Guidebook To The
Petroleum Geology of Western Missouri

Association of Missouri Geologists
29th Annual Meeting
Grandview, Missouri

& Field Trip
Vernon County, Missouri

September 24-25, 1982

Sponsored by
Midcontinent Geological Consultants
Kansas City, Missouri
Association of Missouri Geologists

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29th ANNUAL MEETING
SEPTEMBER 24-25, 1982
PREFACE

On Friday afternoon, we shall visit two of the main oil-producing areas of Jackson County. First will be a visit to the Longview area, where an oil field lies right under the site of the reservoir which will be behind the Longview Dam, currently under construction. Next we will meet at Prairie Energy's Martin City field, where oil is being produced from the Squirrel Sandstone.

Saturday we will journey to Vernon County, scene of production of heavy oil through enhanced recovery methods. Our hosts there from Carmel Energy will give us a tour and some insight as to the geology, oil occurrence, and methods of heavy oil recovery in their field. After this, we have stops at a quarry where asphaltic sandstone has been obtained and at an outcrop of Warner Sandstone, a major reservoir rock. The field trip will end at the outcrop west of Schell City.

As always, a number of willing workers have contributed to the success of the meeting and the field trip. Thanks are expressed to all of them: Alison Sherwood and John Emerson helped with the road logs, and they, John Moylan, and Bruce Netzler furnished papers. Paul Hilpman was the banquet speaker. Our hosts at the stops include the Corps of Engineers and Prairie Energy. Special thanks go to Vincent Young and Carmel Energy. Dick Felton and his students at Northwest Missouri State spent part of their spring break measuring sections and drawing up sketches of them. Mary Ann Cargo helped with the typing and designed the cover for the guidebook.
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PETROLEUM IN MISSOURI--SOMETHING OLD, SOMETHING NEW

It has often been noted that Missouri is a land of great geological diversity, from the Precambrian igneous rocks of the Saint Francis Mountains to the thick sedimentary pile in the Bootheel to the drift-mantled limestones of the northern prairies. Indeed, this is true, and one has only to look over the list of past field trips to know how varied the programs of the Association have been.

Missouri is rich in minerals, stone, and fuels, ranking at or near the top of the list of states in a number of products. Our Association has visited the mines and quarries from which these products come and has examined the structure, stratigraphy, petrology, and geomorphology of the areas involved. We have observed the engineering, academic, and environmental aspects of the geology of most of the state.

This year we add another resource to our list of meeting topics: petroleum. Missouri is not a major producer of petroleum, but within the last five years, production of oil has increased dramatically, and over the past sixty years, a fair amount of natural gas has been produced. The only other time, at least in the past few years, that we visited a petroleum area was the visit to the Laclede underground storage area near Florissant in 1977.

Most of Missouri's petroleum, however, lies in the western tier of counties, so it is there that we visit this year. We shall learn that petroleum, too, is part of the geological heritage of Missouri.
A BRIEF SUMMARY OF OIL AND GAS EXPLORATION
IN WESTERN MISSOURI
by Alison Sherwood

The first recorded test wells in the Forest City Basin were drilled approximately 50 miles south of Kansas City in Miami County, Kansas in 1860. The first two wells were dry, but the third discovered oil (Jewett, 1979). Records show that the first wells drilled in Missouri were in the late 1860's and were drilled near Kansas City, Jackson County. These first wells were shallow and found principally gas with showings of oil.

Drilling continued in the 1870's and was prompted by the existence of asphaltic sandstone outcrops in several counties including Barton, Bates, Lafayette, Ray, and Vernon Counties. In these areas the oil found at the surface had been used for greasing farm implements and machinery. It was believed that large oil reservoirs would be discovered beneath these outcrops. Subsequent drilling failed to prove this, though.

In the 1880's counties in the central and eastern parts of the state were explored for hydrocarbons. The counties involved were Chariton, Macon, Marion, Randolph, and St. Charles. The wells drilled in these counties were all dry. In 1883 oil was discovered near Rich Hill, Bates County. Oil was also discovered near Richmond, Ray County in 1886, and gas at Independence, Jackson County in 1887.

1 Prairie Energy Corp., Overland Park, Kansas
During this period interest in drilling wells to deeper depths to find new pay formations arose. Deep wells were drilled in Jackson, Clinton, Holt, McDonald, and Pettis Counties. All were dry. During the 1880's hydrocarbon shows were found only in Bates, Clay, Jackson, Ray, and Vernon Counties.

During the 1890's oil was discovered near Stotesbury, Vernon County. Between 1902 and 1906 gas was discovered in Belton, Cass County, and oil in southwestern Jackson County. Also during this decade, gas was found at Holt, Clay County, and at Martin City, Jackson County. During this period more deep wells were drilled in Bates, Caldwell, Harrison, Holt, Nodaway, and Vernon Counties. All were dry.

In Missouri, hydrocarbon production has been from Pennsylvanian sediments. An exception is the Corning Field in Holt County, Missouri. This field was discovered in 1960, and production was from the Ordovician formation (Viola). Initial potential was 124.9 barrels of oil per day (Wells, 1960). Another significant field in Missouri is the Tarkio Field. The first well was drilled 2,427 feet to the Hunton and although it had shows in the lower Pennsylvanian, it never produced. An offset was drilled in 1943 which did produce. This field has had significant production by Missouri standards. Total production from 1943 to 1978 was 330,605 barrels.

As mentioned above, most Missouri oil and gas production is from the Pennsylvanian. Production is also on a much smaller scale than it is for the Tarkio Field.
Cumulative oil production for all of Cass County was only 170,000 barrels by 1945, and cumulative gas production for the county was 1,240,330,000 cubic feet (Clair, 1943).

Drilling in western Missouri has continued to the present with periods of intensity interspersed with lulls. The area at present is undergoing active exploration for hydrocarbons, with the pay zones of interest being principally the lower Pennsylvanian Cherokee sands.

REFERENCES


ABANDONMENT OF THE LONGVIEW FIELD

by John Moylan

The Longview Dam is part of the Little Blue River Flood Protection Project authorized by the Flood Control Act of 1968. The project consists of two flood control reservoirs, Longview and Blue Springs, and approximately 15 miles of channel modification along the downstream portion of the stream. Longview Dam is a 1900-foot long rolled earthfill dam with a cut and cover conduit outlet works at the toe of the left (west) valley wall and uncontrolled limited service spillway in the left abutment. The top of the dam is 120 feet above the stream bed. Longview Lake will have 930 surface acres at multipurpose pool level, elevation 891 feet, and 1,960 acres at flood control pool, elevation 909 feet. Construction was started in 1979.

The lake will flood a portion of the Longview oil field. The field was discovered in 1944. Production is from a channel sandstone reportedly in the lower Pleasanton Group. The wells are shallow and range in depth from 230 to 310 feet. Production is reported to have been 34,329 barrels from discovery in 1944 through April 1963. A gravity-flow pilot waterflood was started in 1966 using six injection wells. In more recent years, a pressurized waterflood has been used and during the year or two prior to the acquisition of the field by the Corps of Engineers, a polymer was added to the injection water to enhance recovery further.

1 Corps of Engineers, U. S. Army, Kansas City, Missouri
Production has steadily increased since the last operators, Town Brothers Operating Company, assumed management of the field in 1973.

At flood pool, the lake will inundate the majority of the wells in the field. Several options were studied, ranging from complete subordination of oil rights to complete acquisition. It did not appear feasible to operate any wells below full pool elevation at a profit in an environmentally sound manner. The cost of constructing operating platforms or manmade islands was considered prohibitive. In addition, the cost of transporting oil and salt water in an environmentally safe manner to land storage and disposal would be great. Waterflooding at these shallow depths would be prohibited at least lakeward of the full pool contour in order to preclude fracturing and possible attendant surface leakage. Because of the shallow depth to the producing horizon, inclined drilling or whipstocking out under the lake is impractical. Acquisition of only those wells under the proposed lake was also considered. This option would have resulted in a field with far fewer wells and split by the lake. It was doubtful that this option would allow a profitable situation for the operator. It was decided to acquire the entire Jones and Longview leases. The remaining Nave lease is some distance from the lake, has few wells, a declining production, and appraised to be uneconomical on its own. Acquisition of the field was effected in May 1982.

The acquisition agreement between the Government and Town Brothers allows continued production by the operators
with the requirement that all wells be plugged within 1 year of acquisition except for 5 production and 5 injection wells within the Sherer Road relocation right-of-way which were to be plugged by August 1982. This allows maximum oil recovery prior to closure of the dam. The plugging procedure is intended to provide maximum protection from leakage after impoundment. Preparation of the plugging specifications was coordinated with Town Brothers and the Missouri Geological Survey and reviewed by Dr. Harvey, Chairman of the Missouri Oil and Gas Council.

Early plugging of the 10 wells for the Sherer Road relocation has provided valuable experience for the remaining well plugging. The injection wells contain 6½-inch surface casing set into bedrock and 2-inch production casing to the producing zone. Both are cemented to the surface. Plugging is accomplished by pressure grouting 15 to 16 lb./gal. cement grout through a supply line attached to the 2-inch casing. Injection pressures ranging from 350 to 500 psi force a quantity of grout in excess of that required to fill the pipe into the formation. When the predetermined quantity is injected, a valve at the top of the 2-inch casing is closed, thereby maintaining the pressure until the grout sets. After the grout has set, selected wells are to be pressure tested with water at 300 to 400 psi to assure the integrity of the plugging job. The production wells have 4-inch casing set into the producing zone and the lower 80 to 100 feet is cemented in place. These, too, will be pressure grouted through a supply line attached to the top of the casing. Approximately 21
sacks of cement in a 15 to 16 lb./gal. grout mix are injected, followed by a rubber plug and water. The plug is pushed by water pressure to approximately 200 feet, the valve at the top is then pressure tested, the casing cut off and removed above the plug, and the open hole above the plug backfilled with 15.5 to 16 lb./gal. grout through a 2-inch pipe extending to the top of the plug.
RECENT OIL AND GAS ACTIVITIES IN MISSOURI

by Bruce W. Netzler

Oil and gas in Missouri have been produced primarily from shallow (less than 1,000 feet) wells since the late 1800's. However, the focus of the oil and gas industry has changed from gas production in the late 1800's to the middle 1900's, to oil production since the 1960's. In the near future gas will again be an important resource due to the anticipated decontrol of this commodity.

The following paragraphs contain summaries of the oil and gas activity in Missouri for the years 1978 through 1982. (The 1978 and 1979 summaries were adapted by the author from previous publications by Jack S. Wells, now with Copwel, Inc.) The last section provides production information on the currently producing pools of Missouri. Figure 1 shows the production and monetary value of the oil and gas produced from 1865 through 1981. Figures 2A and 2B show the production and permitting activities from 1966 through 1982. (The 1981 and 1982 data were compiled by Kim E. Haas, Engineering Technician, Missouri Division of Geology and Land Survey.) Figure 3 shows the producing and the abandoned oil and gas fields. Figure 4 shows the areas of current drilling activity and a tabulation of producing wells and permits issued per county for the period 1978 through June 1982. (This figure was compiled by Kim E. Haas.)

