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High-Volume Oil Discovery in Clinton County, Kentucky

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KENTUCKY GEOLOGICAL SURVEY
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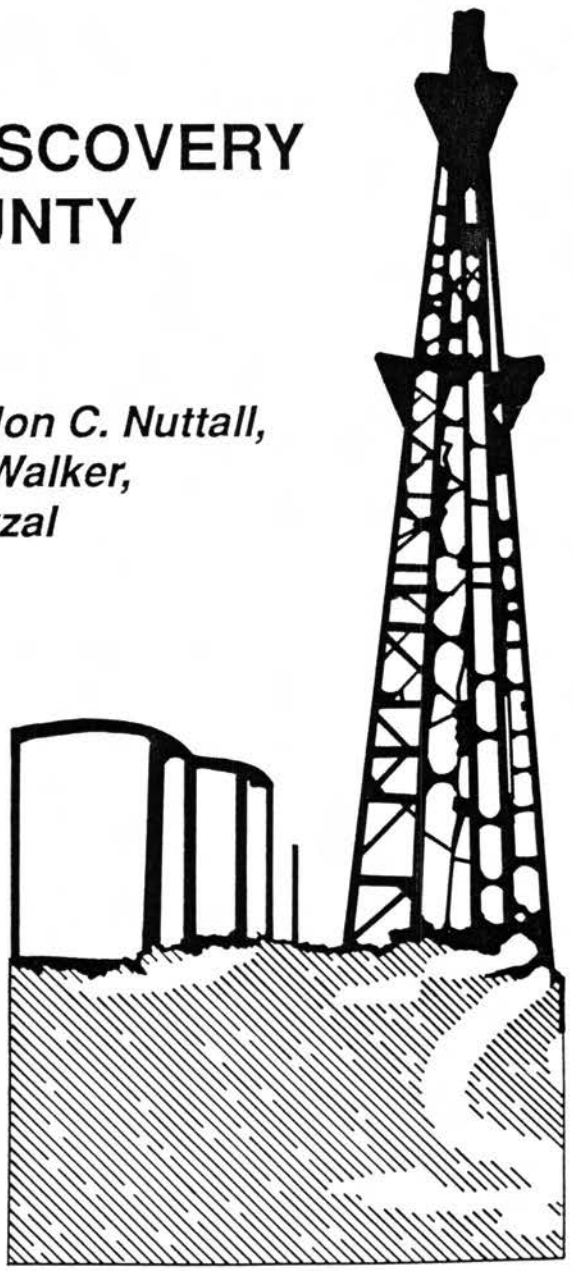

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CONTENTS

ILLUSTRATIONS

HIGH-VOLUME OIL DISCOVERY IN CLINTON COUNTY, KENTUCKY

Terence Hamilton-Smith, Brandon C. Nuttall, Patrick J. Gooding, Dan Walker, and James A. Drahovzal

ABSTRACT

The Syndicated Options Limited of Austria No. 9372 Ferguson Brothers well, located in southern Clinton County, Kentucky, has recently produced oil at reported initial rates of 400 to 130 barrels per hour. Cumulative production for the first 8 weeks of flow following discovery on September 25, 1990, is reported to be nearly 150,000 barrels. The well is the result of deepening a previously abandoned well. Production is from the Middle Ordovician High Bridge Group (equivalent to the Stones River Group of Tennessee) at a depth of 1,008 feet. The reservoir is apparently a fractured carbonate rock, and the fracturing is probably associated with reactivation of a basement fault during the Acadian orogeny of Early to Late Devonian age.

INTRODUCTION

A high-yielding oil well, the Syndicated Options Limited of Austria No. 9372 Ferguson Brothers, was recently completed in Clinton County, south-central Kentucky (Fig. 1). This well has attracted a high degree of regional and national interest (Oil and Gas Journal, 1990; Petroleum Information, 1990). Production for the first 8 weeks is reported to have been nearly 150,000 barrels of oil, with reported rates ranging from 400 to 50 barrels of oil per hour (boph).

The well produces from the Middle Ordovician High Bridge Group, which is equivalent to the Stones River Group of Tennessee. The producing zone is apparently a fractured carbonate reservoir at a depth of 1,008 feet. The high yields are exceptional for the High Bridge Group in this area, and have stimulated a great deal of interest in the local geology and hydrocarbon potential. The purpose of this report is to provide information about the well and present the basic geologic framework of the area in order to encourage effective exploration and development of this significant resource.

The Syndicated Options Limited of Austria 9372 Ferguson Brothers well is located in Carter coordinate section 8-B-53, Albany 7.5-minute quadrangle, in southern Clinton County, Kentucky (Fig. 2). The well is in the Lee Chapel Consolidated field, which was originally discovered in 1975, and is the result of deepening a previously abandoned well. The original well, the Nelson Bishop 4A Ferguson Brothers, was drilled to a depth of 980 feet in March 1987. It was successfully completed as an oil well in the Middle Ordovician High Bridge Group, producing about 3 barrels of oil per day from a fractured interval at 828 to 830 feet. This original well was abandoned and the lease was allowed to lapse.

In 1990, the Nelson Bishop well was acquired by Syndicated Options Limited of Austria. In September 1990, it was determined that approximately 300 feet of debris was filling the bottom of the hole. An air rotary

