

## OIL INVESTIGATIONS IN ILLINOIS.

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## INTRODUCTION.

In the short time available, it is possible to outline only very briefly the investigations by the State Geological Survey, covering the present immense oil fields and other prospective oil areas. I will give first, a brief history of operations in Illinois, then a short statistical statement, an account of the origin and accumulation of oil, and finally an outline of the investigations.

## HISTORICAL STATEMENT.

The first oil excitement spread over the eastern United States in the early part of the "sixties" and extended westward to Illinois. In 1865 the first "wild-cattin'" took place in Clark County, about eight miles north of Casey. Here several wells were drilled in attempts to locate oil and gas but the work was abandoned. A very small amount of oil was found, which, perhaps, would have been greater had proper casing been used. Water drowned out the oil and prevented an earlier discovery of the present extensive field. Oil was found about this time in a sump in a mine near Litchfield, Montgomery County, but its exploitation was delayed until 1882. A small field of 30 wells, that produced several hundred barrels annually, was outlined between 1882 and 1889. Production is wholly abandoned at the present time. The oil came apparently from the Pottsville sands.

A gas field was discovered along an anticline in the Niagara limestone near Pittsfield, Pike County, during 1886. About 30 wells have been drilled and 24 found to be productive in an area covering 4 by 10 miles. Similar prospecting took place near Sparta, Randolph County, in 1888. Several good gas wells were found in the Chester formations of the Mississippian series of rocks. The field was further extended in 1906 and 1908 to the north of Sparta where about 6 wells produced small amounts of oil. Production is all but abandoned now.

Further "wild-cattin'" took place in Crawford County between 1900 and 1904, but this field was not opened until 1906. The Casey region was re-drilled in 1904-1905 and oil was found in commercial quantities. The field spread rapidly and gradually merged into the deeper and deeper pools of Crawford and Law-

rence counties, until at the present time, they cover a narrow strip from 2 to 8 miles wide and about 60 miles long, with an area of about 240 square miles.

Oil was found early in 1908 in a mine near Centralia, Marion County. Prospectors were attracted to the territory and several shallow productive wells were drilled. Later, in 1909, an oil and gas area was tapped north of Sandoval in the same county. This developed rapidly in 1910 and promises at the present time to be an important producer of oil in Illinois. The oil comes from a depth of about 1600 feet in a sand that corresponds to the Kirkwood of Lawrence County. There are now about 40 producing wells which yield over 3500 barrels daily.

Oil and gas have been found in small quantities at other points over the State at Greenville, Carlinville, Jacksonville, Pocahontas, Marissa, Mascoutah, Eldorado, etc. Active drilling is now going on at Duquoin, Nashville, Greenville, Carlyle and other localities.

#### RANK OF ILLINOIS.

Illinois gained ninth place for production and value of oil in 1906, and third place for both in 1907. Since then the State has held third place for production and second for value and has been excelled only by California and Oklahoma. Up to January 1, 1911, about 18,636 wells had been drilled for oil and gas in the State, of which 15 per cent were barren. The remaining 85 per cent have produced since 1905, about 128,000,000 barrels of oil, valued at about \$82,000,000. The present daily output of the fields is about 85,000 barrels. The Ohio Oil Company (Standard) controls most of the production.

#### THE ORIGIN AND ACCUMULATION OF OIL.

The origin of oil is uncertain, but two general theories, called the inorganic and the organic, attempt to explain it. One is largely unacceptable and even the other has many faults. The inorganic theory attributes the origin of petroleum to the breaking down of certain carbides of metals by the action of water in the interior of the earth. It assumes a later condensation of the resulting gases as they arose to cooler strata near the surface. This hypothesis does not apply to all oil fields as well as the organic theory. This second theory is based on the decomposition of vegetable and animal matter, particularly in the limestone and shales near the porous sandstones which now contain the oil. It is recognized that plants and animals were deposited in

the accumulating muds and silts of centuries. These were shut off from the oxygen of the air and other destructive agents, so that, eventually, a peculiar distillation converted the carbon, and other constituents of the once living matter into oils and gases. The distillation was a matter of long ages and the migration of oil to more porous reservoirs than the limestones and shales, was a secondary step.

