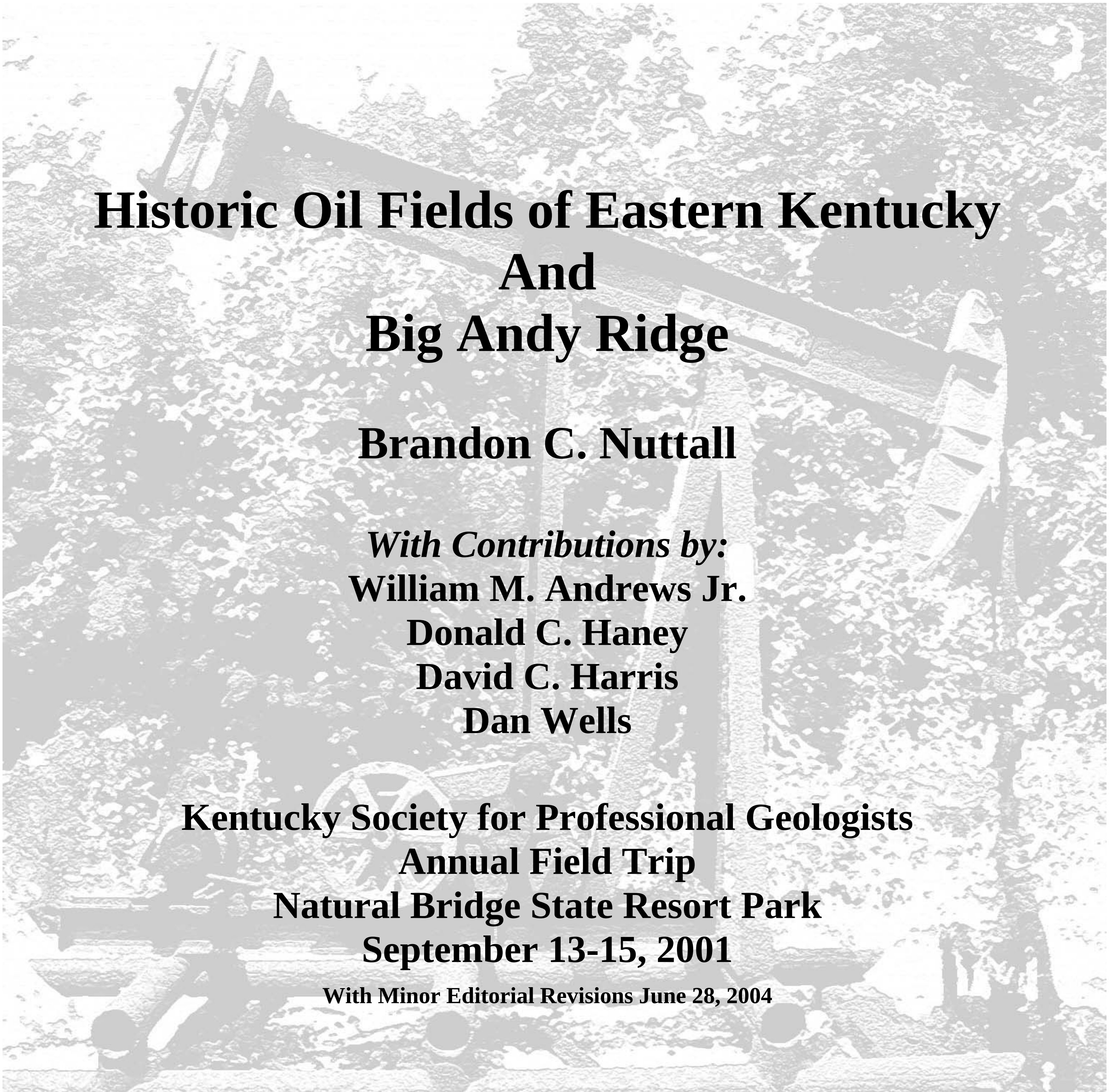

Historic Oil Fields of Eastern Kentucky And Big Andy Ridge

Brandon C. Nuttall

With Contributions by:
William M. Andrews Jr.
Donald C. Haney
David C. Harris
Dan Wells

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Brandon C. Nuttall

Introduction

Estill, Lee, Powell, and Wolfe Counties lie along the dissected Cumberland Escarpment at the northwest edge of the Cumberland Plateau. Much of this rugged area within the Daniel Boone National Forest is known for its steep sandstone bluffs jutting above wooded stream valleys. Few visitors realize the extent to which the natural resources of the area have been exploited. Beginning before the Civil War, the iron, timber, and petroleum industries have gone through many times of boom and bust. Much of the area has been completely denuded of timber, first in the 19th century for charcoal to fire the iron furnaces then again in the early 20th century to fuel the steam engines providing power for drilling rigs. The Big Sinking Oil Field is Kentucky's only giant oil field (more than 100 million barrels of oil production, Figure 1) lies in the center of the area. The important resource history of this area is fast fading into a forgotten backwater.

I'd like to acknowledge the people whose help was essential to compiling this guidebook. First, to my co-authors, Dr. Don Haney, Drew Andrews, Dave Harris, and Dan Wells, blame any errors on me. Cornelius Arthur, Al Nilhaus, Charles Perdue, and Mike Burdette provided excellent guide services and commentary. Sam Pees and Larry Woodfork enthusiastically described much of the rusting, kudzu-covered equipment. Terry Hounshell and Collie Rulo assisted with graphics. Patrick Gooding is a good driver and didn't get too upset when we made a wrong turn. Bob Smith, the editor and publisher of the Three Forks Tradition, granted permission to use historic pictures from the Beattyville newspaper. James Couch, manager and curator, gave us a tour of the Three Forks History Center.

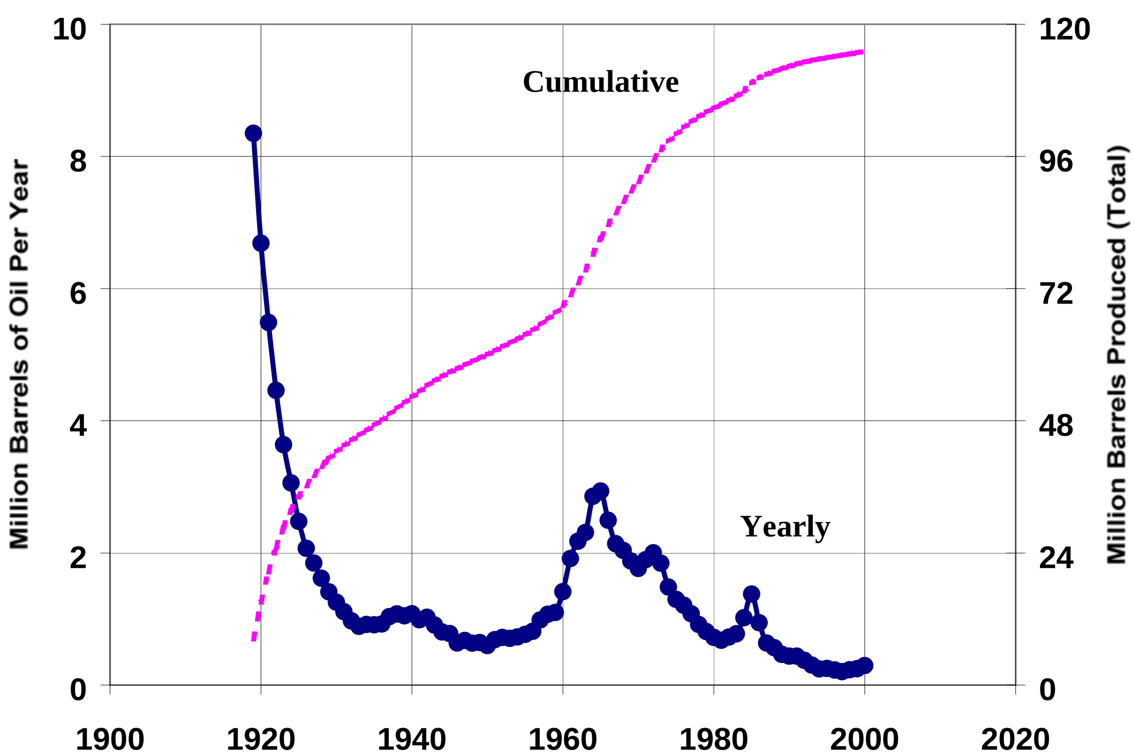


Figure 1. Yearly and cumulative oil production for Estill, Lee, Powell, and Wolfe Counties, 1918 to 2000.

Before Big Sinking

The iron industry in Kentucky was in full swing in the 1850's and fuel for the furnaces was a major concern. As large tracts were clear-cut, alternatives to timber for charcoal were sought. In 1852, having mistaken the Devonian black shale for the black shales in the coal measures of eastern Kentucky, drillers were exploring for coal in the valley of Hardwicks Creek, Estill County, with headwaters near the Estill Furnace. In one of those borings, the "upper portion of the auger was blown out into the air by gas, and the lower so bent in the boring as to stop the work." Another nearby well, drilled by Samuel T. Vaughn to a depth of 405 feet, produced salt water that soon gave way to a flow of rock oil (Lesley, 1861, p. 472).

From the Civil War era to the early 1900's, oil and gas activity is sketchy in the Big Sinking area. The Campton Oil Pool (Wolfe County east of Big Sinking) and the Irvine Field (Estill County, north west of Big Sinking) were discovered in 1903. These discoveries were followed closely by Furnace, Estill County, in 1905. Jillson (1919, p. 9) describes the oil market of 1913 to 1915 as stalemated and over produced. That situation changed with the entry of the United States into World War I. As the price of oil increased to more than $2.00 per barrel, the boom days returned to the area. In 1915, an eastward extension of the Irvine Field was discovered along Tick Fork (Tickey Fork) of Cow Creek by Charles Dulin, a "coolly calculating, resolute, and resourceful operator" (Jillson, 1919, p. 9). Not only did Dulin's well on the Rollins land come in flowing 250 barrels per day, but the oil was struck at a depth of only 200 feet in the "Corniferous" (Figure 2). During this boom period, leases went for as much as $150 per acre (Jillson, 1966, p. 87). In 1917, the Ashley Field was discovered in Powell County (north of Big Sinking). The boom continued with the discovery of Big Sinking in 1918.

Big Sinking

In 1917, Dan Jones, later to become the State Geologist 1934 to 1958, assisted P.J. Nutty in the compilation of a detailed structural geologic map of the Lee County area. As a result of this work, the Eastern Gulf Oil Company drilled and completed the No. 1 Ephriam (or Eph) Angel well on February 21, 1918 along Caves Fork of Big Sinking Creek, near the mouth of Hog Gap Hollow. While this was not the first well in the area, it is considered to be the proof that a major oil resource had been discovered. Originally drilled to a depth of 811 feet, oil was encountered in the "1st pay Corniferous" (Figure 2) below the Devonian Ohio black shale (Jones and McFarlan, 1933).

<table>
<tr><td>Pennsylvanian</td><td colspan="2">Lee-type sands of the Breathitt Group</td></tr>
<tr><td rowspan="4">Mississippian</td><td colspan="2">Pennington Formation</td></tr>
<tr><td colspan="2">Newman Limestone ("Big Lime" of drillers)</td></tr>
<tr><td rowspan="2">Borden Formation</td><td>Renfro and Nada Members</td></tr>
<tr><td>Cowbell Member</td></tr>
<tr><td>Devonian</td><td colspan="2">Ohio Shale (New Albany)</td></tr>
<tr><td colspan="3">Major Unconformity</td></tr>
<tr><td rowspan="3">Silurian</td><td>Lockport dolomite</td><td rowspan="2">Corniferous (corresponds to the Boyle/Bisher interval in outcrop near Irvine)</td></tr>
<tr><td>Keefer sand (Big Six)</td></tr>
<tr><td colspan="2">Crab Orchard shale</td></tr>
</table>

Figure 2. Generalized stratigraphic nomenclature for the Big Sinking Field area.

Pipelines were quickly laid into the producing areas of the field that carried oil to various refineries. Much of the oil from the Caves Fork area made its way north to Campton and from there to refiners. Some oil was delivered by rail from Torrent or by barge via the Kentucky River. The Cumberland Pipe Line Company transported Kentucky "Somerset" grade crude oil to Morgantown, West Virginia where their trunk line joined with the Eureka Pipe Line Company. In 1919, most of this oil was transported to Philadelphia, Pennsylvania (Jillson, 1919).

Some of the oil, however, ended up at a 1,000 barrel per day capacity refinery built to supply lubricating stock for World War I near a rail stop called Leach in Catlettsburg, along the Big Sandy River, south of Ashland, Kentucky (Scott, 1968). In 1918, J. Fred Miles, who had learned of Charles Dulin's oil discovery, organized the Swiss Oil Company with some Louisville and Lexington, Kentucky, partners. By the early 1920's Swiss Oil encountered financial problems and on January 26, 1924, Swiss Oil reorganized under the name of Ashland Refining Company. Paul Blazer would run the new company. In February 1924, Blazer acquired the refinery at Catlettsburg that, expanded and modernized, still operates today.

Peak reported yearly production for the Big Sinking area is 8.35 million barrels produced in 1919 (Figure 1). In 1926, the Petroleum Exploration Company started a repressurization project in Big Sinking, the earliest secondary recovery operation in Kentucky. Production rates continued to decline, however, until 1949 when Preston Oil began a waterflood project on the Smythe lease (Jones, 1952) (shown as "J.D. Smith" in Figure 4 and Figure 5). Annual production reached a low of 600,000 barrels in 1950 then increased to 2.9 million barrels produced in 1965 (Figure 1). These 15 years were the halcyon days of waterflooding in Big Sinking with much of the oil being delivered to the Ashland's Catlettsburg refinery.

Figure 3. Snagged on the road. Jillson (1919, p. 8) aptly titled this picture to illustrate the difficulties of hauling a rig onto location. This was taken on the road from Torrent in 1918.

Geology of Big Sinking

In general, reservoirs in the Big Sinking area are stratigraphic traps associated with the erosion surface developed on the Corniferous. These traps are sealed by the Ohio shale that unconformably overlies the Silurian.