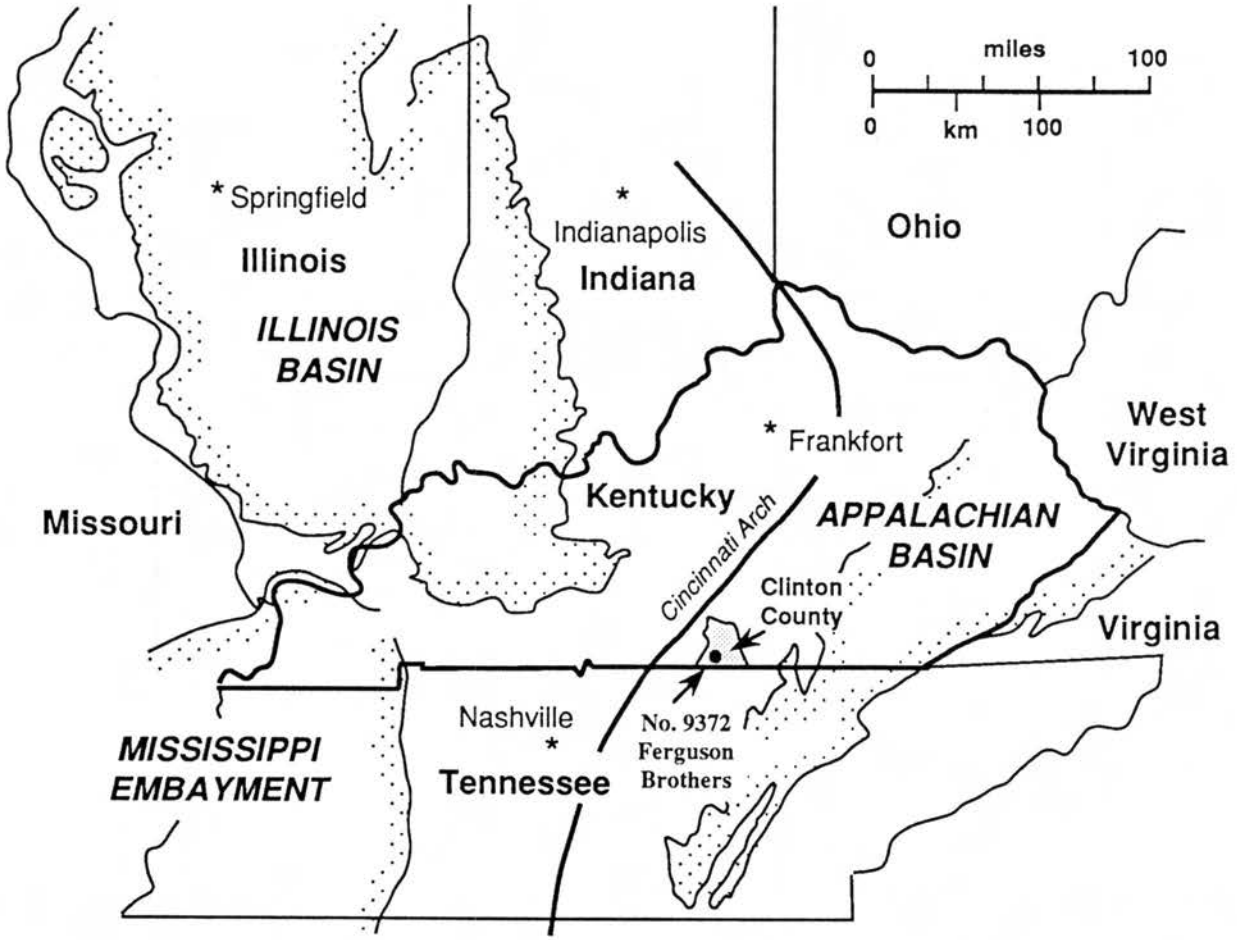


Figure 1. Regional map showing location of Syndicated Options Limited of Austria No. 9372 Ferguson Brothers well, and major tectonic features.

rig was used to clean out and deepen the well. On September 25, after drilling a few feet, the drill stem dropped, indicating an open cavity in the formation. At an estimated total depth of 1,008 feet, the well flowed oil. Although the operator is not required to file State production reports, informally quoted rates of initial production range from 400 to130 boph (Petroleum Information, 1990). The well is reported to have produced nearly 150,000 barrels of oil in its first 8 weeks of operation and is reported to have flowed 50 to 400 barrels per hour during this period.

The Syndicated Options Limited of Austria No. 9372 Ferguson Brothers well was logged and cased prior to deepening, but it had not been tested or stimulated at the time of publication of this report. The drilling rig has not been removed from the wellsite. Surface control has been established using backpressure from four 210-barrel stock tanks installed next to the well. Oil is being pumped from the tanks next to the well to a battery of fourteen 210-barrel stock tanks in a nearby graveled truck-loading area. Oil is then removed from the site by tanker truck.

SURFACE TOPOGRAPHY AND GEOLOGY

Clinton County is located in south-central Kentucky, bordering the Kentucky-Tennessee boundary. The area lies within the Mississippian Plateaus physiographic province. The elevation of the area is approximately 1,000 feet and the topography is diverse. Much of the terrain is gently rolling, with characteristic karst topography. The general surface geology is presented on the 1:250,000-scale Geologic Map of Kentucky (McDowell and others,

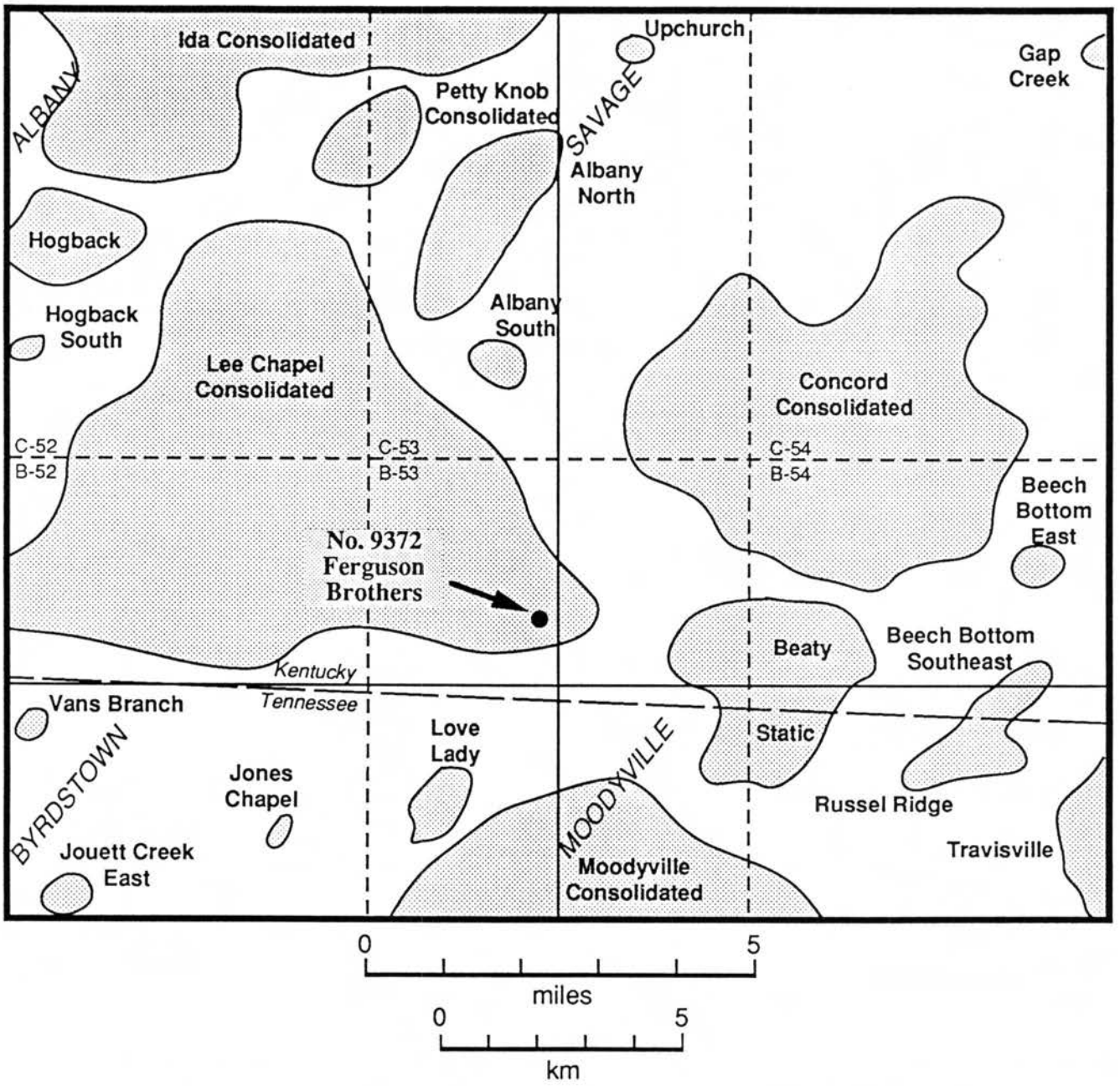


Figure 2. Oil and gas pool map for south-central Kentucky and north-central Tennessee, showing the location of the Ferguson Brothers well.

