OIL PRODUCTION IN ILLINOIS

D. M. COLLINGWOOD, STATE GEOLOGICAL SURVEY, URBANA

Object of the paper: A review of past results and a consideration of the geological basis for guidance in future oil development.[1]

The production of crude petroleum in Illinois for 1922 was nearly 10,000,000 barrels. The peak of Illinois production occurred in 1908, when about 33,000,000 barrels were produced, giving Illinois third place among the states, with Oklahoma leading and California second. These latter have retained their relative prior positions, but newer gusher fields have been discovered in the southwestern and western states, and Illinois has now dropped to eighth place. The decline curve for Illinois (Fig. 1) shows the trend of the annual production from 1905 to 1922 for the whole State and from 1905 to 1918 for individual pools. The decline in 1922 over the previous year was about 6 per cent. The low decline rate is due in part to the long life of the average Illinois oil well.

The main oil fields of Illinois are situated in the southeastern part of the State in Edgar, Coles, Clark, Cumberland, Crawford, Lawrence, and Wabash counties, in which the areal limits have been fairly well defined. Lesser amounts are produced in a number of small fields scattered over southwestern Illinois. These are mostly younger fields and are still being extended. The total actual producing acreage is only about 250 square miles, or the equivalent of about seven townships. This seems very small compared with the total area of the State. The smallness of the actual producing areas is significant and indicates the precariousness of drilling a well just anywhere, even in a general area regarded as having probabilities.

It is absolutely essential to use every guide from geology and from the study of production and drilling data in neighboring or similar areas so that the larger, prob-

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[1] Special acknowledgement is due to the State Geological Survey of Illinois for the information and records on which this paper is based, and to Miss H. Christensen in particular for her kind assistance in the compilation of data and preparation of the accompanying map.

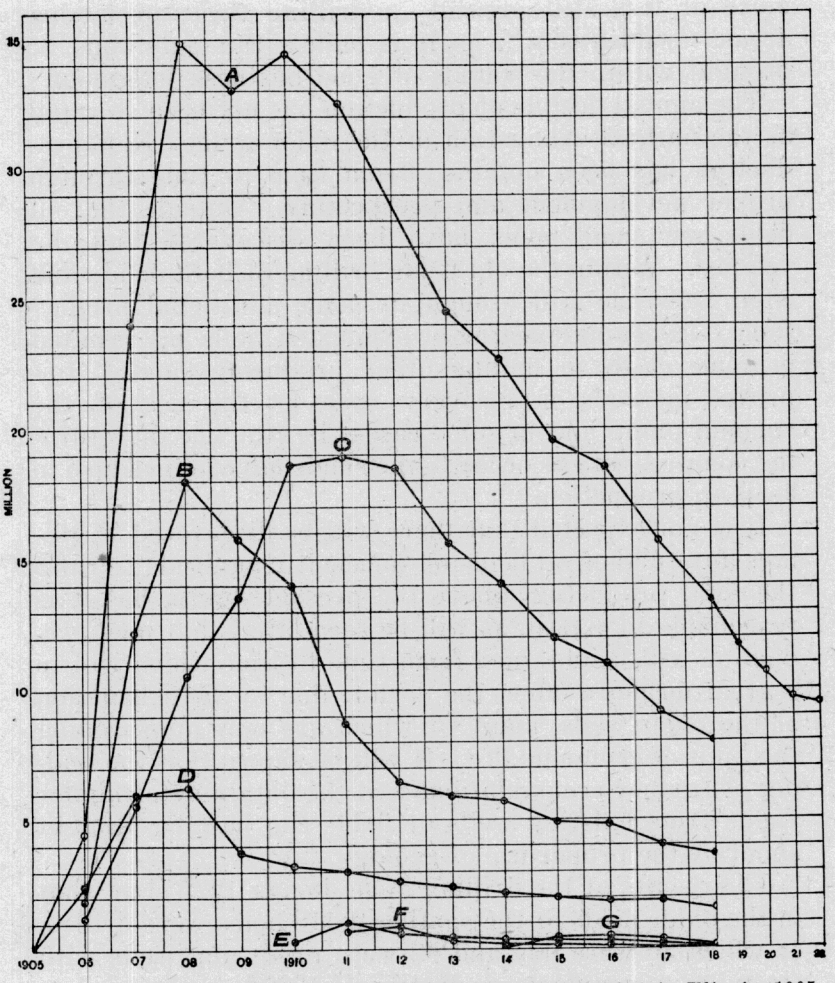

Fig. 1. Diagram showing rise and decline of oil production in Illinois, 1905-1918, expressed in barrels of 42 gallons.[a]

A. Total for State.
B. Crawford County Pool.
C. Lawrence County Pool.
D. Clark County Pool.
E. Sandoval Pool.
F. Carlyle Pool.
G. Plymouth Pool.