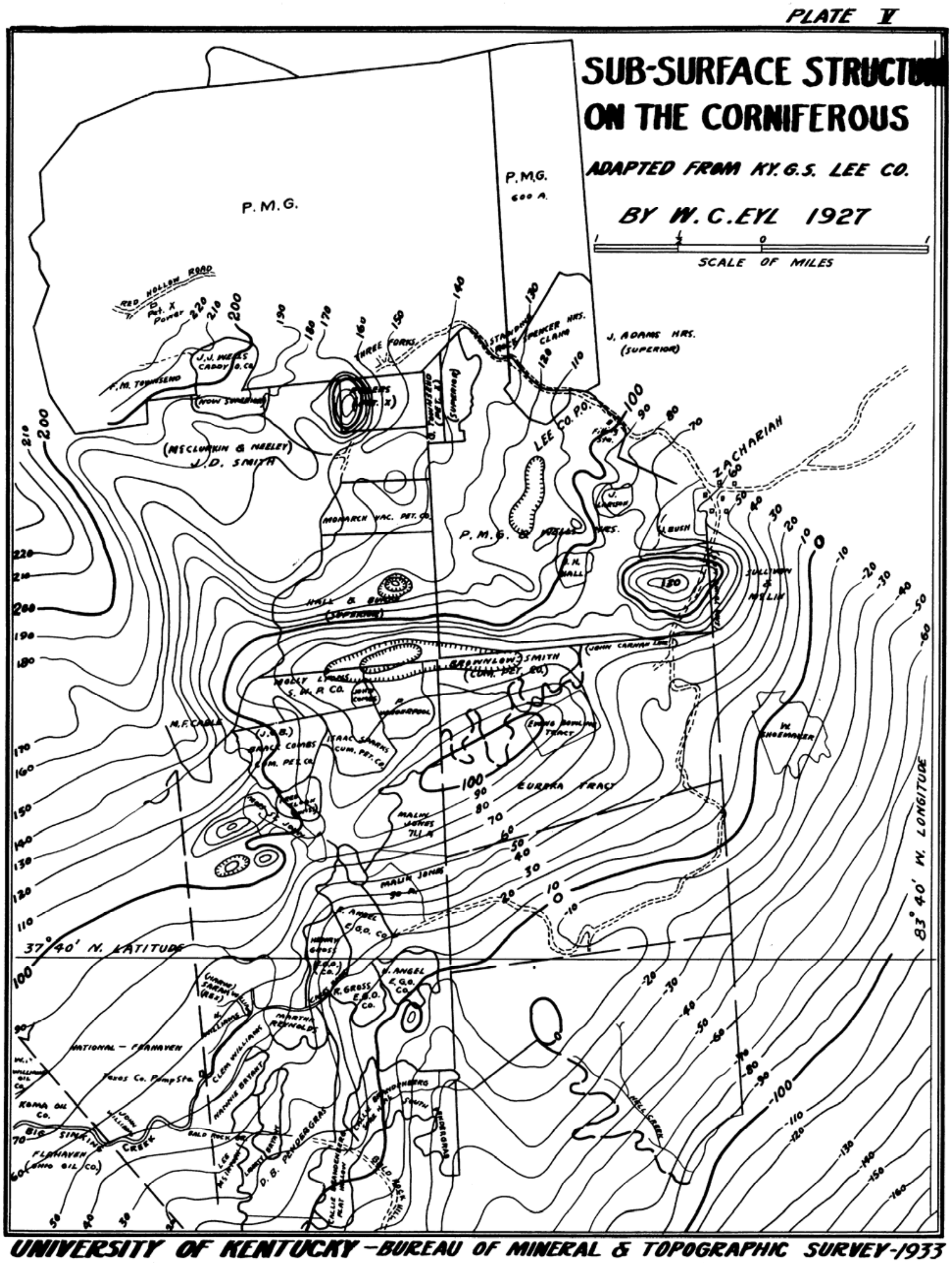


Figure 4. Structure map of the Big Sinking Field (Jones and McFarlan, 1933)

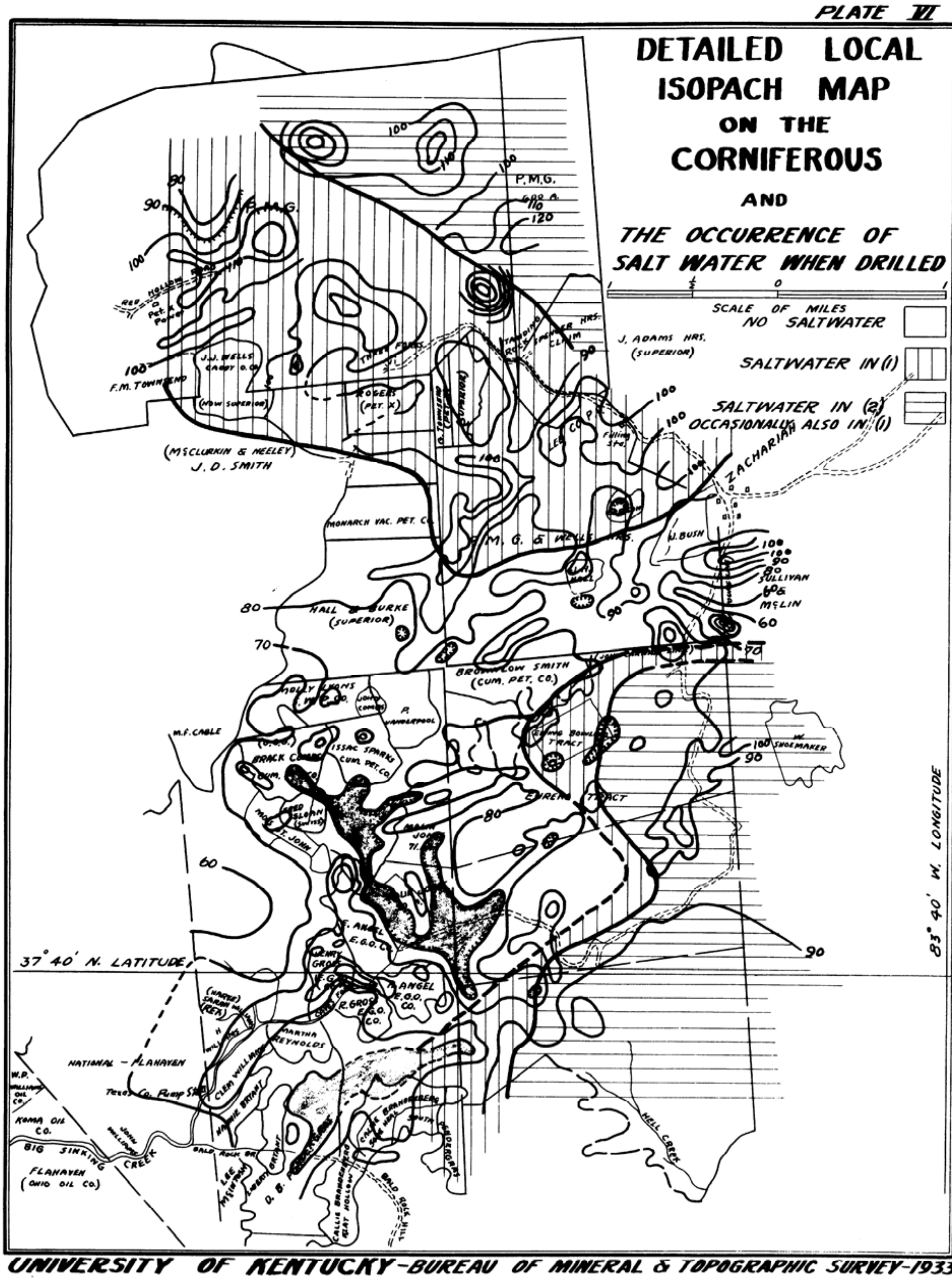


Figure 5. Isopach of the Corniferous (Jones and McFarlan, 1933)

The structure map by W.C. Eyl (Figure 4) shows the Silurian to dip southeastward away from the crest of the Cincinnati Arch and toward the deeper Appalachian Basin to the east. The Eph Angel lease is shown on a northwest trending nose in the southwestern quarter of the map. Figure 5 shows the variability of the thickness of the Corniferous in the area. Key relations between the various pay zones in Big Sinking to the unconformity are illustrated in Figure 6.

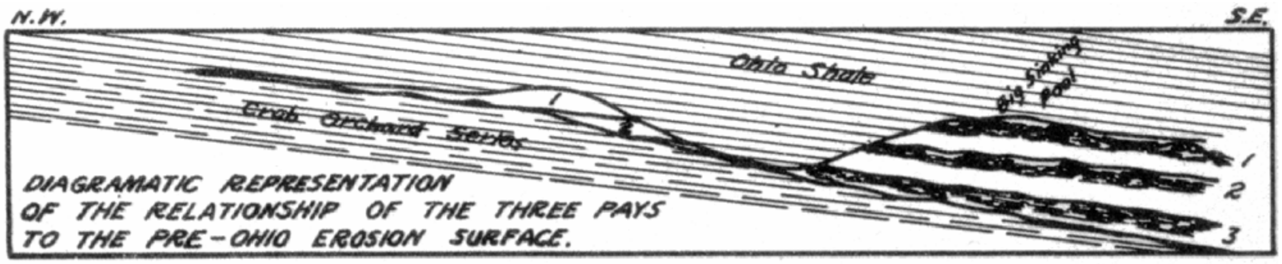


Figure 6. Cross section showing relationship of producing zones in Big Sinking to the unconformity (Jones and McFarlan, 1933)

The Oil Mine at Ravenna

Jillson (1921) documents an experiment to recover crude oil by sinking a mineshaft from the surface to the oil-producing zone. Circa 1920, operators D.W.R Kinney, George W. Eastom, and John McMinn dug a prospecting tunnel near an old oil well on the Hudson farm in Ravenna, Estill County. In addition to crude oil, they proposed to retort the Devonian shale produced by mining to recover additional hydrocarbons. Jillson reported no oil production in his account. This novelty apparently failed and has faded into history. As of this writing, the remains of the oil mine have not been located.

Early Development of the Petroleum Industry in the Appalachian Basin

Donald C. Haney and Brandon C. Nuttall

The history of the petroleum industry centers on, but does not begin with, the Drake well near Titusville, Pennsylvania. Drilled in 1859, this important well marks the emergence of the petroleum industry as we recognize it today. As the 19th century began, it was well known in America and abroad that in parts of Pennsylvania and New York a substance called “rock oil” flowed from springs. Oil was used medically, burned freely, and was used for grease, but its odors were offensive. The expense of whale oil for illumination was increasing, and people were looking for a substitute. Modern machinery required a reliable lubricant; thus great effort was made to make “rock oil” more palatable.

The modern exploitation of petroleum in the Appalachian Basin had its beginnings with drillers in the early 1800’s who were searching for salt brines; salt for food preservation and agriculture was far more important than petroleum. In 1802, the U.S. Congress recognized the value of natural salt springs and seeps in the Northwest Territories (the Ohio River Valley area) and reserved them as too valuable for private ownership. It was inevitable that the process of drilling for brines would encounter some of the shallow petroleum reservoirs known today. In 1806, David and Joseph Ruffner of Charleston, West Virginia, began drilling for salt brines in the Kanawha River Valley, determined they would find a more consistent source of brines. They used a spring, or jack, pole anchored at one end with a rope and bit at the other. It required hard work to pound, or "kick," through the rock and drillers used a variety of arrangements to jump up and down on the rig. In time, the Ruffners devised an iron rod with a steel tip, the rock drill. They finished their 47-foot-deep well January 15, 1808, with a satisfactory flow of strong brine. During this time, the brothers developed many of the methods that later became common. Drillers in the Kanawha Valley originated the conductor, casing, jars, and other tools.

The first salt wells in the area around Tarentum, Pennsylvania, along the Allegheny River near Pittsburgh, were drilled before 1810. By 1820, the area was the state's western center of salt manufacturing. Samuel Kier and his father owned and operated two wells and Kier thought there must be some use for the oil that was often flushed from them. He began by selling it for medicinal purposes, employing salesmen traveling the countryside in gaudy wagons. It was most certainly Kier who purchased the Kentucky oil recovered by the Youngloves.

In the 1826 *American Journal of Science*, Dr. S.P. Hildreth documented the well drilled by a Mr. McKee on Duck Creek just north of Marietta, Ohio. McKee had hit oil while drilling for salt in 1814. In the same journal Dr Hildreth referred to oil and gas development in the Muskingum Valley, and based upon its use in the area predicted, “it would be widely used in the future.” With discoveries at Burning Springs and Marietta, southeastern Ohio and West Virginia were recognized early to be important areas as interest expanded from Pennsylvania and New York.

In 1807, John Francis reported the discovery of saltwater brines along the Big South Fork of the Cumberland River on the property of Richard Slavey. Francis and Slavey obtained a land grant from the State in 1811 on the condition they produce salt. Martin Beatty operated an iron furnace in Virginia and moved to the Wayne County area of southeastern Kentucky in 1817 to try his hand at saltmaking. He acquired property on Oil Well Branch of the South Fork of the Cumberland River, not far from the main settlement routes through the Cumberland Gap. In the winter of 1818–19, his drillers, Huling and Zimmerman, found “rock oil” at an estimated initial flow of 100 barrels per day. Beatty abandoned his oil well but became very successful in the salt industry. He became a state legislator and a member of the Federal Congress. He eventually moved to Texas, and died shortly before the Drake well was drilled. Huling built wooden casks, barreled the oil from Beatty's well, and sold it in Kentucky, Tennessee, Virginia, North Carolina, and Georgia.

