DEEP TEST WELL IN LAWRENCE COUNTY, INDIANA: DRILLING TECHNIQUES AND STRATIGRAPHIC INTERPRETATIONS

by

T. A. DAWSON

Indiana Department of Conservation

GEOLOGICAL SURVEY

Report of Progress No. 22

1960

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Bloomington

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DEEP TEST WELL IN LAWRENCE COUNTY, INDIANA: DRILLING TECHNIQUES AND STRATIGRAPHIC INTERPRETATIONS

By T. A. Dawson

ABSTRACT

The Indiana Farm Bureau Cooperative Association, Inc. No. 1 Luther Brown well in Lawrence County established a new depth record for Indiana of 6,806 feet.

The Farm Bureau No. 1 Brown well was drilled proficiently. Although the drilling cost of $92,541 is high as compared to the cost of the typical test well drilled in the Illinois Basin, drilling probably was effected at a near minimum cost figure. Appropriate equipment was employed, and special emphasis was placed on the mud program and the types of bits used.

The Farm Bureau No. 1 Brownwell is far removed from other deep test wells. As a consequence, important new data on the lithologic character and thickness of the Knox Dolomite, Eau Claire Formation, and Mt. Simon Sandstone were obtained from it. This lower Ordovician and Cambrian rock section is 4,290 feet thick in the well.

INTRODUCTION

The Indiana Farm Bureau Cooperative Association, Inc. No. 1 Luther Brown well is the deepest oil and gas test well to have been drilled in Indiana. It is only the seventh Indiana well to have been drilled into the Precambrian. Drilling was terminated in basalt at 6, 806 feet.

The Farm Bureau No. 1 Brown well is in the SE¼ sec. 20, T. 5 N., R. 2 E., Lawrence County. Geologically, it is situated on the Leesville Anticline (fig. 1), an elongate structure paralleling, and lying to the west of, the Mt. Carmel Fault. It was planned from the start to drill this test well into the Precambrian if oil or gas in commercial quantities was not found before the Precambrian was reached.

This report has been prepared with two objectives in mind, namely, the presentation of operational data and the presentation of stratigraphic information. Because of formation hardness and solution cavities, drilling operations that involve penetration of the lower Ordovician and Cambrian in Indiana are confronted with problems that are not encountered normally in drilling the upper and middle Paleozoic of Indiana. Equipment and techniques employed

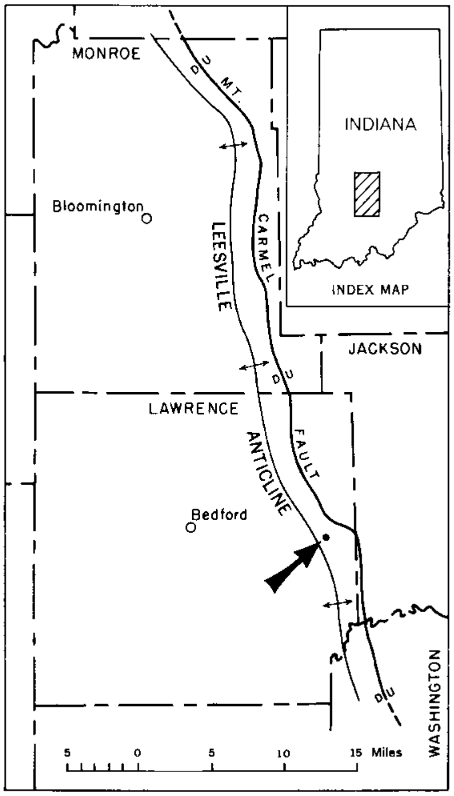


Figure 1. --Map showing location of deep test well in Lawrence County.

in drilling the deep test well in Lawrence County were very effective. Statistical data on the drilling operation are presented for use of those who contemplate drilling test wells into the Knox, Eau Claire, or Mt. Simon formations.

The deep test well in Lawrence County is isolated from other deep test wells; it is more than 100 miles from Precambrian tests in Henry and Wayne Counties and more than 50 miles from an Eau Claire test in Johnson County. The lithology and thickness of the deep formations, that is, the Knox, Eau Claire, and Mt. Simon, are somewhat different, therefore, than might have been expected. The lithologic character of these formations is presented by means of a detailed sample study, and the thickness of various stratigraphic units within the lower Ordovician and Cambrian section in Indiana is presented by means of isopach maps.