[a] Statistics on oil production for individual pools are not available after 1918.

ably barren areas may be discarded and the oil well tests for new production be confined to the small areas of greater promise. Although the element of chance is more or less still present in drilling these promising areas, "wildcatting", as it is called, can only thus be brought within the bounds of good business judgment.

The annual decline of production has not been so rapid as the natural exhaustion of the older wells. New production has been obtained from time to time through proper development and prospecting. Outside the old fields new small pools have been discovered and developed. Within the old fields drilling of both inside and edge wells has still brought in some additional production. Deepening existing or exhausted wells has resulted in some cases in finding other producing sands. Improved methods of recovery such as the use of the vacuum pump and in some cases the practice of returning compressed gas or air to the sands have helped also to keep up production.

It is not expected that there will be discovered in Illinois any further oil fields of sufficient magnitude to raise the total production above the present figure, but it is reasonable to expect, as will be seen later, that new production will be obtained from time to time which will in a great measure offset the decline due to the exhaustion of the older wells, many of which are now approaching the limit of economic life. It will be shown that the finding of further accumulations and the obtaining of higher yields from existing wells or fields can best be brought about by the proper use of geology.

The results of the drilling done during 1922 show that in the older fields of the southeast 118 holes were drilled, of which 36 were dry and 82 were producing wells with a total reported flush production of 1300 barrels per day. These include a few rank wildcats which unfortunately are located often without the basis of reliable judgment. But the majority were drilled in development of inside acreage of light production and to determine the edge limits of the main producing fields. In the resf of the State 223 holes were drilled, of which 53 were dry, while 170 were wells with a reported flush production of 4,590

barrels. These include development wells in and around the older producing small fields, but a large proportion represents wildcat drilling, some of it well advised, more of it ill advised, or lacking any basis but that of "hunch" or superstition, and some based on nothing but a scheme of the promoter to make some money. Fortunately these last two types are becoming scarcer. A summation of the above figures gives a total of 341 holes drilled in the State for the year; 89 were dry holes and 252 were wells bringing in a total flush reported production of 5,890 barrels. The dry holes are 25 per cent of the total wells drilled, or 35 per cent of the number of producing wells. There were 71 wells abandoned in the old fields that had reached the limit of their economic life at the prevailing price of crude oil.

In estimating the economic success of the exploitation of crude oil production, it appears on the basis of these figures that against the value of the oil obtained must be charged not only the overhead, drilling equipment, and producing costs of the producing wells, but also an additional 35 per cent of the drilling cost must be charged to take care of the dry holes drilled incident to the development. A rough estimate at prevailing prices of the value of the new production obtained during the year indicates that after deducting all development charges, the industry shows profitable returns. It is evident, however, that the cost of drilling dry holes must be brought and maintained at a minimum by the utilization of all available information and experience that will enable the best judgment to be used in the location of exploratory drilling. This is one of the main functions of geology as applied to the oil industry. It is one of the objects of the State Geological Survey and of the geologists working for oil interests in the State to localize development and to limit exploratory expenditures to areas where the chances of finding oil are greatest. Only by such guidance can the ratio of dry holes to producing wells be reduced to, and maintained at, a minimum while development of the oil reserves continues.

Correct judgment of the oil geologist must involve the following considerations, and their application in Illinois will be discussed briefly.

