THE STRUCTURAL RELATIONS OF THE OIL FIELDS OF CRAWFORD AND LAWRENCE COUNTIES, ILLINOIS.[1]

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The State Geological Survey began a detailed investigation of the geological conditions in the southern half of the eastern Illinois oil fields in 1908. This work was carried on intermittently and was finally completed January 1, 1912. The specific area of investigation lies in the southern half of Crawford and the central portion of Lawrence counties. The primary object of the work was to determine the cause of the accumulation of oil and gas and to secure facts which would have a bearing on the origin of oil, and also to determine, if possible, the relation of the quantities of oil, gas, salt water, porosity of the sand, etc., to the structural features of the sand.

The work is based upon the elevations and records of 5,200 wells. The method of study is to map, by means of contour lines, or lines through points of equal altitude, the geologic structure of the producing sands. The contours are made upon the positive altitudes of the sands above a datum plane 1,500 feet below mean sea level. These maps show the oil sands as if everything above them had been removed. From the undulations on the surface of the sands and from the initial productions of the wells, the oil, gas and water relations to the structure are observed. The La Salle anticline is the controlling feature of the field.

CRAWFORD COUNTY.

The investigated area in Crawford county lies south of the Illinois Central Railroad, between Oblong and Robinson. There are 2,970 wells mapped in this area, of which 206, or 8.7 per cent, are barren. The productive wells range in initial yield from 1 to 1,600 barrels. The Robinson pool, or that of Crawford county, is about seven miles wide between Robinson and Oblong, but narrows to about three and one-half miles at the southern limit of the county. The western boundary of the field trends northwest and southeast and is sharply defined. The eastern boundary, on the other hand, is very irregular.

[1] This paper with illustrations was published by permission from the Secretary, in Economic Geology, Vol. VII, p. 574, 1912. Also a more complete report with abundant illustrations will appear as Bulletin 22, Illinois State Geological Survey.

All the penetrated rocks in the producing areas of Crawford county belong to the Pennsylvanian series. This series is represented by about 480 feet of the McLeansboro, 300 feet of the Carbondale, and about 100 feet of the Pottsville formations. The rocks are all of sedimentary origin, being principally shales with variable intergradations of sandstones, limestones and coal. The oil sands lie at the top of the Pottsville rocks, which are the lowest members of the Pennsylvanian, and are essentially coarse sandstones, merging into sandy shales at the top, and often split with lenses of shale and pockets of coal.

The Crawford county pools have one general oil-producing zone, known as the Robinson sand, lying between 800 and 975 feet deep. This sand is so broken and lenticular that it offers little opportunity for structural study. In some portions of the field it assumes regularity in its distribution. It is split into two or three persistent lenses that show an average interval of about fifty feet and a thickness of from two to fifty feet. The lenses often merge into each other and are even united in some wells with a maximum thickness of 122 feet. Again, the lenses pinch out, and in several wells are entirely absent.

Owing to the irregular deposition of sands and shales, it is impossible to correlate and contour any sand beds definitely, except the top lens of the Robinson sand. Even this work loses much of its scientific value in places where the sand wedges out or is overlapped.

The altitudes of the top lens are assembled and contoured with intervals of twenty feet. The general structure of the Robinson pool reveals a broad and gentle arch, which is divided into two parts by a transverse basin. The north part of the arch is six miles wide, with its crest ninety-five feet above the lowest explored portions of the limbs. The south part of the arch is about four miles wide and 110 feet high. The 1,100-foot contour follows the limits of the pool in a general way and seems to include most of the productive zone. The small irregularities of the map probably do not represent minor folds, but irregular porosity of the general sand zone, as determined by the driller.

In studying the distribution of oil over Crawford county, the lower lenses are found slightly more productive than the top lens. There is considerable unevenness of distribution due to the following factors:

1. The sands vary in porosity and in many places are practically impervious to oil.

2. The sands thin and thicken rapidly, and in some localities pinch out altogether.

3. The sands are so irregularly interbedded with the shales along the productive zone in some areas as to prohibit extensive collection of oil, gas and water.

4. The best productive areas have twenty to forty feet of sand and are usually free from large amounts of salt water.

5. Local dry spots in the midst of very productive territory cannot be attributed to small depressions or knolls in the sand bodies, but rather to the non-porosity of the bed.