1981), and the detailed geology is shown on the 1:24,000-scale Albany Geologic Quadrangle Map (Lewis and Thaden, 1966). The geology of Tennessee is available on the Geologic Map of Tennessee (Hardeman, 1966).

The surface geology of the Albany quadrangle is dominated by relatively flat-lying St. Louis Limestone of Mississippian age. The Ferguson Brothers well is situated on the alluvium of Spring Creek, with the closest outcrop being Mississippian Fort Payne Formation. The St. Louis Limestone strikes northwest-southeast and dips gently to the northeast. North of the well, this dip is interrupted by a gentle east-west trending structural low (Lewis and Thaden, 1966).

REGIONAL GEOLOGY

The axis of the Cincinnati Arch, a major structural feature that separates the Appalachian Basin to the east from the Illinois Basin to the west, passes just west of Clinton County (Fig. 1). Structural features associated with the Cincinnati Arch are the Jessamine Dome in central Kentucky, the Nashville Dome in central Tennessee, and the intervening Cumberland Saddle. The Cumberland Saddle, centered in northern Cumberland County, Kentucky, is located at the intersection of the Cincinnati Arch with the east-west trending Rome Trough and Rough Creek Graben. The Ferguson Brothers well is located in the Cumberland Saddle on the eastern flank of the Cincinnati Arch, in an area representing the westernmost extent of the Appalachian Basin.

Basement rocks were encountered at a depth of 4,926 feet in the Associated Oil and Gas Exploration Co. No. 1 Sells well, just to the south of Clinton County in Pickett County, Tennessee. In terms of basement geology, the Clinton County area is in the Central Province, lying just west of the Grenville Front and the East Continent Gravity High (Keller and others, 1980, 1981). The area is situated in both gravity (Fig. 3) and magnetic (Fig. 4) lows, which may be interpreted as a southern extension of the Kentucky-Ohio trough (Black, 1985; Drahovzal and others, 1990).

Reactivation of trough-bounding faults or of other faults associated with the Cumberland Saddle may be responsible for fracturing in the Ordovician rocks of Clinton County. Such fault reactivation is known from numerous localities in the region (Black and Haney, 1975; Keller and others, 1981; Dever and others, 1990).

SUBSURFACE STRATIGRAPHY

The general stratigraphy of Clinton County is summarized in Figure 5. In the subsurface, Lower Mississippian and Upper Devonian New Providence and Chattanooga Shales occur beneath the lithologically diverse Fort Payne Formation of Mississippian age. A major unconformity occurs at the base of the Chattanooga Shale, representing the local stratigraphic effect of the Acadian orogeny (Conant and Swanson, 1961; Hamilton-Smith and others, 1989). Beneath the unconformity, in descending order, the following formations occur down to the top of the Knox Group: Cumberland Formation, Leipers Limestone, Clays Ferry Formation, Lexington Limestone, High Bridge Group, and Wells Creek Dolomite (Freeman, 1953). The Wells Creek Dolomite and the High Bridge Group are equivalent to the Black River and Joachim of New York, Michigan, Illinois, and Indiana; the Platteville and Glenwood of Illinois, Wisconsin, and Michigan; the Chazy of Ohio; and the Stones River and Chickamauga of Tennessee, Georgia, and Alabama (Shaver and others, 1984). The unconformity between the Wells Creek Dolomite and the Knox Group marks the simultaneous stratigraphic effects of the local Taconic orogeny and a major event of eustatic sea-level fall. It is marked by the regional development of paleokarst in the upper part of the Knox Group (Mussman and others, 1988; Gooding and others, 1988).

The High Bridge Group consists predominantly of carbonates, and in Clinton County averages about 1,025 feet in thickness (Gooding and others, 1988). In south-central Kentucky, the High Bridge Group consists of two formations: the Camp Nelson Limestone at the base and the overlying Tyrone Limestone. Both formations are composed principally of limestone but contain beds of dolostone. Shale is present in minor amounts. The very fine- to coarse-grained limestone is light olive to brown to dark gray, and contains scattered fossils. The limestone is commonly interbedded with calcareous shale or argillaceous limestone. Zones of light-olive to gray, very fine- to fine-crystalline dolostone and dolomitic limestone may also occur.

Faunal evidence, stratigraphic relationships, depositional textures, and sedimentary structures indicate that the High Bridge Group was deposited under shallow, marine conditions in a tidal-flat environment (Cressman and Noger, 1976; Gooding and others, 1988). Vertical distribution of lithologic types indicates a repeated shallowing-upward depositional sequence, and numerous depositional cycles can be recognized. Mudstone and wackestone textures are dominant while packstones and grainstones are less common. These carbonates range in color from very light gray and light olive gray to dark gray; the lighter shades typically indicate better oxygenated depositional environments. Periodic volcanic ash falls during the Middle Ordovician have resulted in thin bentonite beds in the upper portion of the Tyrone Limestone of the High Bridge Group. In south-central Kentucky, the two most prominent bentonite beds are the "Pencil Cave" (generally correlated with the T-3 bentonite of Tennessee), which occurs about 15 to 25 feet below the contact, and the "Mud Cave," which occurs at or near the contact (Fig. 6). Production in the Ferguson Brothers well occurs in the upper part of the Middle Ordovician High Bridge Group, about 100 feet below the "Pencil Cave" bentonite.