REGIONAL STRUCTURE

The bedded rock formations in Illinois, as far as the drill has reached, are composed mainly of shales, sandstones, and limestones. These beds are so tilted and folded that in central Illinois they form a spoon-shaped basin, a gentle rise continuing out to the edges of the State with the exception of the eastern edge of the basin where the beds rise sharply forming an uplifted fold called the LaSalle anticline. This is the most pronounced uplift or folded structure in Illinois, and the main axis of the folding runs in a direction slightly east of south from the northwest of the State through LaSalle to the vicinity of St. Francisville near the Indiana boundary in the southeast with a general inclination or pitch to the south. In contrast to the dip or inclination of the beds, the rock surface in Illinois was more or less base leveled by erosion, and over this surface was deposited the glacial drift consisting of clay, silts, sands, and gravels, which at the present time cover the surface of most of Illinois. These late deposits are cut through by the present larger rivers and streams exposing the underlying rock, the out-crops of which afford a source of considerable information to the geologist. However, there are large areas where no outcrops can be seen, and the geologist has to derive much of his knowledge of the subsurface conditions from a study of the logs of wells and samples of the rock beds penetrated.

The important relationships of oil to the structure or folding of the bedded rocks was first recognized by I. C. White and is known as the anticlinal theory of oil accumulation. In a general way this has been found to hold true for oil accumulation in Illinois, although oil geologists are recognizing other relationships which are applicable in certain circumstances, and in others modify the application of the anticlinal theory. Thus we note (Figs. 2 and 3) the main oil fields developed along the axis of the LaSalle an-

ticlinal uplift in southeast Illinois. The producing area is subject to certain limitations toward the north, due partly to the pitch of the axis. Most of the oil producing horizons come up to the surface towards the north and have either been eroded or were never deposited.

Other small anticlines or local folds or domes are known in the gently rising beds to the southwest and western parts of the State, some of which have proved productive. No production has been found in Illinois as yet that is not in some way connected with anticlinal structure or doming of the strata.

SHALE CONDITIONS AND POSITION IN THE ROCK SECTION

SHALE AS A SOURCE

Oil is generally believed to have had its origin in shales containing certain kinds of organic material which have been converted by pressure and some heat to the hydrocarbon constituents of oil particles. These were collected by the aid of circulating fluids and rock movements and accumulated in favorable traps in reservoir rocks.

The presence of the necessary shales as a source either in juxtaposition to the reservoir rock or connected with it at some time by porous channels is one of the requisites to bear in mind when considering an area for possible oil accumulation. The exact nature of the shale necessary as a source, its history of sedimentation and subsequent alteration are subjects about which the oil geologist should know to enable him to apply more fully the science of geology to the economic problem of finding oil accumulations. It is hoped that the results of present studies of sedimentation, now being undertaken by some of the leading geologists, will be especially helpful to the oil geologist.

At present, however, ahead of actual drilling, certain areas can be considered as having very slight chance for oil when we know that the underlying or associated rock section does not contain adequate amounts of shale.

IMPERVIOUS CAPPING OF RESERVOIR ROCKS

Shale as an impervious medium overlying reservoir rocks has an important role in the accumulation of oil

in the tops of anticlinal folds and domes. In areas where the known dip or regional rise of the strata has brought a shale capping to the surface where it has been largely or entirely eroded, oil probably would not be retained in an immediately underlying porous rock. Any oil previously accumulated would have escaped long ago during the preglacial erosion. This is applicable in Illinois on the northward extension of the LaSalle anticline due to the southward pitch of the axis, and also around the rim of the central structural basin in southern, western, and northern Illinois where the formations have been truncated by erosion.

SAND AND RESERVOIR ROCKS

Where the necessary capping shales in the rock section are present, the question of reservoir rocks should next be considered. The positions of most of these are known in the Illinois rock section. Structure and area of deposition or subsequent erosion will affect the number of any such horizons that are present and can be penetrated by the drill at any given locality. The probable productivity of the sand, if it contains oil, compared with the cost of drilling necessary is also an important consideration. The records of past drilling and statistical information of oil production of the old fields in Illinois are particularly beneficial in this connection, although many operators have been very slow to realize the great importance of keeping and preserving good records.

There are some lenticular porous sands in Illinois and other beds which grade from impervious to porous, both laterally and vertically. It is quite possible to find oil accumulation in areas of regional folding without the presence of complete local reversals, but for the same reason that oil accumulates gravitationally in the arch of an anticline, so oil in porous lenses with water saturation would be expected in the higher parts of the lenses. There have been cases of this kind in Illinois, notably in the Colmar-Plymouth field, and probably there are others awaiting discovery. It is impossible, however, to obtain any indication of the

presence or actual location of such local petroliferous lenses from surface observations on outcrops, or from the data supplied by former neighboring wells. But horizons containing such lenticular "sands" likely to occur in Illinois are fairly well known and in several localities supply an extra sand chance in addition to the regular sands or more prevalent porous horizons that have produced oil.