This circulation and accumulation of oil, was accomplished by agents such as capillarity, gravity, and gas or rock-pressure. As the minute distillation proceeded the oil was taken up under the influence of gravity and capillarity, and passed into the porous sandstones. An important factor in the accumulation was the "lay" of the rocks. The sedimentary strata were deposited under water horizontally, or practically so, and the natural distillation of oil probably began while the beds were in that position. Subsequent folding of the strata formed series of arches or domes offset by corresponding troughs or basins. The arches are known as anticlines while the depressions are called synclines. When this folding took place, the water, petroleum, and gas within the sandstone formations were forced to move according to the laws of gravitation and hence to distribute themselves according to their specific gravities. The water was the heaviest of the three fluids, and, therefore, sought the synclines as far as possible, depending of course, upon the porosity of the sands. Its tendency was to displace the oil and gas, forcing the oil to float on the water and the gas to rise still higher. The oil was enabled to rise as far as the water extended up the slopes of the synclines, while the gas was able to free itself and rise to the highest place in the porous bed, usually the crest of the anticlines. The surface of the oil sand on the anticline may be pitted or undulating and this condition may affect an extensive area or only a few acres of ground. Though the general accumulation of oil and gas is governed by the anticline proper, covering many miles, the segregation of pools may be caused by smaller folds on the large one. This intricate system of synclines and arches on the parent fold is coupled with variation in the porosity of the sands and the two conditions greatly affect the distribution of oil and gas. It is readily recognized that either factor may explain the local presence of dry holes within productive territory.

A segregation of oil may take place along a bench or sometimes called a structural "terrace", much in the same manner as

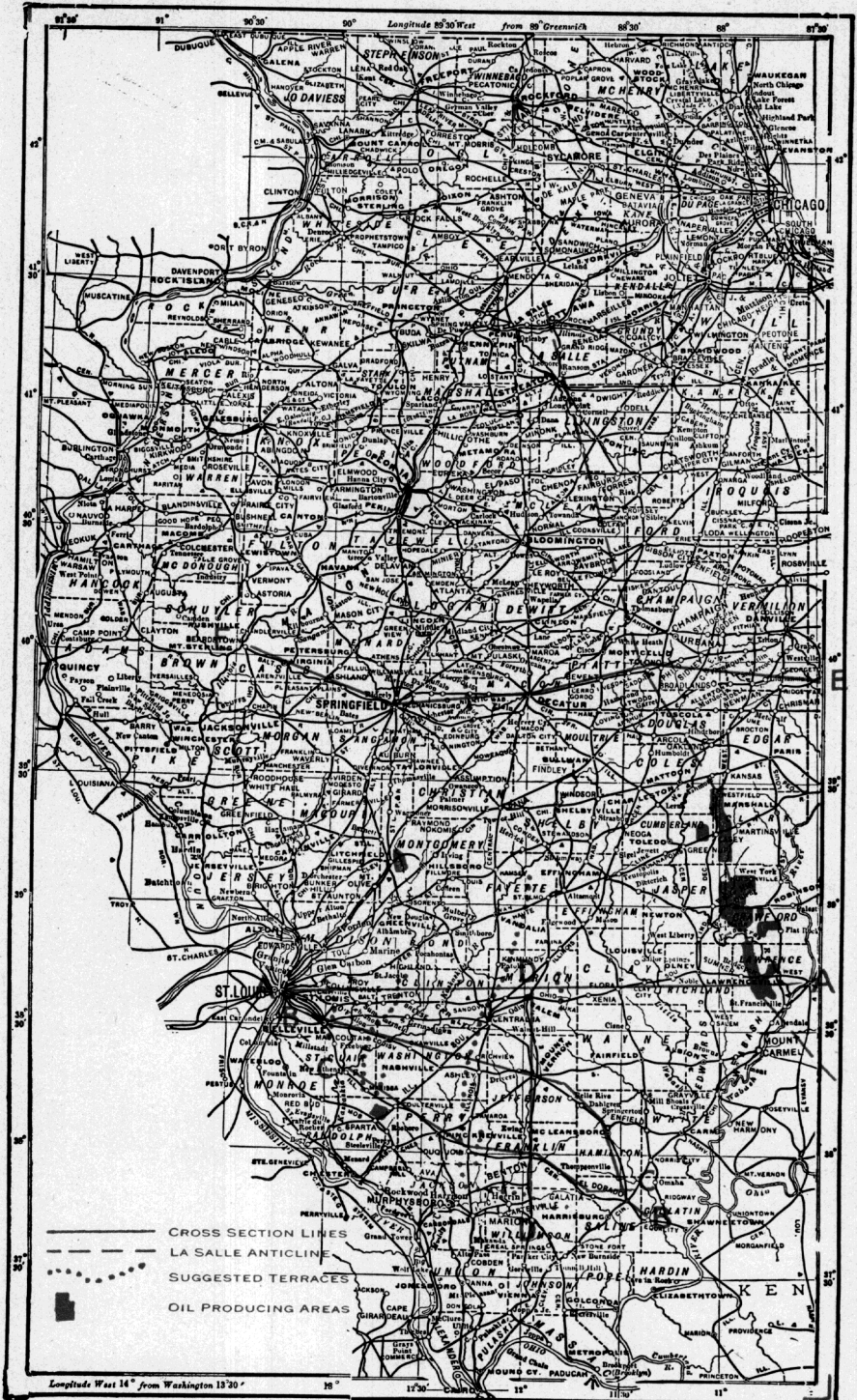
in the anticlines and synclines. The "terrace", strictly speaking, is an interruption in the uniform dip of the sides of a basin, giving rise to an approximately horizontal plane. Such benches are to be found upon the sides of the great structural basin in southern and central Illinois. The water in the basin enables the oil to rise to the "terrace", where it is trapped by friction. Any oil, originally in the sloping sand above the bench, may migrate farther up the general incline until it is caught by some other barrier.