The "Great American Well," located near Burkesville in Cumberland County, Kentucky, was drilled in 1829. Even though not strictly within the Appalachian Basin, the well would have a far-reaching influence on the future development of the industry. The well was drilled to a depth of about 171 feet and came in a gusher. The drill bit and rope shot out of hole and a solid stream of oil was “thrown to the top of the surrounding trees.” Oil flowed into the Cumberland River and covered the surface of the river downstream for 40 or 50 miles. The well produced an estimated 50,000 barrels of oil from 1829 to 1860. In the 1850's, Samuel M. Kier of Pittsburgh was selling “Kier’s Petroleum or Rock Oil, Nature’s Remedy Celebrated for its Wonderful Curative Powers, taken from a Well Four Hundred Feet below the Earth’s Surface.” In 1848, Kier's wife developed tuberculosis and the doctor prescribed "American Medicinal Oil," which came from a well in Kentucky, probably the "Great American Well."

The stage was set for the emerging industry. Petroleum was being found, mostly to the detriment of salt-brine production, but how could it be used other than as a folk remedy? Paraffin, discovered in 1830 by Reichenback and Christison, could be distilled from coal and shale and could be used both as lamp fuel and as a substitute for spermaceti in candle making. In 1848, a plant was started in Derbyshire, England, to extract paraffin from shales, and Dr. James Young patented his process in 1850. Abraham Gesner, a Canadian geologist, immigrated to the United States, where he devised and patented a method to distill kerosene from petroleum in 1848. After witnessing the accidental burning of a local canal, Samuel M. Kier developed a lamp and an odorless fuel and by 1858, he was distributing his "carbon oil" lamps in Pittsburgh. Kier never patented either the distillation process or his lamp. His success in the oil business, however, attracted the attentions of Jonathan G. Eveleth and George H. Bissell.

Eveleth and Bissell came to New Haven, Connecticut, for the purpose of “disposing” certain lands in western Pennsylvania. They had collected a sample of Seneca Oil and sent it for analysis to Professor Benjamin Silliman, Jr., of Yale College. In 1855, Silliman distilled the sample and reported its properties referring to its use for illumination. Eveleth and Bissell formed the Pennsylvania Rock Oil Company to develop lands around Oil Creek near Titusville, Pennsylvania. After control of the Pennsylvania Rock Oil Company fell out of their hands, the company retained E.L. Drake to determine what the company really owned. A lease on the lands still controlled by Eveleth and Bissell was issued to the Pennsylvania Rock Oil Company, but before drilling could commence, the New Haven stockholders formed a new company called the Seneca Oil Company. In March 1858, E.L. Drake was appointed president of the Seneca Oil Company and in the spring of that year, began his development of the property.

Beginning with the discovery of the Beaver Creek Field (Floyd County, Kentucky, 1892) and culminating with the discovery of the Big Sinking Field in Estill and Lee Counties of Kentucky in 1918, the industry expanded farther to the south in the Appalachian Basin. Big Sinking Field is still in production and has produced over 120 million barrels. Although that level of production is not now considered major, it was a very significant for the early part of the 20th century.

The record of Appalachian Basin petroleum production is illustrated in Figure 7. It begins with 2,000 barrels produced in 1859 in Pennsylvania. Peak yearly production occurred in 1891, 1896, 1897, and 1900 with more than 50 million barrels produced each year. During this period, Pennsylvania, West Virginia, and Ohio dominated production; New York produced small amounts of oil. By 1901, with cumulative production exceeding 1 billion barrels, basin production had begun its decline. After 1900, peak production exceeded 30 million barrels yearly during both World Wars and as a result of the discovery of Knox oil production in the Morrow Fields of Ohio in the 1960's. Total cumulative production for the basin through 1999 exceeds 3.5 billion barrels.

The Appalachian Basin is a mature petroleum province. Its long history of drilling, however, is misleading. Exploited thoroughly at shallow depths, much of the deep Paleozoic strata remain undrilled. Considering the Basin's vicinity to major industrial centers, the application of modern exploration ideas and technology will undoubtedly yield the entrepreneur many opportunities for oil and especially natural gas production.

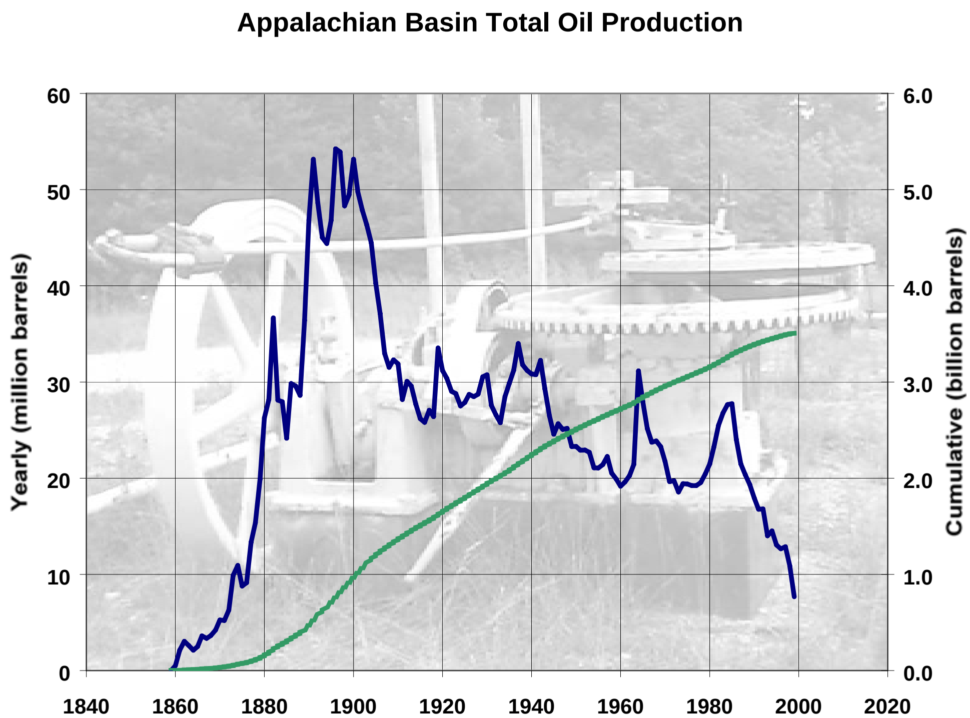


Figure 7. Appalachian Basin historic oil production.

Irvine-Paint Creek Fault System, Eastern Kentucky

David C. Harris
Kentucky Geological Survey

The Irvine-Paint Creek Fault System (IPCFS) comprises a complex series of normal faults mapped at the surface across a large part of eastern Kentucky. The fault system is named for it’s geographic location, from Irvine (Estill County) to Paint Creek in Johnson County. The fault system actually continues west of Estill County, to Lincoln County, where it terminates at the Lexington Fault System. The IPCFS trends east-northeast across eastern Kentucky, and is parallel to the Kentucky River Fault System father to the north (Figure 8). The overall relative motion on the IPCFS is normal, and down to the south-southeast, but the western half of the trend consists of narrow (0.5–1 mile wide) structural grabens bounded by normal faults.

The IPCFS is rooted in Precambrian metamorphic rocks of the Grenville Province, and developed during the early Cambrian. The faults have been reactivated numerous times throughout the Paleozoic, and possibly more recently. It lies within the Rome Trough, a failed Cambrian rift basin that developed inland from the continental margin during opening of the Iapetus (proto-Atlantic) Ocean (Thomas, 1991) (Fig.1). It extends from central Kentucky, across West

Virginia, into Pennsylvania and New York. In Kentucky the Rome Trough is bounded on the north by the Kentucky River Fault System, on the west by the Lexington Fault System, and on the south by the Rockcastle Fault System (Figure 8). Movement on these faults was most active during the Early to Middle Cambrian, as evidenced by a greatly thickened section of sedimentary rocks within the Trough. The IPCFS is the major boundary fault of the rift, with much greater displacement that the Kentucky River Fault System to the north. It forms a second down to the south step into the deepest part of the trough. The surface expression of the IPCFS ends at the Paint Creek Uplift in Johnson County. Recent seismic data and drilling in Elliott County have revealed a subsurface fault that connects the eastern end of the IPCFS with the Kentucky River Fault System to the north. This normal fault, the Isonville Fault, trends north-south and is downthrown to the east (Lynch and others, 1999). It is the trapping fault for the Homer gas field, producing from the Rome Formation in Elliott County.

On the surface, the IPCFS cuts rocks from Upper Ordovician to Pennsylvanian. In the field trip area, the IPCFS primarily occurs in Mississippian and Pennsylvanian rocks. Stop 1 is an excellent exposure of the IPCFS, with Pennsylvanian downthrown against Mississippian rocks. The Glencairn Fault of the IPCFS has a throw of about 60 feet here, as mapped by Weir (1974). In the subsurface, the IPCFS has a total displacement of 100-150 feet at the Devonian Ohio Shale level and 200-250 feet at the Ordovician Knox Group. Relief across the fault system at Precambrian basement level is 4,000 to 6,000 feet as mapped by Drahovzal and Noger (1995). This large displacement occurred during the Cambrian, during extension of the Rome Trough. The much smaller displacements in the younger units indicate that most of the early Paleozoic movement was filled by syntectonic sedimentation in the Rome Trough, and that reactivation was relatively minor.

The IPCFS has been reactivated numerous times since the Cambrian, and it has affected the deposition and preservation of many Paleozoic units. Dever (1999) provides a good summary of the stratigraphic effects of the fault on Ordovician through Pennsylvanian formations in eastern Kentucky.

Economic Significance of Irvine-Paint Creek Fault System

The IPCFS has influenced the distribution of hydrocarbons and coal in eastern Kentucky. The IPCFS is unrelated to the giant Big Sinking Oil Field, south of the fault, in Lee and surrounding counties. Big Sinking is primarily a stratigraphic trap, producing from the Silurian Lockport Dolomite and Big Six Sandstone. Other smaller hydrocarbon accumulations are related to the IPCFS, and a good example is the Furnace Field in Estill and Powell Counties. This field produced gas from the Ordovician St. Peter Sandstone (McGuire and Howell, 1963; Humphreys and Watson, 1997). The field lies on the southern, upthrown side of a graben within the IPCFS. It contained low-BTU gas that was not of commercial quality, but was used for injection into the Big Sinking reservoir to maintain pressure. Newly discovered gas production in the Cambrian rocks of the Rome Trough has resulted in new deep drilling along the IPCFS and related faults in the last 5 years (Harris and Baranoski, 1996; Lynch and others, 1999). No new deep gas discoveries directly related to the IPCFS have been made to date.

The distribution and thickness of Pennsylvanian coal beds and sandstones were also influenced by the IPCFS. Coals thin and pinch-out north of the fault, indicating recurrent movement and relief across the fault during the Pennsylvanian (Horne, 1979; Dever, 1999).

The IPCFS lacks significant hydrothermal mineralization like other central Kentucky faults of a similar age and origin (Lexington and Kentucky River Fault systems) (Anderson and others, 1982, Plate 1). The lack of mineralization at the surface along the IPCFS is likely due to the more argillaceous Upper Ordovician carbonates and younger clastic rocks present along the faults. These were apparently not as conducive to hosting mineralization as the cleaner Middle Ordovician carbonates (Lexington Limestone and High Bridge Group) (W.A. Anderson, personal comm., 2001).

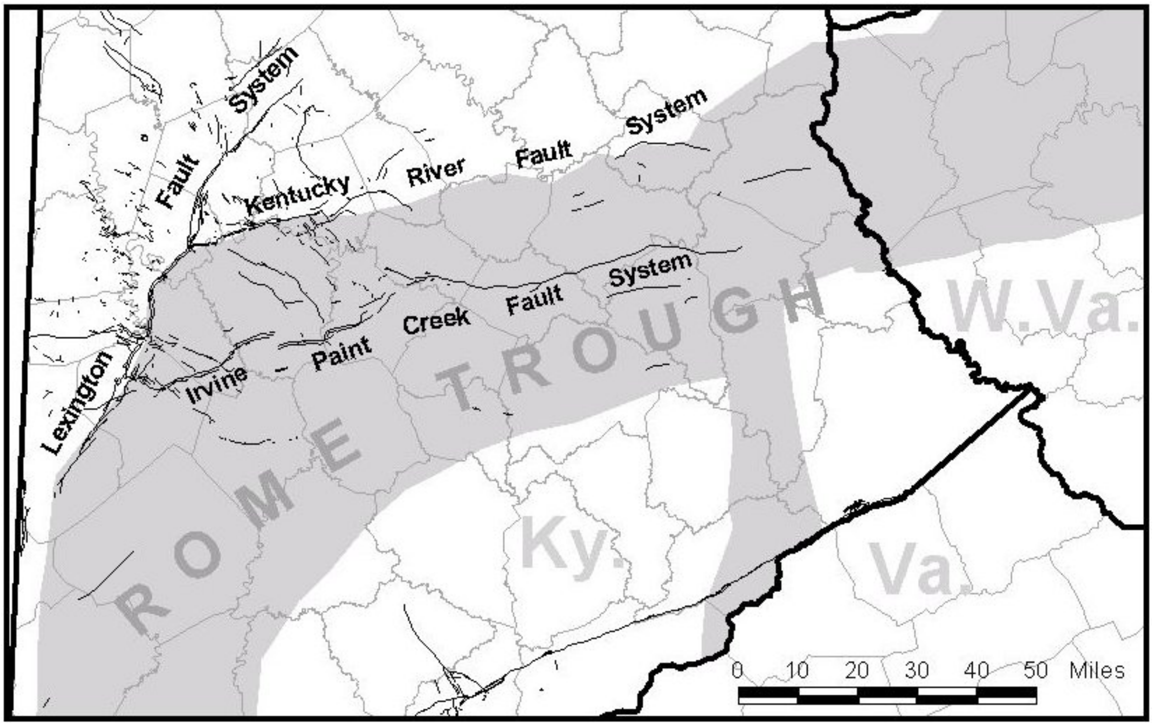


Figure 8. Mapped surface location of the Irvine–Paint Creek Fault System in eastern Kentucky. The fault is a secondary bounding fault within the Rome Trough rift, and is downthrown to the south–southeast.