1 Geologist, Division of Geology and Land Survey, Rolla, Mo.
### Figure 1

**PRODUCTION AND VALUE DATA – MISSOURI OIL AND GAS**

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*Missouri average price per barrel
Figure 2a
PERMITS ISSUED
1966-1981
ESTIMATED FOR 1982

Figure 2b
OIL PRODUCTION IN MISSOURI
1966 - 1981
ESTIMATED FOR 1982
Figure 3. Oil and gas fields of Missouri with locations of certain exploratory wells.
Figure 4
OIL AND GAS IN MISSOURI
1978 - JUNE, 1982
By
Kim E. Haas

LEGEND

 Counties with Oil Production
 Drilling Activities Currently Underway
 Areas of Potential Oil and Gas

1980

Producing Wells
Atchison 8 Vernon 648
Cass 46 Jackson 132
Jackson 142 Livingston 2
Platte 6 Plate 7
St. Louis 20 Ray 8
Vernon 83 Bates 5
Totals 305 881

Permits Issued

1978

Producing Wells
Atchison 3 Cass 71
Cass 33 Jackson 181
Jackson 71 Vernon 148
St. Louis 20 Clay 1
Vernon 40
Totals 167 440

Permits Issued

1979

Producing Wells
Atchison 9 Cass 112
Cass 76 Jackson 229
Jackson 192 Vernon 44
Platte 6 Bates 20
St. Louis 29 Plate 15
Vernon 20 Buchanan 2
Barton 10 Livingston 1
Putnam 4 Clay 1
Totals 225 136 553

1981

Producing Wells
Atchison 9 Cass 105
Cass 46 Jackson 89
Jackson 76 McDonald 1
Platte 8 Atchison 4
St. Louis 20 Newton 1
Vernon 156 Nodaway 1
Barton 10 Platte 1
Putnam 4 Caldwell 1
Totals 459 304

JUNE 1982
Figure 5 shows three pools in southwest Jackson and northwest Cass Counties and the location of the producing wells in this area. These pools are just south of Kansas City and many of the wells can be seen from Highway 150 and other roads in the area.

1978

In 1978, exploration and development drilling was limited to the western part of the state, which includes the Forest City and Cherokee basins. There were 48 permits to drill issued by the State Oil and Gas Council; 42 of these wells were drilled and completed. Three were cancelled and 3 were started but not completed by year's end. Completions, in addition to the 42 wells permitted in 1978, included 7 carry-overs or suspended wells from 1977, which brought the total completions to 49. One discovery well is included among these.

This oil discovery was the Ke-La-Da Enterprises 1 Hall in Cass County. An apparent gas discovery, the Ke-La-Da Enterprises 1 Shideler was located in Cass County also. As a result of these two small field discoveries, considerable leasing activity has been reported, and should result in some increase in drilling activity for both Missouri and adjoining parts of eastern Kansas.

Other developments in Missouri include the evaluation of a heavy oil recovery process by Carmel Energy, Inc., with DOE funding. This project has been conducted in an older producing field in Vernon County. Current data indi-
cate that the process is economically feasible and should result in increased production. As might be expected, a considerable amount of both development and exploration activity is anticipated for this area of heavy oil accumulations.

No significant deep tests were drilled for oil or gas in Missouri; however, a deep test in the Bootheel area of southeastern Missouri, drilled by United States Geological Survey for installation of instrumentation for seismic evaluation, penetrated over 2,000 ft. of coastal sediments (Cretaceous and Tertiary) and approximately 1,000 ft. of Paleozoic rocks (Cambrian). A depth of 3,000 ft. was reached by the first of the year, and the well was abandoned.

1979

Exploration and development drilling in 1979 was again limited to the western part of the state, which includes the Forest City and Cherokee basins. The Missouri Oil and Gas Council issued 136 permits to drill; 49 of these wells were drilled and completed, 9 were cancelled by year's end. Most of the 81 completions for 1979 were development wells. Of the 9 new-field wildcats, 4 were successful oil-well attempts and the remaining 5 were unsuccessful gas attempts.

There were 5 Outpost/Extensions drilled, all in Jackson County, attempting to determine the extent of the Longview oil field (Fig. 3). This field was slated to be inundated by a United States Army Corps of Engineers' lake
by early 1983.

Development drilling in the Longview Field and in the Eastburn Field (Fig. 3), Vernon County, Missouri, together with the initiation of a water-flood operation in the Longview Field, resulted in a dramatic increase in production in 1979. Production in 1978 was 53,600 bbls, with 1979 production totaling 90,600 bbls. The successful application of Carmel Energy, Inc.'s patented Vapor-Therm process in the heavy oil deposits of Barton and Vernon Counties was expected to result in a large amount of both wildcat and development drilling in this part of Missouri in 1980 with corresponding increases in production.

1980

Exploration and development drilling in 1980 was not limited to the western tier of counties as in 1979. New field wildcats were drilled in Linn, Livingston, Bates, Platte, and Clark Counties; all were dry (Fig. 4). Drilling activity increased dramatically over last year, with 880 permits issued in 1980 compared to 136 in 1979. Of these 880 permits, 236 were cancelled as of year's end, 273 have not yet been drilled, 304 were completed, and the status of 67 drilled development wells is uncertain at this time. One hundred fifty-two wells were drilled for stratigraphic information.

Production increased 44% over last year to 130,350 barrels in 1980 compared to 90,600 barrels in 1979. This increase for 1980 was due to development and expansion of
the Eastburn Field, Vernon County; further development of the Longview Field, Jackson County; the northward expansion of the Walton Pool of Cass County into Jackson County; and, to a lesser extent, the reopening of the Riverside Field in Platte County (Fig. 3). It is estimated that production in 1981 will increase at least as much as it did in 1980. This estimated increase is based on the aggressive expansion program in the Eastburn Field, Vernon County, and the discovery of the northward extension of the Walton Pool into Jackson County.

The Longview Field is still slated to be inundated by a United States Army Corps of Engineers' lake by the middle 1980's.

The number of companies interested in oil and gas exploration in Missouri has increased greatly since 1979. At the beginning of 1980, eleven companies were producing crude oil. Presently Missouri has 35 companies either exploring for or producing oil. Four Canadian companies are currently interested in exploration for heavy oil in Missouri.

1981

1981 showed a 200% increase in New Field Wildcats (NFW) over 1980. NFW's were drilled in Linn, Livingston, Ray, Clinton, Buchanan, and Cass Counties (Fig. 4). All were unsuccessful, except 3 that were drilled in Ray County by Protaal Resources, Inc. These wells encountered heavy oil at approximately 200 feet deep in the Hepler sandstone.
of the lower Pleasanton Group, Pennsylvanian. The Teegarden 17-8 (section 8, T. 54N., R. 28W.) (map #3, Fig. 3) will be recompleted so that the heavy oil may be produced when economically feasible. At present these NFW's are shut-in.

Several successful Outpost/Extension wells were drilled in Cass and Jackson Counties which mainly expanded the productive area of the Walton Pool (Fig. 3). The Cassco Asphalt Co. (Rogers #1) (map #4, Fig. 3) completed a gas extension well in section 19, T. 45N., R. 32W. in Cass County. This well was drilled to extend the area of production of a home-use gas well completed in 1974. The Rogers #1 was tested at 475 mcf and is waiting on pipeline hook-up.

Jennings Drilling Co. drilled an extension well (Dunlap #1, section 9, T. 46N., R. 33W.) (map #5, Fig. 3) in Cass County that will probably lead the way in connecting the Walton Pool to the north with the Clark-Miller Pool to the south. This area has been given the name High Blue Pool (Fig. 5).

All Outpost/Extension wells were drilled with the Pennsylvanian sandstones as their primary objective.

Missouri produced 226,207 bbls of oil from 440 wells during 1981. Jackson County led the state with 128,528 bbls which was a little more than half of Missouri's production, followed by Vernon County, (heavy oil-43,975 bbls), Cass County (26,152 bbls), St. Louis County (19,167
bbls), Atchison County (7,259 bbls), and Platte County (1,125 bbls).

Production increased 70% over last year's production which was 133,256 bbls. This increase for 1981 was due in part to the northward expansion of the Eastburn Field (Fig. 3) in Vernon County, where production increased 40% over last year. The Eastburn Field produces heavy oil, and in this field a number of Enhanced Oil Recovery (EOR) processes have been used by Carmel Energy, Inc., with varying degrees of success.

The Longview Pool (Fig. 3), which has been producing oil since pre-1966, is slated to be plugged and flooded by the United States Army Corps of Engineers for a lake by mid 1980's. Accelerated production processes were initiated to extract as much oil as possible and to depressurize the formation. This accelerated production has accounted for 10,000 more bbls being produced from the Longview Pool in 1981 than were produced in 1980.

The remaining increase in production is a result of the expansion of the Walton Pool (Fig. 3) in Cass and Jackson Counties. This pool was the hottest area for drilling and production in Missouri in 1981.

1982

Drilling in 1982 has continued to increase over last year. Most of the activity is in the Jackson-Cass County area and in Vernon County. The areas between the north-south trending Clark-Miller Pool, High Blue Pool, Walton
Pool and West Grandview Pool are the most promising. Eventually these areas will be connected into one large field trending north-south (Fig. 3 and 5).

In Vernon County the heavy oil business is receiving much attention. Carmel Energy's Eastburn Field is expanding north with continued anticipated expansion slated for the mid 1980's. Several other companies are also producing heavy oil, but on a very small scale. The Vernon County heavy oil deposits are quite shallow, approximately 200 feet deep, and due to this, many companies choose this area to test their processes and ideas. A EOR research project using a solvent-surfactant solution is scheduled for the near future.

The Forest City Basin of northwest Missouri has received some attention this year with 5 deep wells being drilled. These wells had Devonian beds as their objectives, and all were non-productive. Several ran into drilling problems due to a loss of drilling fluids into porous zones. The Forest City Basin holds the possibility of good production, but has been virtually unexplored at this time.

The Lincoln Fold area of northeast Missouri has received interest recently due to the oil finds in Brown County, Illinois, in the lower-most Silurian System, Alexandrian Series, Kankakee-Edgewood Formation (Fig. 4).

The Bootheel of Missouri (Embayment Area) shows promise of deep production but is even more unexplored than the Forest City Basin (Fig. 4). Some leasing has been done by
Dow Chemical, Exxon and a consortium of independents, with some other majors expressing interest. According to Ira Satterfield, Geologist & Chief of the Oil and Gas/Subsurface Geology Section, Missouri Geological Survey, this area has its good and bad points. "Hydrocarbon potential for the area does exist based on the following evidence: 1) source rocks are present; 2) a thick sequence of Paleozoic rocks present - 8000'+; and 3) up to 3000' of unconsolidated sediment. Some of the negative features of this area are: 1) numerous faults; 2) the area is active seismically; and 3) the thick unconsolidated materials present many drilling problems."