Salt water does not uniformly fill the rocks of the region, although there are many dry strata which are porous. Great quantities of salt water occur upon the limbs of the anticline beyond the productive area and in the Illinois basin to the west. All the lenses of the Robinson sand are well saturated along the definite boundary line on the western side of the pool. The upper lenses are generally barren of water within the pool, while the lower lenses reveal water across the fold and, in some localities, under the oil. Since the oil lies near the top of the lower sand lens, but few wells pass through the oil stratum into the water, for fear of drowning out the oil.

It is obvious from the position of the water and oil along the La Salle anticline that the water has controlled the accumulation of oil in the arch. The water probably has originally permitted the oil to migrate long distances up the slope of the Illinois basin into the arch. This was effective for all lenses of the Robinson sand, although the degree of saturation is variable over the crest of the arch.

LAWRENCE COUNTY.

The oil field of Lawrence county offered the best opportunity for geological study because of the depth and number of oil horizons and the abundance of records. The field is seventeen miles long and three miles wide. There were 2,180 wells studied, of which 156 or 5½ per cent were dry. The range of initial production lies between 1 and 2,400 barrels. The field trends northwest and southeast, with the northern limit on the Crawford-Lawrence county line. The field changes its course about twenty degrees near Bridgeport. The western edge of the field is well defined like that of Crawford county, and similarly. The eastern edge is irregular. The Lawrence county field is the richest in

Illinois, and has produced more large wells with steadier yield than the rest of the fields combined.

The explored rocks of Lawrence county lie in the Pennsylvanian and Mississippian series. The former are from 800 to 1,300 feet thick; the latter are, as a rule, penetrated only to a depth of about 475 feet.

The Pennsylvanian rocks of Lawrence county include a shallow producing sand at the south end of the field, probably in the McLeansboro formations; the Bridgeport sand, of three lenses, in the upper part of the Pottsville formations, and corresponding to the Robinson sand of Crawford county; and the Buchanan sand in the basal portion of the Pottsville rocks.

The Mississippian rocks underlie the Pennsylvanian and contain the most important oil sands. The upper part is known as the Birdsville and Tribune (Chester), followed by the Ste. Genevieve and the St. Louis limestones. The Chester beds include the so-called "Gas," Kirkwood and Tracey sands, while the Ste. Genevieve contains the rich McClosky sand. The sand names are those of land-owners upon whose farm the sand was first tapped. The Chester rocks average 365 feet in thickness, in comparison with 700 feet in southwestern Illinois.

The "Gas" sand, or first sand in the Chester, produces gas locally over Petty township of Lawrence county. It is 125 feet beneath the top limestone of the Chester and 198 feet lower than the Buchanan sand of the overlying Pottsville.

The Kirkwood sand is the most widespread producing horizon in Illinois, as well as in Lawrence county. It is correlated with the Sparta sand of Randolph county, the Carlyle sand of Clinton county, the Lindley sand of Bond county, the Benoist sand of Sandoval in Marion county, all of Illinois, and the Oakland City sand of Pike county, Indiana. The Kirkwood sand shows excellent initial production and long continued yield. It is the most reliable of all the sands. The oil is "sweet," or with small percentage of sulphur. The top of the Kirkwood sand is 192 feet beneath the top of the Chester, sixty-seven feet below the top of the "Gas" sand, and usually lies about in the middle of the Chester rocks.

The Tracey sand is stratigraphically equivalent to the Cypress sandstone, and is usually about 317 feet lower than the top of the Chester and 114 feet beneath the Kirkwood sand. This sand yields gas under high pressures and some oil. The gas has a rank odor and the oil from this sand is "sour," both due to the

large sulphur content. The Tracey sand is so closely associated with the underlying limestones that its oil and gas probably had their origin from the included marine animal life of the limestones.

The Ste. Genevieve limestone has a total thickness of eighty-five feet and contains the McClosky sand, which has proven the most prolific oil horizon in Illinois, because of exceptional initial flow and steady yield. This pool has been instrumental in upholding the Illinois production when other sections were declining. The range of depth for the sand is 1,550 to 1,850 feet, or about 446 feet lower than the top of the Chester and 104 feet beneath the top of the Tracey sand. The oil is found twenty to fifty feet in the limestone.