Brief Overview of the Red River Iron District

William M. Andrews Jr.
Kentucky Geological Survey

The Red River Iron District flourished from the late 18th century until the late 19th century in the area between the Red River and Kentucky River in Powell and Estill Counties. The industry located in this area because of the abundance of the three main natural resources needed to make iron. At least two different iron ores were available in the region: siderite nodules and layers from the Borden Formation along valley margins, and limonite from atop the St. Louis Limestone on ridgetops. The limestone itself was mined to serve as a "flux" in the furnaces, while the abundant timber resources provided fuel for the iron-making process. Coal was available nearby, but attempts to use it with the furnace technology in the area were not successful.

Making Iron

Although a few dozen stone chimneys are all that remain of the 100 or more iron furnace complexes in Kentucky, the original furnace communities were large centers of activity, often employing hundreds of people. Operation of the furnaces was very complex, and involved a myriad of tasks to successfully produce iron. Because transportation was one of the largest expenses, the ore, limestone, and fuel were typically produced in the area surrounding the furnace. The local timber was cut down, and converted into charcoal, then hauled to the furnace. Limestone and iron ore were also produced nearby, usually by surface mining, and hauled to the furnace stockpile.

The furnace chimney was usually situated adjacent to a nearby hillside, so that ore and charcoal could be loaded in from the top by way of a ramp or platform from the hillside. Before going into blast, a wood fire was built inside the chimney to dry it out. A clay plug was used to block the drainage way form the bottom of the furnace so that molten iron would not escape too early. The charcoal, iron ore, and limestone were then added to the furnace in layers until it was full. Then the charcoal would be ignited, and a blast engine would begin forcing air through the chimney from below. The roar of a furnace in full blast could be heard for miles, and the glow lit up the country skyline for miles around. As the charcoal and ore were consumed, the ingredients were periodically added to keep the furnace in blast 24 hours a day.

As the temperature increased in the furnace, the iron would separate from the raw ore, and the impurities would float on top of the molten iron. As the level of the molten material rose in the furnace, the slag containing all the impurities could be released in small batches and discarded. Once enough molten iron had accumulated, the plug was swiftly removed, allowed the iron to stream out into pre-molded channels in the casting shed below the furnace. As a long channel filled up, the flow would be diverted into small, short bays to the side. The result resembled a sow with feeding piglets and thus the short bars came to be known as “pig iron.” In some cases, the raw cast iron was worked at forges adjacent to the furnace, and other times shipped to markets to be made into other products.

Red River Iron District

Iron production in the Red River area began in the Clay City area in 1787 with primitive forges separating iron from the local siderite, and sending it via flatboats and wagons to Lexington and points west. The completion of the Red River Furnace at Clay City in 1807 began the large-scale production of iron in the area. This furnace was torn down in 1830, and reconstructed on the ridge between Stanton and Irvine as the Estill Furnace in 1832. The Estill Furnace was rebuilt in 1849, and continued operation until 1888. The Cottage Furnace was built on the ridge near the Estill Furnace in 1854, and closed in 1879.

The last furnace built in the region was the Fitchburg Furnace, which went into blast in 1870. The Fitchburg Furnace, a double-chimney structure, was the largest built in Kentucky. It was equipped with the latest technology available at the time. Large capital investments were put into the furnace, related buildings, and transportation infrastructure. The high capacity of the furnaces, however, led to rapid depletion of the ores and timber resources of the vicinity, and high transportation costs shut the Fitchburg complex down in 1874 after only a few years of production.

Figure 9. Name plate at the Fitchburg Furnace.

BIG ANDY OIL POOL, BRETAGNE G.P.

Dan Wells, Consulting Geologist

Pool Data:

Location:	Lee and Wolfe Counties, KY, N-71 & O-71
Discovery year:	1961
Reservoir:	Keefer Sandstone
Number of productive wells:	622
Cumulative production:	~2,300,000 BO (1/1/2001)

Ravenna Oil Company
#5P Naomi Martin Heirs
3-N-71

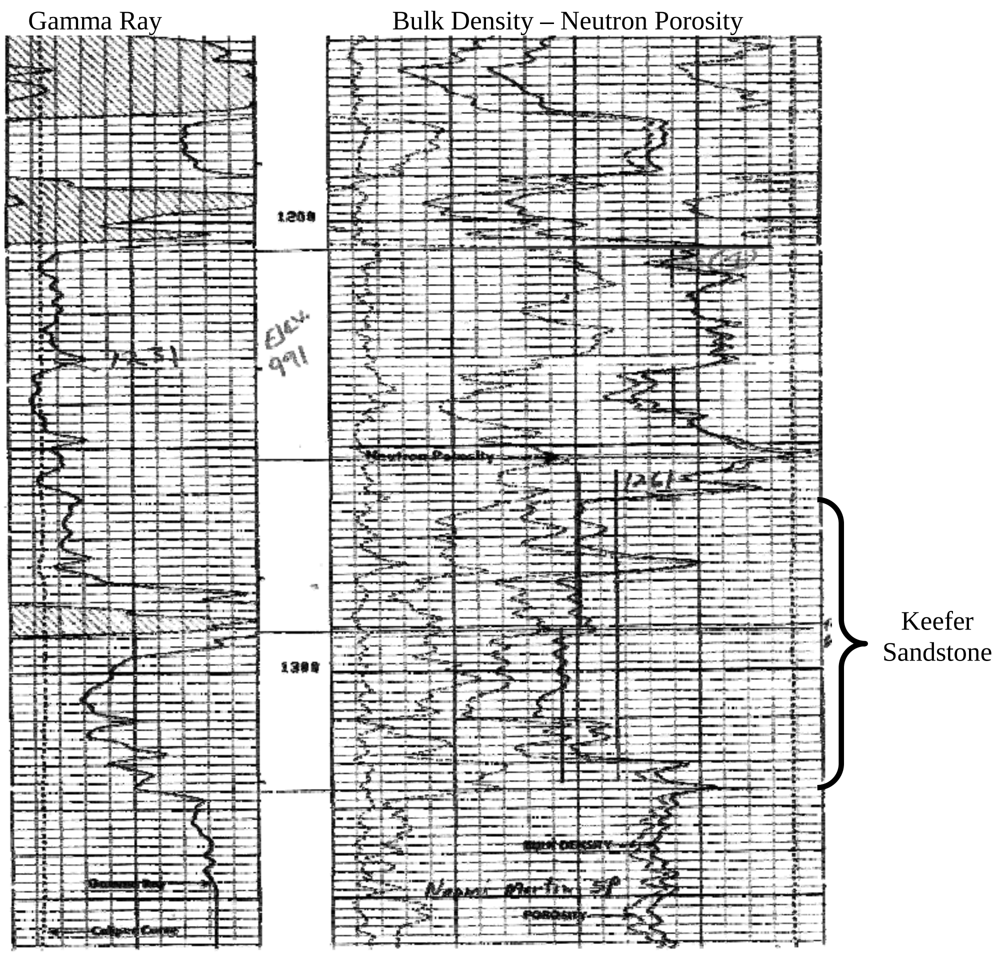


Figure 10. Type electric log of the Keefer Sandstone section in Big Andy Ridge.

Discussion

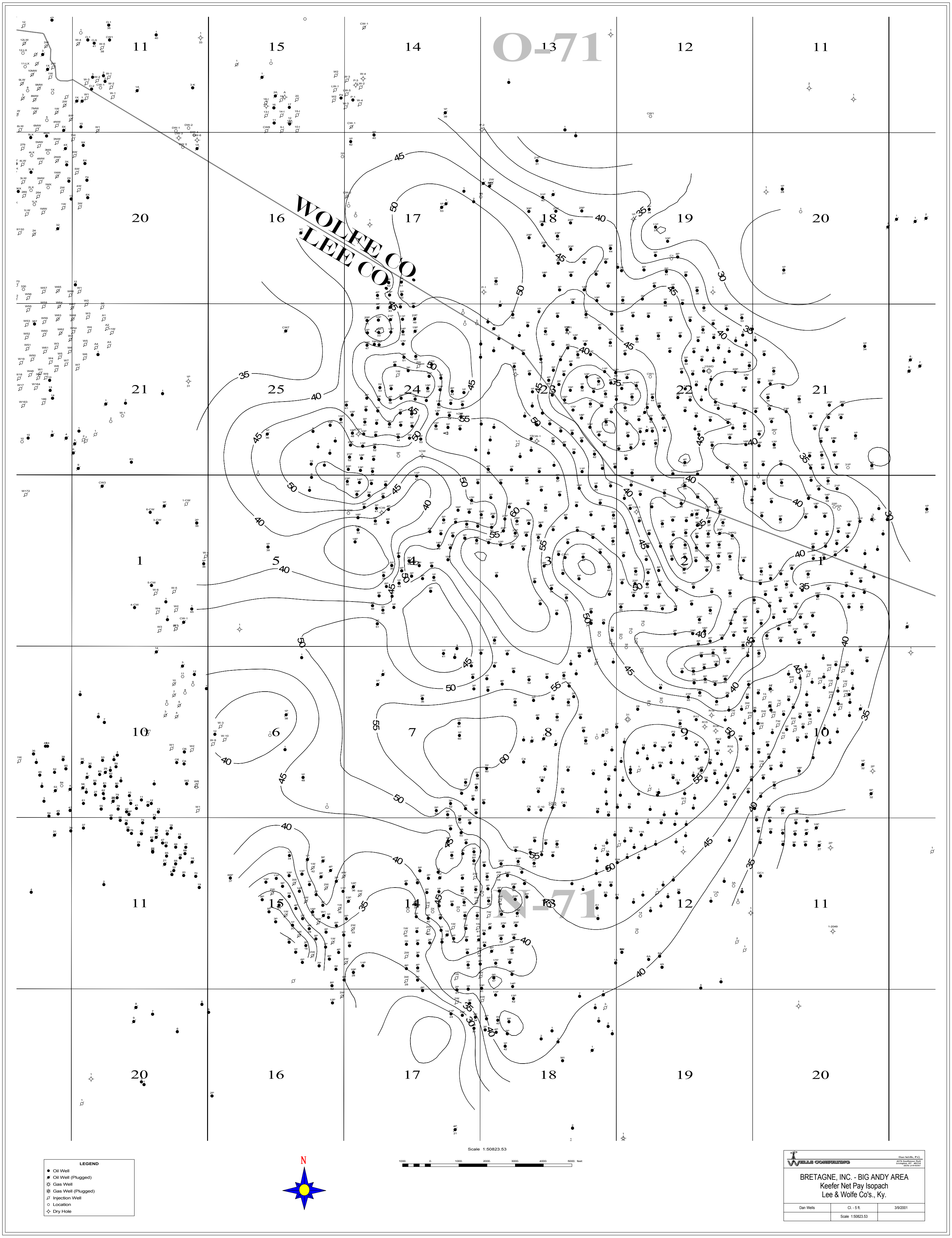
The Keefer Sandstone reservoir is composed of very fine to fine grained, well sorted, subangular quartz grains in a dolomitic cement. It also contains abundant pyrite or altered pyrite (?). Clay content is unknown. The sandstone generally exhibits a coarsening upward sequence and is more friable in the upper portions of the sand body. The high gamma ray measurements within the Keefer are not associated with increased shale content. It is postulated the high gamma ray is related to radioactive elements left behind after fluid movement through the sand body during diagenesis. Porosity in the Keefer Sandstone averages about 16% with little variation. However, permeability shows wide variation both vertically and laterally with values ranging <1 md to >100 md.

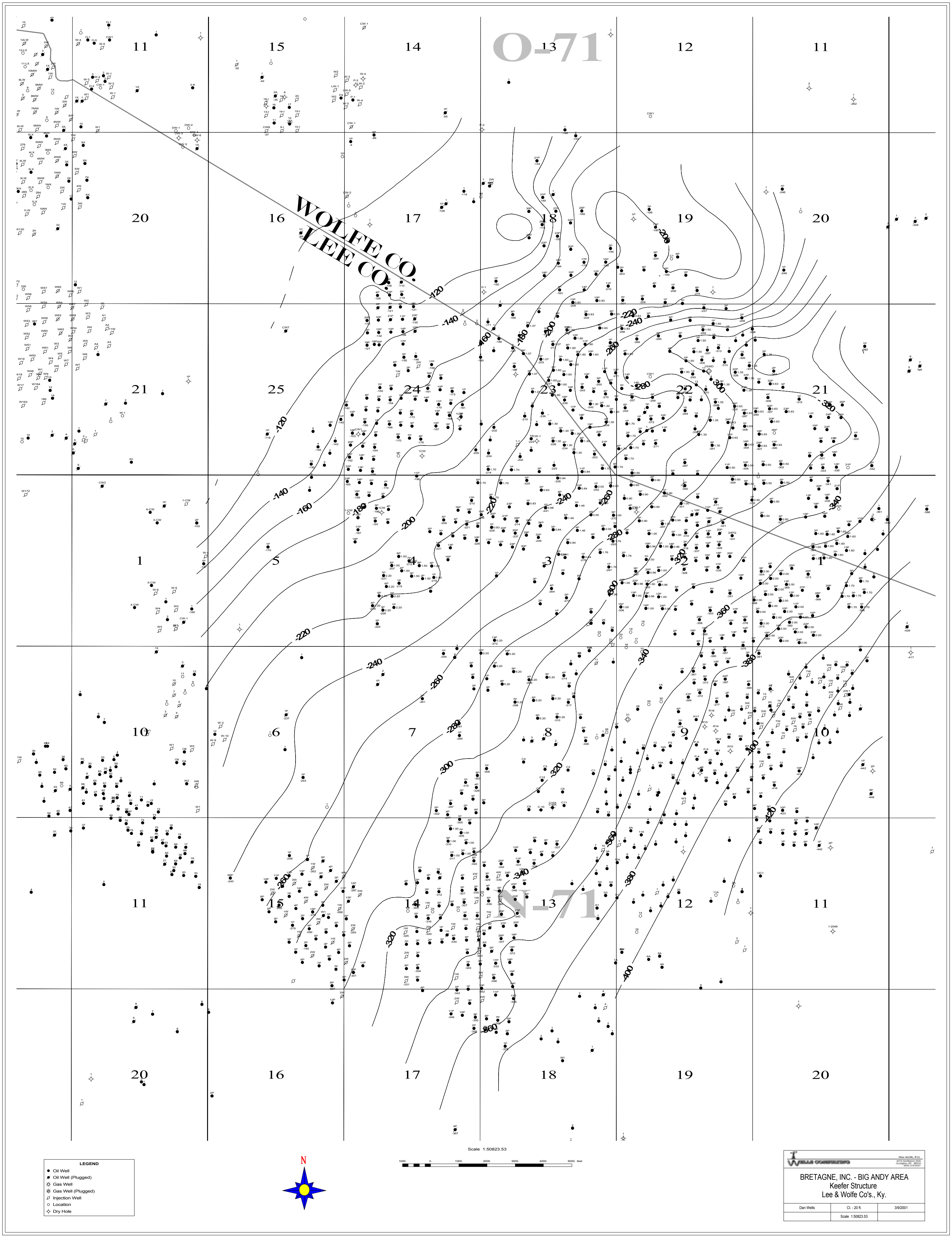
Trapping in the Big Andy pool appears to be stratigraphic, controlled by vertical and lateral variations in permeability. Structure on top of the Keefer Sandstone mostly shows only regional dip to the southeast except for an east-west trending structural trough in the northern portion of the pool. This trough is related to some minor faulting associated with the deeper basement faults of the Johnson Creek fault system. There is also a fairly well developed natural fracture system trending northeast-southwest in the Big Andy area. This natural fracture system has provided ideal reservoir conditions for the nitrogen injection secondary recovery project currently being implemented by Bretagne.

