University of Kentucky
College of Arts and Sciences

KENTUCKY GEOLOGICAL SURVEY

ARTHUR C. McFARLAN, Director
DANIEL J. JONES, State Geologist

SERIES IX

BULLETIN — NO. 9

Geology of the Guffie Area,
McLean and Daviess Counties, Kentucky

By
RICHARD L. BOWEN

Printed by the Authority of the State of Kentucky

LEXINGTON, KENTUCKY
1952
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LETTER OF TRANSMITTAL

April 9, 1952

Dean M. M. White
College of Arts & Sciences
University of Kentucky

Dear Dean White:

The Kentucky Geological Survey is publishing Bulletin No. 9, "Geology of the Guffie Area, McLean and Daviess Counties, Kentucky." It is a report on an oil field in an area adjoining that covered in Bulletin No. 1 of the current Survey series. It is an analysis of geological factors controlling the occurrence of these pools and is a further guide for exploratory work in this Basin.

The report was prepared by Mr. Bowen as a thesis for the Master's degree at Indiana University, under the direction of the staff of that department.

Sincerely yours,

Arthur C. McFarlan
Director
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INTRODUCTION

The purpose of this report is to present the structural relationships of the Guffie area in McLean and Daviess Counties, Kentucky, as determined by surface and subsurface geologic methods and the results of magnetometer traverses. In addition, discussions of the stratigraphy and history of the field are presented.

The writer wishes to acknowledge with gratitude: the suggestion of R. E. Stouder, Louisville, Kentucky, advising the study of the Guffie area; the criticisms, suggestions, and advice of Ralph E. Esarey and Judson Mead, Indiana University, during the time of field work and the preparation of this report; the aid of the Kentucky Geological Survey and Preston McGrain; and the considerable aid, advice, and material given him by the personnel of the oil companies having interests in this field. Especially is credit due to Fred M. Ellis of the J. C. Miller Oil Company for his time and materials, freely given to the writer during his stay in Owensboro while doing the field work for this report.

The Guffie area is located in the northern part of McLean County and the southwestern part of Daviess County, Kentucky. See figure 1 for an index to state and county lines. It is located in sections 8, 9, 10, 11, 12, 13, 18, 19, 20, 21, 22, and 23-N-27 and sections 14, 15, 16, 17, 24, and 25-N-28 of the Carter coordinate system. State Highway 140 passes through the center of the field in an east-west direction, and county roads serve the remainder. There are two villages, Cleopatra and Guffie, within the area that have given names to oil pools surrounding them. Guffie itself is 5 miles north of Calhoun, county seat of McLean County, and is the village from which the name of the area is taken. The area studied included 13 square miles.

Previously published geological works concerning this district include the reconnaissance surface studies of Hutchinson¹ in 1912 and Robinson² in 1931; and subsurface studies of other oil fields in the immediate vicinity by Wesley³ in 1936 on the Livermore pool, Jacobsen⁴ in 1950 on the Island area, both of McLean County, and

Bruce in 1949 on the Utica oil field, Daviess County. In addition to such geologic reports, maps of the Calhoun and Sutherland quadrangles (U. S. G. S., 1/62,500) and aerial photos (1/16,500, 1950 series) from the Agricultural and Industrial Development Board of Kentucky were available. Data from drillers' logs, electric logs, and core analyses were extended to the writer by those companies drilling here.

GEOLOGIC SETTING

Topographically, the area is one of low rolling hills rising above the alluviated valleys of small creeks which are tributaries of the Green River. The alluviated valleys make up approximately 60 percent of the area and have a general elevation of from 380 to 420 feet; the hills rise to a maximum of about 580 feet; and the relief totals approximately 200 feet. The topography, in general, does not reflect the structural conditions of the area; however, in sections 11, 12, and 13-N-27 there is a suggestion of a fault line scarp along the County Line fault, the higher elevations being on the upthrown side of the fault. Outcrops are fairly common in the hills, but they are found in the valleys only where the alluvial cover is thin, permitting exposures in stream beds.

Physiographically, this district is located in the Shawnee section of the Interior Low Plateau Province. This section is characterized by hills formed on Chester and Pennsylvanian sandstones and surrounded by silt-filled valleys.

The tectonic and structural relationships are expressed in the facts that the Guffie area is located at approximately the center of the Kentucky lobe of the Eastern Interior Coal Basin and that the axis of the Rough Creek-Shawnetown fault system passes just to the south of the field. The structural features are primarily controlled by the fault system. Since the Guffie area is in the center of the Kentucky lobe, the geologic section is somewhat thicker than districts to the north and south. The basement is between 7,000 and 8,000 feet below the present land surface; a well drilled in section 17-N-28 stopped in the Tyrone limestone of Middle Ordovician age at a depth of 5,415 feet.