PRESENCE OF LOCAL FOLDS AND UNCONFORMITIES

The stratigraphic position and the nature of the shale and reservoir rocks may be ideal, but in Illinois at least the oil accumulations are associated with anticlinal folding or doming of the beds. This, then, is of vital importance in recommending the most likely places for oil tests. In addition to the extension of the old fields on the La-Salle-St. Francisville uplift there are many local minor structural anticlines and domes in the south and west parts of the State. The knowledge of the presence and location of these structures is one of the keys to the wise location of exploratory test wells.

In Illinois, as elsewhere, there have been time intervals of erosion accompanied in some instances by some tilting or warping of the strata between successive depositions of sedimentary strata. The bedding of the overlying strata may not, then, conform exactly with the bedding or the eroded surface of the underlying formations. This sometimes results in favorable traps in reservoir rocks suitably capped or pinched in by impervious beds, but they can not be predicted directly from knowledge of the dip of the strata outcropping at the surface. The presence of such unconformities at certain horizons is known, however, from other geological evidence, and their influence on oil accumulation can be more or less evaluated by the oil geologist.

The geological information that the oil geologist can bring to bear on the oil problems of Illinois can be obtained in part by studies and surveys of rock outcrops, but in very large measure it must be obtained through the study of subsurface records and samples of cuttings taken from drilling wells. The State Geological Survey

has available extensive information of this kind. Bulletins are published frequently and cooperation is maintained with those interested in oil development. Based on the study of the accumulated subsurface data and the original surveys and surface observations of the Survey, the accompanying map (Figs. 2 and 3) has been prepared to show in a general way the location of the various oil producing areas of Illinois, the localities where favorable structures exist, and the proportion of those outlined that have been tested and found productive. General inferences may be drawn as to the probabilities of finding further producing areas in Illinois and the general geographic position of the areas of greater promise.

Outside of the actual producing areas in Illinois, with which may be classed probable extensions, the remainder of the State can be divided approximately into provinces representing, according to our present knowledge, four different grades of merit as to the chance of finding commercial accumulations of oil: (1) best possibilities; (2) possible; (3) improbable; and (4) very improbable. The differentiation has been made largely on the basis of known or expected presence of favorable structure.

(1) An area of best possibilities may be described as extending north from the common line of Cumberland and Clark counties where the LaSalle anticlinal uplift is developed into two folds, one axis continuing west of north through LaSalle County, while the other appears to run more directly north to Iroquois and Kankakee counties. The area north of the producing fields immediately along these axes has good possibilities where slight cross folding is present. In this same class should be included an area immediately west of the central structural basin, running south from western McLean County, including the west portion of DeWitt and Macon counties, the east half of Logan and Sangamon counties, of Christian, Montgomery, Macoupin, Madison, Bond, a west portion of Fayette and Marion, Clinton, most of Washington, St. Clair, Randolph, Perry, Jackson counties, and possibly in the southern part of the State, parts of Franklin, Williamson, Saline, Gallatin, and portions of adjoining counties to the south; and in addition, the area

in the west including the east half of Jersey, most of Greene, Scott, Brown, and Schuyler counties, with adjoining parts of Cass, Morgan, Pike, and Adams, most of McDonough, with adjoining parts of Fulton, Knox, and Hancock counties.

(2) The second grade considered "possible" should include the rest of the State not included in the two following grades.

(3) The area considered "improbable" includes the central structural basin running south on the west of the LaSalle anticlinal uplift, including small parts of LaSalle, Marshall, Woodford, and Livingston, the central north and south portions of McLean, most of DeWitt, east half of Macon, Piatt, Moultrie, Shelby, west portions of Douglas, Coles, and Cumberland, Jasper, Effingham, east portion of Fayette, all but a western part of Marion, Clay, Richland, west part of Lawrence, Edwards, Wayne, most of Jefferson, Hamilton, and White counties, with adjoining portions of Saline and Gallatin counties.