Gross thickness of the Keefer Sandstone shows little variation within the pool ranging from 65 to 75 feet. The Keefer thins to the west toward the Silurian pinchout. A net pay isopach of the Keefer Sandstone illustrates trends of bulk density values less than 2.55 gm/cc. The dominant trend of thickening and thinning illustrated by this isopach is NNW-SSE. However, there is also some east-west component in the isopach. The bulk density values are probably controlled by diagenetic alteration of the sandstone after deposition. It is interesting that the dominant trend in the net pay isopach is approximately perpendicular to the present day natural fracture trend in the pool.

Bretagne is currently injecting nitrogen in the Big Andy reservoir in a cyclic process to enhance oil production. The nitrogen injection process has increased production significantly and Bretagne has patented the technique with the U.S. Patent office. Bernie Miller (Bretagne G.P.) and Robert Gaudin (Nitrogen Oil Recovery Systems) have written and article describing the process in detail. The article, published in the September, 2000 Petroleum Technology supplement of World Oil Magazine is available online at:

http://www.worldoil.com/Magazine/MAGAZINE_DETAIL.asp?ART_ID=2396&MONTH_YEAR=Sep-2000


O-71
N-71
WOLFE CO.
LEE CO.
Scale 1:50823.53
1000 0 1000 2000 3000 4000 5000 feet
N
LEGEND
Oil Well
Oil Well (Plugged)
Gas Well
Gas Well (Plugged)
Injection Well
Location
Dry Hole
WELLS CONSULTING
Dan Wells, P.G.
4276 Southmoor Park
Lexington, KY 40514
(859) 219-9597
BRETAGNE, INC. - BIG ANDY AREA
Keefer Net Pay Isopach
Lee & Wolfe Co's., Ky.
Dan Wells
Cl. - 5 ft.
3/9/2001
Scale 1:50823.53



O-71
N-71
WOLFE CO.
LEE CO.
Scale 1:50823.53
N
LEGEND
Oil Well
Oil Well (Plugged)
Gas Well
Gas Well (Plugged)
Injection Well
Location
Dry Hole
WELLS CONSULTING
BRETAGNE, INC. - BIG ANDY AREA
Keefer Structure
Lee & Wolfe Co's., Ky.
Dan Wells
CI. - 20 ft.
3/9/2001
Scale 1:50823.53

Road Log

This road log includes global positioning system (GPS) waypoint data. These waypoints have an associated latitude and longitude location expressed as decimal degrees based on the WGS84 datum. Waypoint data incorporated in this road log was collected using a Garmin GPS 12Map receiver and downloaded to an ASCII text file using the Waypoint Plus software available (free) at http://www.tapr.org/~kh2z/Waypoint/. The text file of GPS route and waypoint data is printed as Appendix A.

Day 1. Natural Bridge State Park to Fitchburg Furnace

0.0 NATBRP 37.780437469 -83.6804259662 NATURAL BRIDGE STATE PARK
Begin mileage at intersection of Highway 11 and Natural Bridge State Resort Park entrance. Starting on the Slade 1:24,000-scale topographic or geologic quadrangle map. From park entrance, turn right (south) on Highway 11.

0.6 Park road to cottages and Natural Bridge Trail to right.

STOP 1. Irvine-Paint Creek Fault

1.9 IRVPCK 37.759644985 -83.6703569535 IRVINE-PAINT CREEK FAULT
Pull over just beyond the sign for the Cliffview Resort

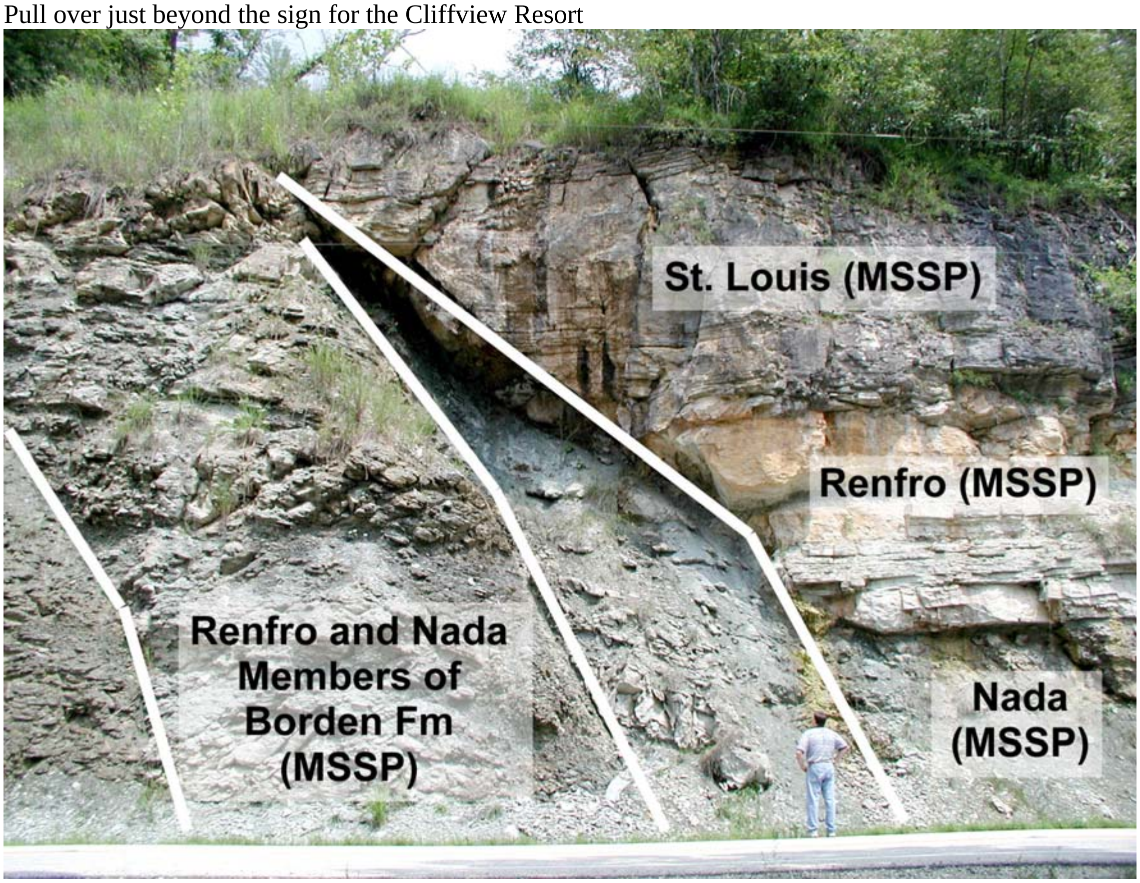


Figure 13. Exposure of Irvine Paint Creek Fault System on Highway 11, south of Natural Bridge State Park.

2.9 Enter Zachariah 1:24,000-scale topographic or geologic quadrangle map.

4.9 TORENT 37.715892792 -83.6629486922 TORRENT, KY

Torrent was the railhead for delivery of most supplies and equipment into the Big Sinking area. In addition, crude oil was picked up here for delivery to the refineries by rail.

6.5 Intersection with State Road 715 (to left), continue south on Highway 11.

6.8 ZACH-- 37.704949379 -83.6834139470 ZACHARIAH, KY
Intersection with State Road 1036 at Zachariah. Enter Lee County.

8.1 ZOE 37.680358887 -83.6840576772 ZOE, KY

10.4 ASHLND 37.662291527 -83.6940301303 HWY 11--ASHLAND CAMP LOOP
Turn right onto Ashland Camp Loop (old Highway 11)

10.6 INT01 37.664608955 -83.6927212123 ASHLND CAMP LOOP--CAVE FORK RD
Bear left onto gravel road past Aardvark Woodworking shop

STOP 2. Ashland water filtration plant

11.2 TINT05 37.667162418 -83.6977262143 WATER FILTRATION PLANT
Entrance to Ashland water filtration plant

Figure 14. Redwood water filtration and conditioning tanks.

Figure 15. Detail of tank showing string packing between planks.

CVFK01 37.667162418 -83.7011165265 OVERLOOK OF BATTERY 1

11.7 CVFK02 37.667441368 -83.7047160510 BATTERY 2
Ashland oil storage tank battery

12.0 Bear left, down hill, and continue along Caves Fork Creek

12.1 Abandoned pump jack (disconnected from electric service)

CVFK03 37.666819096 -83.7074733619 CENTRAL POWER HOUSE

Central powerhouse (not visited), probably still has engine and flywheels.

STOP 3. Eastern Gulf Oil property

12.6 CVFK05 37.661261559 -83.7177301291 EASTERN GULF SHOP BUILDING
These buildings are in the vicinity of the confluence of Caves Fork Creek and Hog Gap Hollow, the site of the Ephriam Angel lease. The Eastern Gulf Oil no. 1 Eph. Angel, completed February 21, 1918, was the discovery well of the Big Sinking oil field. The well was drilled to a total depth of 897 feet and completed in the 1st pay of the Corniferous (Silurian Lockport dolomite).

Figure 16. One of the oldest existing buildings on the former Eastern Gulf Oil Company properties.

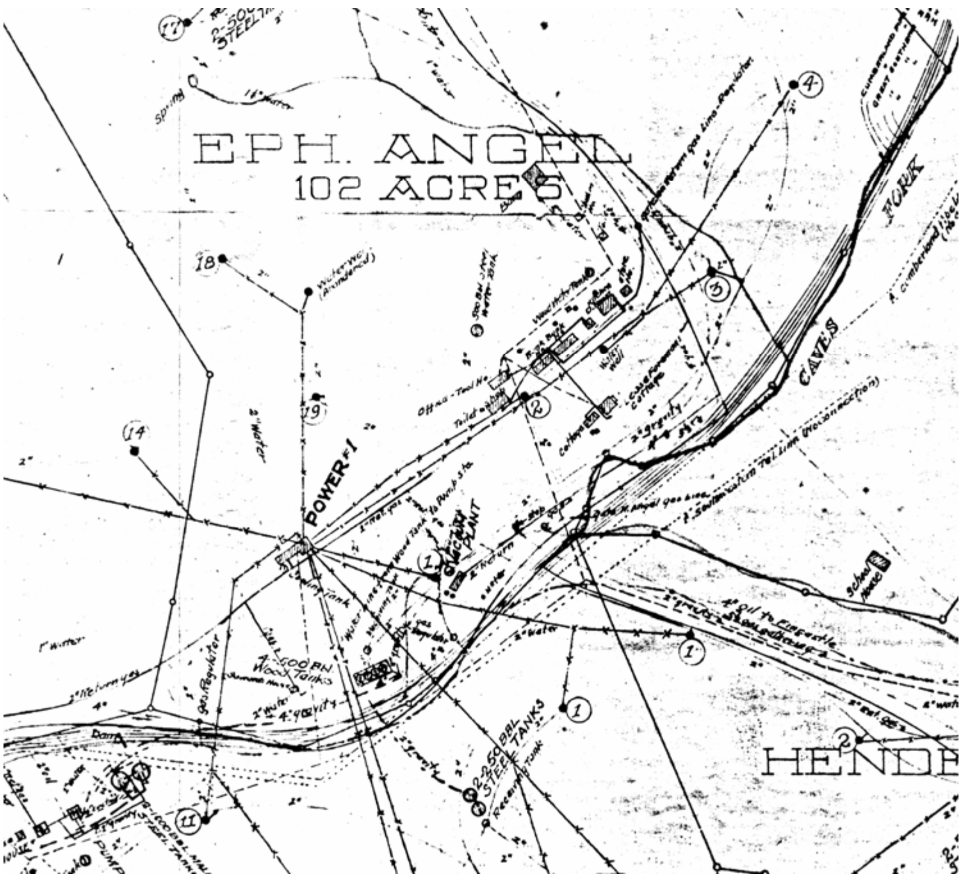


Figure 17. Discovery well of Big Sinking. The Eastern Gulf Oil Company no. 1 Ephriam Angel is held to be the discovery well of the Big Sinking oil field. This is part of the map of the Eastern Gulf Oil properties along Caves Fork drawn in 1923.

