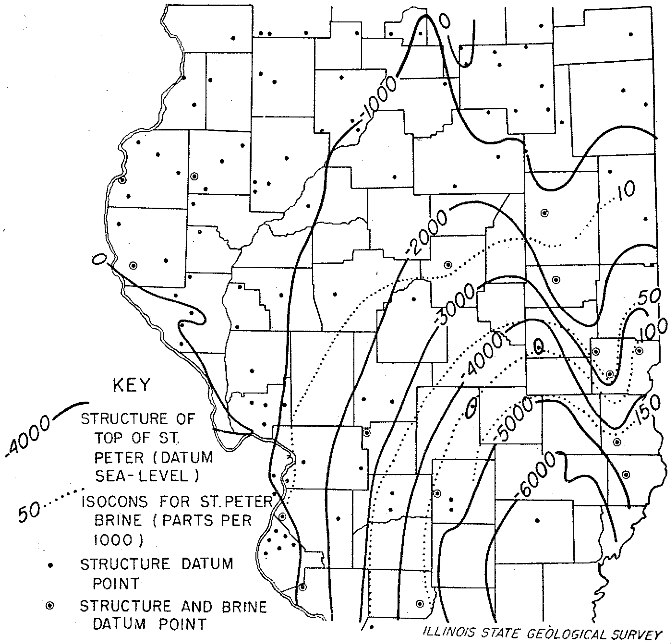

FIG. 152.—Structure of top of St. Peter formation and isocons for St. Peter brine, Eastern Interior basin (Workman and Bell, 1949).

near the border of the basin reach the basement rocks. Control is confined to the cross arches which separate the Eastern Interior from the Michigan basin at the north and the Black Warrior basin at the south. A single combined Black Warrior-Eastern Interior-Michigan basin is shown west of the Cincinnati arch. If the basins were separate in Cambrian and early Ordovician time, more pre-St. Peter sedimentary rocks should be in the Eastern Interior basin. Despite the extreme conservatism expressed in Figure 153, the Cincinnati axis is clearly indicated as a pre-St. Peter positive element. That this is true is emphatically shown by sections along the tops of the two cross arches (Cohee, 1945a, Fig. 1, and Freeman, 1949, p. 1658, Fig. 2), contrary to the widely accepted but erroneous dating of the Cincinnati axis as late Middle Ordovician.

North of the basin, about 38,000 square miles in Illinois and Wisconsin have 1,000 feet or more of sediments. Oil possibilities are negligible despite the presence of 23,000 cubic miles of sedimentary rocks, largely Ordovician and Cambrian. Nearly 1,000 water wells in southern Wisconsin and more than 250 in northern Illinois reach the Mt. Simon, the basal sandstone, and thousands of additional wells stop within the pre-St. Peter sequence of rocks where fresh water is abundant, both in sandstones and in dolomites.

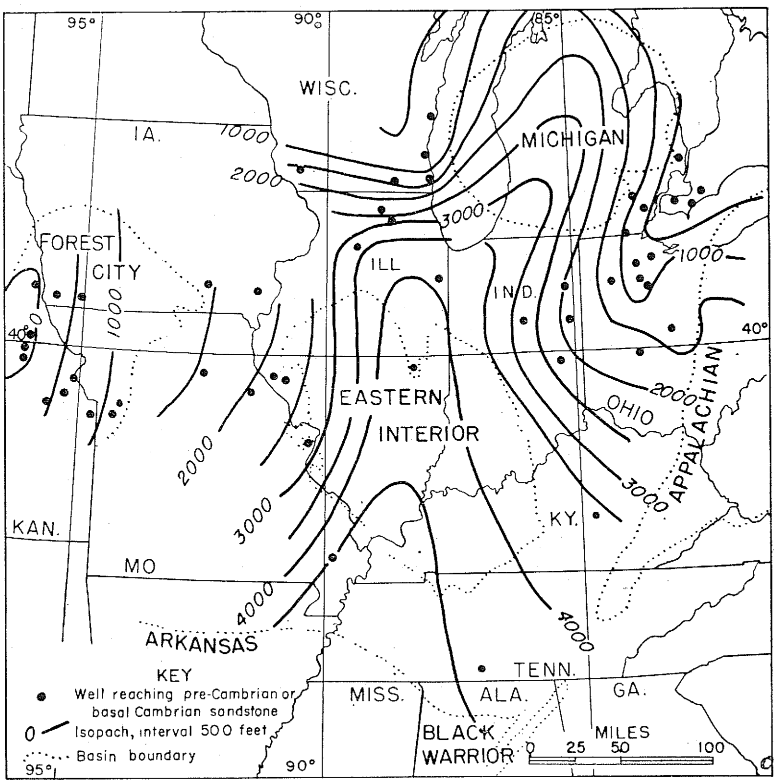

FIG. 153.—Thickness of pre-St. Peter (Lower Ordovician and Cambrian) rocks, Eastern Interior basin. Basins are outlined by sea-level contours on top of Devonian limestone.

In the basin itself, the main dolomite sequence, the Knox, which is equivalent to Ellenburger or Arbuckle in age, has been reached in seven wells, none of which penetrates more than a few hundred feet. The Knox is about 3,000 feet thick southeast of the Eastern Interior basin but only 1,500 feet thick west and north of the basin, where sandstones become prominent parts of the section toward the area in which the rocks contain fresh water. Recent studies of these sediments north and southeast of the basin provide clues to the type of rock and the conditions in the basin area.

Pinch-out porosity belts in the Knox are exemplified by the Galesville sandstone in northern Illinois (Workman and Bell, 1948, p. 2051, Fig. 6). The highly permeable Galesville sandstone disappears north of the edge of the basin, but it is probable that other permeable zones pinch out within the basin area. For example, the Trempealeau dolomite is extremely permeable, even cavernous, in northern Illinois and, despite uncertainty in correlation, it is obvious that the equivalent strata in Kentucky and Tennessee must be much less permeable. All pre-St. Peter structures known in northern Illinois or Indiana are reflected in rocks above the unconformity at the base of the St. Peter, but the isopach map of the upper part of the Knox in central Kentucky (Freeman, 1949, p. 1663, Fig. 3) suggests erosion of pre-St. Peter folds of considerable magnitude in this region which do not correspond with post-St. Peter folds.

According to one of several possible correlations of pre-Knox beds, three facies, represented by the Eau Claire sandstone, 300–500 feet thick north of the basin, the Nolichucky shale, 600–800 feet thick east of the basin on the Cincinnati and the LaSalle arches, and the Bonneterre limestone, 400–1,300 feet thick southwest of the basin, should interfinger in the basin area.

Beneath the Eau Claire equivalents, the basal sandstones, largely continental in origin, attain a thickness in excess of 2,000 feet along the saddle separating the Illinois and Michigan basins. The thickness of 1,000–1,400 feet assigned these sandstones in Figures 147 and 153 appears conservative. A few feet of limestone above the basement rocks, but beneath 600 feet of quartzitic sand that was penetrated in a test well drilled on the Cincinnati arch in central Kentucky, suggests that Middle or Lower Cambrian seas may have entered the Eastern Interior basin.

Exploration of the lower strata in the Eastern Interior basin is very costly. Reliable seismograph reflections have not been obtained beneath the "Trenton." Two hundred and eighteen rock and core bits were used in drilling 7,205 feet to test the St. Peter sandstone near the center of the basin, and 240 bits were used in drilling to the basement rocks in the 6,117-foot test well drilled on the Cincinnati arch in Kentucky. Continuous diamond coring may be cheaper than conventional drilling in these very hard beds.

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