SUBSURFACE STRUCTURE

Structure on the "Pencil Cave" bentonite in the area of the Ferguson Brothers well is shown in Figure 7. Structure on top of the Knox Group is shown in Figure 8. The relative complexity of the top of Knox

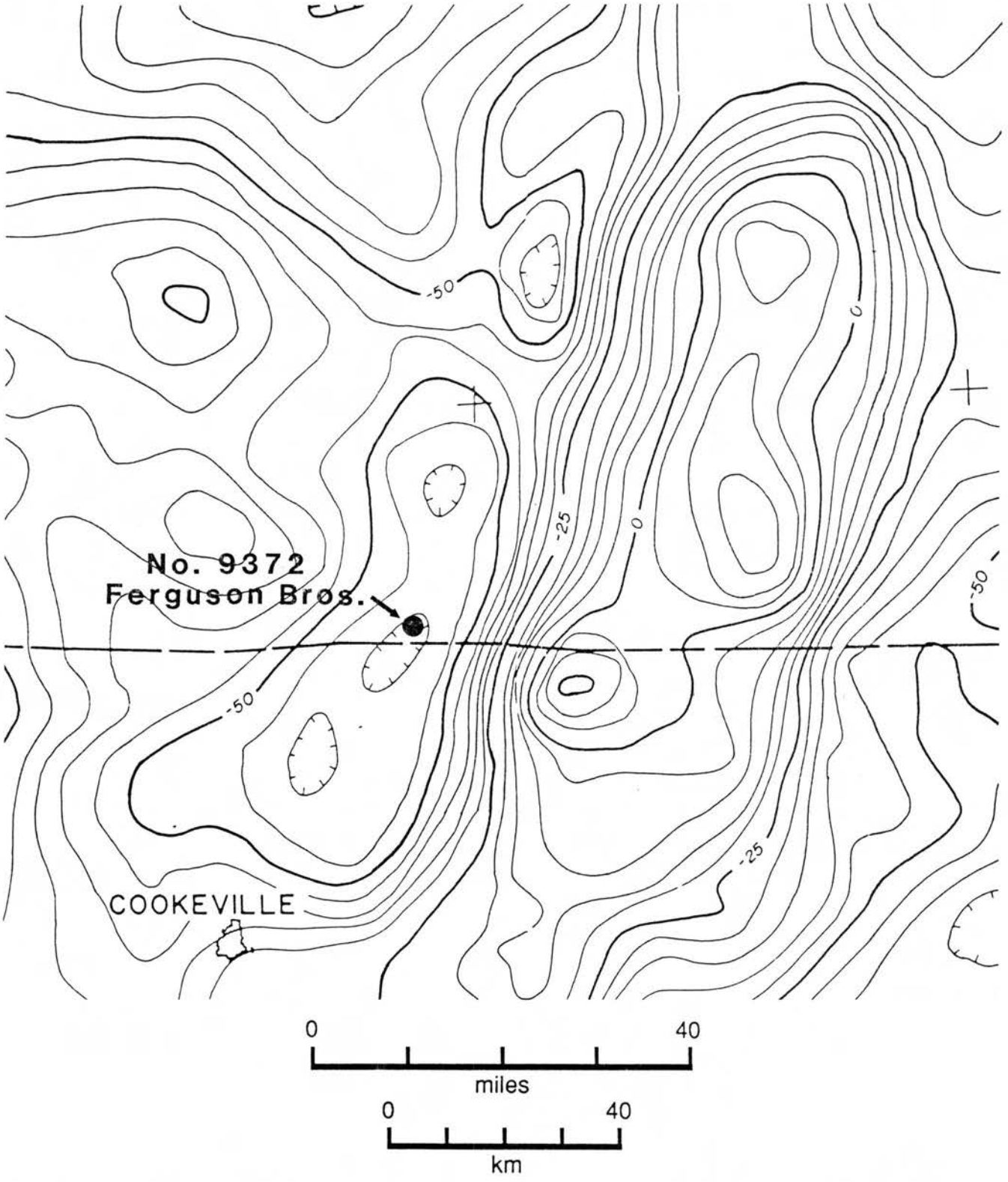


Figure 3. Regional Bouguer gravity anomaly map (modified from Keller and others, 1980), showing location of Syndicated Options Limited of Austria No. 9372 Ferguson Brothers well. Contour interval is 5 milligals. Scale is 1:1,000,000.