SURFACE STRATIGRAPHY

The surface stratigraphy of the Guffie area is composed of rocks of the Lisman and Carbondale formations of middle Pennsylvanian age, Pliocene gravels, and Recent alluvium. The Pennsylvanian

LITHOLOGIC LOG
MILLER & SHIA RELLA
WRIGHT BROS. NO. 11
GUFFIE AREA
20-N-27
MCLEAN COUNTY, KENTUCKY.

LEGEND

COAL  SANDSTONE  SILTSTONE  SHALE  LIMESTONE
- GNEISS  MET. PASTE  FORMATION  CHERT  OIL SHAPE

FIGURE 2
formations (fig. 2) primarily consist of highly micaceous shales and siltstones and argillaceous fine-grained sandstones. No attempt was made to map these rocks, since other methods could be used to determine structures of this field. However, outcrops of the Providence limestone and the No. 9 coal of the Carbondale formation are frequent north of the County Line fault. Indeed, the Providence, a black to dark-gray, saccharoidal, finely crystalline, medium-gray to brown weathering limestone, 8 to 14 feet in thickness, seems to be the resistant ledge holding up the hills to the north of the County Line fault. The No. 9 coal, a 4- to 7-foot thick bituminous coal, 70 to 80 feet beneath the Providence limestone, is mined commercially from these hills. Within the valleys of the area the surface is characterized by alluvium or undifferentiated siltstones, shales, or sandstones of the Lisman formation.

SUBSURFACE STRATIGRAPHY

A typical lithologic log and a typical electric log showing the various formations and the correlations herein used are given on figures 2 and 3 respectively.

Pennsylvanian System

In the subsurface rocks, the Providence limestone and the No. 9 coal again are present as prominent marker beds. The No. 9 coal is of special importance since it was on the basis of test holes drilled to this formation that the Guffie pool structure was discovered, and for that reason a map showing the structure of the area as represented by the top of the No. 9 coal is presented (fig. 4). This coal occurs 975 to 1,050 feet above the base of the Pennsylvanian. This sequence of rocks, approximately 1,000 feet thick, is composed of undifferentiated sandstones, siltstones, limestones, and coals. Three 30 to 80 feet thick water-bearing sandstone zones are recognized by the drillers within the area and show up strikingly on the electric logs available. Two coal seams that have thicknesses of more than 3 feet are commonly logged. They occur 100 and 500 to 550 feet below the No. 9 coal. Oil shows are common and gas shows not unusual. One well in the Panther pool produced gas from a Pennsylvanian sandstone for local use. The only production of oil from the Pennsylvanian rocks occurs in the center of the Guffie pool. At this point, a sand 600 feet below the No. 9 coal, probably of Caseyville age, is the reservoir rock for three wells. Oil in this formation probably accumulated from oil-bearing shales in the adjacent Pennsylvanian rocks. The Pennsylvanian sediments except the limestones and coals are typically micaceous, but they share the common characteristic of being argillaceous. Occasional zones bearing pyrite or siderite are noted in sample study. The sandstones are notably fragmental, fine-grained, equigranular, and composed of clear quartz; however, those sandstones immediately above the base of the Pennsylvanian rocks tend to be less equigranular than is usual in the sediments of this area and to contain high amounts of vein-type, white quartz fragments.
Mississippian System

Chester Series

The rocks of greatest importance in this report are those of Chester age, since these contain the zones from which more than three-quarters of the oil so far produced has been taken. In general, the Chester formations are rather easily separated, and they correspond closely to the standard correlations for the Kentucky lobe of the Eastern Interior Coal Basin as given by Swann and Atherton\(^7\) and by Jacobsen.\(^8\) A complete general discussion of Chester correlations may be secured from the papers by Weller and Sutton\(^9\) and Swann and Atherton\(^10\) which describe surface and subsurface occurrences respectively.

There is in this district general agreement on correlations of the formations by the geologists and petroleum engineers who work there. In addition, the drillers have come to recognize the various formations, and, as a result, the drillers' logs are usually reliable. In the discussion to follow, the commonly used geological name of a formation will be given first; if the drillers have used a different name, it will be given in parentheses.