In studying the theories and the actual facts in the oil fields it is found that the oil and gas in the main fields occur along the crest of the LaSalle anticline. That in Marion County occurs on a "terrace" or irregular dome. Enough information is at hand to show that wet sands predominate in Illinois and that the oil and gas are captive in the highest portions of raised structure, according to the theory stated. It has been further shown that practically all localities in Illinois, yielding oil and gas to date, lie along anticlines, domes, or terraces. Therefore, the general conclusion follows that any area within the State, or out of it, for that matter, underlain by suitable formations and these structural features, will bear investigation for the presence of oil and gas.

#### INVESTIGATIONS OF THE GEOLOGICAL SURVEY.

The Survey began an investigation of the main fields in 1908, with a view of determining certain peculiar conditions existing in the oil horizons. The elevations above sea level and logs of about 5,000 wells were taken in the southern half of the productive area. These records were plotted and contour maps were made upon each sand. The maps, about 15 in number, are being studied at the present time and an effort is being made to find the relation of the quantities of oil, salt-water, porosity of the sand, etc., to the structural features of the sand. It is believed that these maps will be of large service in the further development of this important field and also that they will yield valuable data for the study of the laws governing the genesis and accumulation of oil and gas. The report will include also the commercial features peculiar to the Illinois fields.

The work upon the report of the main fields has been interrupted to prepare a paper in response to many inquiries received by the Survey, relative to the conditions and localities favorable for the accumulation of oil and gas outside of the main fields. They have been, chiefly, questions regarding structural features,



Map of Illinois showing oil fields, cross-section lines, position of structural terraces and of the La Salle anticline.

such as anticlinal folds, dips of coals, oil seeps, depths to the oil sands, etc. The determination of structural features outside of the main fields seemed formidable because of the immense expanse of flat territory, so covered with drift as to conceal the sequence of formations and practically all evidence of folding and faulting. The only means available was to construct several geological cross-sections of Illinois and to point out the irregularities occurring in some key horizon. The folds serve to outline prospective drilling areas to the oil operators but the adjoining basins or slopes are not so favorable.

Plate 1 indicates the location of the sections which were constructed.