ACKNOWLEDGMENTS

Special acknowledgment is due Mr. Alfred A. Kiltz, Manager of Production and Refining, Petroleum Department, Indiana Farm Bureau Cooperative Association, Inc. Mr. Kiltz's desire to extract the maximum amount of basic information from the deep test well in Lawrence County resulted in a collection of well logs of immense value to the research geologist and to the oil industry. Mr. Kiltz, in addition, made available operational details that are shown in the tables of this report.

Dan M. Sullivan, of the Indiana Geological Survey, aided in the preparation of the sample study presented in this report and assisted

in the compilation of data used in preparing the tables and maps presented in this report.

DRILLING OPERATION

The cost of drilling the Indiana Farm Bureau Cooperative Association, Inc. No. 1 Luther Brown well was $92,541 (table 1). Few wells drilled in the Illinois Basin have cost as much, and yet it is doubtful that this well could have been drilled more cheaply. The drilling operation was effected proficiently, and operational details should serve as a valuable guide to those who drill deep holes into the Knox, Eau Claire, and Mt. Simon formations in the future.

The major factors in the operational success of the deep test well in Lawrence County were equipment, mud program, and bits. Selection of rotary tools, rather than cable tools, was probably the most important decision made in formulating the drilling plan for this deep test well. Basic equipment units used consisted of a National 50 drawworks powered by a set of GM twin-6 diesels (each engine rated at 325 horsepower), a Lee C. Moore 87-foot derrick, an Emsco D-300 mud pump (7½ inches x 14 inches) powered by a set of GM twin-6 diesel engines, and 4½-inch OD drill pipe. The rig was mounted on a 6-foot substructure to facilitate installation of a blowout preventer. Six drill collars were used in drilling the upper part of the hole, and eight drill collars were used in drilling the lower part of the hole; all drill collars used were 30 feet long and weighed 90 pounds per foot. The 1? -inch drill line was strung through six sheaves of the blocks.

Cable tools are not effective in drilling the porous, cavernous Knox Dolomite. Where cable tools are employed to drill the Knox, more time may be spent in casing off water than in drilling. The writer knows of one cable-tool operation that was scheduled to test the Mt. Simon Sandstone but was abandoned at a depth of 1,640 feet after little more than 400 feet of Knox was penetrated because of the inability to cope with water; the decision to abandon was not made, however, until more than $40,000 had been spent on the hole.

The second important factor in the operational success of this deep test well was the mud program. Mud cost is shown in table 1; mud materials used, in table 2; and mud properties, in table 3. The mud cost of $7,751 may appear high, but this expenditure undoubtedly contributed materially to holding down the overall cost of the drilling operation. Rotary holes that are drilled through the cavernous Knox Dolomite are exposed to the hazard of lost circulation. Maintenance of good mud unquestionably did much to reduce this hazard in the drilling of the Farm Bureau No. 1 Brown well. Lost circulation