Another area of similar status is the trough or syncline between the two folds of the LaSalle uplift flanking the areas along the axes including parts of Ford, Champaign, Douglas, and Coles counties. Also the flank on the east of the uplift including parts of Iroquois, Vermilion, Edgar, Clark, and Crawford counties should be included.

In the general area in the northern part of the State where, due to the northward regional rise of the strata particularly along the axis of the pitching LaSalle uplift, most of the formations containing oil horizons are not present. The so-called Trenton or Galena limestone and the underlying St. Peter sandstone outcrop here. Oil has never to our knowledge been obtained in commercial quantities from the St. Peter or underlying older formations. These contain few shales and apparently have not the requisite source or favorable conditions governing accumulation of oil. The areas on the flanks of the anticline where no adequate capping exists for the outcropping Galena limestone should be included also in the improbable area. This includes most of Winnebago, Boone, with adjoining portions of McHenry

and Stephenson, most of DeKalb with adjoining portions of Ogle, Lee, LaSalle, and Kendall counties on the east, and parts of JoDaviess, Carroll, Whiteside, Lee, and Bureau counties on the west of an area along the axis of the LaSalle uplift and other minor folds.

(4) The central area last mentioned along the axis of the LaSalle uplift in the north of the State must be considered as very improbable, and is so graded because even the Trenton is absent here or very thin and no oil has ever been found geologically below it. This area includes the adjoining parts of JoDaviess, Stephenson, Carroll, and Ogle, the central part of Lee, and small parts of Bureau and LaSalle counties.

THE ANALYSIS OF RESULTS OBTAINED IN TESTING THE AREA REGARDED AS HAVING BEST POSSIBILITIES PROJECTED AS A FORECAST FOR FUTURE SUCCESS

The areas of the northward extension of the LaSalle anticlinal uplift have very few outcrops, and little or no testing has been done in the areas of greater promise. (Figs. 2 and 3.) Although these areas have potential possibilities of production from one or two horizons, no definite percentage of success to be expected in test drilling can be suggested.

The results obtained in the remainder of the area of best possibilities are given in the following table:

Portion of Illinois	Structures mapped in detail (10-, 20-, and 25-foot structure contours) average of two oil horizon chances									Further structures expected in area now mapped only on large scale (50-foot structure contours); 50 per cent of structures mapped on small scale assumed; similar sand and regional structural conditions			Further structures expected in area now unmapped; similar sand and regional structural conditions		
	(1) Area mapped in detail	(2) Number of structures mapped in detail	(3) Number of structures completely or partially tested		(4) Number of structures found productive		(5) Productivity per cent (4b) of (3a)	(6) Number of structures untested	(7) Structures expected to be productive in those untested from (5)	(8) Area mapped on large scale	(9) Number of structures to be expected from (2) and (1) less 50 per cent	(10) Number of structures expected to be productive in this area from (5)	(11) Area unmapped	(12) Number of structures to be expected from (2) and (1)	(13) Number of structures expected to be productive in this area from (5)
			Total Number	Per cent of Complete testing	Actual number at present	Plus allowance for complete testing									
	Square miles		(3a)	(3b)	(4a)	(4b)				Square miles			Square miles		
Western.....	2442	22	16	68	3	4.4	27	6	1.6	508	2.3	.6	2785	25.	6.8
Central.....	2763	24	24	83	12	14.4	60	...	...	3854	17.	10.	48	.4	.2
Southern.....	1820	19	9	62	2	3.2	35	10	3.5	924	4.8	1.7	375	3.9	1.4
Total or Averages.....	7025	65	49	...	17	22	...	16	5	5286	24	12	3208	29	8

By using percentages from the past results of exploration, we can estimate very roughly the amount of new local accumulations of oil that future exploration may be expected to find.

In completing the thorough testing of the structures now defined and partially tested we may expect the equivalent of finding five new local producing structures.

In the remainder of the area of best possibilities where regional structure and the number of sand chances are similar to the areas that have been mapped in detail we may expect to find further structures in proportion to areal extent as already obtained in the studied areas as follows:

(a) In areas where large scale mapping has already been done we may expect the equivalent of 24 further smaller structures of which about 12 may be expected to be productive.