The general sections were chosen along lines showing the greatest number of wells and coal bores and at the same time crossing the great structural basin of Illinois. The identification or correlation of various beds in each section presents a general idea of the stratigraphy and structure of the lower portion of the State. The four sections presented here include only a portion of the work accomplished by the Survey. The cross-sections were constructed by plotting records with uniform symbols and scale. They are located with respect to their distance from the nearest town and to their position above sea level. Correlation lines, drawn between similar formations in adjoining records, picture any rise or fall. Thus section A-A, (plate II.) giving the most complete geological data across the State, presents a complete picture of the great structural basin of central Illinois. The section is drawn from St. Louis, Mo., to Vincennes, Ind., and crosses the Sandoval and Lawrence County oil fields. In this and the other sections, there is indicated a conspicuous spoon-shaped basin, with its long axis paralleling the LaSalle anticline and extending from the north line of Stephenson County past LaSalle, Cerro Gordo, Lovington, Olney, and continuing to the southwest county of Indiana. The deepest part of the basin lies in the vicinity of Wayne, Hamilton, Edwards, and White counties, where the rocks lie comparatively flat and the basin broad. Towards this basin, with local exceptions, all the rocks of Illinois and of Western Indiana, dip gently. Attention is called to the key horizon or the No. 6 coal, which is definitely known over about one-half the section, while in the remainder, it is doubtfully identified.

The accompanying printed sections indicating the order and

character of the strata, were published by Bain\*, and are modified slightly to agree with later conclusions.

Overlying the consolidated rocks of the State except in the extreme southern and the northwestern counties, there is a varying thickness of glacial deposits or "drift." These clays, sands, gravels, etc., are commonly encountered in drilling before hard rock is reached. Locally, they contain gas, but the pressure is usually slight and the life of the individual wells is short. While it is not possible in every case to absolutely exclude the possibility of these wells representing leakage from lower reservoirs, a sufficient explanation of them is believed to be found in the decay of woody material buried in the drift itself.

The stratigraphic section for southern Illinois is most important in the study of oil possibilities. The formations promising best production are indicated by italic and occur chiefly in the Carboniferous system. Possible oil "sands" are suggested also in the Ordovician and Silurian systems, especially in central and southern Illinois.

*Northern Illinois Section.*

This section is intended to be representative for that portion of the State lying north of Rock Island, La Salle and Kankakee.

Carboniferous. (Pennsylvanian.)	"Coal measures," mainly middle part; consisting of coal, shale, sandstone, and limestone; 575 feet thick; no known gas or oil. Unconformity.
Devonian.	Limestone; 150 feet thick. Unconformity.
Silurian.	Niagara limestone; dolomite; 335-388 feet thick; <i>containing frequent seepages of bitumen in the vicinity of Chicago.</i> Unconformity.
Ordovician.	Cincinnatian shales and limestone; 68-250 feet thick. Unconformity. Galena-Trenton; mainly dolomite, a little limestone and shale at the base; 300-440 feet thick; a very persistent " <i>oil rock</i> " or <i>petroliferous shale in the lower portion.</i> St. Peter sandstone; friable sandstone 150-275 feet thick; heavily water-bearing. Lower Magnesian dolomitic limestone; 450-811 feet thick; all but upper part known from well records; rests on Potsdam sandstone, known only from well records.

\*Bain, H. Foster, Petroleum fields in Illinois in 1907: Bull. Ill. State Geol. Survey No. 8, pp. 273-312.

*Central Illinois Section.*

For the region south of Rock Island, La Salle and Kankakee, and north of the mouth of the Illinois River and Danville.