Since the beginning of the decontrol of oil in 1978, drilling activity in Missouri has increased and will probably continue to increase if the price per barrel of oil stabilizes. The future of Missouri oil is promising, but some deep production from the Forest City Basin, Lincoln Arch in northeast Missouri, and/or Bootheel (Embayment Area) of southeast Missouri, needs to be found if Missouri is to rise from its rank of 30 out of the 33 oil producing states (Fig. 4).

The following information is about the producing oil pools of Missouri. Presently there is no gas being sold commercially in Missouri. However, several home-use gas wells are permitted each year and our records show approximately 15 of these wells in use.

Oil production in Missouri is predominantly from sand-
stones in the Pennsylvanian System. The only exception is
the Florissant Field located in northeast St. Louis County
which produces from the Kimmswick Formation of the Ordovician
System with an average present production of 1.5 BOPD/well.
The API gravity of the oil is 34.5° (Fig. 3). Accumulative
production from 1953 to July, 1982, is 968,478 bbls of oil.

The Tarkio Field located in Atchison County produces
from the sandstones of the Bluejacket Formation, Cherokee
Group, and presently averages 2 BOPD/well. The API gravity
of the oil is 26° (Fig. 3). Production from 1943 to June,
1982, is 356,298 bbls of oil.

The Riverside Pool located in southeast Platte County
produces from the Squirrel Sandstone of the Lagonda Form-
ation, upper Cherokee Group and presently averages .5
BOPD/well. The API gravity of the oil is 24° to 26° (Fig.
3). Production for 1978 to present is approximately 13,650
bbls of oil.

The Longview Pool produces from sands in the basal
Pleasanton and upper Marmaton Groups presently averaging
1.3 BOPD/well. The API gravity of the oil is 27° (Fig.
3). Accumulative production from 1944 through March, 1982,
is approximately 272,400 bbls of oil.

The Walton Pool located in southwest Jackson and north-
west Cass Counties produces from the Englevale Sandstone
(Peru) of the Labette Formation, Marmaton Group and the
Squirrel Sandstone of the Lagonda Formation, upper Cherokee
Group. Present production ranges from .5 to 2 BOPD/well
with API gravities from $24.5^\circ$ to $27.7^\circ$ (Fig. 3 and 5). Accumulative production from 1971 to 1982 is 148,711 bbls of oil.

The High Blue Pool located in northwest Cass County produces from the Squirrel Sandstone of the Lagonda Formation, Cherokee Group and at present averages 3.5 BOPD/well with an API gravity of $25.1^\circ$ (Fig. 3 and 5). Production began in December of 1981 and as of June, 1982, 1965 bbls of oil have been produced.

The Clark-Miller Pool located in northwest Cass County produces from the Squirrel Sandstone of the Lagonda Formation, upper Cherokee Group and at present averages 1 BOPD/well with an API gravity of $24^\circ$ (Fig. 3 and 5). Accumulative production from 1966 to June of 1982 is 277,058 bbls of oil.

The Eastburn Pool located in western Vernon County produces from the Eastburn Sandstone of the lower Cherokee Group, and presently averages 1 BOPD/well with an API gravity from $21.5^\circ$ to $23.5^\circ$ (Fig. 3 and 5). Production began in late 1978 and as of June, 1982, 124,608 bbls of oil have been produced.
THE "CHEROKEE" OUTCROP IN WESTERN MISSOURI

by John W. Emerson

The basal Pennsylvanian rocks outcrop in a belt along Barton, Vernon, Cedar, St. Clair, Henry, Benton, Johnson, and Pettis Counties. The nature of these formations and their relationship to the underlying rocks is best studied south of the glacial cover in Lafayette and Saline Counties.

One of the earliest studies of the Cherokee was in Johnson County. In 1868 Broadhead studied Cherokee strata along the Missouri Pacific Railroad and subdivided it into the Clear Fork, Knob Noster, and Warrensburg "groups" (Hinds and Greene, 1915). I have studied and mapped some of these rock units in Henry, Johnson, and Pettis Counties. Missile-site cores in these counties are of great assistance in correlation of surface outcrops.

Previous workers have studied isolated outcrops and correlated them by using the principle of position in sequence. The numerous channel and sheet sandstones exposed in adjoining portions of these three counties have been assigned a Cherokee age by convention. There is no doubt of their assignment if they are intercalated with other Cherokee rocks. Most of the thicker sandstones are linear valley-fill deposits, are the surface formation, and are unconformable on the rocks below. In such instances earlier workers have assigned these rock units a name based on the rock unit they overlie disconformably (Emerson, 1977).

Such sandstones lying on the Mississippian and older

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carbonates could be as old as Chesterian, Morrowan, or Atokan. If they overlie Des Moinesian strata, they could be Missourian, Virgilian, or even younger. The only way to properly ascertain their stratigraphic relationships is by detailed field mapping and by using the tools of the sedimentologist: mineralogy, grain size, sorting, and paleocurrent directions. The sandstones are not notably fossiliferous, but Ossian (1974) has shown that careful collecting in similar sandstones can be productive, especially of pollen and spores.

Morrowan and Atokan formations containing quartzose sandstones are recognized in southern Missouri (Searight and Howe, 1961). Recent work in Iowa (Lemish and others, 1981) has disclosed up to 400 feet of Atokan rocks below the Cherokee. In southern Illinois the sandstones of the Chesterian formations, Caseyville Formation (Morrowan), the Abbott and Spoon Formations (Atokan), and the Cherokee have been described in detail in both the surface and subsurface. In both Iowa and Illinois the wealth of detailed work done on the Pennsylvanian may serve as a guide to conditions in Missouri.

In Illinois (Siever, 1951) and Iowa (Lemish and others, 1981), the lower Pennsylvanian fills valleys incised up to 200 feet in pre-Pennsylvanian rocks. The streams flowed south and southwest across Illinois and most of Iowa. The only exception to the south and southwest paleotransport direction was in western Iowa where there was eastward flow adjacent to the Nemaha Ridge.

The thick, elongate, southwest-trending Mississippian
and Pennsylvanian sandstones in the Illinois Basin are considered to be fluvial, deltaic, or estuarine (Potter, 1963). Very thick elongate sandstone bodies are probably "stacked" or multistory, created by overlapping channels. Similar interpretation is made for Iowa (Lemish and others, 1981).

Schumm (1977) called attention to the fact that although such linear sand bodies are usually called paleochannel deposits, they are more accurately termed valley-fill deposits. They are composed of sediments deposited by a stream which shifted laterally, aggraded, and eroded at different times. Therefore, channel lag, point bar, natural levee, crevasse splay, and backswamp sediments would all be present in the valley-fill.

I have divided the "Cherokee" sandstones that I have mapped in the Johnson-Henry-Pettis County area into four general types. Their distribution is shown in Figure 1 and their descriptions are as follows:

TYPE A

In Pettis County, south of Sweet Springs and north of Sedalia, there are linear sandstone bodies which are disconformable on the Burlington or Keokuk (Emerson, 1981). These sandstones are very different from the other Pennsylvanian sandstones outcropping in Johnson, Pettis, and Henry Counties. These northern Pettis County sandstones are quartz arenites, very fine grained, angular to subangular, and contain no visible mica, feldspar, or carbonaceous material. Due to erosion, they seldom exceed 10 feet in thickness. Crossbedding
indicates a southwest transport direction. Their petrographic composition closely resembles the Chester sandstone of the Illinois Basin (Potter, 1963; Siever, 1953; Atherton and others, 1960), and the southern Appalachians (Emerson, 1966). The source was probably reworked sedimentary rocks such as the St. Peter or Roubidoux sandstones.

TYPE B

This sandstone has a channel form and is exposed along the south side of the Blackwater River in northeast Johnson County. It is a fine-to-medium grained quartz arenite, feldspathic, and very micaceous. The sandstone has abundant crossbedding indicating a westerly transport direction. Up to 45 feet is exposed along the river bluffs. It is unconformable on shales, claystones, and siltstones. There appears to be no basal conglomerate. Two water wells drilled in this channel show 80 feet of sandstone in one and 100 feet in the other. Ken Anderson, formerly with the Missouri Survey, found one of these to be very unusual for this area in that from surface to 80 feet was sandstone, black shale to 180 feet, and Mississippian at 180 feet. This sequence is more like the Warner-Riverton relationship in Vernon County.

Fossil tree stumps of considerable size are found in the upper part of this locality. It appears likely that this is a Cherokee sandstone and may have been deposited as a deltaic distributary channel prograding over black prodelta shales or claystones and siltstones of the delta front.

TYPE C

An unnamed valley-fill sandstone has been traced from
the Saline-Pettis county border southwest across Pettis, Johnson, and Henry Counties to the South Grand River. There are sandstone outcrops to the north, in Saline County, which may be part of the same rock unit, but this area has not been studied.

The sandstone is disconformable on Pennsylvanian and Mississippian rocks and was first noted by Richard Gentile in the 1960's while logging three Pettis County missile-site cores. The sandstones were 70, 85, and 87 feet thick. He described them as fine grained, arkosic, micaceous, cross-bedded sandstone. A basal chert conglomerate was present. Water wells in the channel also indicate more than 70 feet of sandstone.

Surface mapping of outcrops was begun by myself and students in 1976. The crossbedding directions are dominantly south and southwest. Although thick outcrops are sparse in the northern part due to lack of drainage dissection, more than 70 feet is exposed in Henry County along the bluffs of Tebo Creek. This thick sandstone exposure, disconformable on Des Moinesian rocks, was noted by Marbut (1898).

Where the valley-fill sandstone overlies Pennsylvanian rocks, its basal conglomerate contains granule to boulder size clasts of coal, shale, siltstone, crinoid columnals, abundant ironstone concretions, and chunks of limestone with Chaetetes. In this aspect it resembles the basal Warrensburg Sandstone (Emerson, 1975). Where the sandstone is disconformable on Mississippian or older carbonates, the basal conglomerate resembles that of the Warner Sandstone in St.
Clair and Cedar Counties.

Thin-section petrography of samples from Pettis and Henry Counties shows this sandstone to be quartz arenite and lithic arenite. Metamorphic rock fragments range from 5 to 13 percent, K-feldspar 4 to 6 percent, and plagioclase a trace to 2 percent.

Although some exposures of this rock unit have been previously mapped as Cherokee, it is obviously post-Des Moinesian. It is similar to the Warrensburg and Moberly Sandstones in its lithology, thickness, and linear pattern. I would like to designate it as the Calhoun Sandstone for its excellent exposures along Tebo Creek near Calhoun, Henry County.

The Calhoun Sandstone petrology indicates a probable Canadian Shield source as do the Pennsylvanian sandstones of the Illinois Basin and the Warrensburg and Moberly Sandstones in Missouri. Similar sandstones are found in scattered outcrops in northern Missouri and Iowa.

**TYPE D**

Sheet sandstones which are argillaceous and micaceous quartz arenites and quartz wackes. These deposits are usually crossbedded and/or ripple marked. One of these is the surface formation over a large area near Knob Noster, but it can be traced to the nearby Bristle Ridge (Marmaton) escarpment where it underlies the younger rocks. This sandstone is probably correlative with the Lagonda Formation. It may be a deltaic distributary or inter-distributary sandstone.