Table 1.--*Cost data*

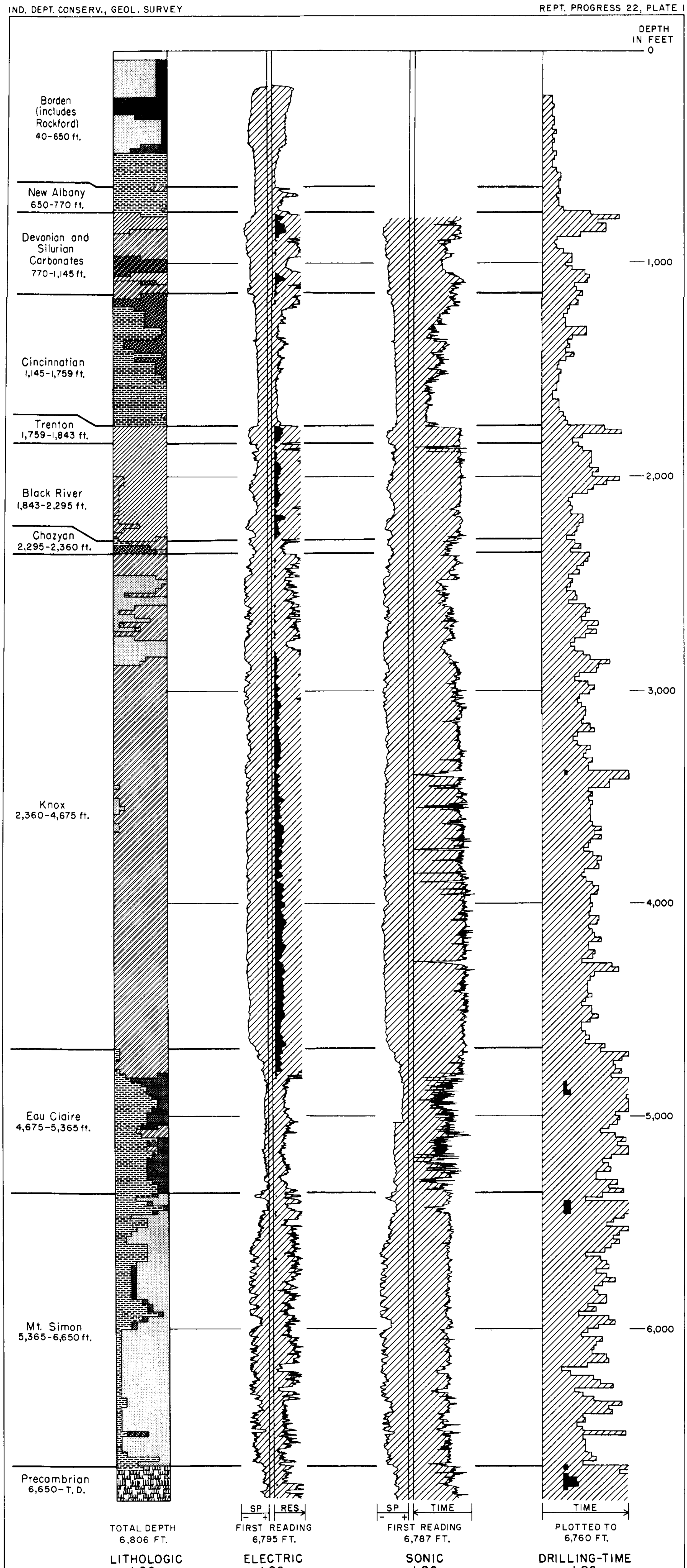
[Courtesy Indiana Farm Bureau Cooperative Association, Inc.]

Item	Cost
Contractor (rig, drill pipe, labor, and insurance)--	$47,518.70
Bits---	10,720.85
Mud and chemicals (includes lost-circulation material) ---------------------------------------	7, 751.15
Fuel and grease ---	5,025.85
Hauling (includes moving rig approximately 100 miles) ---	5,061.40
Miscellaneous (permit, waterline, corehead and core barrel, reamers, surface casing, cement, logging, etc.) ---	16,463.21
Total cost ----------------------------------	$92,541.16

was experienced only two times--at depths of 3, 542 feet and 4, 268 feet. (For the indicated cavernous character of the Knox at these depths, see the sonic log on plate 1.) Each time that mud was lost in the hole, circulation was reestablished by administering effectively lost circulation materials (table 2). Downtime directly and indirectly attributable to lost circulation totaled 30 hours 34 minutes.

The wise selection of bits was the third important factor in the operational success of the deep test well. The bit record is shown in table 4, and the cost of bits is shown in table 1. Use of the RGl hard-formation bit at depth did much to hold down the overall cost of the drilling operation. These bits are costly, and expenditures for them represent a major part of the total bit cost. Their rate of penetration was very satisfactory, however, and, more important, their use did much to curtail roundtrip downtime for bit changing. Several of the RGl bits were used 70 to 85 hours.

Deviation surveys are shown in table 5. Allowable deviation



EXPLANATION

Stratigraphic-unit footages are based on the sample description (p. 15). Scale 1 inch to 500 feet.

Lithologic Log. *Lithology is plotted in 20-foot units. Where multiple lithologies are shown for a single 20-foot unit, each lithology is plotted to the nearest 10 percent. Only basic lithologies are plotted; for lithologic details, see sample description. Lithologies plotted are shale, siltstone, sandstone (also quartz), limestone, argillaceous limestone, dolomite, argillaceous dolomite, and basalt.*

Electric Log. *The SP curve is plotted on a conventional 100-millivolt scale. The resistivity curve shown is the short normal (64 inch spacing); it is plotted on a 100-ohm m²/m primary scale and a 1,000-ohm m²/m secondary scale (black).*