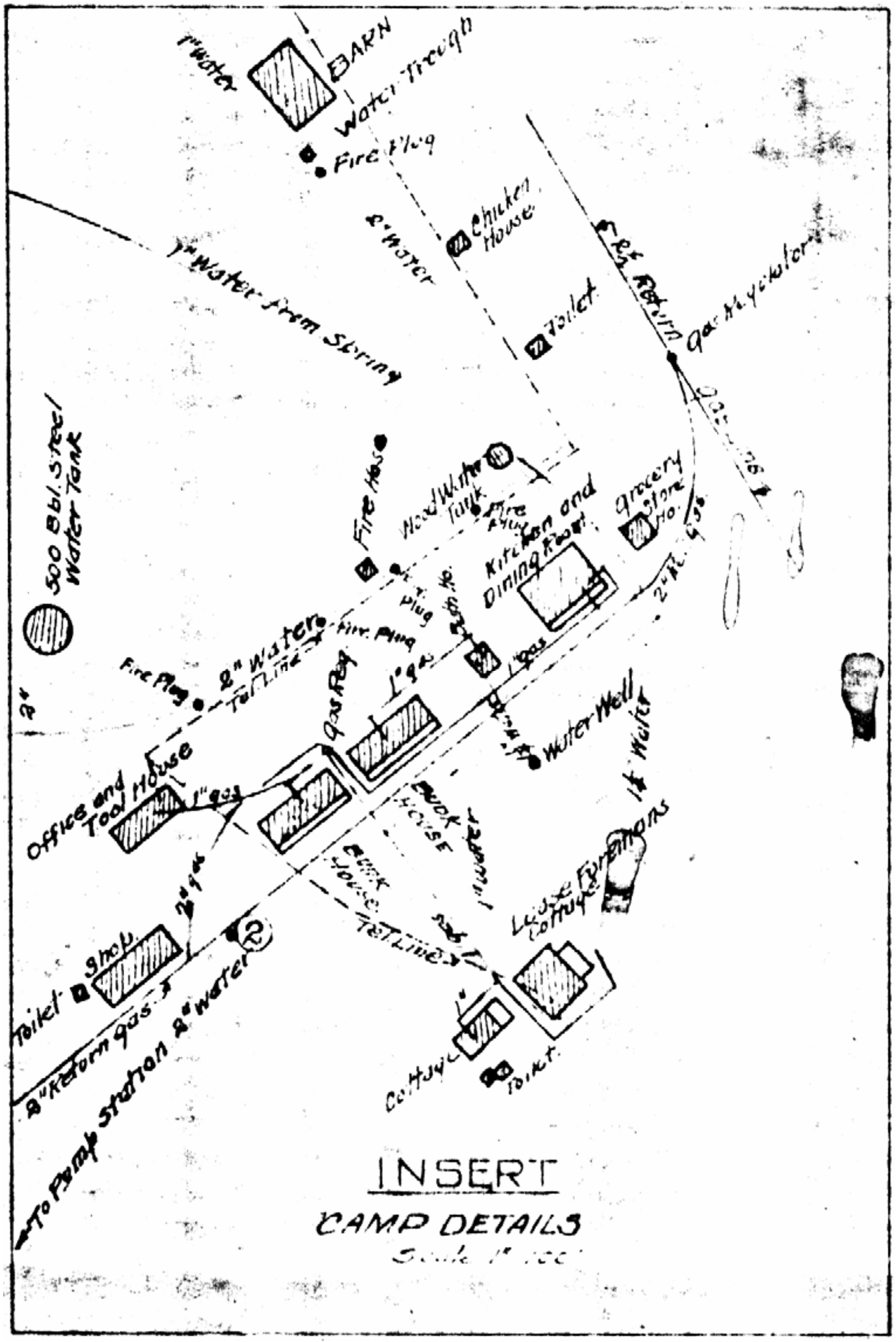
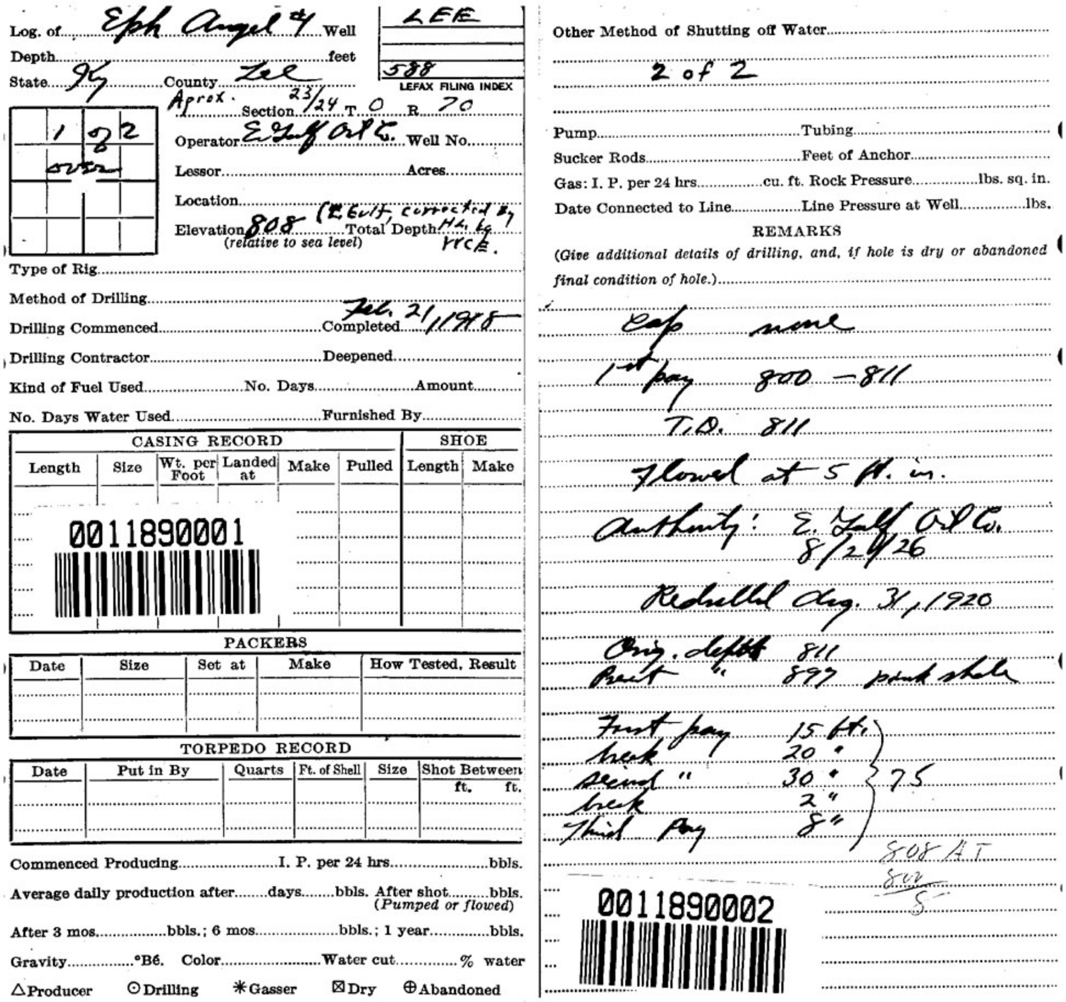


Figure 18. Eastern Gulf Oil Camp on Caves Fork. This detail of the camp on shows the location of everything from the foreman's cottage to out houses and chicken coops. The location of the camp is shown in Figure 17.



Log. of Eph Angel 4 Well | LEE
Depth feet | 588
State Ky County Lee | LEFAX FILING INDEX
Aprox. Section 23/24 T. O R. 70

1 8 2
over

Operator E Gulf Oil Co. Well No.
Lessor Acres
Location
Elevation 808 (E Gulf, corrected by WCE) Total Depth
(relative to sea level)
Type of Rig
Method of Drilling
Drilling Commenced Completed Feb. 21, 1918
Drilling Contractor Deepened
Kind of Fuel Used No. Days Amount
No. Days Water Used Furnished By

CASING RECORD / SHOE

Length	Size	Wt. per Foot	Landed at	Make	Pulled	Length	Make

0011890001

PACKERS

Date	Size	Set at	Make	How Tested, Result

TORPEDO RECORD

Date	Put in By	Quarts	Ft. of Shell	Size	Shot Between ft. ft.

Commenced Producing I. P. per 24 hrs bbls.
Average daily production after days bbls. After shot bbls. (Pumped or flowed)
After 3 mos. bbls.; 6 mos. bbls.; 1 year bbls.
Gravity °Bé. Color Water cut % water
△Producer ⊙Drilling ✳Gasser ⊠Dry ⊕Abandoned

Other Method of Shutting off Water
2 of 2
Pump Tubing
Sucker Rods Feet of Anchor
Gas: I. P. per 24 hrs cu. ft. Rock Pressure lbs. sq. in.
Date Connected to Line Line Pressure at Well lbs.

REMARKS

(Give additional details of drilling, and, if hole is dry or abandoned final condition of hole.)

Cap none
1st pay 800 – 811
T.D. 811
Flowed at 5 ft. in.
authority: E. Gulf Oil Co. 8/24/26
Redrilled Aug. 31, 1920
Orig. depth 811
Rest " 897 pink shale
First pay 15 ft.
break 20 "
Second " 30 " 75
break 2 "
Third Pay 8 "
808 AT
808
5

0011890002

Figure 19. Scout ticket compiled by W.C. Eyl from information supplied by Eastern Gulf Oil describing the drilling and completion of the No. 1 Eph Angel.

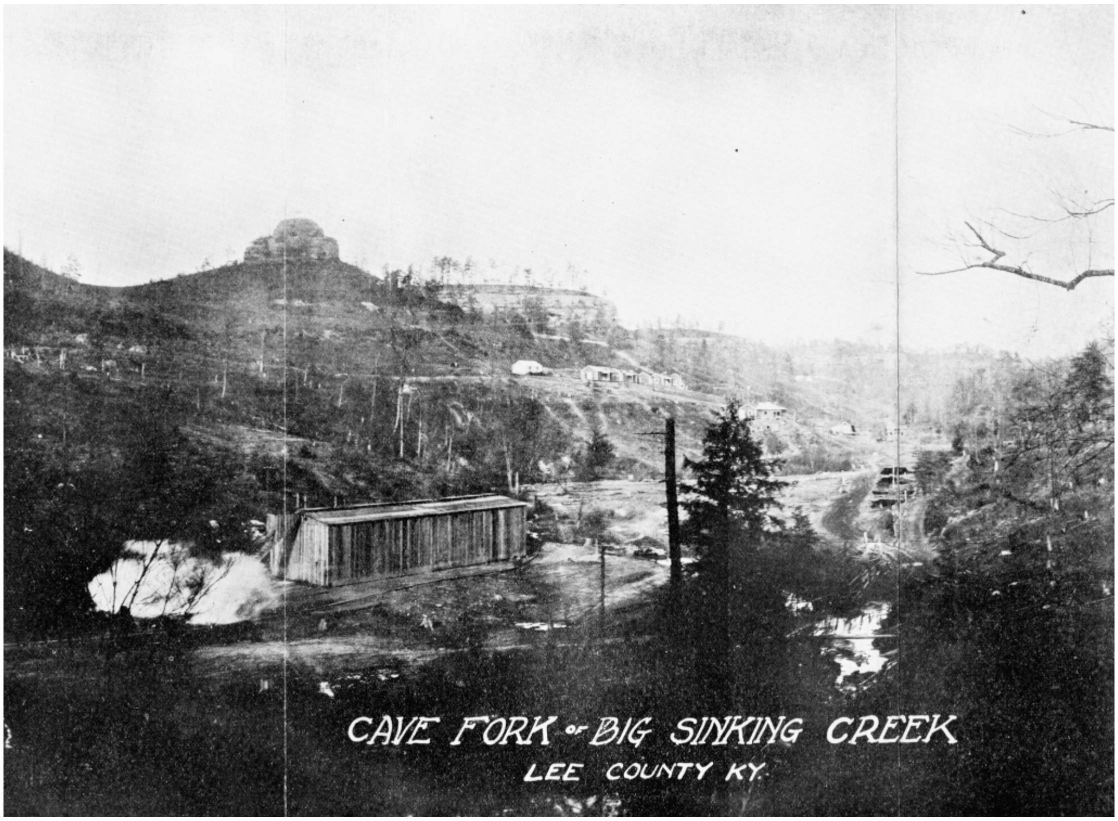


Figure 20. Caves Fork of Big Sinking, circa 1920. This is a view northeastward along the valley of Caves Fork (our field trip route). It is part of a panorama taken before 1920 that appears in Jillson (KGS Series 5, Bulletin 1, 1920). Notice the area is nearly completely denuded of trees used to fire the steam boilers for drilling wells. Building below the bluff in the background are probably those shown on the Eastern Gulf map (Figure 17 and Figure 18)

Figure 21. Modern view eastward along Caves Fork Road of bluff from which 1920 photo was probably taken.

12.7 Exercise caution when fording creek. (This one should have water only in wet weather.) Note the oil gathering lines in the creek.

12.8 Continue right at fork in road

13.3 Exercise caution when fording creek.

13.4 FIXRD 37.658064365 -83.7295425776 FORD AT FIXER RD
Exercise caution when fording Big Sinking Creek. Turn right onto Fixer Road.

STOP 4. Bretagne water filtration plant

13.9 BRGN01 37.663557529 -83.7326700334 BRETAGNE WOODEN TANK

Figure 22. Water filtration plant on lease owned by Bretagne. Note end of Jones Ridge to east. Five wells have been drilled on the 3 acres at the end of the ridge and are accessible only by a wooden bridge. There are 4 producers and one injection wells on the lease.

14.1 Bear right at fork

14.2 Bear right at fork

14.9 FIXER2 37.673749924 -83.7238402013 CUMBERLAND GAS PLANT OVERLOOK
Near this site Cumberland Gas Plant manufactured napalm during World War I. An explosion in the engine room in 1931 killed two men and destroyed the plant.

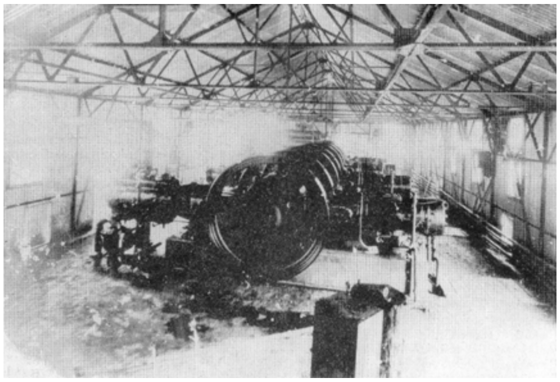


Figure 23. Engine room at the Cumberland Gas Plant ca 1930. Photo courtesy of Bob Smith, Three Forks Tradition, Beattyville.