There are many similar Cherokee sandstones exposed in creek banks in central and eastern Johnson County. It is clear that there needs to be a great deal of detailed sedi-
mentological and paleontological work on these sandstones in order to elucidate their correct stratigraphic relationships.

A good model would be the study of the Indian Cave Sandstone in southeast Nebraska and in adjoining Iowa and Missouri (Ossian, 1974). The Indian Cave is considered to be a basal Permian channel sand by the Nebraska and Missouri Surveys. Ossian's lithofacies analysis indicated at least 8 different fluvial-deltaic complexes of different ages. There was some marine reworking into chenier-type bars. Ossian collected 36 species of invertebrates, 37 species of vertebrates, and 80 palynomorphs. The fossil evidence indicated a Virgilian age for these rock units.

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THE SQUIRREL SAND, A DES MOINESIAN FLUVIAL-DELTAIC COMPLEX

by David N. Cargo

The Squirrel Sand is a unit consisting of one, and in many places, two or three stacked sandstones that constitute a channel system within the Lagonda Formation in western Missouri, eastern Kansas, and Oklahoma. The name "Squirrel" is a drillers' term and not a formal stratigraphic name. The sandstone has yielded much of the oil in western Missouri, especially in Cass and Jackson Counties. It is typical of many Cherokee sands, and because it is a favorite drilling target, well control is fairly good and the unit can be studied rather easily.

The Pennsylvanian of Jackson and Cass Counties includes strata belonging to the Des Moinesian and Missourian Series. Older Atokan rocks (the Riverton Shale) are present in Vernon County but are not thought to be present as far north as Cass County. Younger Virgilian rocks crop out west of Olathe and Kansas City, Kansas. Figure 1 shows the geologic column for the Kansas City area from the top of the Mississippian to the base of the Kansas City Group of Missourian age. This includes the sandstone units which produce oil and gas in the area. Of these, the Squirrel is the most important producer.

The name "Squirrel" originated from drillers who noticed that the sand "jumped around" as a squirrel supposedly does, in allusion to its position in the section with respect to the more nearly constant stratigraphic positions of limestones.

1 Consultant, Kansas City, Mo.
<table>
<thead>
<tr>
<th>Missourian Series</th>
<th>Kansas City Group</th>
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<tr>
<td>Pleasanton Group</td>
<td>(not divided into formations)</td>
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<tr>
<td>Holdenville Sh.</td>
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<tr>
<td>Lenapah Fm.</td>
<td>ls. and sh.</td>
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<td>Nowata Fm.</td>
<td>incl Wayside ss.</td>
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<td>Altamont Ls.</td>
<td>ls. and sh.</td>
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<tr>
<td>Bandera Fm.</td>
<td>incl Bandera Quarry ss. and Mulberry coal</td>
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<tr>
<td>Pawnee Ls.</td>
<td>incl Myrick Station ls.</td>
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<tr>
<td>Labette Sh.</td>
<td>incl Lexington coal and Englevale ss. (= &quot;Peru&quot; ss)</td>
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<td>Fort Scott Ls.</td>
<td>ls. and sh.</td>
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<tr>
<td>Excello Sh.</td>
<td>sh. and coal</td>
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<tr>
<td>Mulky Fm.</td>
<td>sh., Mulky coal at top</td>
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<td>Breezy Hill Ls.</td>
<td>ls. and sh.</td>
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<td>Lagonda Fm.</td>
<td>slty sh. and Squirrel ss.</td>
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<tr>
<td>Bevier Fm.</td>
<td>sh., ls., and Bevier coal</td>
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<td>Verdigris Ls.</td>
<td>incl Ardmore Ls.</td>
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<td>Croweburg to</td>
<td>incl minor sandstones; not readable distinguishable in subsurface</td>
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<tr>
<td>Seville Fms.</td>
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<td>undifferentiated</td>
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<td>Bluejacket Fm.</td>
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<td>Warner Fm.</td>
<td>incl Warner ss. (= &quot;Burgess&quot;)</td>
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<td>Mississippian</td>
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Figure 1 - Stratigraphic Column for the Cherokee, Marmaton, and Pleasanton Groups, Cass and Jackson Counties, Missouri.
such as the Fort Scott above and the Ardmore below. The Squirrel is a fine to medium grained sandstone with varying amounts of clay and very fine grained muscovite. Its average thickness is around 20 feet, but the variation is from 0 to at least 60 feet. In the centers of major channels the unit is apt to be medium grained, have less clay, and bear water. Toward the edges of the channel, the deposits are finer, more clayey, less porous, and seemingly less wet. Overbank deposits consist of Lagonda shale, siltstone, or sandy shale, and are low in porosity and permeability. Wells in these areas record no Squirrel in their drillers' logs.

The Squirrel sand appears to comprise a number of channels. Some of these coalesce, some bifurcate, and some lie stratigraphically one on top another. It is entirely likely that in a well where the sand is very thick, the anomalous thickness represents two channels that cross there or lie one above the other along the same general trend. The upper channel erodes into the lower in many cases, so that a single sand may appear in the well record.

The fact that the Squirrel includes more than one channel can be seen in a number of logs, where an upper and a lower Squirrel have been picked. In other cases only the upper or only the lower channel may be present. Most likely there are even more than two channel levels over the entire region, although not in any one spot. This, then, is the probable reason for the variation in stratigraphic position of the Squirrel with respect to the Fort Scott and accounts for the origin of the name "Squirrel."

Distances of the Squirrel below the Fort Scott may vary
from 3 or 4 feet to perhaps as much as 100 feet. Strictly speaking, a sandstone only 3 or 4 feet below the Fort Scott is probably not a Squirrel sand but instead may be a minor sand developed in either the Mulky or the Excello Formation, both of which are present to some extent in the area. Conventional oilfield usage, however, places the Squirrel as the first sand unit below the Fort Scott.

The mid-continent Pennsylvanian is typified by a cyclothemic sequence of sediments that forms an important series of strata, both from an academic and from an economic standpoint. The portion of the sequence which lies in the Jackson-Cass area is not as thick as the portion farther west in Kansas or especially, in Oklahoma, but the existence there of three or four sands containing petroleum is the basis of almost the entire petroleum industry of Missouri. The Cherokee portion of the cyclothemic sequence contains mainly clastics and coal and virtually no limestone except for the Seville and the Ardmore.

At the end of the Mississippian, this part of Missouri and everywhere to the north was above sea level. Extensive weathering and erosion took place, causing a surface of considerable relief to form across the surficial limestones. Valleys and intervening ridges were developed on this surface, so that as a result, the early Cherokee deposition was influenced by the topography. Later the valleys became filled as an enormous deltaic system built over the region.

A basin of deposition, the Cherokee Sea, was present in Oklahoma, southeastern Kansas, and southwestern and western
Missouri. This basin received deposits from three directions. One was from the west, where the Nemaha Arch was raised above sea level. The part of this which lay in Nebraska and north-eastern Kansas had Precambrian granite exposed which became the sediment source from the west. The Ozarks formed another source of sediment, this one from the east and southeast. This source probably was active only until some time during the early Des Moinesian, after which the land area was low or disappeared altogether under transgressing seas. A third sediment supply came from the north and northeast, where a vast land area extended beyond Iowa (Lemish, Chamberlain, and Mason, 1981).

Landward of the shoreline, active erosion dominated. In low areas, however, deposition took place, primarily in river valleys and along coastlines. Thus, some of the sediments are continental, consisting of fluvial channel sands and other valley-fill sediments and coastal plain sheets of shale and siltstone, as well as coal that formed in swampy areas in coastal regions. Seaward, an extensive delta began to take shape, prograding into the Cherokee Sea. Resembling the modern Mississippi Delta, but larger, the area had no clear separation between strictly continental river valley deposition, deltaic channel and inter-channel deposition, and offshore marine deposition. Furthermore, the shoreline configuration continually changed, as the sediment supply waxed and waned and as sea level rose or fell. In the Cherokee, Marmaton, and Pleasanton sections, therefore, one can
observe the cyclical changes from marine to nonmarine conditions and back again.

A typical delta plain is shown schematically in Figure 2, as adapted from Coleman (1976). The delta plain consists of an upper part, a lower part, and a subaqueous part. The subaqueous part is that which lies below the low-tide line. Its deposits are wholly shaped by marine agents, which consist of waves, currents, and tides. In the Cherokee Sea of Squirrel time, the subaqueous portion lay to the south of Cass County. Although its position fluctuated, it probably remained south and southwest of the area throughout most of the time of Cherokee deposition. Marine incursions represented by the Ardmore Limestone and Marmaton limestones were rapid, flooding a nearly flat-lying coastal plain over a distance of hundreds of miles. Deposition of clastic sediments in the delta was interrupted at these times, and the delta was left preserved beneath the sheets of shallow-water marine limestone.

The lower deltaic plain is characterized by the interaction of both marine and fluvial processes. It is likely that much of what is seen in the Cherokee formed in this environment. Many of the channel sands are extensions of the incoming rivers that built out across the lower delta. This situation would be analogous to that in the lower Mississippi Delta today in the vicinity of the passes. Between the channels there are flat expanses of silts and clays deposited by the rivers and shaped partly by marine agents.
The upper deltaic plain at one time is under marine influence, but as the delta builds seaward, marine processes abandon it. After marine abandonment, the upper plain lies above the reach of highest tides and becomes entirely shaped by fluvial processes. Here are developed river channels, flood plains, and coal swamps. In periods of aridity, brief in the Cherokee, Marmaton, and Pleasanton, red beds formed. Red beds are more common in the later Pennsylvanian and the Permian, when conditions were changing more to aridity. A few are present, however, in Cass and Jackson Counties. Noted as "red rock" on drillers' logs, they are useful for making correlations on a local scale.

It is difficult if not impossible to determine the boundary between the lower and upper deltaic plain. The boundary
is gradational, there being no precise point at which a stream channel becomes a deltaic channel. Very likely, the channel systems of the Squirrel include portions of each. Oil occurrences do not seem to be restricted in any way to one or the other.

Above the upper deltaic plain lies the valley of the main river that feeds sediment to the delta. The valley is sediment-filled, and the sediments are alluvial. The deposits in the Cass-Jackson area for the most part do not seem to belong to the alluvial valleys. Instead, these valleys are located farther to the north and northeast in Iowa.

As previously noted, the Squirrel consists of many separate channels or channel segments. It is the nature of a large, compound delta to be continually changing. Two types of changes may be distinguished. One is channel-switching; the other is delta lobe-switching. In the first case, as a river brings loads of sediment that eventually build up and even block a channel, it may break out and form a new channel across the inter-channel plain. In this way, a system of distributaries forms. There appears to be a braided effect in the case of the Squirrel, as well as others, where channels both split and rejoin. In delta lobe-switching, the entire channel system moves over, usually as the result of a very large flood upstream. A new lobe of the delta then begins to build and the old one is abandoned. The Mississippi, for example, has 7 lobes that are recognizable and datable in historic sequence (Morgan, 1976). The 1973 flood, generally agreed to have been at least a 500-year flood, would have
caused the abandonment of the present deltaic lobe (including the area upstream past New Orleans) and establishment of a new lobe down the Atchafalaya River, were it not for the existence of floodgates at Old River and Morganza. Such a situation was prevalent in the delta complex of the Cherokee and explains the complicated system of interwoven and stacked channels of the Squirrel sand.