Kinkaid formation ("Chester lime"):

Throughout the area, the lower Kinkaid limestone is present as the first continuous thick limestone unit of Mississippian age. The lower Kinkaid is a 25- to 35-foot thick, massive bed of finely crystalline, saccharoidal, slightly shaly, crinoidal, mottled gray limestone. Owing to the irregular nature of the Mississippian-Pennsylvanian unconformity, units of the Kinkaid formation overlying the lower Kinkaid limestone are absent in many parts of the field. Where higher members of this formation occur, a 5- to 10-foot thick limestone is found. It is usually 25 feet above the top of the lower Kinkaid limestone. The interval between these limestones is composed of shale with local sand lenses reaching 10 feet in thickness. Where the higher limestone is absent, it is commonly


\(^8\) Jacobsen, Lynn, op. cit., pp. 7-15.


replaced by channel-type sands that are argillaceous, fragmental, and less well-sorted than is usual for the Mississippian and Pennsylvanian sands of this area, which are normally rather equigranular in nature. The character of the unconformity and subsequent sedimentation has permitted structures shown on Pennsylvanian horizons to closely reflect the structures expressed on the stratigraphically lower Mississippian horizons. (Compare figs. 4 and 5.) Differential compaction of the Pennsylvanian deposits over higher portions of the post-Mississippian surface has not been an important factor in forming Pennsylvanian structures of the area. A map showing the structure on the base of the lower Kinkaid limestone is presented (fig. 5).

Degonia formation:

The Degonia is a 60- to 75-foot thick unit of greenish to gray, slightly calcareous shale. It slakes easily and contains interbedded thin, shaly, brown-gray limestone members. Occasionally, sand lenses are noted by drillers.

Clore formation:

The Clore is a gray-brown, shaly, finely crystalline, slightly fossiliferous limestone section with intercalated calcareous shale members. As a unit, it varies from 30 to 40 feet in thickness.

Palestine formation:

The Palestine is composed mostly of a slaking, silty, laminated, gray to brown to black shale, varying in thickness from 50 to 70 feet.

Menard formation:

This formation commonly occurs in the form of three limestone members with shale separations. The upper two limestones are separated from the lower one by 30 to 50 feet of shale. The upper unit consists of the following: a 25-foot thick mottled tan to gray, fragmental, slightly cherty, shaly limestone; a 5- to 15-foot thick green, red, and gray shale member; and a 5- to 8-foot tan to gray finely granular limestone beneath. This unit is often called the Upper or Massive Menard. The next unit, that of the 30 to 50 feet of silty, slightly calcareous, gray and green shale, is given no name. The lowermost limestone, which is fragmental and crinoidal, is called the Lower or Little Menard limestone.

Waltersburg formation ("Big Mud"):

The Waltersburg here occurs as a shale that deserves the apt name, "Big Mud," given it by drillers in the area. It is a 60- to 70-foot section of gray, laminated shale that slakes very easily on exposure to water.
FIGURE 5
STRUCTURE MAP
OF
GUFFIE AREA
MCLEAN & DAVIESS COUNTIES, KENTUCKY
WITH CONTOURS ON THE BASE OF THE KINSAID LIMESTONE

NOTE:
CONTOUR INTERVAL 25 FT
DATA MEAN SEA LEVEL

LEGEND:
1 DRY HOLE
3 PRODUCING WELL
1 DRILLING WELL

SCALE
1 INCH = 4,320 FEET

MCLEAN CO
DAVIESS CO
GUFFIE POOL
Cleopatra Pool
COUNTY LINE FAULT
Blenville Extension Pool
Vienna formation ("1st Brown lime"):

The Vienna is persistent throughout the area as a 5- to 10-foot bed of fragmental tan to gray-brown limestone containing abundant crinoid and limestone fragments cemented by calcite. Occasionally there is found above the usual Vienna limestone a 5-foot bed of limestone rather erratic in distribution. It is separated from the lower limestone by a 2- to 4-foot shale break. The structure on the Vienna limestone is very closely associated with that of the Tar Springs formation. Figure 6 shows the structure on the base of the Vienna limestone.

Tar Springs formation ("Jett" sand):

The Tar Springs contains the most important producing interval in the Guffie area. It is the most variable in lithologic character of all the Chester formations, containing all types of sediments from medium-grained sandstones to limestones. The Tar Springs sands are commonly fine and equigranular and grade from tightly to poorly cemented. Those which are poorly cemented are most frequently associated with oil occurrences. A core analysis from a well in the East Guffie pool (Sohio No. 7 E. T. Wilhite) showed the sand to have 20 percent average porosity and an average of 40 to 45 millidarcies of permeability with 6.5 percent of oil saturation. Within its 50 to 80 feet of thickness, this formation may contain as many as three separate sand bodies separated by silty, laminated shales and occasionally by thin limestone lenses. Pyrite is common in the Tar Springs, particularly at the contact with the upper Glen Dean limestone.

The most prominent characteristic of this formation is lenticularity of sand bodies. See figures 7 and 8 for cross sections that show lenticularity within the Tar Springs and other formations of the lower part of the Chester series.

The most common producing portion of the Tar Springs is the central sand zone which may reach 50 feet in thickness in the Tar Springs proper and may reach 80 feet where it is continuous with sandstones of the upper part of the Glen Dean formation. This continuity is common where Tar Springs sands filled in shallow (10- to 30-foot) depressions on the post-Glen Dean erosion surface. The distribution of production from this zone is shown on figure 1, which gives data on the producing zones in each pool. In addition, figure 9 shows the thickness of Tar Springs sand bodies.