The detailed structure of the Lawrence county oil field is shown by five contour maps of oil sands and four cross-sections of the field. The structure map of the top of the Kirkwood sand is representative of the lay of the rocks in the area. The altitudes of this sand are assembled and contoured with twenty-foot interval. The most conspicuous feature revealed is a double plunging anticline or elongated dome lying in section 30, Petty township, which is 400 feet high and 3 miles wide. The crest of this dome lies within the 680-foot contour. The sand dips from the crest of the dome northward at the rate of forty-one feet per mile; southward, sixty-three feet per mile; eastward, 194 feet per mile; and westward, 228 feet per mile. The sand dips southward from the dome into a small syncline in the southwest corner of Lawrence township and then spreads fanlike in its structure to the southeast through Lawrence and Dennison townships on to a broad plateau-like crest of the major fold. In this locality the sand lies at the 400-foot contour level. The southern limits of the field seem to gradually dip lower than the producing zone of the sand. Whether the major fold continues to dip and merge into the southeastern side of the Eastern Interior Coal basin, or the dip is local, as seems to be the case between Crawford and Lawrence counties, is not known.

The other structure maps of the Buchanan, "Gas," Tracey and McClosky sands corroborate and conform to the structure of the Kirkwood sand, with the exception of very minor irregularities. In addition to these maps, four cross-sections were made to show the nature of the crest of the La Salle anticline, as well as its flanks. The A-A cross-section presents the structure of the sands along the crest of the anticline and lengthwise through the oil field. The section is valuable for its picture of the double

plunging anticline, the convergence of the sands at the northern end and the mergence of the dome into the flat at the southern end of the field. The sands are generally parallel with local irregularities that seem due in most cases to the thinning and thickening of the sand. The remaining sections are plotted crosswise to the fold and reveal the amplitude of the arch.

The largest amounts of oil in the Lawrence county field are in the extensive flat area in the southern half of the field, and at a level of about sixty feet below the crest of the dome in the northern division.

The sands of Lawrence county show abundant water along the lower flanks of the anticline and but little through the center of the field, except in the lower Bridgeport and Buchanan sands. These Pottsville rocks appear well saturated with water over the entire field and into the limbs of the La Salle fold. The underlying Chester sands are not uniformly saturated with water, but seem to have lines of saturation along the limbs of the fold, more particularly along the western side.

SUMMARY.

The features of the structure maps and their individual oil, gas and salt water relations, just described, are sufficiently similar to permit general conclusions regarding the accumulations of oil and gas in Crawford and Lawrence counties. These conclusions add to the general fund of evidence relating to the accumulation of oil and gas in raised rocks.

The greater part of Illinois lies within the Eastern Interior coal basin, which is, broadly speaking, an extensive spoon-shaped basin, with its axis extending along a line, through Cerro Gordo, Lovington and Olney and into its deepest part in Wayne, Hamilton and Edwards counties. The east side of the basin rises into a strong longitudinal fold known as the La Salle anticline. The ascent is at the average rate of about fifty feet per mile, but it is more rapid in Lawrence county, as shown by contours of the very sharp apex of the anticlinal dome. The basin and lower flanks of the fold are known to yield abundant water in all the sands which are productive in the main fields. The uppermost part of the flanks of the major fold contain abundant oil. The western limits of the fields are abrupt, and beyond this line the sands are wholly water-bearing. Enough data are at hand to conclude that this is a line of water saturation and that above this line and over the fold most of the sands are oil-bearing.

The accumulation of oil and gas in their present position may be looked upon as ideal, and is presumably due to the following factors:

1. There is an extensive anticline with a marked basin on at least one side.

2. The depressions on both sides of the fold, showing abundant water, comprise extensive "feeding" areas for the arch.

3. The sands are commonly porous, and hence form suitable reservoirs.

4. There are abundant shales and some limestones overlying the sandstones, which probably serve as impervious covers to the reservoirs.

5. The sands in both limbs of the anticline are abundantly saturated with salt water, which is probably instrumental in holding the oil and gas captive in its present position.

6. Although the general structure of the oil fields is dominated by a major fold, its crest is very irregular and is interrupted by numerous minor domes and transverse depressions, which, together with irregularities in porosity, have been instrumental in segregating the pools.

7. With one exception, the best collection of oil was found over the broad flat areas. The domes over the entire field are logical gas reservoirs, but, contrary to expectation, the largest amounts of gas and oil do not lie at the apexes of the domes, but a short distance below.