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GEOLOGY AND HEAVY OIL OF VERNON COUNTY

by

David N. Cargo\textsuperscript{1,2}

Vernon County has had some production of various mineral resources for many years. Coal has been mined both from strip mines and underground mines for over a hundred years from a number of coal seams in the Cherokee Group. Asphaltic sandstone has been quarried from the Cherokee. Minor amounts of sandstone and limestone have been quarried for dimension stone, road metal, and agricultural lime, and at least three limestone quarries are presently active. Crushed stone, however, is more easily obtained from tailings in the Joplin lead district to the south. Fire clay was produced in various places and used locally in the manufacture of tile and brick.

It has been known for many years that Vernon County has significant deposits of oil located in shallow sands of the Cherokee Group. Early settlers used the tarry residue gathered at surface outcrops for wagonwheel grease, and gas was produced for home heating use as early as 1909. A few local entrepreneurs produced oil in the 1920's to 1940's, and major oil companies, including Shell and Cities Service, have drilled test holes more recently. The oil is heavy and black, with an API gravity of 15\textdegree{} to 24\textdegree{}.

Economics discouraged exploitation of the resource because of the gravity and therefore viscosity, of the oil, in

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\textsuperscript{2} The author would like to express his thanks to L and B Leasing, Hutchinson, Kansas, for permission to publish this material.
spite of the fact that drilling depths are mostly less than 200 feet.

Exposed Strata

The surface rocks of Vernon County are almost entirely of Pennsylvanian age (Figure 1). A few outcrops of Mississippian rocks, totalling less than 6 square miles in area, appear along the extreme east edge of the county. The Pennsylvanian rocks include rocks of the Des Moinesian and probable Atokan Series. A geologic column is given in Figure 1.

Mississippian strata include the Warsaw and Keokuk-Burlington Formations. They are composed predominantly of limestone and contain varying amounts of chert. The surface of the Mississippian is one of erosion, with valleys cutting into it here and there. These have been filled with Pennsylvanian sediments. No evidence of oil or gas has been seen in the Mississippian.

The lowest Pennsylvanian unit is a discontinuous layer of conglomerate and sandstone assigned to the "Graydon" Formation. It consists largely of chert derived from underlying Mississippian rocks. The Riverton Formation lies above the Graydon, or where the Grayson is absent, directly upon the Mississippian. It is mainly shale, with some sandstone. Three coal zones are present in the Riverton. In the old study by Greene and Pond (1926) the Riverton was termed the Dederick Shale. The Graydon and Riverton are considered to be Atokan in age.
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<td>Bluejacket sandstone</td>
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<td>Rowe</td>
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<td>Warner sandstone</td>
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<tr>
<td></td>
<td>Atokan</td>
<td>Riverton shale, thin coals</td>
<td>Graydon discontinuous basal conglomerate</td>
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<td></td>
<td>(=Dederick)</td>
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<td>Warsaw</td>
<td>Burlington-Keokuk</td>
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<td>Chouteau Group, including Northview Shale</td>
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<td>Jefferson City Dol.</td>
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<td>Eminence Dol.</td>
<td>Potosi Dol.</td>
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<td>Derby-Doe-Run Dol.</td>
<td>Davis Fm.</td>
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<td>Lamotte Ss. (=Reagan Ss.)</td>
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<td></td>
<td>Arkose, conglomerate, shale</td>
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<tr>
<td>Precambrian</td>
<td></td>
<td>Granite, rhyolite, gneiss, schist</td>
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Figure 1 - Stratigraphic Column for Vernon County, Missouri
The lowest Des Moinesian unit is the Warner Formation. The Warner, consisting mainly of sandstone, has been called the Clear Creek Sandstone (Greene and Pond, 1926) and "Bartlesville" by some drillers. It is unlikely that this sandstone in Vernon County can be directly correlated with the Bartlesville, and the name Clear Creek has been superseded because of its use as the name of a Middle Devonian unit elsewhere. The Warner may include conglomerate at its base, and further up, is sandstone with silty and shaly zones interbedded with the sands. The sandstone is oil-bearing or is impregnated with asphalt over much of the county. It is a prime target for exploration and is known to contain oil in many places. Lithologically, the Warner is friable, poorly cemented, fine to coarse grained, and micaceous. An average thickness might be around 30 feet. Outcrops of the Warner occur in the central and eastern parts of the county, and the area east of the outcrop along the east edge of the county must be discounted as a potentially productive area, as there is only the Riverton Shale and the Mississippian present at the surface there.

The Rowe and Drywood Formations lie above the Warner. Both of these units consist of shales and coals and are not readily separable in drillers' or mechanical logs. Some sandstone does occur in the Drywood near the town of Deerfield from which bitumen has been reported. Possibly this zone correlates with the Eastburn Sand.

Oil also occurs in the Bluejacket Sandstone above the
Drywood. The Bluejacket is potentially productive in parts of the county. It is lithologically similar to the Warner but is less extensive in area. The Bluejacket has, like the Warner, been correlated with the Bartlesville of Kansas and Oklahoma. This correlation is more likely than one between the Warner and the Bartlesville.

The Seville Formation, a marine unit that includes a thin gray limestone, lies above the Bluejacket. This is the lowest readily identifiable Pennsylvanian limestone, but it is not everywhere present in Vernon County. Above the Seville are cyclical series of shale, underclay, and coal. These are the Weir, Tebo, Scammon, Mineral, Lagonda, Mulky, and Excello Formations in order, oldest to youngest. Some thin limestones and sandstones are present in these units. The most notable sand is the Squirrel sand in the Lagonda Formation, but it is present only in thin, shaley, discontinuous patches, if at all, in the northwest corner of the county.

The formations from the Warner through the Excello comprise the Cherokee Group and form the outcrops over the great majority of the surface of Vernon County.

The Marmaton Group crops out mainly in the northwest part of the county and near the tops of the various "mounds" such as Blue Mound. Where the Cherokee is characteristically composed of shale and sandstone, the Marmaton has these lithologies plus considerable limestone. The basal unit is the Fort Scott, which consists of a lower limestone, the Blackjack Creek, and an upper limestone, the Higginsville, separated by a shale. The limestones of the Fort Scott are
fairly resistant and form a low escarpment that separates the Nevada plain (the geomorphic expression of the Cherokee outcrops) from the higher, more rolling country to the northwest, known as the Warrensburg plain.

Pre-Pennsylvanian rocks include Mississippian limestones, dolomites of Cambrian and Ordovician age, and Precambrian igneous and metamorphic rocks. Depths to the Precambrian in seven wells reported by the Missouri Survey range from 1005 to 2094 feet. No oil or gas production or shows have been found in pre-Pennsylvanian strata.

Prominent structural features of the county include portions of the Vernon Syncline, the Swartz-Garland Dome, the Schell City-Rich Hill Anticline, and a fault zone lying roughly parallel to the latter anticline. The general trend of these structures is west-northwest.

The Vernon Syncline, which lies along the boundary between T35N and T36N from R33W eastward an indeterminate distance, has Precambrian metamorphic rocks of probable sedimentary origin which are believed to be preserved in a syncline dating back to the Precambrian (McCracken, 1971).

The Swartz-Garland Dome, the eastern flank of which is located in section 6, T34N, R33W, is a small closed dome in the Cherokee Group (McCracken, 1971).

The Schell City-Rich Hill Anticline, which lies along the northeast corner of the county, is a large asymmetrical anticline. Some exploratory drilling has been done along this structure, but the nature of closure, if any, is unknown.
Parallel to the Schell City-Rich Hill Anticline, detailed field mapping has disclosed that limestone beds, the Higginsville in particular, have been faulted along the southwest limb of the anticline. Structurally disturbed strata have also been recognized in rocks of Cherokee age (Gentile, 1976).

Elsewhere in the county, structures are gentle and subdued with regional dips of only 10 to 15 feet per mile, with dips as great as 100 feet per mile occurring in the west central portion of the county from Nevada westward. This appears to be an area of fairly intense deformation with some of the resulting anticlinal structures showing indications of closure (Figure 2).

At the present time, the oil of Vernon County is attracting considerable attention from operators who are pursuing some form or another of enhanced oil recovery (EOR). It is obvious from the drillers’ logs, sample logs, and mechanical logs that have been accumulated from hundreds of holes put down over the years that large quantities of oil are present in the shallow sandstones of Vernon County. At the same time, however, production of this oil using enhanced recovery or some unconventional method such as mining will be highly dependent on the world and domestic economic and energy situations over the next few years.

*The outcrop of Warner Sandstone at Stop 4 on the field trip lies approximately 0.5 mile northeast of the crest of the anticline.
EAST–WEST CROSS SECTION through VERNON COUNTY MISSOURI

Fig. 2

DNR 5
DNR 7
DNR 2
DNR 3
DNR 19
DNR 20
DNR 21
DNR 22

Surface
Seville
Bluejacket
Rowe–Dinwood
California
Maysville

General American 1–1
Shell 191–C
Shell 63
Shell El

0
100
3
Feet
miles

STATE OF KANSAS

DNC, 1982
Attempts at producing oil in Vernon County in the past were largely unsuccessful in recovering oil in economic quantities because of the high viscosity of the oil. Recent development of the Eastburn Field by Carmel Energy using enhanced recovery has been successful, however, and the entry of other operators into the area further strengthens the development picture. Carmel regards its secondary recovery process as, if not perfected, at least sufficiently developed to be commercial.

Reports by the Missouri and Kansas Geological Surveys for the U. S. Department of Energy have been prepared on the heavy oil and tar sands of the region. These include summaries of the results of core-drilling in Barton and Vernon Counties in Missouri and Bourbon, Crawford, and Cherokee Counties in Kansas. A resource base of oil in place is summarized in Table 1. Both reports state that the quantity of oil present is much lower than that estimated by previous workers and further, that none of the resource could be regarded as reserves, that is, economically producible under market and technological conditions at the time of those writings.

Two responses can be made to the conclusions of the survey reports. First, the amounts of resource present seem to be approximately correct. While both reports seriously downgraded the earlier estimates, they still point to the presence of very large amounts of oil in the area. The early estimates were based on far less data and on unrealistic appraisals, some of which were pure fantasy, such as one
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<tr>
<td>Missouri*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bluejacket (Upper plus Lower)</td>
<td>511,979,000 bbls</td>
<td></td>
</tr>
<tr>
<td>Upper Warner</td>
<td>1,165,139,000</td>
<td></td>
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<tr>
<td>Lower Warner</td>
<td>226,316,000</td>
<td></td>
</tr>
<tr>
<td>Eastburn</td>
<td>not available</td>
<td></td>
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<tr>
<td>Kansas**</td>
<td></td>
<td></td>
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<tr>
<td>Combined units</td>
<td>225,000,000</td>
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<tr>
<td>Total</td>
<td>2,128,434,000 bbls</td>
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*Figures from Wells (1979); includes total of "conservative" and "speculative" figures.