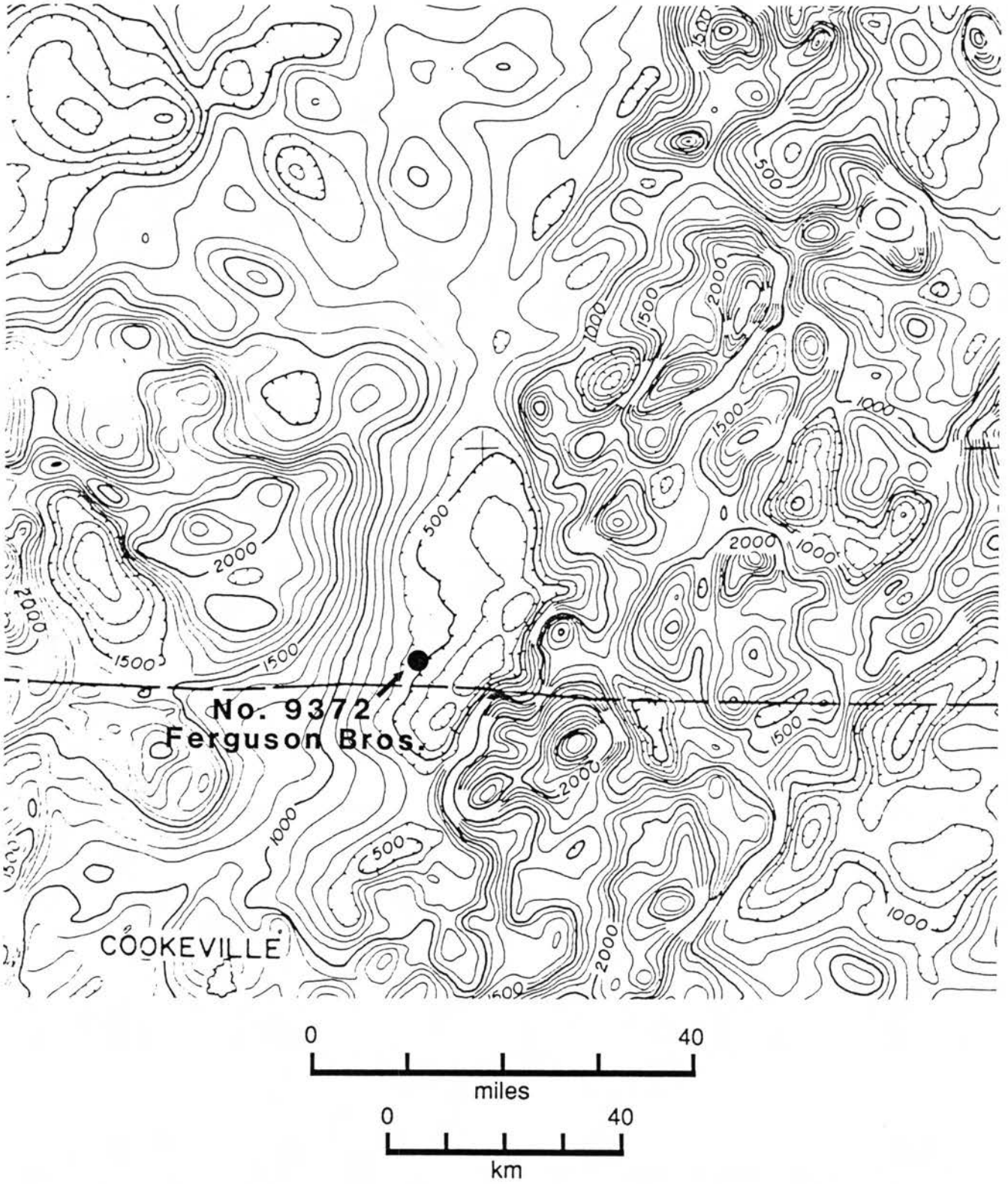
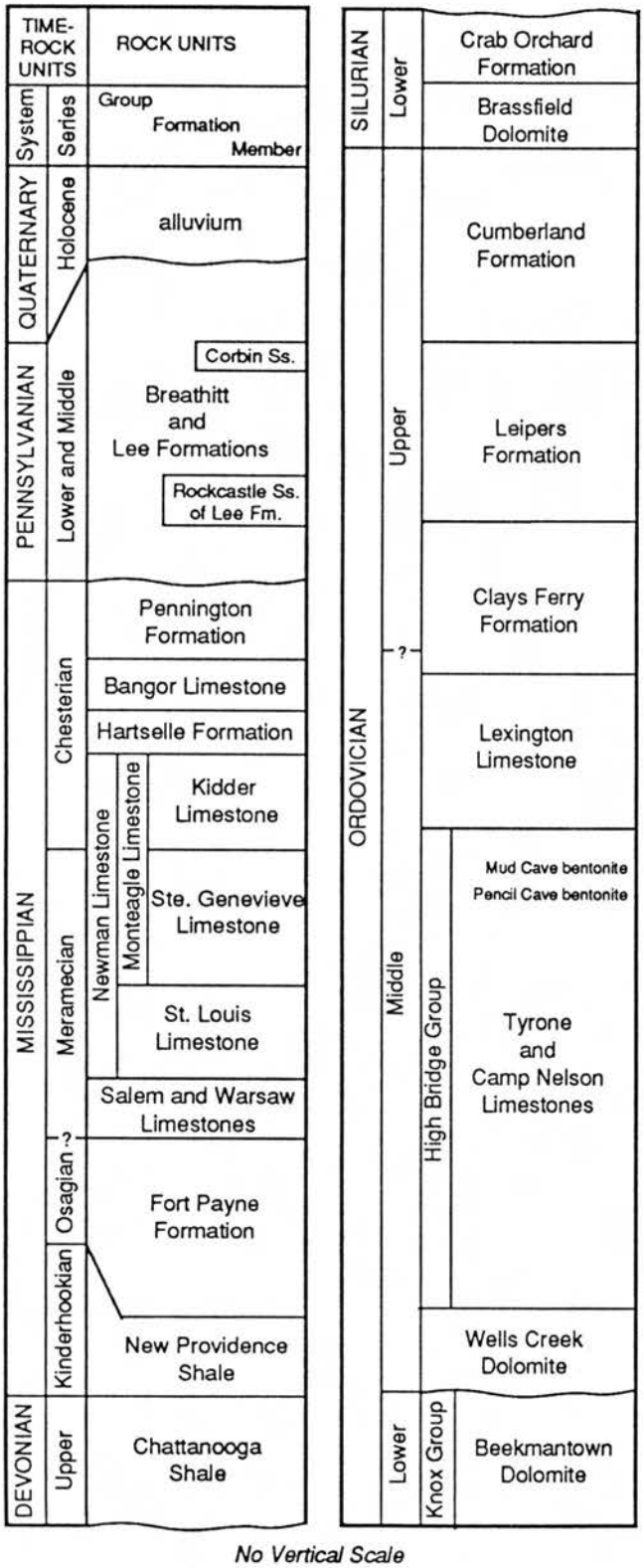


Figure 4. Regional total magnetic intensity anomaly map (modified from Johnson and others, 1980), showing location of Syndicated Options Limited of Austria No. 9372 Ferguson Brothers well. Contour interval is 100 gammas (nT). Scale is 1:1,000,000.



No Vertical Scale

Figure 5. Generalized geologic column for Clinton County, south-central Kentucky (modified from Dugan and Henning, 1983).

surface is due to the irregular karst paleotopography of the unconformity surface. Both maps show a generally northeast-trending low in the vicinity of the well, modified by an east-west trending high to the northwest. Comparison to the magnetic and gravity maps (Figs. 3, 4) shows a general similarity of form, suggesting basement control of structure in the Ordovician section. Structure on the base of the St. Louis Limestone (Lewis and Thaden, 1966) shows a very different form, suggesting that basement and Ordovician structure may not be fully reflected at the Mississippian level. This contrast may be explained by reactivation of basement structures during the Acadian orogeny (Devonian), resulting in the upward propagation of faults through the Ordovician and Silurian section, and their subsequent burial by relatively undisturbed Mississippian beds. The structure as discerned from surface geology, therefore, may be misleading when applied to pre-Devonian reservoirs in the area.

OIL PRODUCTION

Clinton County is projected to contribute approximately 6 percent of the State's total oil in 1990. Oil production from 1920 to present is shown in Figure 9. Beginning in 1980, a drilling boom in Clinton County pushed oil production from less than 50,000 barrels in 1979 to nearly 400,000 barrels in 1982. Only 55,000 barrels of oil were produced in Clinton County in 1989, but over 220,000 barrels are projected for 1990. The Ferguson Brothers well is expected to contribute about 67 percent of the total production for Clinton County in 1990.

Commercial quantities of hydrocarbons are being produced in many areas of Clinton County. Figure 2 shows oil pools that are near the recent discovery; the Kentucky portion of the area contains more than 2,000 producing oil wells. These pools are producing from relatively shallow zones, primarily from fractured Ordovician carbonate reservoirs, including the Lexington Limestone, High Bridge Group, Wells Creek Dolomite, and the Knox Group, at drilling depths from 600 to 2,100 feet.

The Ferguson Brothers well is in the eastern part of the Lee Chapel Consolidated Field. The discovery well of the Lee Chapel Field was the Tenexco Company No. 1 John K. Cummings, Sr., in Carter coordinate section 3-B-52. It was drilled to a total depth of 2,000 feet and completed for 150 thousand cubic feet of gas per day (mcfgpd) from the Knox Group in May 1975. In July 1980, the discovery well of the Huntersville Pool, the Ewert Wilson No. 1 Warn Butler, was completed in Carter coordinate section 7-B-53 for 1 bopd in the Knox. These two fields, and several others, were combined into Lee Chapel Consolidated Field in 1982.