Although the Tar Springs is not productive of oil in all the pools, it usually contains oil shows. These oil shows are noted even when conditions are not structurally favorable for oil accumulations. It seems probable that there is continuous porosity in the Tar Springs, but this formation is productive only where closure due to doming or faulting occurs. Gas is usually associated with Tar Springs oil.
LENSICULARITY OF THE LOWER CHESTER
GUFFIE AREA, MCLEAN & DAVIESS COUNTIES, KENTUCKY

FIGURE 8
Glen Dean formation:

The Glen Dean contains the second productive zone in the Chester rocks of the Guffie area. The highest unit of this formation is a 7- to 13-foot, saccharoidal to fragmental, tan limestone ("2d Brown lime" or upper Glen Dean limestone). The middle unit is a variable section, 25 to 45 feet in thickness, consisting of calcareous shales, siltstones, and fine-grained sandstones. The lowest member is a massive, 25- to 35-foot, tan to gray, crystalline, fragmental limestone that is occasionally oolitic or cherty ("Little" lime or lower Glen Dean limestone). The sand section in the Glen Dean is productive of oil and gas from a porosity trap in the East Guffie pool. In the central part of the Guffie dome, sufficient erosion has taken place to allow the Tar Springs and Glen Dean sands to form one continuous unit. This zone serves as an oil reservoir that may be as much as 85 feet in thickness. However, seldom is more than 40 feet of this thickness saturated.

Hardinsburg formation ("Jones" sand):

The Hardinsburg varies from 40 to 80 feet in thickness; of this, up to 60 feet may be fine, silty, slightly pyritic sand. This sand may occur in a continuous section or it may contain intercalated shale or siltstone breaks. Although oil shows are frequent in this formation, it is productive in only a few wells and is commonly noted as being a water-bearing sand.

Golconda formation ("Big lime").

The Golconda limestone occurs as a unit of 50 to 80 feet of 5- to 15-foot limestone beds with shale breaks between them. The limestone is usually tan to gray, fragmental with numerous fossil remains, primarily crinoid stems, and it may be rather oolitic in the middle members. Chert inclusions are common. The shales are black to gray, laminated, and easily slaked on exposure to water. The basal limestone unit of the Golconda, a member 10 to 20 feet thick, has a strikingly high resistivity curve which is of much use in electric log correlations.

"Jackson":

The section of shale, siltstone, and sandstone occurring beneath the Golconda and above the next prominent continuous limestone has been given the name "Jackson" by some drillers. Never formally recognized, it is commonly correlated as equivalent to the Cypress sandstone of Indiana. It is a natural unit for this part of Kentucky and has been so described by Bruce,\textsuperscript{11} and Jacobsen,\textsuperscript{12} For a more complete discussion, see Swann and Atherton.\textsuperscript{13} Productive of oil in the Guffie pool and commonly having oil shows associated in

\textsuperscript{11} Bruce, C. H., op. cit., pp. 7-8.
\textsuperscript{12} Jacobsen, Lynn, op. cit., p. 13.
\textsuperscript{13} Swann, D. H., and Atherton, Elwood, op. 277-279.
other parts of the area, it is of sufficient importance as a producing formation that an isopachous map of the sand thickness within the "Jackson" is included (fig. 10). The "Jackson" sand is the most continuous and least variable sand body in the greater part of the Guffie area. There is a prominent 10- to 20-foot section of red and green laminated shale at the top of the "Jackson" that forms a good marker horizon. Beneath this zone is found a gray-black, platy shale and a sand section of angular, equigranular, fine-grained, clear quartz sand. The sand is bound by calcareous cement and has 10 to 20 percent porosity. The sand and dark shale unit totals 30 to 40 feet in thickness.

"Barlow":

Persistent throughout the Guffie area is an 8- to 10-foot limestone, composed of fossil fragments and calcite rhombs, tan to mottled gray-brown in color, dense, and cemented by calcite. Because the variations in structure on this horizon closely indicate the occurrence of oil in the Cypress sandstone beneath, a structure map on the base of the "Barlow" limestone was prepared to show this relationship (fig. 11).

**Cypress formation ("Barlow" sand):**

The Cypress sandstone occurs as a 40- to 50-foot section of sand and shale. The top 10 to 20 feet is composed of gray, laminated shale; and underneath this unit is found a sandstone which grades into siltstone laterally and vertically. The sand, according to a core analysis (Sohio No. 2 E. T. Wilhite) from the East Guffie pool, averages 80 millidarcies of permeability and 18 percent porosity. It is usually silty and fine-grained. A red shale parting is common about 20 feet above the base of this unit. Since this is an important producing formation, figure 12, which shows sand thicknesses within the Cypress, is included.