Figure 24. The Cumberland Gas Plant ca 1920. Engine room is to right. Photo courtesy of Bob Smith, Three Forks Tradition, Beattyville.

15.0 Just beyond the bridge to the left, the vertical rod marks an abandoned well head. The power has been disconnected and the pump jack removed.

STOP 5. Fixer, Kentucky

15.3 FIXER3 37.677483559 -83.7190122250 FIXER PO

Figure 25. The town of Fixer was a bustling center of oil field activity around the time of the discovery of Big Sinking. The abandoned store is on the site of the old Fixer Post Office. From here back to the main highway, wells are present in almost every direction every 400 feet. The photo to left was taken circa 1918 (photo courtesy Bob Smith, Three Forks Tradition, Beattyville). In contrast, this abandoned building is on the site of the post office.

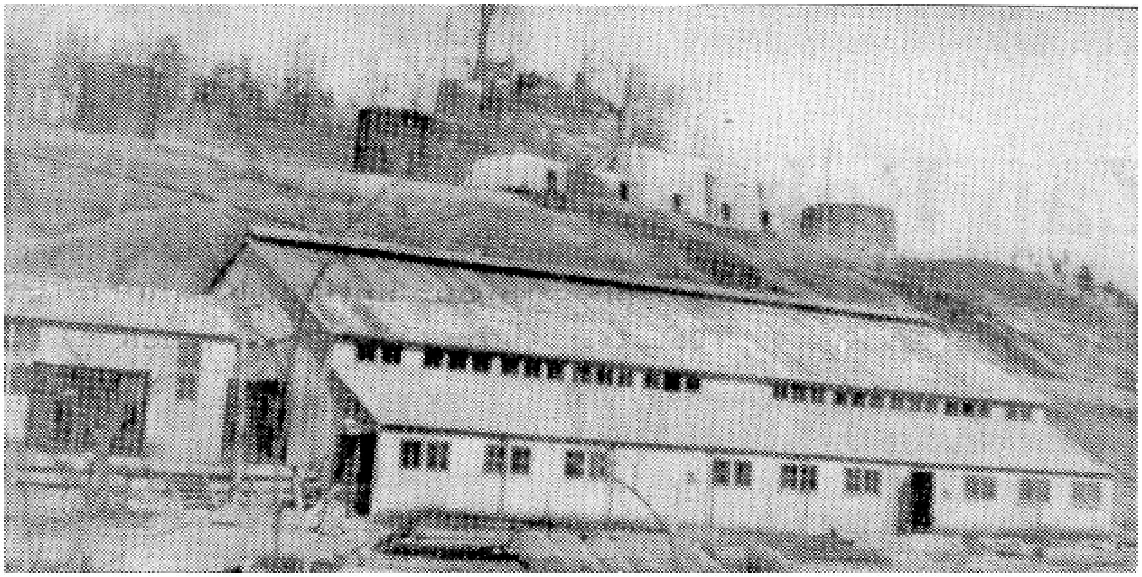


Figure 26. The Swiss Oil Plant at Fixer in 1920. Swiss Oil reorganized and became Ashland Refining in 1924. Photo courtesy of Bob Smith, Three Forks Tradition, Beattyville.

17.9	Turn right at T intersection onto old Highway 11 loop.			
18.1	FIXER5	37.687096596	-83.6844117288	FIXER RD--HWY 11
	Turn right south onto Highway 11			
22.4	HWY498	37.638752460	-83.6972916964	HWY 498 WEST
	Junction with State Road 498, turn right onto 498.			
	SR498-	37.636220455	-83.7161476258	STATE ROAD 498
24.9	HWY52D	37.627422810	-83.7297625188	STATE ROAD 498--HWY 52
	Junction with Highway 52, turn right onto 52.			
	SR399-	37.623109818	-83.7676996831	STATE ROAD 399
29.2	Bridge over Big Sinking Creek. Note the U.S. Geological Survey stream gauging station on left. Data for this station are online at the USGS web site (www.usgs.gov, site number 03282075)			
	HWY52A	37.651412487	-83.8010717276	
32.3	Enter Estill County			
33.4	Bucyrus Erie service rig to right and truck mounted rig on left, parked in field.			
34.7	SR1571	37.669823170	-83.8578111771	STATE ROAD 1571
35.5	SR1398	37.666625977	-83.8696289901	SR1571--SR1398

STOP 6. Tank farm at Texola

36.7	TEXOLA	37.654223442	-83.8721663598	TANK FARM ON KY R

(This stop is optional depending on time constraints and possible insurance problems.)

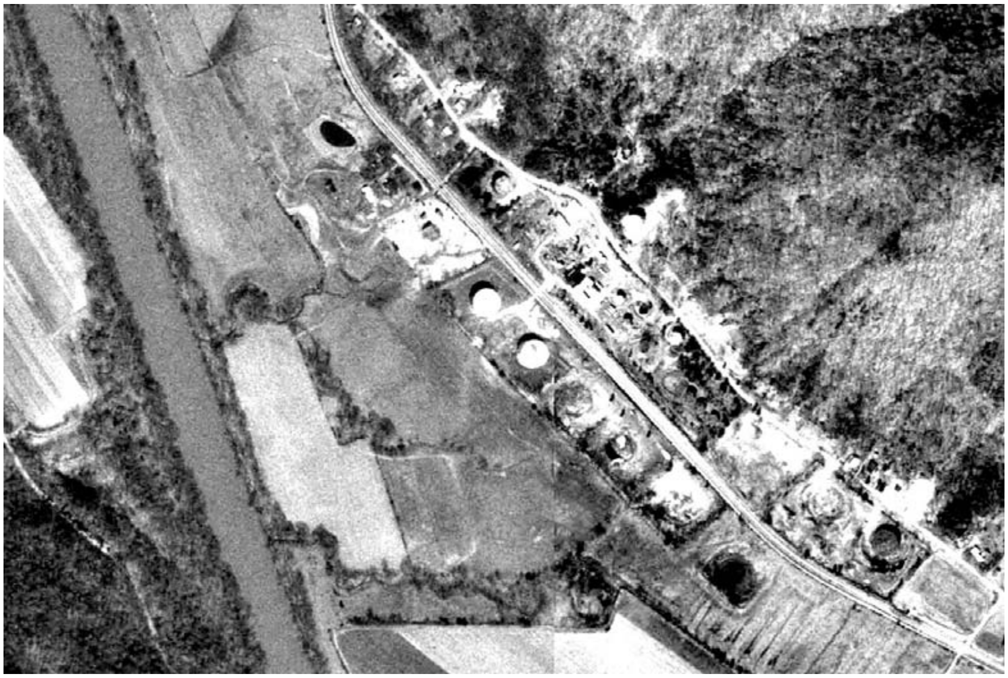


Figure 27. The tank farm at Texola where thousands of barrels of oil a day were shipped by rail and barge. Image extracted from digital orthophoto quarter quadrangles (DOQQ) available on the Web.

37.8 Right onto State Road 1571

38.6	SR1571	37.669823170	-83.8578111771	STATE ROAD 1571

Left onto Highway 52

40.1	SR975	37.688598633	-83.8584710006	HWY 52--SR 975

Historic marker. Turn right (north) onto 975. At bottom of hill, continue left on 975 at intersection with state road 1182.

FITCHBURG FURNACE (LUNCH)

43.4	FTCHFR	37.732994556	-83.8522911910	FITCHBURG FURNACE

Turn left into parking lot for furnace historic site. Designated parking to right along north boundary of site.

Figure 28. The furnace at Fitchburg.

Day 1. Fitchburg Furnace to Natural Bridge State Park

	FTCHFR	37.732994556	-83.8522911910	FITCHBURG FURNACE

Turn right (south) and return to Highway 52.

46.8	SR975	37.688598633	-83.8584710006	HWY 52--SR 975

Turn right (west) on Highway 52.

52.5	TICKY	37.702696323	-83.9222861174	TICKY FK RD

Turn right (north) onto Tickey Fork Connector road.

52.6 Turn right at T intersection onto Tickey Fork Road

STOP 7. Vacuum and power shed

54.0	NILHAS	37.722716331	-83.9158219937	VACUUM SHED

This is the private property. Al Nilhas has consented to allow us to visit his vacuum and central power shed. Remember that space in the shed is very limited; it was not designed for visitors.

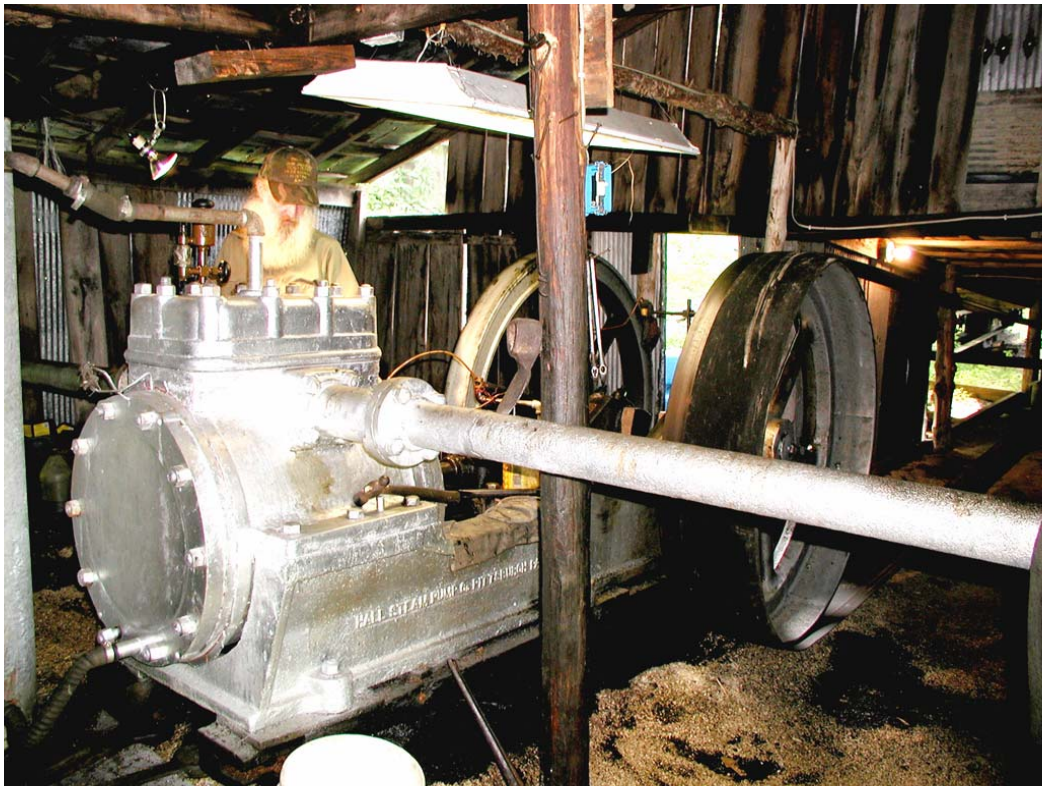


Figure 29. Vacuum pump. Above, one-cylinder vacuum pump operated by Al Nilhas. The unit is belt driven (drive belt on flywheel to right) with a 10-horsepower motor also used for pumping wells.

Figure 30. Gear box. Gearbox used to drive cable to pump producing wells. Belt on pulley to left is connected to drive shaft from the shed. The "pitman" on the right is used to convert rotational motion to the back and forth reciprocating motion required to pump wells.

Figure 31. Pitman assembly. Detail of pitman assembly showing hook (hanging on chain) at the end of the pump drive cable and the eyelets (on the pitman) used to "hook up" wells.

Figure 32. Swing post. A "swing post" (left) is used to turn corners on the cable-driven central power system. Cables are attached to the wooden arms that pivot about the vertical post. When everything is hooked to the cable system, 26 wells and the vacuum pump are all powered by the single 10-horsepower electric motor.

Figure 33. Turning corners. Another method of turning corners is to anchor the drive cable to a post with a short length of cable.

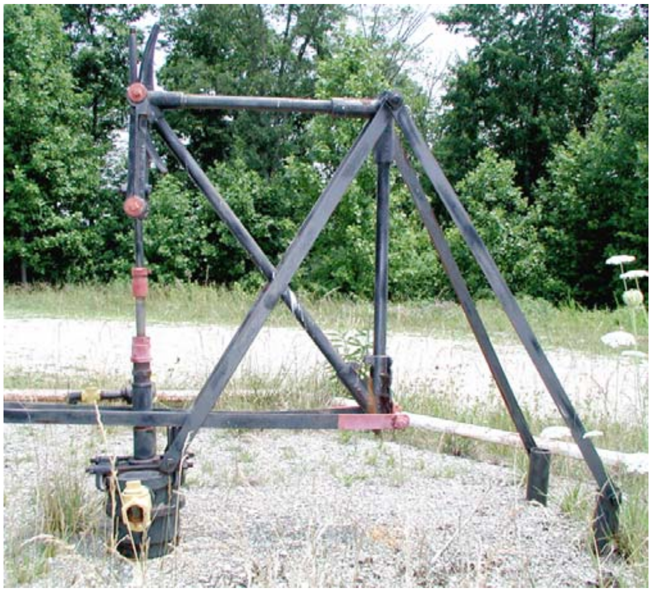


Figure 34. Jones Jack. A Jones jack was often used to lift the crude oil. A cable or rod line was attached to the base (red shackle) below the apex of the support tripod. As the cable pulled it, the arms pivoted at the apex, lifting the rods. Downhole, a ball valve assembly controlled the flow of oil.

55.4	TICKY	37.702696323	-83.9222861174	TICKY FORK ROAD (LEFT)
58.0	PITTS	37.710721493	-83.8844669703	LEFT ON 213 N
61.0	MARCUM	37.742693424	-83.8708628062	MARCUM
64.0	ESTLFR	37.762219906	-83.8319278602	ESTILL FURNACE

At the intersection, continue straight onto 1057 (High Rock Road).