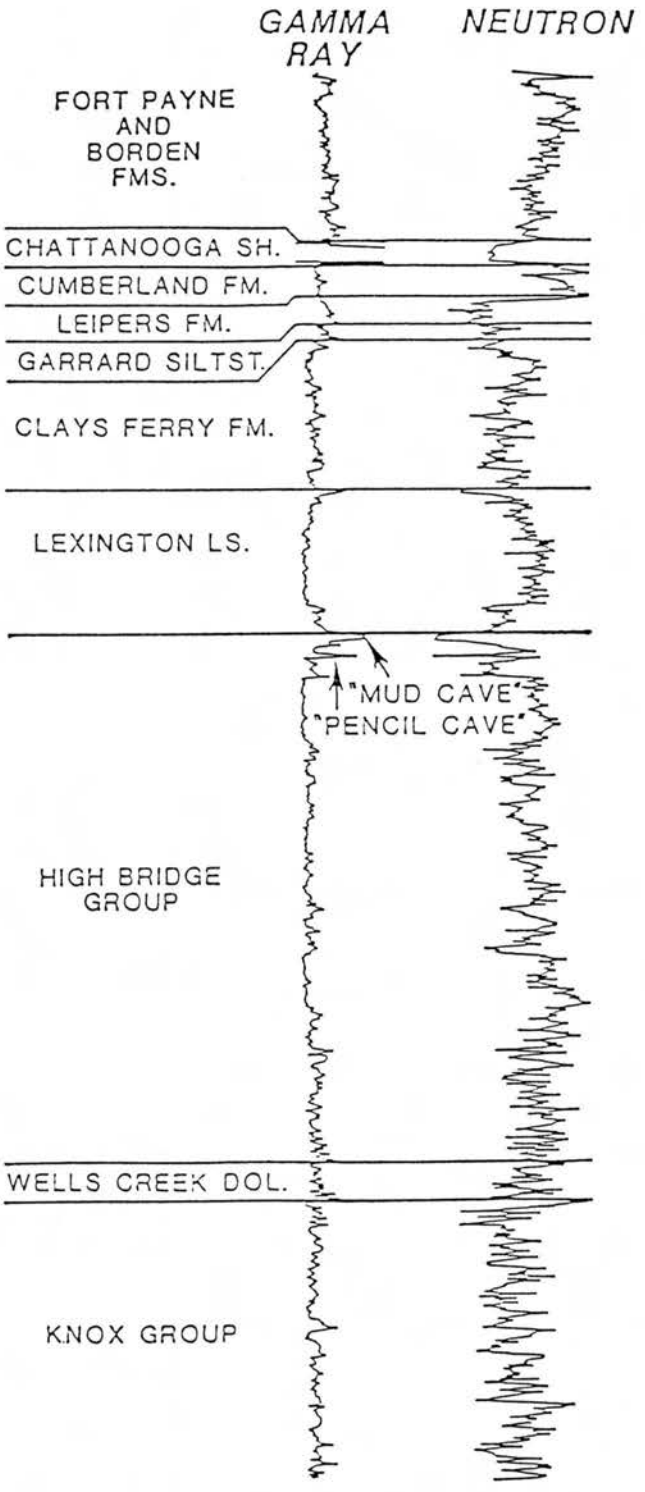


Figure 6. Typical geophysical log for south-central Kentucky (modified from Gooding and others, 1988).

RESERVOIR CHARACTER

Much of the production in the area is assumed to be related to fractures in the limestone and dolostone, and this is thought to be the reason for the wide variations in production from one well to another. Typical wells in the area produce an average of 2 bopd. Little information about subsurface fractures is available for the area, but a general surface lineament study was prepared by McHaffie (1981). The lineaments mapped in the Clinton County area are shown in Figure 10. However, given the general dissimilarity noted in the gross structure between the Mississippian and the Ordovician sections, there appears to be only a limited relationship between the Ordovician fracturing and the surface lineaments.

Fractured reservoirs of the Knox Group are related mainly to paleokarst brecciation (Mussman and others, 1988). Fractured reservoirs of the younger Ordovician units are probably due to tectonic deformation, rather than resulting from paleokarst brecciation. Regionally, the dominant style of tectonic deformation is reactivation of basement faults. Most of these fractured oil reservoirs contain gas, and some wells have been gas producers.

The lack of core, logs, and detailed production data from the producing interval in the Ferguson Brothers well precludes a definitive reservoir analysis. Fracture production is suggested by the high initial rate of as much as 400 boph, with the sustained rate of over 40 boph suggesting a relatively large and well-connected fracture network. A substantial, and probably overpressured, fracture zone is implied. Such fractures would constitute a broad zone formed in response to the propagation of a master fault (Atkinson, 1987). The fracture zone would be parallel to the fault, with its width depending on the lithology, the magnitude of offset on the master fault, the confining stress during faulting, and possibly other factors. Fracture intensity would decrease exponentially with distance away from the fault plane. The fault itself would be expected to dip at a high angle. Low production rates from the original Nelson Bishop 4A Ferguson Brothers well show that the accumulation in the Syndicated Options well had an effective seal, suggesting that the fault had not propagated to the surface. If this reservoir model is correct, the main exploration problem will be identification of the trend of the master basement fault.

Tectonic fractures of this nature are known to be sensitive to pressure, with fracture closure resulting from decrease of reservoir pressure due to production (Jones, 1975; Reiss, 1980). Such closure results in an irreversible collapse of the fracture system, with an accompanying decrease in reservoir permeability and volume, and a consequent loss of recoverable reserves. This problem may be particularly serious in overpressured reservoirs. One positive feature of the