**Paint Creek formation ("Bethel" lime):**

The Paint Creek limestone occurs as a limestone unit that may be 20 to 25 feet in thickness when the upper and lower limestone members are not separated. When these members are separated, by shale or sandstone, a total thickness of 45 feet may be reached. The limestone members are highly oolitic with subordinate occurrence of fragmental material. They are light tan to light gray in color and may contain a small amount of chert. The upper lime member is 15 to 20 feet thick; the lower, 8 to 12 feet. The sand of the intermediate unit is fine-grained, usually silty, equigranular, and angular.

**Bethel formation:**

The Bethel sandstone is a prominent producing interval. It is commonly a unit, 30 to 50 feet in thickness, composed of pyritic shale and sand. As is usual with the sands of this area, the sand is angular, equigranular, and fine-grained.
FIGURE 12
ISOPACHOUS MAP
OF GUFFIE AREA
MELEAN & DAVIESS COUNTIES, KENTUCKY
SHOWING THICKNESS OF SAND WITHIN
THE CYPRESS SANDSTONE

NOTE:
ISOPACH INTERVAL 5 FT.

LEGEND:
- DRY HOLE
- PRODUCING WELL

SCALE
1000 2000 3000 4000 5000 4000 3000 2000 1000
FEET

N

N

CRAVES McLEAN CO.

CLEOPATRA POOL

EDWARDS POOL

BONDHOLDERS POOL

PANTHER POOL

GUFFIE POOL

GUFFIE POOL

GLENSVILLE EXTENSION POOL

27 27
28 28

24

23 22 21 25 24

In addition, it has about 10 to 15 percent porosity and is cemented by calcite. Gas is commonly associated with Bethel oil. An isopachous map of the thickness of sand within this formation has been prepared (fig. 13).

Renault formation:

The Renault contains as its highest member a 22- to 28-foot, slightly oolitic, pyritic, cherty limestone. It is medium to light tan-gray in color, slightly fossiliferous, and becomes shaly in the lower part. The middle member is a unit composed of shale and sandstone up to 55 feet in thickness. Of this thickness up to 50 feet may be sandstone ("Cunningham break") that is silty, fine-grained, and composed of clear, angular, equigranular quartz grains. Especially notable is finely disseminated pyrite on the sand grains; and a small amount of glauconite is also seen. This unit occasionally has oil shows in it and is productive in a few wells in the eastern part of the Guffie area. The lowest unit of the Renault is a 40- to 50-foot section of limestone for which no samples were available. From electric logs, it is apparently composed of an upper 22- to 25-foot limestone bed with a shale break beneath, up to 3 feet in thickness, followed by 15 to 20 feet of limestone. As the Renault is the lowest unit for which reliable depth data are available, a structural map on the top of the Renault formation is presented (fig. 14).

Aux Vases formation:

The Aux Vases is represented by 8 to 13 feet of red and green shale in the Guffie area.

Middle and Lower Mississippian Formations

Ste. Genevieve formation:

The Ste. Genevieve is the lowest formation to which most of the wells have penetrated. It is the only formation in this area in which oil is produced from limestone. Two zones of production and oil saturation are recognized. The higher zone is usually 40 feet below the top of the Ste. Genevieve and is oolitic in texture. Both oil and gas (used for repressuring) are taken from this upper zone; it contains only shows of oil in the northern and western parts of the area, but commercial oil is produced from it in the Glenville Extension pool. The lower zone is 80 to 100 feet below the top of the Ste. Genevieve and also is highly oolitic; it is most prominent in the southern and eastern parts of the Guffie area. The lower zone is productive of oil in the Guffie and Glenville Extension pools. Oil production from the Ste. Genevieve is apparently less dependent on structural control than that from any other producing zones. Oil accumulation unfortunately seems to be in lenticular, porous oolitic zones. A zone carrying sulphur water is frequently found 130 to 150 feet into the Ste. Genevieve. This marks the lowest penetration of almost all wells within the area.
FIGURE 13
ISOPACHOUS MAP
OF
GUFFIE AREA
MCEAN & DAVIESS COUNTIES, KENTUCKY
SHOWING THICKNESS OF SAND WITHIN
THE BETHES FORMATION

-NOTE-
ISOPACH INTERVAL 5 FT

-LEGEND-
* DRY HOLE
* PRODUCING WELL

SCALE
000 2000 3000 4000 5000 6000 7000 8000 9000 10000 11000 FEET

GLECPATRA POOL
GUFFIE POOL
EDWARDS POOL
BOWHOLDERS POOL
GLENNVILLE EXTENSION POOL
Below a depth of 60 feet the Ste. Genevieve is recognized to be somewhat dolomitic.