**Figures from Ebanks et al (1977).

Table 1 - Estimates of Amount of Heavy Oil Resources in the "Tar Sands" of Southwestern Missouri and Southeastern Kansas.
which suggested that 30 billion barrels of oil are present in Vernon County. Present information suggests that a number of fields can be discovered and developed, each capable of yielding a few million barrels. If, for example, 5 percent of the 1.4 billion barrels estimated conservatively by the Missouri Survey (Wells, 1979) to be present is recoverable, then the reserves would be 70 million barrels. This figure, while reasonably within the realm of possibility, is only by way of example, and does not represent an estimate using hard data.

Second, the statements in the survey reports that none of the oil can be considered as reserves were made in 1977 and 1979. Oil prices were lower then than now, and secondary recovery technology appropriate to the area had not been developed. The fact that commercial amounts of oil are now being produced means that at least some of the resource base can be elevated to a reserves category.

The productive or potentially productive zones occur in the Riverton, Warner, and Bluejacket Formations. Following is a description of the units and some comments on their origin. The units of interest are sandstones lying between the top of the Mississippian to the top of the Bluejacket. These are the Lower and Upper Warner, Eastburn, and Lower and Upper Bluejacket. They are not formal stratigraphic units but are usable local designations. The Lower Warner is a sand within the Riverton Formation and is possibly correlative with the true Warner of Oklahoma. The Upper Warner, often called simply Warner, is the thickest, most widespread sandstone in the county and is the main part of the Warner Formation of southwest
Missouri. The Eastburn lies above the Warner and appears to be of rather limited areal extent along the Missouri-Kansas state line. The lower Bluejacket is present over much of the county but is exposed or eroded throughout most of the eastern part. It is nearly as widespread as the Upper Warner but does not attain the thickness of the Upper Warner. The Upper Bluejacket is a discontinuous unit present only in isolated pockets. It does not attain any great thickness and is generally silty or shaly and thus is the least favorable of the units discussed for oil production possibilities.

The Riverton Formation, of Atokan age, consists mainly of shale with lesser amounts of sandstone and coal. Exposures are present along the more deeply incised portions of the major streams, especially in the eastern half of the county. Greene and Pond (1927) called the same shale unit the Dederick Shale, after exposures near the town of Dederick, just west of Eldorado Springs.

The Riverton is present over the entire county except in the small areas where the Mississippian crops out. It is a continuous blanket of fairly uniform thickness, averaging about 45 feet.

The shale portion of the Riverton is black to dark gray, weathering orange, fissile to thinly fissile, and with layers of iron carbonate and coal. The coal has been mined in a number of places. Three coals are present, of which the lowest is thickest, ranging up to 3 feet. Greene and Pond (1927) report that the Riverton ("Dederick") contains "valuable coal beds" in the eastern part of Vernon and in the
neighboring counties of Cedar, Dade, and Barton. They also report that the upper coal has been mined near Nevada and Clear Creek.

The sand portion of the Riverton includes the Lower Warner. It is developed best along the Kansas-Missouri border, where it reaches thicknesses of 30 to 40 feet. Toward the eastern portion of the county, it becomes more poorly developed and finally ceases to exist as a discernible sand body. The quality of sand ranges from a clean, coarse grained quartz sandstone in the thicker parts to a silty-shaly sand toward the east. Large-scale cross-bedding and ripple cross-bedding were reported by Wells (1979).

Oil occurrence within the Lower Warner is generally restricted to the western edge of the county, and shows are commonly described as "dead oil stain" and "gilsonite spots."

The Upper Warner Sandstone is part of what is known in Missouri as the Warner Formation. It is, judging from what is said in the literature, stratigraphically above the Warner of Oklahoma. Thus, there is a problem in nomenclature. No attempt will be made to solve it here, but the sand will simply be referred to as the Upper Warner sand, which lies above the Lower Warner and the intervening shale of the rest of the Riverton. The Warner Formation of Missouri is defined as lying between the Rowe Coal and the Riverton. The Upper Warner is the best developed of the sands described here. It attains thicknesses in excess of 80 feet in parts of the county. As with the Lower Warner, the quality of the Upper Warner sand ranges from a clean, fine grained quartz
sandstone to a silty, shaly sandstone. The isopach of the Upper Warner shows a westward trend (Figure 3) which seems to fit the fluvial-deltaic system used by Ebanks (1977) to describe the depositional environment of the Cherokee strata in the adjoining area of Kansas.

Field observation of outcrops of the Upper Warner reveals distinct channels of clean sand with large scale cross-bedding and inter-channel areas of silty, shaly sand with thin coal lenses and woody plant material (Figure 4).

This sand represents the most favorable target for exploration. In areas where the sand is thick and relatively clean, there have been several reports of "live bleeding oil." As seen in Table 1, the greatest percentage of the oil in the region is in the Upper Warner.

The Eastburn sand is a lens within the Rowe-Drywood, probably in the upper part of the Drywood portion. It is present in the western part of the county and is the producing zone in Carmel Energy's Eastburn Field southwest of Deerfield, Missouri. This sand unit has an average thickness of about 5 feet but is as much as 30 feet thick in the productive area. It is difficult to correlate the Eastburn with anything in the outcrop, but there are enough outcrops of Rowe-Drywood along Drywood Creek that this might be a good possibility for further study. The sand is mostly a very fine to medium grained sand containing quartz, some rock fragments, mica, and clay. Cement includes kaolinite, calcite, and siderite (Ebanks and Weber, 1982).

The Lower Bluejacket sand is the next best developed
Sandstone, tan, very fine grained to fine grained (62–177 μm), well-sorted to very well-sorted, micaeous, subangular, well-cemented

Sandstone, tan, very fine grained, very well-sorted, micaeous, subangular, well-cemented

Sandstone, weathers gray to tan, very fine grained, very well-sorted, subangular, well-cemented

Sandstone, fine grained (125–177 μm), well-sorted, micaeous, subangular, well-cemented, very slightly asphaltic, cross-bedded in places.

Sandstone, weathers gray to tan, very fine to fine grained (62–250 μm), very well to well-sorted, well cemented, micaeous, subangular

Figure 4 - Measured section at north end of outcrop of Bluejacket Sandstone, east side of U.S. Highway 71, SW¼, NW¼, Sec. 9, T36N, R31W, Vernon County, Missouri, south of Marmaton River Bridge. Geology by Steve Allee, Janice Mather, Debbie Wait, Cindy Moore, and Ken Elliott, Northwest Missouri State University. ¼"=1'
after the Upper Warner, although it does not reach the thickness of the Upper Warner. It is up to 25 feet thick and averages 10 to 15 feet thick. The overall characteristics of grain size, porosity, permeability, sorting, abundance of fines, and matrix materials as reported by Wells (1979) make this a rather poor reservoir rock. Generally it is fine grained, grading through siltstone to thinly laminated silty shale. Even though the sand is not an ideal reservoir, the areal extent of the unit may make it an important reservoir in some places.

The sandstones of the heavy oil area were deposited during the Atokan and lower Des Moinesian intervals. At the close of Mississippian deposition, there was widespread uplift, exposing the limestone to deep and prolonged erosion. As a result, an irregular surface was developed on the Mississippian which included valleys and karst topography. The relief is sufficient to cause problems in contouring the Mississippian for structural interpretations.

Weathering of the Mississippian left a residue of broken rock fragments including much chert. The cherty zone ranges up to a few feet in thickness. It cannot be easily distinguished in electrical or radioactivity logs. In some places there is no cherty zone present. For example, Riverston Shale lies on fresh, unweathered limestone where Highway 97 crosses Horse Creek just east of the Cedar County line.

Following the period of weathering and erosion of the limestone surface, a vast array of Pennsylvanian sediment was laid down as streams brought clay, silt, and sand to the
delta that covered many thousands of square miles. In the vicinity of Vernon County, drainage from the Ozark uplift westward into the Cherokee Sea in southeastern Kansas probably added a significant amount of sediment to the area. Although cross bedding seems to be to the south in many outcrops, the isopach map of the Upper Warner (Figure 3) supports the idea that drainage was westerly. Other isopachs, drawn by the author, of various units suggest that there may have been a shift to more southerly drainage after the Upper Warner was laid down. Patterns in younger deposits such as the Squirrel sand in Cass and Jackson Counties show that drainage in these was mainly from the north toward the south and southwest.

The area which is now Vernon County consisted of a complex of stream channels, flood plains, and delta. The channels are interpreted as being distributary channels in the upper or middle part of the delta. Areas between channels where sands are thinner or are replaced by shales are deltaic plains where mud and coal were laid down. Fossils of Calamites and other large plants found in the Riverton Formation suggest either that those plants grew there in place or that the woody fragments were floated in from upstream. No marine fossils were found in the few localities visited.

The hydrocarbon content of the sandstone originated from the vast amount of organic material that accumulated in the delta. Much of the area was undergoing rapid deposition with apparently little disturbance or destructive wave action because the shoreline was further off to the west. Shifting
sedimentation patterns caused deposition of shales over the channels, trapping the oil. Traps appear to be wholly stratigraphic, and areas of hydrocarbon concentration do not coincide with structural highs.

None of the sands is a blanket or sheetlike deposit. Some of the earlier inflated estimates of the oil resources of the area were erroneously made on the assumption that the sands were, if not uniformly thick, at least thicker and more nearly continuous over the area than is actually the case. Instead, it would appear that the most porous and permeable reservoir rocks are the channels, which occupy only a fraction of the total deposit.

Ebanks et al (1977) indicate that the highest degree of oil saturation is in the tightest sands. They attribute this to the flushing action of water in the more porous sands as well as to chemical reaction of the oil with the water. Experience with the Squirrel sand farther to the north suggests that flushing action is significant, as considerable water is produced there in thicker, cleaner sections of the channels.

Cores from older wells and from the Heavy Oil and Tar Sands project test holes (Wells, 1977 and 1979, Ebanks et al, 1977), as well as field examination of the outcrops, indicate that the various sandstones are highly variable in nature. Clean, porous sands occur in thick, massive lenses in some areas, but there is much interbedding with tight sand and shale. Phosphate, siderite, hematite, and clay nodules abound. Many of the zones are effectively plugged with clay, muscovite, and carbonaceous residue. These lie in thin par-
tings and form a block to vertical fluid movement. This can be a problem in formation stimulation and recovery of the oil. Because the sand bodies are lens-shaped, these permeability barriers also exist laterally.

Core analyses show porosities averaging about 18.5 percent for the Bluejacket and 22 percent for the Warner. These are good, but the permeability barriers may negatively offset the value of the good porosity in many areas. Permeabilities range from 1 or 2 millidarcies to over 700 millidarcies. Because favorable reservoir conditions may change to unfavorable over only a few feet laterally, the existing well control is not of sufficient density to map porosity and permeability changes except within developed fields.

There are two or three possibilities for recovery of the oil. One is by enhanced recovery from conventionally drilled wells. The other is by mining.