Sonic Log. *The SP curve is plotted on a conventional 100-millivolt scale; the offset in the SP curve at 5,020 feet is a manual shift. The interval-transit-time curve is plotted on a 40-100-microsecond scale. Time increases on the interval-transit-time curve correspond to increases in porosity.*

Drilling-Time Log. *Drilling time is plotted in 20-foot units on a primary scale of 0-400 minutes and a secondary scale (black) of 0-1,600 minutes. Plotting is to the nearest 10 minutes on the primary scale and to the nearest 40 minutes on the secondary scale.*

GRAPHIC CORRELATION OF LOGS FROM DEEP TEST WELL IN LAWRENCE COUNTY established for the drilling program was 3 degrees, and maximum deviation recorded was 2¾ degrees.

Drilling of the Farm Bureau No. 1 Brown well was initiated on April 15, 1959. Surface casing was set at 166 feet after drilling was effected to a depth of 220 feet. Drilling below 220 feet began on April 17, 1959, and was terminated at 6,800 feet on June 22, 1959. The interval 6,800 feet to 6,806 feet (total depth) was cored. Elapsed time for drilling the 6,580 feet between 220 feet and 6,800 feet was 66 days; thus, the average rate of penetration was almost exactly 100 feet per day.

Total downtime, that is, time for making drill-stem connections, roundtrips for bit changes, servicing the rig and pump, mixing mud, circulating, and lost circulation, was 365 hours. Drilling time was 1,223 hours (see table 4); thus, on an average, for more than 46 minutes out of each hour that this operation was being conducted between the depths of 220 feet and 6,800 feet, actual drilling was being effected. This good record can be attributed to a sound drilling plan, that is, the use of appropriate equipment, a well-formulated mud program, and wise selection of bits.

Table 2.--*Mud materials*

[Compiled from daily drilling report.]

Date	Depth (ft)	Magcogle (100-lb bags)	Magcobar (100-lb bags)	Quebracho (lb)	Caustic soda (lb)	Tannathin (lb)	Magcophos (lb)	Soda ash (lb)	Bicarbonate (lb)	Cypan (lb)	Magcofibeer (40-lb bags)	Leatherflock (25-lb bags)	Cell-o-seal (25-lb bags)	Saedust[1]
1959														
Apr. 18 - - - -	320-585	169	- - -	150	75	- -	- -	600	- - -	- - -	- - -	- -	- -	-
Apr. 19- - - -	585-770	7	200	- - -	- -	- -	- -	- - -	- - -	- - -	- - -	- -	- -	-
Apr. 20 - - - -	770-824	10	40	- - -	- -	- -	- -	- - -	- - -	- - -	- - -	- -	- -	-
Apr. 21 - - - -	824-981	- - -	50	- - -	- -	- -	- -	- - -	- - -	- - -	- - -	- -	- -	-
Apr. 23 - - - -	1,129-1,307	- - -	- - -	25	25	- -	25	- - -	- - -	- - -	- - -	- -	- -	-
Apr. 24 - - - -	1,307-1,483	10	- - -	50	50	- -	25	- - -	- - -	- - -	- - -	- -	- -	-
Apr. 25 - - - -	1,483-1,766	- - -	- - -	25	25	- -	25	- - -	- - -	- - -	- - -	- -	- -	-
Apr. 26 - - - -	1,766-1,866	- - -	- - -	50	25	- -	- -	- - -	- - -	- - -	- - -	- -	- -	-
Apr. 27 - - - -	1,866-1,967	20	- - -	50	25	- -	- -	- - -	- - -	- - -	- - -	- -	- -	-
Apr. 28 - - - -	1,967-2,062	5	- - -	50	25	- -	- -	- - -	- - -	- - -	- - -	- -	- -	-
Apr. 29 - - - -	2,062-2,208	- - -	- - -	50	25	- -	- -	100	- - -	50	- - -	- -	- -	-
Apr. 30 - - - -	2,208-2,363	- - -	- - -	50	25	- -	- -	- - -	- - -	- - -	- - -	- -	- -	-
May 1 - - - -	2,363-2,504	30	- - -	50	25	- -	- -	- - -	- - -	- - -	7½	- -	- -	-
May 2 - - - -	2,504-2,626	- - -	- - -	50	25	- -	- -	- - -	- - -	- - -	- - -	- -	- -	-
May 3 - - - -	2,626-2,737	10	- - -	50	25	- -	- -	- - -	- - -	- - -	- - -	- -	- -	-
May 4 - - - -	2,737-2,861	25	- - -	50	25	- -	- -	- - -	- - -	- - -	- - -	- -	- -	-
May 5 - - - -	2,861-2,958	- - -	- - -	50	25	- -	- -	100	- - -	- - -	- - -	- -	- -	-
May 6 - - - -	2,958-3,059	10	- - -	50	25	- -	- -	- - -	- - -	50	2	- -	2	-
May 7 - - - -	3,059-3,167	45	- - -	- - -	25	50	- -	- - -	- - -	- - -	2	- -	1	-
May 8 - - - -	3,187-3,273	20	- - -	50	25	- -	- -	- - -	- - -	- - -	- - -	1	- -	-
May 9 - - - -	3,273-3,360	15	- - -	- - -	25	50	- -	- - -	- - -	- - -	- - -	- -	- -	-
May 10 - - - -	3,360-3,400	15	- - -	50	25	- -	- -	- - -	- - -	- - -	- - -	- -	- -	-
May 11 - - - -	3,400-3,462	20	- - -	25	- -	50	- -	- - -	- - -	- - -	1	- -	- -	-
May 12 - - - -	3,462-3,542	25	- - -	50	25	- -	- -	- - -	- - -	- - -	2	3	2	-
May 13 - - - -	3,542-3,569	179	- - -	- - -	- -	- -	- -	- - -	- - -	- - -	20	14	11	X
May 14 - - - -	3,569-3,656	60	- - -	50	25	- -	- -	300	- - -	- - -	4	1	1	X
May 15 - - - -	3,656-3,752	50	- - -	- - -	25	50	- -	- - -	- - -	- - -	1	- -	- -	X
May 16 - - - -	3,752-3,813	16	- - -	- - -	- -	- -	- -	200	100	50	1	1	- -	-
May 17 - - - -	3,813-3,934	35	- - -	50	25	- -	- -	- - -	- - -	- - -	- - -	- -	- -	X
May 18 - - - -	3,934-4,048	7	- - -	50	25	- -	- -	100	- - -	- - -	- - -	1	- -	X
May 19 - - - -	4,048-4,142	46	- - -	- - -	25	50	- -	- - -	- - -	- - -	4	2	1	X
May 20 - - - -	4,142-4,254	65	- - -	50	25	- -	- -	- - -	- - -	- - -	1	- -	- -	X