The producing zones in the Ste. Genevieve have been called "McClosky" by the drillers and by Jacobsen.\(^{14}\) It seems probable that they are about 75 to 125 feet above the true "McClosky" which represents zones in the Fredonia member of the Ste. Genevieve formation. It is more probable that the zones in the Guffie area represent "O'Hara" production from the Levias member, although Jones\(^{15}\) quotes Mrs. Freeman as recognizing a zone only 100 feet below the "Cunningham" as "McClosky." If "McClosky" is to be defined as any producing oolitic zone of the Ste. Genevieve, this usage is permissible; if "McClosky" is defined as Fredonia production only, as is the practice in Illinois, it might be better to list the producing zones in Kentucky that are high in the Ste. Genevieve as "Zone No. 1," "Zone No. 2," and so on. The writer prefers the latter usage. Since no definite division of the Ste. Genevieve of this area is possible because of lack of samples, this "McClosky" question must remain unsettled for the present.

**Pre-Ste. Genevieve formations:**

Two wells have penetrated deeply into the pre-Ste. Genevieve formations: the Miller and Shiarella No. 5 Elizabeth Paris, section 17-N-28, and the Miller and Shiarella No. 21 T. A. Wiggins, section 20-N-27. These wells indicate that over 300 feet of St. Louis limestone and 150 to 200 feet of Salem limestone are present. The Salem-Harrodsburg and Harrodsburg-Borden contacts have not been distinguished satisfactorily in samples. There appears to be an interval of approximately 850 feet between the top of the Salem and the top of the Rockford limestone. The latter is a 10-foot limestone in the lower part of the Mississippian system.

**Devonian, Silurian, and Ordovician Systems**

The New Albany black shale is 260 feet thick here. Below it is an interval of 280 feet which includes the Hamilton and Jeffersonville limestones. Beneath this sequence is 25 to 35 feet of Dutch Creek sand which gave a show of oil in the Miller and Shiarella No. 5 Elizabeth Paris. The Miller and Shiarella No. 21 T. A. Wiggins was drilled later as a Dutch Creek test and proved to be dry. Underneath the Dutch Creek, there are 400 feet of Devonian rocks, all limestone. The Silurian is represented by 550 feet of rocks, mostly limestones. The Miller and Shiarella No. 5 Elizabeth Paris, which stopped in the Tyrone limestone, penetrated 680 feet of Ordovician rocks.


The initial oil pool of the area was discovered by drilling a surface structure worked out by N. W. Shiarella. This is the Panther pool, opened upon completion of the Miller and Shiarella No. 1 T. P. Miller, May 6, 1943, in the Bethel sand. It remained a flowing well (from a dissolved gas drive) for over a year. In January, 1945, it was shot with nitroglycerine and placed on the pump. The Guffie pool was opened October 23, 1946, when the Miller and Shiarella No. 1 T. A. Wiggins was completed in the Tar Springs sand with an initial oil production of 90 barrels per day. This well was located on the basis of information obtained from seven test holes drilled to the No. 9 coal from which the domed structure was suspected. Other pools, including the Cleopatra pool, completed in the Bethel and Cypress sands by the Miller and Shiarella No. 1 O. B. Leachman on October 26, 1947, with an initial oil production of 140 barrels per day, were discovered by exploratory wildcatting and further structural work from test holes to the No. 9 coal. The greatest initial oil production was 650 barrels per day from the Miller and Shiarella No. 2 T. A. Sandefur in the Guffie pool. Completion practices include shooting the sand reservoirs and acidizing the oolitic zones. The oil is transported by pipeline to Owensboro.

As earlier noted, except for lensing in the upper Glen Dean sand and the porosity control in the oolitic zones of the Ste. Genevieve, oil accumulations are primarily controlled by the fortuitous combination of structural traps and porous zones. An active water drive has been noted in the Cleopatra pool, but this and all other pools are dependent on dissolved gas drives and pumping for recovery at the present time.

Exploration is continuing by wildcatting and outpost wells, five rigs being active in February, 1951. Many shallow wells, both dry and producing, are being drilled again to test for deeper producing zones.

Total production from the area has been slightly in excess of 3 million barrels as of January 1, 1951, and potential production on the order of 10 to 15 million barrels is probable. A graph showing the monthly production rate is given in figure 15.

STRUCTURAL RELATIONSHIPS

A good summary concerning the regional structure in the Kentucky lobe of the Eastern Interior Coal Basin is given in Clark and Royds' paper on structural trends and fault systems. In general, the structural features in the Guffie area are controlled by the Rough Creek-Shawneetown fault system.