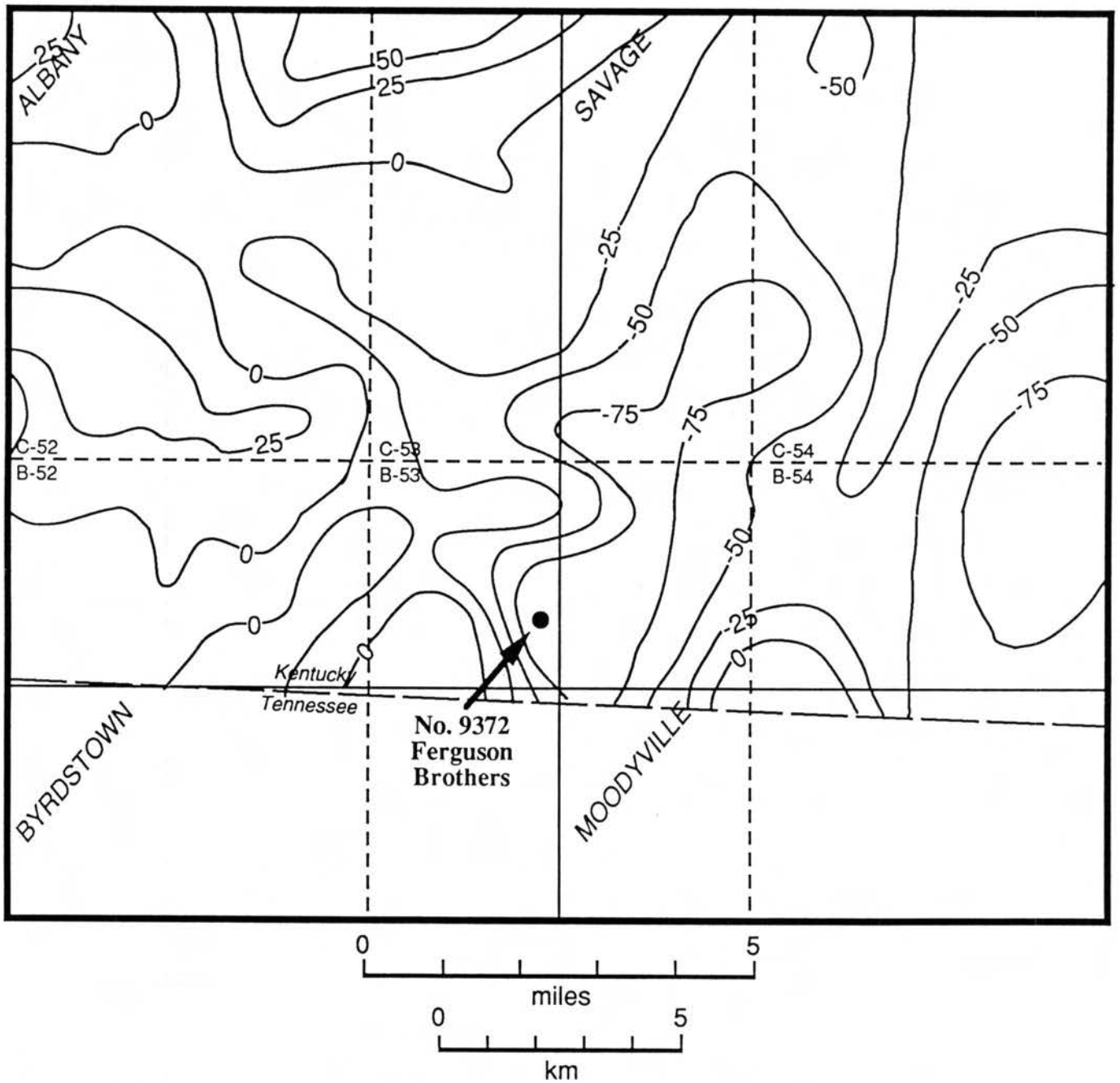


Figure 7. Structure map of the "Pencil Cave" bentonite in the vicinity of the Syndicated Options Limited of Austria No. 9372 Ferguson Brothers well (modified from Gooding, 1983). Datum is sea level. Contour interval is 25 feet.

fractures in the High Bridge Group may be partial mineralization due to hydrothermal fluid movement. If present, this secondary mineralization may be expected to reduce the pressure sensitivity of the fracture system by providing a natural proppant, which would locally bridge the fracture walls and keep them apart.

There are also three production practices that can reduce any potential reservoir damage from fracture closure. First, a sand proppant can be injected into the fracture system from the wellbore, preventing fracture closure in the region near the wellbore, which would experience the greatest pressure decline. Second, flow channels may be etched into the fracture faces by

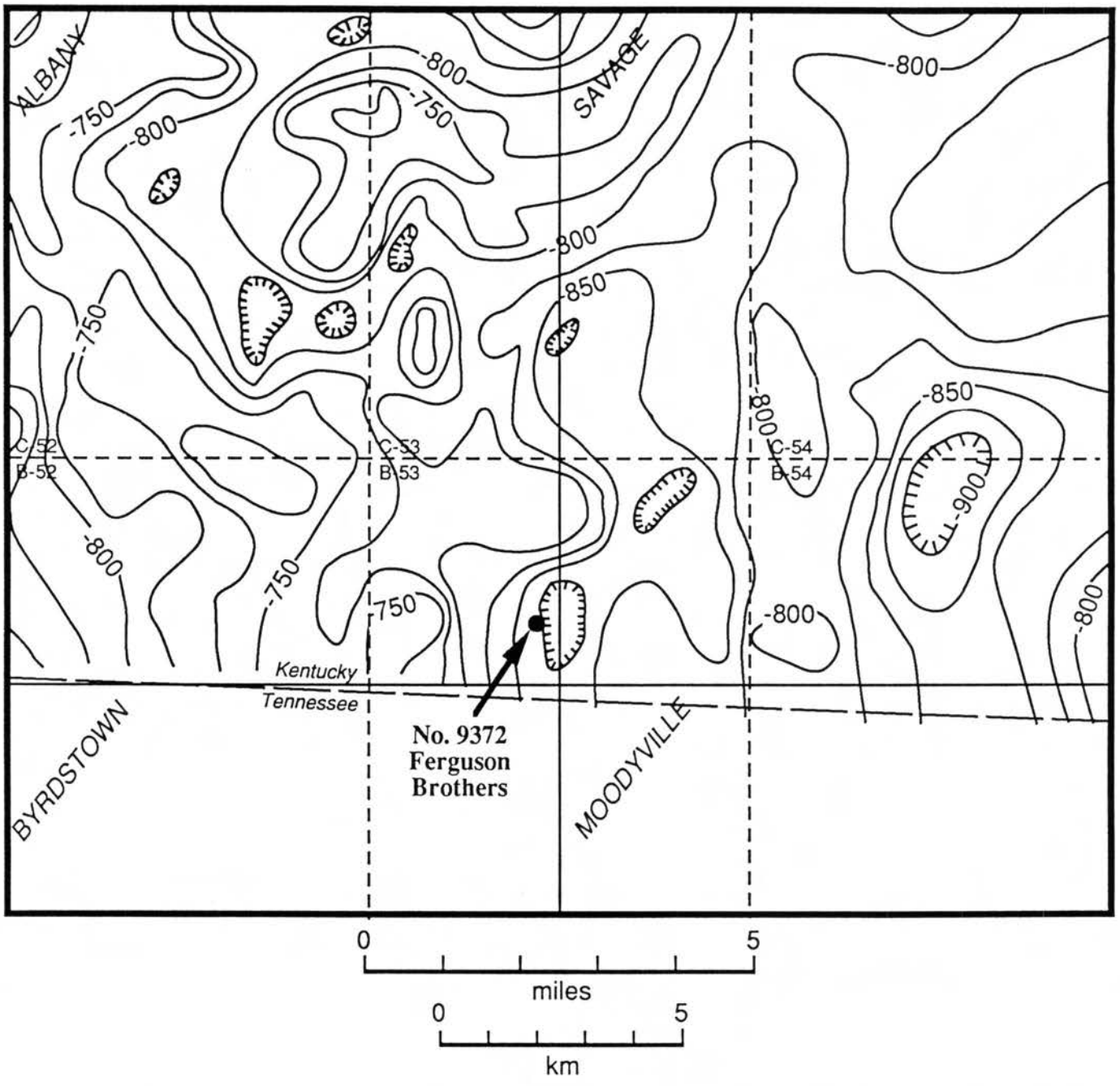


Figure 8. Structure map of the top of the Knox Group in the vicinity of the Ferguson Brothers well (modified from Gooding, 1983). Datum is sea level. Contour interval is 25 feet.

acid stimulation, which would allow flow even after fracture closure (Frederickson, 1986). More generally, effective reservoir pressure maintenance from the beginning of production, using water or gas injection, could prevent any problem of fracture system collapse.