Carboniferous. (Pennsylvanian.)	<p>"Coal measures," upper part; coal, shale, limestone, and sandstone; 600-700 feet thick.</p> <p>"Coal measures," middle part; shale, sandstone, and coal including approximately from "No. 2 coal" to "No. 6 coal;" 300 feet thick.</p> <p>"Coal measures," basal part; (Pottsville equivalents), including coal, clay, shale, and sandstone; mainly the beds associated with the "No. 1 coals" of the western part of the State, and of irregular thickness, found in deep borings elsewhere; 50-150 feet thick; <i>small amounts of oil and gas reported, but origin not certain.</i></p> <p>Unconformity.</p>
Carboniferous. (Mississippian.)	<p>Chester; irregular thickness of sandstone, shale and limestone, recognized in a few borings; generally absent in this territory; 0-50 feet thick.</p> <p>Unconformity.</p> <p>St. Louis, Salem, Ste. Genevieve; limestone, non-magnesian, partly cherty and partly oolitic; 50-100 feet thick. Osage group, Warsaw, Keokuk, and Burlington; shales and limestone, the latter often cherty; 250-350 feet thick; <i>crude petroleum in geodes near the top of the Keokuk.</i></p> <p>Kinderhook; shales, limestones, and sandstones; 80-150 feet thick.</p> <p>Unconformity.</p>
Devonian.	<p>Limestone; 15 feet thick.</p> <p>Unconformity.</p>
Silurian.	<p>Niagara; dolomite; 50-120 feet thick; <i>gas at Pittsfield in Pike County, and oil seepage in Calhoun County.</i></p>
Ordovician.	<p>Cincinnatian; shales; 40-100 feet thick.</p> <p>Unconformity.</p> <p>Galena-Trenton; dolomite; 300-400 feet thick; <i>oil seepage at Calhoun County.</i></p> <p>St. Peter; sandstone; 130 feet exposed; heavily water-bearing.</p>

*Southern Illinois Section.*

For the area south of the mouth of the Illinois River and Danville, including the principal oil and gas producing districts.

Tertiary.	<p>Lafayette, Porters Creek and Lagrange; sands, clays, and ferruginous conglomerate found in extreme southern counties only; 150 feet thick.</p>
Cretaceous.	<p>Ripley; sands and clays in extreme southern portion of the State only; 20-40 feet thick.</p> <p>Unconformity.</p>

Carboniferous. (Pennsylvanian.)	<p>"Coal measures," upper part; coal, shale, sandstone, and limestone; 500-700 feet thick; <i>contains the oil and gas sands of the Westfield, Siggins and Casey pools.</i></p> <p>"Coal measures," middle part; coal, shale, sandstone, and limestone; 400-650 feet thick; <i>including probably the lower pay of the Johnson Township pool in Clark County, and possibly the Robinson sand.</i></p> <p>"Coal measures," basal part (Pottsville equivalents); sandstone, conglomerate, shale, and thin coals; 50 to 500 feet thick; including the <i>Buchanan sand and probably the Robinson and Bridgeport sands, with the greater part at least of the productive sand of Montgomery County. The oil sand of Princeton, Ind., may possibly belong in this group.</i></p> <p>Unconformity.</p>
Carboniferous. (Mississippian.)	<p>Chester group; limestone, shales and sandstones, usually three well defined limestones (non-cherty) and generally with red shale at the base; 500 feet thick; <i>includes the Kirkwood oil sand of Lawrence County; a gas sand at Vincennes, Ind.; the gas and oil sands at Sparta in Randolph County; the Stein and Benoist oil sands of Marion County; the Lindley gas sand of Greenville, Bond County, and the oil sand of Oakland City, Ind.; the three latter sands being the equivalents of the Kirkwood sand.</i></p> <p>Cypress; sandstone, massive, coarse-grained; fairly regular in a thickness of 80 to 150 feet; not known to have been prospected for gas or oil; Tracey sand.</p> <p>Unconformity.</p> <p>Ste. Genevieve, St. Louis and Salem; limestone, partly cherty and partly oolitic; 250-400 feet thick; McClosky sand.</p> <p>Osage group (Burlington, Keokuk, Warsaw); limestone often cherty with some shale; 200 feet thick.</p> <p>Kinderhook; mainly shale, some limestone; 50 feet thick.</p>
Devonian.	Limestone, sandstone, shale; limited in outcrop to southern counties; 500-700 feet thick.
Silurian.	Niagara and Clinton; limestone; in southern counties only; 100-110 feet thick.
Ordovician.	<p>Cincinnatian; limestone, shale, and sandstone; 100 feet thick.</p> <p>Unconformity.</p> <p>Galena-Trenton; limestone, non-magnesian; 80 feet thick.</p>

It is not necessary to present the details of the stratigraphy along the A-A section. There is plainly shown the varying thickness of drift deposits, and particularly the thickening of the "Coal Measures" or Pennsylvanian rocks, toward the basin. The

upper rocks are characterized by coals, thin limestones, and shale. They are shown to be thickest in the south-central part of the State along the axis of the main basin or syncline. From this region they become thinner as the formations rise towards the borders of the State. This due partly to surface erosion and partly to variation in original deposition.