The first method is now being used by Carmel and Mapco Production. Carmel Energy is using or has experimented with both steam flooding through an injection well and "huff and puff" steam injection into production wells. Steam flooding is considered to be more successful at the Eastburn Field than the other method. Mapco is constructing a carbon dioxide injection facility on their lease in section 29, T36N, R33W. Depths along the western edge of the county are 200 to 300 feet to the producing zones, so that there is effectively no reservoir pressure. It may prove to be true that carbon dioxide and other chemical methods of enhanced recovery are more effective in deeper horizons where pressures are higher.
Mining of the bituminous sandstone might well be considered for the eastern part of the county. The first report by Wells (1977), on strippable tar sands, suggested the possibilities of mining in areas where the sands lie near the surface. Quarries south of Bellamy and elsewhere produced bituminous sandstone for a few years. The Bellamy pit, now partly filled with water, is about 300 feet across. The sandstone with the oil is about 8 feet below the ground surface and is black in color, weathering to a light gray on the outside. It has a distinctly petroliferous odor, and the water in the pit has an oily scum on it. Mining was done there by the Silica Rock Products Company in section 24, T34N, R30W, who used the material for road blacktopping.

REFERENCES CITED


"DEEP" OIL IN WESTERN MISSOURI
by John W. Emerson

The focus of the 1982 meeting is on Cherokee oil and gas production from western Vernon, Bates, Cass, and Jackson Counties. We should not, however, overlook the early day efforts to find "deep" production in the eastern parts of these counties and in neighboring Lafayette and Johnson County. A "deep" well in this area would be 2000 feet.

In the early 1900's there were a number of wells drilled in these areas in search of "Trenton" production. The Trenton Formation was named in 1838 for its type section in Oneida County, New York. It belongs to the Champlainian Series of the Ordovician System. "Trenton" is a drillers term for limestone from this portion of the Ordovician section. In Missouri and Illinois the "Trenton" would be equivalent to the Plattin-Kimmswick interval.

The discovery of the giant Lima-Indiana Field at the northern juncture of Indiana and Ohio in 1896 sparked a great "Trenton" play all over the Midwest. By the end of 1939 the Lima-Indiana Field had produced 107,000,000 barrels of oil and 800,000,000,000 cubic feet of gas (Cohee, 1941).

In Lafayette County the Higginsville Prospecting Company well drilled in 1898 reported a "Trenton" show. In 1902 the City of Higginsville drilled a water well which reported a "Trenton" show.

Most of the early cable tool oil tests in Missouri were drilled by promoters who reported amazing and abundant shows

1 Professor of Geology, CMSU, Warrensburg, Missouri
of oil and gas. One of the more active of these appears to have been S. J. Hatch of Kansas City. Some very entertaining stories can be gleaned from well files of the Missouri Geological Survey. A few of these have been abstracted as follows:

**Case A: Cass County, 1918-1919**

The Missouri Oil Company of Delaware test was drilled by W. E. Niles of Kansas City. The company changed its name to the Latour Oil Company in 1919 and the farm name was the Ratzlaff No. 1. In 1918 and in 1919, Niles sent a number of oil-stained sand samples to the Survey but made no mention of the interval from which they were obtained. The well had a T. D. of 1808 feet in a red sand, probably granite wash. The drillers log reported an oil show only at 1700 feet.

A log of the Niles well was found in papers of the Estate of S. J. Hatch of Kansas City. His log indicated a "Trenton" show at 1500 feet in addition to the deeper show. Also on this log was a notation that Mallory and Pallette of Warrensburg had been in his office for consultation.

**Case B: Jackson County, 1923**

The Lewis, Martin, and Reiser Winfrey No. 1 near Buckner reported 11 different oil shows between 1200 and 1800 feet. A wonderful well! But no production.

**Case C: A Jackson County Comedy Classic!**

The Lewis, Martin, and Reiser Perrin No. 1 was drilled in 1924, 1925, and 1926 near Buckner. A long series of letters between Lewis and the Survey staff read something like this:

- Sept., 1924 - Samples are from the Gasconade: SURVEY
- Oct., 1924 - Samples are from the Davis: SURVEY
- Nov., 1924 - Last samples are granite. No sedimentary
Nov. 12, 1924 - Still drilling, black foam coming up from bailer: LEWIS
Nov. 13, 1924 - Doubt it petroleum: SURVEY
Nov. 17, 1924 - Sending cuttings and bottle of foam: LEWIS
Dec. 1, 1924 - Cuttings granite, black stuff grease: SURVEY
Dec. 26, 1924 - At 2670 feet, still black foam: LEWIS
Jan., 1925 - Cuttings still granite, no oil shows: SURVEY
Feb., 1925 - At 2835 feet, still getting oil: LEWIS
Mar., 1925 - At 2920 feet there is a change from red granite to green metamorphic rock: SURVEY
June, 1925 - Still drilling, still getting black foam: LEWIS
Nov. 10, 1925 - Down to 3926 feet. Look carefully at sample #708: LEWIS
Nov. 13, 1925 - #708 is black mica granite: SURVEY
Jan., 1926 - Samples from 4080 feet are granite: SURVEY

A letter concerning this well was sent to the Survey from
V. F. Master, a Kansas City geologist on Jan. 29, 1926. It said, "looks like this one is being kept going for a meal ticket. The same applies to the Guy well as it hit granite months ago and is still drilling." He also stated "Hatch was at the location and said there was a good Trenton showing in the Rich Hill well."

A log from the nearby Guy well, found in the papers of the S. J. Hatch estate, indicated 15 different oil shows, including oil in shelly lime at 2187 feet and 2203 feet. The Survey geologist who logged the cuttings said that the sample from 2188 feet was granite and also that "S. J. Hatch made this location and probably most of the oil."

Case D: Johnson County, 1923-1925

A deep oil test just north of Warrensburg was drilled by Well A. Pallette, the gentleman who had consulted with S. J. Hatch about the Niles well in Jackson County. This well reportedly went about 1800 feet. Papers from the S. J.
Hatch estate included a lithologic log showing eight different showings of oil, one of gas, and one of zinc, between 1000 and 1600 feet.

The stories about this well led to an offset drilled in 1965 by George Norris from Kansas. This well was drilled to 1115 feet and the attempt to drill further was abandoned when funds ran low. The well produces abundant water.

**Case E: Southeast Bates County, 1939**

The Monarch Royalty Corporation of Kansas, whose office was in Tulsa, Oklahoma, drilled a 1434-foot test. They presented the Survey with a bottle of oil skimmed from the hole and claimed that they had sent Sinclair a sample cut which had an excellent showing of oil. They were mystified as to why the Missouri Survey geologists couldn't find oil in their sample cut.

Cities Service and a few other large companies drilled several deep tests in Jackson and Cass Counties in the early 1960's but apparently found nothing interesting.

The failure of the early wildcat wells and the later efforts of the 1960's should not condemn western central Missouri deep projects. This part of the state has many untested anticlines.

An excellent analog for western Missouri possibilities would be the Dupo Field, St. Clair County, Illinois, seven miles southeast of St. Louis. This field is on the north end of a northwest trending, north plunging anticline, with a steep west dip and a gentle east dip. The Dupo Field produces from the "Trenton" (Kimmswick) at depths of 500-700
feet. The field was discovered in 1928 and by 1940 cumulative production was 1,275,000 barrels from 670 acres (Cohee, 1941). By 1964 the field had produced 2,865,000 barrels of 33° API gravity oil (Misra, 1964).

Western Missouri has the same type of structures and similar rocks. They await the drill!

REFERENCES CITED


1. Marmaton River Bridge on Highway 71 to Carmel Energy.

mile  cum.

0.0 0.0 Bridge over Marmaton River on U.S. 71 (proceeding south)
0.1 0.1 STOP NO. 1. Park cars as far off onto right shoulder as possible. This is a busy highway, so use caution. Outcrop of Bluejacket channel sandstone.

0.8 0.9 Junction with Rte. M. Stay on 71.
3.2 4.1 Highland Avenue.
0.5 4.6 Nevada City Limit.
0.2 4.8 Exit to right onto Business Rte. 71.
0.7 5.5 Curve to right.
0.5 6.0 Stay on four-lane.
0.2 6.2 Junction of U.S. 71 and U.S. 54. Turn right (west) onto 54 and proceed west through town.
1.0 7.2 Cottey College.
0.5 7.7 West city limits of Nevada. Continue on four-lane divided highway 54.
1.3 9.0 Bridge over Little Drywood Creek.
1.9 10.9 Junction with Rte. 43. Stay on 54.
0.1 11.0 Highway 54 narrows to 2 lanes. Caution.
0.3 11.3 Outcrop of Rowe-Drywood shale north of road along creek bank.

2.7 14.0 Excellent exposure of Warner, Rowe-Drywood, and Bluejacket along banks of Dry Wood Creek, especially by abandoned bridge abutment. Because of the difficulty of parking cars on the curve in the highway here, no stop will be made. The Warner is the massive sandstone by the abutment; the Bluejacket caps the hill to the east.
0.3 14.3 Narrow bridge -- caution.
0.4 14.7 Curve to southwest (left).
0.2 14.9 Enter Deerfield, population 95.
0.6 15.5 Junction with Rte. H; continue west on 54.
3.3 18.8 Overpass across Kansas City Southern Railroad.
0.8 19.6 Junction of U.S. 54 with Rte. T. Turn south onto Rte. T. toward Eve.
0.3 19.9 Cross tracks of Missouri, Kansas, and Texas Railroad -- Caution. Rough crossing! Downtown Eve.
2.7 22.6 Road is traversing upper Cherokee shales. Fort Scott limestones cap the hills to the west. Junction with Rte. KK; continue south on T.
0.5 23.1 Oil field of Carmel Energy to east of road.
1.0 24.1 Bridge across Moores Branch Creek.
0.1 24.2 STOP NO. 2, Carmel Energy, Inc. headquarters. Turn left into parking lot.

END OF ROAD LOG FOR MORNING LEG OF TRIP. After leaving Carmel Energy's Eastburn Field, return to Nevada for lunch at the Eagles clubhouse, which is just past the two motels on the east end of town on Highway 54.

Afternoon leg of field trip: Leave Eagles clubhouse and proceed to U.S. 71. Turn south on 71 and continue for 10.4 to junction of 71 and Rte. DD.

0.0 0.0 Junction of Highway 71 and Rte. DD. Turn left (east) across median onto Rte. DD. Caution!
0.4 0.4 Cross tracks of Missouri Pacific Railroad -- Caution.
3.1 3.5 Outcrop of Warner Sandstone in ditch along south edge of road. This area is floored by Warner, with a veneer of weathered Rowe-Drywood shales lying on top of the Warner.
0.5 4.0 Bridge over Little Clear Creek.
0.1 4.1 Curve to south.
0.2 4.3 Outcrops of Rowe-Drywood along both sides of road.
0.6 4.9 Curve to east.
0.6 5.5 Bridge over Clear Creek. This southeast part of the county consists mostly of Warner at the surface, with softer Riverton Shale exposed below the Warner where the streams have eroded through the Warner. The presence of the sandstone at the surface results in a much more rugged topography than that to the west and north where a thicker sequence of Cherokee shales is eroded into a nearly level plain.