MONTHLY PRODUCTION OF OIL FROM THE
GUFFIE AREA, MCLEAN AND DAVIESS
COUNTIES, KENTUCKY

FIGURE 15
Typical of this portion of that system are extensive northwest trending high-angle faults and shorter northeast trending transverse faults (Bruce, Jacobsen, and Robinson). These faults, coupled with incidental flexures, result in domes and anticlines that frequently are productive of oil.

In particular, the Guffie area, because of its proximity to the axis of the Rough Creek-Shawneeetown fault system, which lies 3 to 5 miles south of the area mapped, has been affected by the forces responsible for the faulting.

The general deformation of the rocks is readily seen by examining any of the structure maps (figs. 4, 5, 6, 11, and 14) and the structural cross section (fig. 16). The net vertical displacement of rocks reaches a maximum of 250 to 300 feet along the northwest trending normal faults. The eastern side of a north-south horizontal transverse fault, in section 16 and 25, has been displaced 1,000 feet to the north. The total relief on the flexure within the graben reaches a maximum of 350 feet on the No. 9 coal horizon. One item not shown on the maps referred to is a small, local thrust fault found about 1,000 feet south of the county line in section 11-N-27 in a road cut at that point. No evidence of this fault was seen by the writer at any other point. Significantly, a magnetometer traverse adjacent to the road at that point showed an anomaly at the outcrop line of this fault. The thrust fault at this point has an apparent displacement of 50 feet. A red sandstone has overridden a blue clay shale and dips of 60° to 70° in the shale as well as fault gouge have been produced. The maximum apparent dip of the sandstone is 20°.

It has been noted by earlier writers (Clark and Royds and Jacobsen) that there is a tendency for faults in the Rough Creek-Shawneeetown fault system to vary in strike and amount of dip along any given fault. This tendency is the probable explanation for the change of strike from N. 62°W. on the surface to a more northerly direction at depth of the two parallel faults passing through the Bondholders pool, section 22-N-27.

In addition to faulting, folding has taken place in the Guffie area. The major fold is the northwest trending flexure present in the graben. Superimposed on this major feature are the smaller elongate domes of the Guffie and Cleopatra pools.

On the basis of field evidence and the maps prepared from well

data and magnetometer traverses, the structural history may be interpreted as follows:

1. With the beginning of movements connected with the Rough Creek-Shawneetown disturbance, some compressive forces placed a stress on the Guffie area, creating the northwest trending elongate flexure whose most prominent local features are the Guffie and Cleopatra domes. At this time, the minor thrust noted above took place as a result of the compressive stress. The presence of this thrust further suggests that the sedimentary column was comparatively thin (on the order of hundreds of feet) above this point, for otherwise, flowage type stress-relieving crinulations or other small flexures would have formed under the combined vertical load and horizontal stress. A light vertical load causes fracture type slippage and thus thrust faulting would be more probable. The fact that faulting was apparently local in nature, from the smallness of displacement seen, supports the above, for a large amount of movement was not required to relieve the stresses imposed on the rocks.

2. With the continuance of the Rough Creek-Shawneetown disturbance, compressive loading was replaced by tensional relaxation forces. At this time, the three faults striking N. 62° W. (the County Line fault and its parallels, the two faults passing through the Bondholders pool) developed as normal faults. The normal faulting allowed the previously established flexure to be preserved in form while the tensional forces were satisfied by the formation of the graben. The change in strike of the two faults in the Bondholders pool was probably related to the faulting then taking place southeast of the Guffie area at Grindstone Hill which is a complexly faulted area in itself. It should be noted that the fault marking the southern boundary of the Utica field is almost certainly a continuation of the County Line fault.

3. There yet remained some forces connected with the Rough Creek-Shawneetown disturbance. A torque set up by some of these resulted in the formation of the north-south horizontal transverse fault in sections 16-N-28 and 25-N-28, which offset previously developed structures on its eastern side 1,000 feet to the north.

MAGNETOMETER WORK

Traverses as noted on figure 1 were made with 50- and 100-foot station intervals across the County Line fault. The purpose of these traverses was to determine whether there would be correlation between magnetically observed anomalies and known structure. A further purpose was to use magnetometer work for tracing faults

MAGNETOMETER TRAVERSE ACROSS COUNTY LINE
FAULT ON LINE 18-29.5, SEC. 13-N-27, MCLEAN
COUNTY, KENTUCKY

FIGURE 17

X-OBSERVED READING
if it was found that a good correlation existed. A typical curve obtained from the traverses made is shown in figure 17. The other traverses gave curves that were quite similar in form. The traverses were made with a Ruska Type VI vertical magnetometer having a sensitivity of 9.3 ±0.1 gammas per scale division. Six readings were taken at each station, and the results were reduced relative to a base point (located in section 13-N-27). The observed curve is in experimental agreement with theoretical considerations in that a magnetic sheet cutting the surface and having a southerly dip as does the County Line fault should have a curve roughly as shown in figure 18. The magnetic field should be most intense at the point at which the body cuts the surface and should reach a minimum shortly to the north of a south-dipping sheet.