The massive Pottsville sandstones underlie the "Coal Measures" proper and are a part of the Pennsylvanian series. The Pottsville sands are often interbedded with shales and hence the top is difficult to identify, owing to the merging of the sands with overlying shaly rocks. The correlations in the cross-sections were based, for the most part, upon the top of the thick sand, immediately underlying the conspicuous shaly rocks. There is also a usual absence of limestone strata in them, thus differing distinctly from the underlying Mississippian rocks. The several sections show that the Pottsville is practically absent west of an irregular line drawn from Springfield through Carlyle to Coulterville. It is also absent north of Springfield, except possibly in the vicinity to the northeast. A thickness of 450 feet along the C-C section, presented later, decreases to 300 feet along the A-A section, and to 50 or 100 feet along the E-E. These sandstones are very productive in the main fields, and are called the Buchanan from the name of the farm on which oil was first found in that sand.

The Mississippian series lying in the Carboniferous, next below the Pennsylvania, contains the most widely productive oil sands in the State. The upper part of the Mississippian includes the Chester rocks, characterized by a succession of limestones, red shales, and sandstones. The top of these rocks is marked by the first limestone below the Pottsville. The red shales are important horizon markers with the oil men, signifying the approach to such sands as the Kirkwood, Tracey and McClosky. The Kirkwood sand of Lawrence County, the Benoist sand of Marion County, Lindley sand of Bond County, and the Sparta sand of Randolph County, all belong to the same horizon and underlie the Chester red shales. Oil men scarcely ever drill below the Chester rocks and into the massive St. Louis limestones, the "big line." In several cases, however, deep wells have been drilled in search of the Trenton or Niagara.

The oil of the main fields comes from the following sands:

COUNTY.	NAME OF SAND	DEPTH—FEET.
Clark Edgar Cumberland Coles Crawford Lawrence Lawrence Lawrence Lawrence Lawrence	Shallow  Robinson Bridgeport Buchanan Kirkwood Tracey McClosky	375- 500  750- 950 850-1000 1300-1400 1450-1600 1690-1750 1800-1890

The structure of the cross-section is indicated by the "lay" of the coal. The coal outcrops several miles east of St. Louis, along the bluffs of the Mississippi. It dips gently from that point but irregularly at several places along the section. In the vicinity of Sandoval the coal is seen to lie rather flat and then dip suddenly into the deeper part of the basin. The new oil field at this town lies along this deformation, which extends southward to Duquoin and possibly northward between Brownstown and Vandalia, Pana and Tower Hill to Niantic. The rocks rise from the axis of the basin to the LaSalle anticline at a fast rate and then decline gently and rise again into Indiana. The main oil fields of Southeastern Illinois lie at the top of the anticline. The formations below the No. 6 coal rise in a similar fashion and corroborate the structure. The Kirkwood sand correlation line indicates the sharp rise over the LaSalle anticline.

It may be mentioned at this point that the survey has collected complete samples from about 20 wells over the main fields, from depths of 800 to 2000 feet. Studies of these will almost certainly identify the No. 6 coal over the anticline and permit closer classification of all the oil producing formations.

The promising structural features along the A-A section are, the flat "terrace" at O'Fallon, the mild arch at Aviston, the slight arch at Carlyle, the irregular Sandoval and Odin "terrace" and the Iuka fold.