0.2 5.7 Outcrops of Rowe-Drywood along road.

1.3 7.0 Outcrop of massive Warner Sandstone along west bank of Walnut Creek. Curve; bridge across Walnut Creek.

1.0 8.0 Curve to south -- caution, sharp turn. Rowe-Drywood crops out just west of curve.

0.2 8.2 Bellamy. In a burst of civic pride, someone has painted the sign blue. The old sign, however, used to give the population (14).

0.6 8.8 STOP NO. 3. Asphalitic sandstone quarry. Turn left into parking area just off road. Because of broken glass, nails, etc., we will walk the quarter mile to the quarry. Bring hammers. See Figure 1.

--- 8.8 Leave quarry and turn south on Rte. DD.

1.3 10.1 Junction with Rtes. A and B. Turn east (left) on Rte. B.

0.7 10.8 Outcrop of Rowe-Drywood along roadside.

1.2 12.0 Junction with Rte. NN. Turn north on NN toward Montevallo. Outcrops of flaggy sandstone of Rowe-Drywood next to road at intersection.

0.2 12.2 Note fireplace chimney of house at left of road. It is made of locally quarried sandstone.

0.3 12.5 Old building at west edge of road is made of local sandstone. The marks in the blocks are made by a stone-chisel; are not ripple marks. Much sandstone was formerly quarried for construction and used in foundations, fireplaces, and pillars at driveway entrances. Most of it is asphalitic with a faint salt and pepper appearance.

1.1 13.6 Cherokee shales in ditch along road. The orange color of this part of the section contrasts with the drab colors west of Highway 71.
Warner Sandstone

Sandstone, tan, very fine grained, argillaceous, micaceous, well sorted, subangular, well cemented, platy, non-bituminous

6'-0" Sandstone, light tan to white, very fine grained, micaceous, well sorted, well cemented, sub-angular

3" Clay, thin layer

3'-9" Sandstone, tan with light brown layers, fine grained, micaceous, well sorted, subangular, well cemented, bituminous

1'-0" Sandstone, tan, very fine grained, micaceous, well sorted, well cemented, subangular, some bituminous coal

5'-10" Sandstone, light gray on outside, black inside, fine grained, micaceous, well sorted, well cemented, subangular, ripple marked, heavily impregnated with bitumen

Figure 1 - Measured section at quarry at Stop 3, SW ¼, Sec. 24, T34N, R30W, Vernon County, Missouri. Geology by Steve Allee, Janice Mather, Debbie Wait, Cindy Moore, and Ken Elliott, Northwest Missouri State University.
0.5 14.1 Curve to east, then north, then east, and so on. Stay on blacktop. Outcrops of lower Cherokee are present at numerous places along route. The route is on an upland floored by Warner.

4.8 18.9 Junction with Rte E, Montevallo to right. Turn west (left) onto Rte. E. This hilly area is formed by differential erosion of Warner (resistant) and Riverton (non-resistant).

2.1 21.0 Entrance to Batesco stone quarry. Crushed limestone is being obtained from the Mississippian. An overburden of a few feet of easily strippable Riverton shale is present.

0.5 21.5 Descend into valley of McCarty Creek. There are good outcrops of Warner along McCarty and Clear Creeks.

0.2 21.7 Bridge over McCarty Creek. Creek has eroded through Warner into Riverton.

0.3 22.0 Outcrop of Warner Sandstone.

3.0 25.0 Turn right from Rte. E onto gravel road and jog to left, then right (north). This place is called Sandstone on the map. Continue north on gravel road.

0.3 25.3 Cross Texaco-Cities Service Pipe Line.

2.8 28.1 Junction with Rte. K -- stop. Turn east on K.

0.5 28.6 Curve to north.

0.7 29.3 Curve to east.

1.1 30.4 H-9 Missile Silo. There are numerous missile silos in this region. Each is about 90-100 feet deep. Core samples were taken from each and were described in detail. This has provided good information about the subsurface formations. The logs are available from the Missouri Survey in Rolla.

0.4 30.8 Curves next two miles.

2.8 33.6 Outcrop of Warner Sandstone. Bridge across West Fork of Clear Creek.

0.2 33.8 Outcrop of Warner east of road.

0.4 34.2 Junction with U.S. 54 -- stop. Turn east to Dederick. The type locality of the Dederick Shale, now the Riverton, is along Clear Creek on the east edge of town.
0.2 34.4 Junction 54 and Rte. AA (in town). Turn north on AA -- caution, this is a left turn from a busy highway. Proceed north on Rte. AA.

0.7 35.1 Curve to east. Water tower.

0.3 35.4 Curve to north.

0.9 36.3 Creek, outcrop of Warner in banks.

2.0 38.3 Junction with Rte. EE. Continue north on AA. This area is a plain underlain just beneath the surface by Warner Sandstone.

0.5 38.8 H-11 Missile Silo.

1.5 40.3 Cross Kitten Creek.

0.6 40.9 Outcrop of Warner along roadside.

2.1 43.0 J-7 Missile Silo.

2.5 45.5 Outcrop of Warner in side road.

0.2 45.7 Junction with Rte RA. RA goes east to Schell-Osage Wildlife Area. Greene and Pond (1926) report numerous outcrops of Mississippian in the area to the east of here, but these are not readily found. Large blocks of weathered limestone and chert, highly fossiliferous, are present as "float."

0.6 46.3 Schell City. Turn west at Bandstand and follow highway through curves out of town.

1.0 47.3 Junction with Rte. C. Proceed west on C.

1.9 49.2 Junction with Rte. M. Leave Rte. C and continue west on Rte. M.

0.8 50.0 STOP NO. 4. Large outcrop of Warner Sandstone along east side of valley of Lady's Branch. Park off highway east of outcrops. See Fig. 2.

END OF FIELD TRIP AND ROAD LOG. To leave area, one can continue ahead on Rte. M back to U.S. 71 at Nevada, or return to U.S. 54 at Dederick and go east through El Dorado Springs to join highways to the east, or return to Rte. AA and turn north and go across the new bridge over the Osage to Rte. B. Rte. B connects with Highway 13 near Osceola and Highway 71 at Rich Hill. The last-named is the best route to Kansas City, and from it, a side trip can be made to the best exposures of the Riverton and its associated coal beds. (See supplemental log).
Warner Sandstone

6'-0"  Sandstone, tan, fine grained (125-177µ), well sorted, subangular, micaceous, well cemented

5"  Sandstone, as ab., w/ limonite and coal seams

1'-5"  Sandstone, red, v f grained (68-88µ), subangular, well cemented, micaceous, coaly, fossil plants, carbonaceous, claystone cgl.

3'-0"  Sandstone, reddish brown, fine grained (177-250µ), well sorted, well cemented, subangular, micaceous, coal seams, with claystone conglomerate at the base

4'-0"  Sandstone, gray, very fine grained (62-88µ), very well sorted, well cemented, micaceous, subangular

2'-0"  Sandstone, gray, very fine grained (62-88µ), well sorted, subangular, micaceous, well cemented, clay ironstone nodules

1'-9"  Sandstone, gray, very fine grained (62-88µ), very well sorted, well cemented, micaceous, subangular

Figure 2 - Measured section at outcrop of Warner Sandstone on south edge of Route M, NE 1/4 NW 1/4, Sec. 1, T37N, R30W, Vernon County, Missouri, 3 miles west of Schell City. Geology by Steve Allee, Janice Mather, Debbie Wait, Cindy Moore, and Ken Elliott, Northwest Missouri State University.
SUPPLEMENTAL ROAD LOGS

1. Dederick, Missouri to Venter Bluff outcrop of Warner Sandstone.

0.0 0.0 Begin log at junction of Rtes AA and 54 in Dederick, Mo.

0.4 0.4 Clear Creek. Outcrops of Riverton Shale along the banks of the creek formed the type locality of the Dederick Shale of Greene and Pond in their Geology of Vernon County (1926).

1.9 2.3 Road to limestone quarry one quarter mile north. This is one of the three major limestone quarries in Vernon County. Rock is taken from the Mississippian.

0.4 2.7 Outcrop of Mississippian along north side of highway at base of hill.

0.1 2.8 Cross Fly Creek.

0.7 3.5 Junction with Rte. HH to south. Vernon-Cedar County Line.

2.4 5.9 Junction with Rte. 82. Stay on 54 through El Dorado Springs.

0.5 6.4 Junction with Rte. 32. Stay on 54.

0.5 6.9 Outcrop of Warner Sandstone at east edge of El Dorado Springs.

1.8 8.7 Outcrops of residual chert at top of Mississippian.

1.3 10.0 H-5 Missile Site.

2.9 12.9 Junction with Rte. 39. Stay on 54.

0.2 13.1 East edge of Cedar Springs.

1.1 14.2 H-4 Missile Site.

1.2 15.4 Good outcrop of Warner Sandstone. Note cross bedding.

3.7 19.1 West end of Venter Bluff outcrop of Warner Sandstone. The Warner is very well exposed here. A section and description are given on pages 22-23 of the GSA guidebook on the Pennsylvanian of Missouri, along with more complete descriptions of the outcrops along this segment.

0.0 0.0 Stop 4 -- outcrop of Warner Ss on Rte. M west of Schell City. Return to junction of Rtes. C and AA.

2.7 2.7 Junction with Rte. AA. Turn north onto AA.

2.6 5.3 Pavement ends. Continue north on gravel road.

0.4 5.7 Bridge across Osage River. This is the upper end of the Schell-Osage Wildlife Area. Entering Bates County.

2.5 8.2 Junction with Rte. B. Turn west onto B.

1.6 9.8 Junction with Rte. O. Turn south onto O to Prairie City.

1.0 10.8 Enter Prairie City. End of pavement. Turn west onto gravel road.

0.5 11.3 Cross Willow Branch Creek.

0.5 11.8 Junction with road going south. Turn onto this road and proceed south.

1.0 12.8 T-intersection. Turn left (east).

0.4 13.2 Intersection and end of gravel. Turn south onto dirt road. If it has been raining, this last segment is probably impassable; otherwise okay.

0.5 13.7 Old steel truss bridge across Bates County Drainage Ditch (called No. 1 Bridge across Mariais Des Cygnes (sic) Drainage Ditch on old Papinsville Quadrangle). Excellent outcrops of the Riverton Formation appear along the banks of this ditch. The coal seams are readily visible. The bluffs across to the south of here are comprised of Warner Sandstone. A photograph and a description of Halleys Bluff are given in Greene and Pond (1926). Pierre Chouteau built a stockade there, and the bluff was mentioned in the annals of the Zebulon Pike expedition.

0.9 14.6 Retrace route to T-intersection. Continue west to Papinsville, pop. 29, pecan capital of Missouri.

2.1 16.7 Junction with Rte. N in Papinsville. Continue north on N.

1.7 18.4 Junction with Rte. B. Turn west onto B.

7.0 25.4 Junction with U.S. 71 at Rich Hill.