When the traverses were made, only an approximate location of the surficial fault trace was known. Field work done in the vicinity of observed anomalies disclosed a zone of crushed fragmental rock that was the fault trace. As a result of the field work based on this recognition, the discovery was made that the most southerly "fault" was actually a set of two parallel faults. This reason alone was a sufficient justification of magnetometer traverses. In addition, however, the traverses in each case enabled an exact positioning of the fault trace, one of the primary objects of such measurements.

The magnetic anomaly at the fault trace results from the fact that ground waters circulating among the rocks of the area have tended to concentrate iron-rich materials such as limonite and hematite in the gouge along the fault. The concentration of these minerals along this surface apparently furnishes sufficient susceptibility contrast to make mapping of faults possible by magnetometer work.

FUTURE POSSIBILITIES

Although there is little need for further work other than drilling in a field so well explored as the Guffie area, some suggestions may be offered concerning further geophysical work in the adjacent regions.

Magnetometer work in this area has shown that it is possible to trace faults where surface work is difficult if there is sufficient mineralization along the fault. Magnetometer work here requires short distances between station locations, for if there is a thick alluvial cover, anomalies are comparatively small and quickly lose definition.

Earth resistivity work holds promise even for areas covered by alluvium where faults are suspected. Lee and Hemberger report good results in the western Kentucky fluor spar area where deep weathering and other factors prevented satisfactory geological work.

Figure 18

Intensity of Magnetic Field

Magnetic Sheet

S

N

Surface
While gravity meter surveys might possibly delineate structures favorable to oil accumulations in this region, such work is of unknown value as no gravity surveys have been made in this area.

The close correlation between the No. 9 coal and Chester structure suggests that shallow seismic refraction work using comparatively inexpensive equipment and a shallow reference horizon such as the No. 9 coal or the Providence limestone might prove valuable in the location of promising structures. Undoubtedly, reflection seismic methods on the limestones of Chester age and lower series of rocks would be of great assistance in working out the general structure of the area.

Within the Guffie area, the Chester sands and oolitic zones of the Ste. Genevieve limestone are lenticular. In spite of this, porosity traps have until now been much less important than traps based on structural closure. However, there may be other favorable locations for accumulation of oil in porosity traps. It is probable that new pools opened in porosity traps will be comparatively small, for the density of drilling in the Guffie area precludes the discovery of any large pools. Many of the wells drilled into the Ste. Genevieve have failed to penetrate the full thickness of this formation. Some productive oolitic zones in the lower part of this formation may thereby have been missed.

The most favorable conditions for accumulation of oil in the Guffie area are: (1) a structural closure or terrace, (2) the presence of moderately porous, comparatively non-argillaceous sandstones, and (3) closely associated possible source rocks such as shales or shaly limestones. These conditions are in close agreement with the general conclusions of Russell24 concerning oil and gas accumulations in western Kentucky.

Unconformities have had very little effect on oil accumulation in the Guffie area other than permitting the increase of thickness of the Tar Springs sands where erosion had cut through the upper Glen Dean limestone. Differential compaction has either played a small part in the formation of the structural features of this field or its effects have been cancelled in various horizons, since structures persist in approximately the same locations and intensities from the No. 9 coal to the top of the Renault. Faulting has affected the stratigraphic section only in shortening and displacing sections in beds adjacent to faults. The porosity has apparently not been affected by faulting.

Further recovery from the now productive pools should be enhanced by the present practice of returning gas which was produced with the oil to the reservoir for pressure maintenance. It is also probable that water flooding will aid in secondary recovery.

The most likely method of increasing production is the extension by outpost wells of the present producing areas as shown in figure 1. Admittedly there is not much area in the Guffie pool undrilled, but the Cleopatra and Panther pools, as well as others, might increase production considerably by further testing of possible extensions.

The one possible structural feature left undrilled is the offset portion of the Guffie dome in sections 16 and 17-N-28. Production may be obtained here in the Tar Springs and Ste. Genevieve formations.

A test of the Devonian possibilities in the Glenville Extension pool which is located from subsurface data is warranted. The suggested location would be at approximately the center of the pool as it is now known. Tests to deeper horizons such as the Trenton or St. Peter should be carefully considered from economic and geological standpoints. More practical from an economic standpoint to begin with would be the practice of testing all possible oolitic zones in the Ste. Genevieve and continuing wells through the Salem limestone, coring at frequent intervals. The Salem tests might prove a new reservoir rock as oil and gas production is common from this formation throughout the Eastern Interior Basin.
SELECTED REFERENCES