The C-C section (plate III) is plotted along a line from New Athens to Duquoin, Benton, Rileyville and Eldorado. It follows the Illinois Central railway closely between these points and is especially valuable since it is based on a large number of coal bores and mine records. There are several attractive structural features exhibited, especially one at Duquoin. After passing the

Coulterville syncline, the coal rises toward Pinckneyville and forms an anticline between there and Duquoin. This is about 8 miles wide. The coal presents a remarkable dip of over 400 feet in about  $2\frac{1}{2}$  miles, immediately east of Duquoin. This offers excellent opportunity for the migration of oil into the anticline and as several wells already drilled indicate, the sands on the slope are thoroughly saturated with water. The Duquoin anticline extends to the southwest towards Murphysboro and is shown by the coal contours recently published by E. W. Shaw on the Murphysboro quadrangle. From Duquoin northward it probably passes west of Tamaroa and Dubois, and between Nashville and Ashley. It is considered to be a continuation of the Sandoval "terrace," already spoken of. The crest of this structure is higher at Duquoin than at Sandoval and hence has a slope downward to the north of Duquoin. At Duquoin the dip is from about 400 feet above to several feet below sea level, while at Centralia the dip is from sea level downward. The fold is narrowing in its axial width northward from Duquoin.

The most promising structural features along this section are enumerated as follows:

1. The Marissa flat.
2. The Tilden anticline.
3. The Duquoin anticline.
4. The second Duquoin arch.

The D-D cross-section (plate IV) was drawn from Marion in Williamson County to Salem in Marion County. It crosses the southern slope of the Illinois basin and shows the position of the coal from south to north. The dip along the southern slope of the basin is about 50 feet per mile. There is a slight flattening of the coal between wells 5 and 6. A "terrace" occurs between wells 8 and 9, south of Benton, and a slight bench is shown at well No. 11.

The E-E cross-section (plate V) is the most northern one and is plotted along a line from Beardstown in Cass County to the State line near Danville in Vermilion County. The section reveals the relations of the lower rocks on the western side of the State; the shallow character of the Illinois basin in the northern part of the State; and the La Salle anticline. It is particularly valuable from a stratigraphical point of view, since the Chester rocks are shown to be absent around Springfield and present to a small degree in the basin at Decatur. The Pottsville is very thin along this section. The only significant feature in the structure exists

at Niantic. A very small arch is shown in the No. 6 coal. It is noticeable that from this point eastward there is a rapid dip of the coal into the basin. It is suggested that the Niantic deformation may be a continuation of the Sandoval-Duquoin "terrace." All the formations show a decided rise into the La Salle anticline at Tolono. The crest of this arch is thought to be west of Tolono in the vicinity of Sadorous.

Other sections, not presented here, show similar features in the key horizon and seem to corroborate the presence of the previously mentioned minor folds along the broad western flank of the Illinois basin.

Besides structural cross-sections, detailed contour maps on the No. 6 coal have been made of some areas. (plate VI, coal contour map of Marion County.) That for the new Sandoval oil field is presented here. The position of the coal in the several mines and wells along the western side of the county were noted, and also the surface elevations at each. Contours of 25 feet interval were made from these data. The dips in the various directions are portrayed and warrant definite conclusions regarding the present and future drilling. The structure of the coal is further shown by the use of profiles drawn between prominent points on the contour maps, in such position that they are at right angles to the dip. They are intended merely to make clear the mental picture to those who are not familiar with contouring.

The present active oil field near Sandoval seems to be bounded by the 125-foot coal contour, and the best area to further develop that field lies within the confines of that line. This includes the town of Sandoval and the area southeast of it. The most promising area, however, is in and about the crest of the dome-like structure in section 29. Oil has already been found in shallow sands in this structure, but the lower sands are even more promising.

The similarity of the structure south of Centralia to that of Duquoin leads to the conclusion that a structural "terrace" exists slightly to the west of Centralia, and hence offers prospective territory. The so-called "terrace" is irregular but possibly continuous throughout Fayette, Marion, Washington and Perry counties.

Reference to plate I indicates the position of various deformations discussed. It will be readily seen that the western flank of the Illinois basin holds promise of new oil fields and that possibly the northern portion of the La Salle anticline will bear investiga-

tion in the older formations. The center of the basin or main syncline of the State is not promising for prospectors. It has been sufficiently drilled at an aggregate expense that is astounding, to corroborate the theories just explained. Future drilling should be based on the scientific investigation which has been outlined here.