(b) In areas as yet altogether unmapped we may expect relatively the equivalent of about 29 local structures, of which about 8 may be the proportion of those found productive.

CONCLUSION

To the 17 producing structures that we have today we may expect to add the equivalent of five more when all the structures now outlined have been tested thoroughly. It is also to be expected that about 50 other local folds or favorable structures may yet be found of which a proportion of something like 20 may be expected to be productive. This is slightly more than the number of producing small structures that we have had up to the present.

It appears, therefore, that there are many local oil accumulations capable of supplying commercial production that yet await discovery in Illinois. The proper use of geology, both surface and subsurface, will insure the greatest efficiency in the exploration and development of these resources so that the industry may continue on a paying basis. Owing to the slowness with which subsurface information comes to light the development of the potential reserves will extend over a number of years.

The new production being obtained from time to time will continue to offset partially the natural decline of the older wells, and serve to maintain the annual production of Illinois with a very low decline rate.

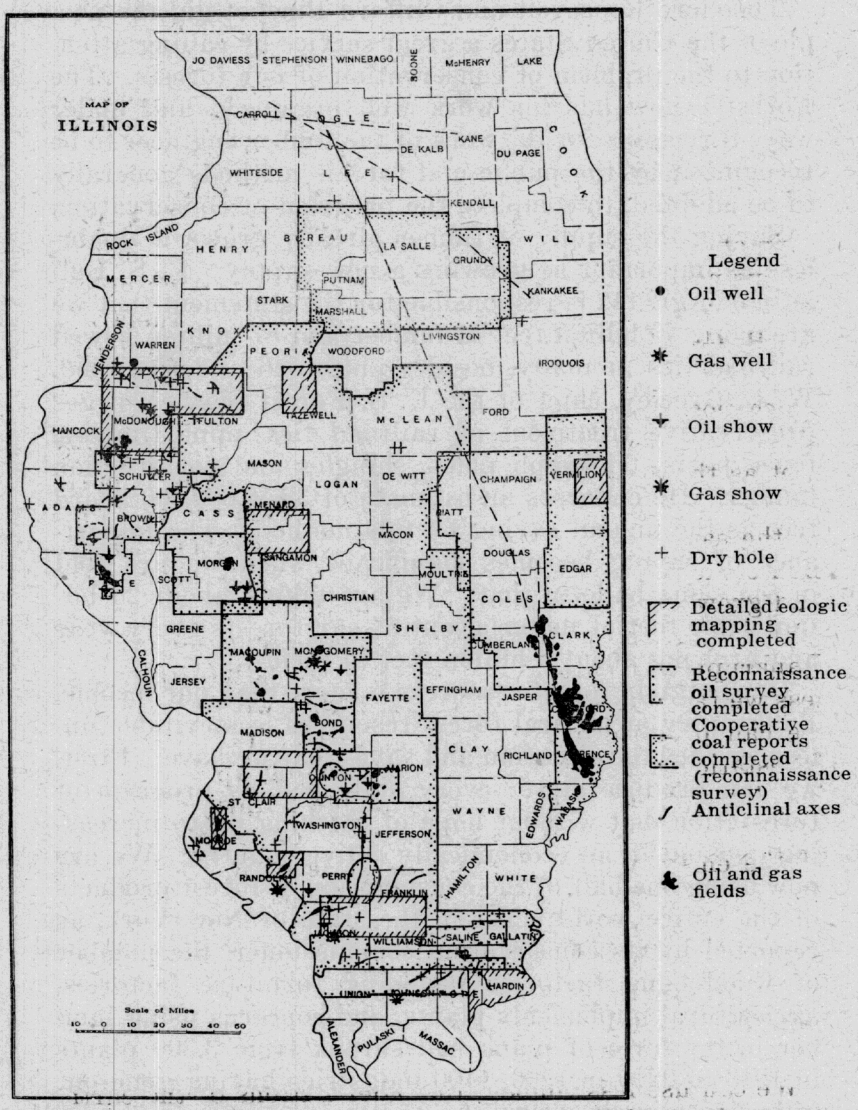

Fig. 2. Map of Illinois showing location of oil and gas fields, anticlinal axes and results of testing the anticlinal structures. Outlined areas indicate whether detailed or reconnaissance geologic surveys have been completed.