64.1 At Y intersection, bear left (uphill) to continue on 1057.

64.2 Enter Powell County

64.6 Left at intersection (continue on main road)

67	PILOT	37.775287628	-83.7831384782	RT TO BIG SNKNG

Sharp right onto Rogers Church-Mountain Chapel (Pilot) Road

	HLHLRD	37.740097046	-83.7652588729	HALL HILL RD
	Left onto Hall Hill Road			
	HW1639	37.736835480	-83.7521535996	HWY 1639
73.4	SR1639	37.745547295	-83.7423742656	GO RIGHT UP HILL
	Turn right (uphill) onto Barker Branch Road			
74.7	NARROW	37.739582062	-83.7304759864	HEAD OF VALLEY
77.0	TINT03	37.716107368	-83.7217534427	LEFT AT T INTERSECTION
	Turn left at intersection onto state road 1036			

STOP 8. Sun Oil Yard

77.9	SUNOIL	37.716686726	-83.7085623387	SUN OIL YARD

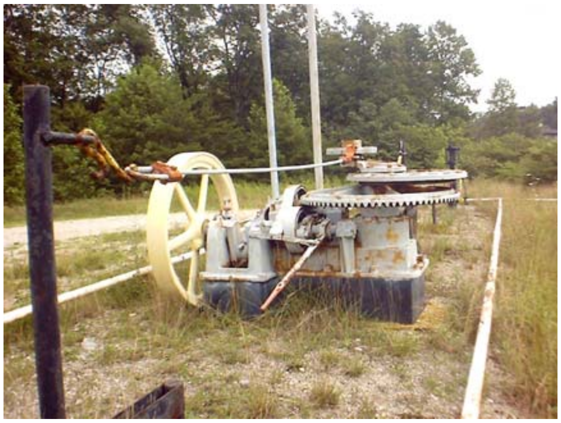


Figure 35. A Frick engine, a one cylinder, natural gas powered engine commonly used to provide power to pump multiple wells. The eccentric (the flat, toothed wheel to right) alternately pushed and pulled rod lines.

Figure 36. Detail of eccentric showing attachments for rod lines.

78.0 Standing Rock is located at the intersection of the Lee, Powell, and Wolfe County boundaries

78.1 Big Bend Road (goes to another "Narrows" with three arches in a row.)

78.9	PETEX	37.711064816	-83.6951727513	PETEX HEADQUARTERS

Figure 37. The field office of the Petroleum Exploration Company was home to Bill McCrosky in the 1930's and 40's. Later, the building was used by The Wiser Oil Company. Now, the building is owned by Bretagne and used as their field office in the area. The town of Leeco was originally a company town built by Petroleum Exploration.

80.0	ZACH--	37.704949379	-83.6834139470	ZACHARIAH, KY

Intersection with Highway 11. Turn left (north) to return to Natural Bridge SRP.

86.8	NATBRP	37.780437469	-83.6804259662	NATURAL BRIDGE STATE PARK

Day 2. Big Andy Ridge

0.0	NATBRP	37.780437469	-83.6804259662	NATURAL BRIDGE STATE PARK

Begin mileage at intersection of Highway 11 and Natural Bridge State Resort Park entrance. Starting on the Slade 1:24,000-scale topographic or geologic quadrangle map. From park entrance, turn right (south) on Highway 11.

	IRVPCK	37.759644985	-83.6703569535	IRVINE-PAINT CREEK FAULT
	TORENT	37.715892792	-83.6629486922	TORRENT, KY
5.6	SR715	37.706365585	-83.6760807876	HWY 11--STATE ROAD 715

Intersection of Highway 11 and state road 715. Turn left onto 715.

6.4 Entrance to Cliffview Resort

8.3	SR2016	37.728424072	-83.6471558455	BIG ANDY ROAD

Intersection with state road 2016, Big Andy Road. Turn right onto Big Andy Road.

11.5 BOOTH 37.696151733 -83.6327362899 BOOTH RIDGE ROAD
Intersection with Booth Ridge Road. Bear right and continue on 2016.

11.9 Note large concretion on display in yard to left.

13.0 Enter Lee County.

HOBBRD 37.668278217 -83.6272109393 HOBBS ROAD
(Additional tank batteries and active producing wells along Hobbs Road.)

14.9 Turn right at CO2 sign past kudzu patch to enter drive to Bretagne nitrogen plant.

15.0 Note pump jack on timer to right.

STOP 9. Bretagne Atmospheric Nitrogen Recovery Plant

15.1 BRNG02 37.662312984 -83.6349625234 NITROGEN PLANT
Atmospheric nitrogen recovery plant. Nitrogen is injected in cyclic phases to enhance oil production in the low-pressure reservoir. To return, turn left onto Big Andy Road and continue back to the intersection with Booth Ridge Road.

Figure 38. Bretagne atmospheric nitrogen recovery facility.

HOBBRD 37.668278217 -83.6272109393 HOBBS ROAD

18.3 BOOTH 37.696151733 -83.6327362899 BOOTH RIDGE ROAD
Intersection with Booth Ridge Road. Turn right onto Booth Ridge Road.

19.4 Bear left at Y and continue south on main road.

20.4 BRNG03 37.685852051 -83.6070299987 BRETAGNE TANKS
Bretagne tank battery. Note fiberglass separator tanks.

21.4 Bear right (uphill) on main road.

STOP 10. Bretagne Lease Power Generator

21.5	BRNG05	37.674758434	-83.5995198134	POWER GENERATOR

Turn left to Bretagne tank battery. Generator behind tank battery is using natural gas produced from the lease to generate electricity for operating the lease (power for pump jacks and others).

Figure 39. Generator and gas separator tank for power generation from produced natural gas.

Last stop on field trip, return to Natural Bridge State Park.

	BRNG03	37.685852051	-83.6070299987	BRETAGNE TANKS
24.7	BOOTH	37.696151733	-83.6327362899	BOOTH RIDGE ROAD

Intersection with Big Andy Road. Turn right (north) onto Big Andy Road (state road 2016).

27.8	SR2016	37.728424072	-83.6471558455	BIG ANDY ROAD

Intersection with state road 715. Turn left (south) on 715.

30.5	SR715	37.706365585	-83.6760807876	HWY 11--STATE ROAD 715

Intersection with Highway 11. Turn right (north) on 11.

	TORENT	37.715892792	-83.6629486922	TORRENT, KY
	IRVPCK	37.759644985	-83.6703569535	IRVINE-PAINT CREEK FAULT
36.1	NATBRP	37.780437469	-83.6804259662	NATURAL BRIDGE STATE PARK

End of field trip. Have a safe trip home.

References

Anderson, W.A., Trace, R.D., and McGrain, P., 1982, Barite deposits of Kentucky: Kentucky Geological Survey, Series XI, Bulletin 1, 56 p.

Dever, G.R., 1999, Tectonic Implications of Erosional and Depositional Features in Upper Meramecian and Lower Chesterian (Mississippian) Rocks of South-Central and East-Central Kentucky: Kentucky Geological Survey, Bulletin 5, Series XI, 67 p.

Drahovzal, J.A. and Noger, M.C., 1995, Preliminary Map of the Structure of the Precambrian Surface in Eastern Kentucky: Kentucky Geological Survey, Map and Chart Series 8, Series XI.

Fig, D.F., 1975, Fitchburg Furnace, self-published, 143 pp.

Harris, D.C., and Baranoski, M.T., 1996, Play Cpk: Cambrian Pre-Knox Group Play: *in* Roen, J.B. and Walker, B.J. (eds.), The Atlas of Major Appalachian Gas Plays, US Department of Energy, Washington, D.C., p. 188-192.

Horne, J.C., 1979, Sedimentary responses to contemporaneous tectonism: *in* Ferm, J.C., and Horne, J.C., (eds.), Carboniferous depositional environments in the Appalachian region: Columbia, University of South Carolina, Department of Geology, Carolina Coal Group, p. 259-265.

Jillson, W.R., 1919, Sketch of the development of the oil and gas industry in Kentucky during the past century (1819-1919), The mineral and forest resources of Kentucky: Department of Geology and Forestry, Frankfort, Ky, Series 5, vol. 1, no. 1, April, 1919, p. 3-28.

Jillson, W.R., 1921, A new method of producing crude oil in Kentucky, in Jillson, W.R., ed., The Sixth Geological Survey: Frankfort, KY, Kentucky Geological Survey, Series 6, Volume 6, p. 149-154.

Jillson, W.R., 1964, The Red River Iron Works. Frankfort, Ky: Roberts Printing Co., 30 pp.

Jillson, W.R., 1966, The geology of Estill County, Kentucky: Frankfort, Ky., Roberts Printing Co., 112 p.

Jones, D.J., chairman of the Kentucky Secondary Recovery Committee, 1952, Summary of Secondary Operations in Kentucky to 1951 Including Annual Kentucky Oil Production by Counties: Kentucky Geological Survey, Series 9, Reprint 5, 17 p.

Jones, D.J., and McFarlan, A.C., 1933, Geology of the Big Sinking Pool, Lee County, Kentucky: Kentucky Geological Survey, Series 7, Bulletin 1 (reprinted 1934), 18 p.

Lesley, J., 1861, Topographical and geological report of the country along the outcrop base line, following the western margin of the eastern coal field of the state of Kentucky through the counties of Carter, Rowan, Morgan, Bath, Montgomery, Powell, Estill, Owsley, Jackson, Rockcastle, Pulaski, Wayne, and Clinton, from a survey made during the years 1858-9, in Owen, D.D., ed., Fourth report of the Geological Survey in Kentucky, made during the years 1858 and 1859: Frankfort, Kentucky Geological Survey, Series 1, Volume 4, p. 438-494.

Lynch, R. W., D. M. Mumpower, and M. L. Hay, 1999, Rome-Trough structural geology and Cambrian stratigraphy of Elliott and Morgan Counties, Kentucky: 1999 GSA Northeastern Section Meeting Abstracts with Programs, v.31, n.2, p. A-31.

Moore, P.N., 1884, Report on the Iron Ores and Iron Manufacture of the Kentucky Red River Region. Frankfort, Ky.: Kentucky Geological Survey, Series 2, vol. C, p. 211-244.

Scott, O.J., 1968, The exception, the story of Ashland Oil and Refining Company: New York, McGraw-Hill, 450 p.

Thomas, W.A., 1991, The Appalachian-Ouachita rifter margin of southeastern North America: Geological Society of America Bulletin, v. 103, no. 3, p. 415-431.

Weir, G.W., 1974, Geologic Map of the Slade Quadrangle, East-Central Kentucky, U.S. Geological Survey, Geologic Quadrangle Map GQ-1183.

Appendix A. Route and waypoint information

These data were downloaded from a Garmin GPS 12Map global positioning system receiver using the Waypoint+ freeware available from http://www.tapr.org/~kh2z/Waypoint/. Some of the data included represent sites visited while planning the field trip but were not visited during the trip.

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Datum,WGS84,WGS84,0,0,0,0,0
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RP,D,TORENT, 37.715892792, -83.6629486922,12/31/1989,00:00:00,TORRENT KY
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RP,D,SR2016, 37.728424072, -83.6471558455,12/31/1989,00:00:00,BIG ANDY RD
RP,D,BOOTH , 37.696151733, -83.6327362899,12/31/1989,00:00:00,BOOTH RIDGE RD
RP,D,HOBBRD, 37.668278217, -83.6272109393,12/31/1989,00:00:00,HOBBS RD
RP,D,BRNG02, 37.662312984, -83.6349625234,12/31/1989,00:00:00,NITROGEN PLANT
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RP,D,SR2016, 37.728424072, -83.6471558455,12/31/1989,00:00:00,BIG ANDY RD
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RP,D,SR975 , 37.688598633, -83.8584710006,12/31/1989,00:00:00,HWY 52--SR 975
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RP,D,CVFK02, 37.667441368, -83.7047160510,12/31/1989,00:00:00,BATTERY 2
RP,D,CVFK03, 37.666819096, -83.7074733619,12/31/1989,00:00:00,CENTRAL POWER HOUSE
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RP,D,FIXRD , 37.658064365, -83.7295425776,12/31/1989,00:00:00,FORD AT FIXER RD
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RP,D,FIXER2, 37.673749924, -83.7238402013,12/31/1989,00:00:00,CMBD GAS PLANT OVERL
RP,D,FIXER3, 37.677483559, -83.7190122250,12/31/1989,00:00:00,FIXER PO
RP,D,FIXER5, 37.687096596, -83.6844117288,12/31/1989,00:00:00,FIXER RD--HWY 11
RP,D,HWY498, 37.638752460, -83.6972916964,12/31/1989,00:00:00,HWY 498 WEST
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WP,D,ASHLND, 37.662291527, -83.6940301303,12/31/1989,00:00:00,HWY 11--ASHLAND CAMP
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WP,D,BRNG04, 37.664608955, -83.5999006871,12/31/1989,00:00:00,BRETAGNE PUMP JACK
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WP,D,FIXER3, 37.677483559, -83.7190122250,12/31/1989,00:00:00,FIXER PO
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WP,D,HWY52B, 37.682869434, -83.9488936309,12/31/1989,00:00:00,H52-SR1571
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WP,D,PETEX , 37.711064816, -83.6951727513,12/31/1989,00:00:00,PETEX HEADQUARTERS
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WP,D,PITTS , 37.710721493, -83.8844669703,12/31/1989,00:00:00,LFT ON 213 N
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WP,D,RODS01, 37.683084011, -83.7043888215,12/31/1989,00:00:00,ABND WELL W RODS
WP,D,SEPRAT, 37.727286816, -83.9137405995,12/31/1989,00:00:00,WOODEN SEPARATOR
WP,D,SHLGLF, 37.709949017, -83.6893738154,12/31/1989,00:00:00,SHELL AND GULF PUMPS
WP,D,SNAKE1, 37.658257484, -83.7235237006,12/31/1989,00:00:00,COPPERHEAD ON ROCKS
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WP,D,SR1639, 37.745547295, -83.7423742656,12/31/1989,00:00:00,GO RIGHT UP HILL
WP,D,SR2016, 37.728424072, -83.6471558455,12/31/1989,00:00:00,BIG ANDY RD
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WP,D,ZOE , 37.680358887, -83.6840576772,12/31/1989,00:00:00,ZOE KY
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