FUTURE POTENTIAL

The results of the Ferguson Brothers well show the significant potential for high-yield production from fractured reservoirs in south-central Kentucky.

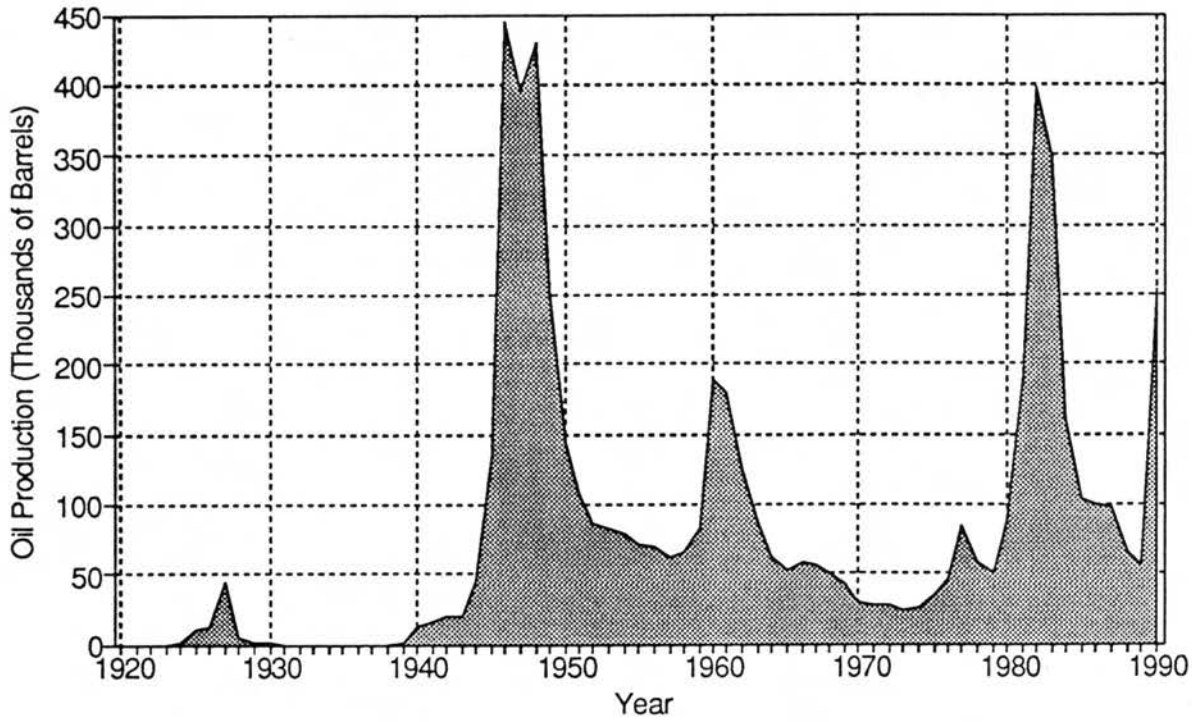


Figure 9. Oil production in Clinton County, 1920 to 1990 (projected).

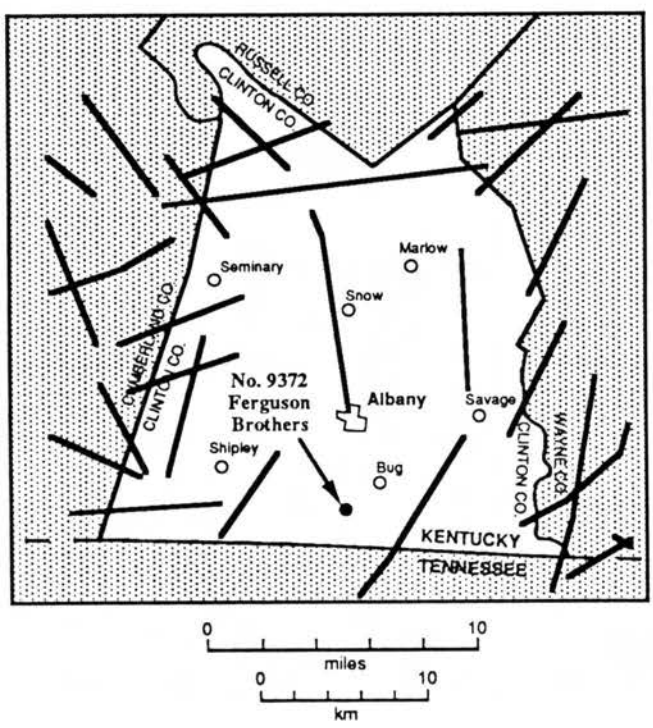


Figure 10. Surface linear features occurring in Clinton County (modified from McHaffie, 1981).

Successful exploration and development can be enhanced by the increased use of currently available information and technology. The Kentucky Geological Survey has information on file for wells throughout the State. This includes 30 wells in Carter coordinate B-53 for which geophysical logs are available. Eight of these wells have compensated formation density or compensated neutron density logs. Nearby wells with geophysical logs include the IDACO wells on the O. Poore lease in 11-B-53, and the Southland Energy wells on the Clyde Ferrill lease in 10-B-53. A sample description and a geophysical fracture survey are available for the Ferguson Brothers well. The evaluation of fractured reservoirs in future wells would be substantially improved by cutting oriented, full-diameter cores and running geophysical logs specifically designed for fracture detection. Such information can be very useful in the development of an effective drilling program.

Clinton County had a large ratio (1.1) of footage drilled to barrels of oil produced in 1989, compared to Henderson County (0.07) and Leslie County (0.2), the most prolific oil-producing counties in the State (Nuttall, 1990). Of the 32 permits issued in Carter coordinate B-53 since October 1, 1990, only one has been reported as a producer to date. The Robo Enterprises, Incorporated No. 1 Matthews, located approximately 1,500 feet northwest of the Ferguson

Brothers well, is reported to be flowing at the rate of 50 boph at the time of this report (Kincheloe, pers. comm., 1990).

Part of the low success rate in Clinton County is probably due to the difficulty in locating fractured reservoirs. Elsewhere in the world, horizontal or slant drilling has been relatively successful in the discovery and production of fractured reservoirs. Permits have been issued for the drilling of four horizontal wells as Ordovician Knox tests in nearby Cumberland County; the successful outcome of these wells may encourage future drilling for fractured reservoirs in the High Bridge Group in Clinton County.

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