May 21 - - - -	4,254-4,303	253	- - -	- -	- -	- -	- -	- - -	- - -	- - -	22	10	7	X
May 22 - - - -	4,303-4,411	116	- - -	- -	- -	- -	- -	- - -	- - -	50	12	5	- -	X
May 23 - - - -	4,411-4,496	36	- - -	50	25	- -	- -	- - -	- - -	- - -	3	- -	- -	X
May 24 - - - -	4,496-4,615	80	- - -	- -	- -	- -	50	- - -	- - -	- - -	4	4	1	X
May 25 - - - -	4,615-4,712	57	- - -	- -	- -	- -	- -	200	- - -	- - -	- -	- -	1	X
May 26 - - - -	4,712-4,777	51	- - -	- -	- -	- -	- -	- - -	- - -	- - -	- -	2	1	X
May 27 - - - -	4,777-4,828	30	- - -	50	25	- -	- -	- - -	- - -	- - -	5	- -	- -	X
May 28 - - - -	4,828-4,885	- - -	- - -	50	25	- -	- -	200	- - -	50	- -	- -	- -	X
May 29 - - - -	4,885-4,952	15	- - -	100	75	50	- -	- - -	- - -	- - -	- -	- -	- -	-
May 30 - - - -	4,952-5,021	65	- - -	50	50	- -	25	200	- - -	100	- -	- -	- -	X
May 31 - - - -	5,021-5,093	10	- - -	25	50	- -	- -	100	- - -	- - -	2	1	- -	X
June 1 - - - - -	5,093-5,156	32	- - -	- -	- -	- -	- -	- - -	- - -	- - -	- -	2	- -	-
June 3 - - - - -	5,236-5,327	60	- - -	50	25	- -	- -	100	- - -	50	- -	- -	- -	-
June 4 - - - - -	5,327-5,412	- - -	- - -	- -	25	50	- -	100	- - -	50	- -	- -	- -	-
June 5 - - - - -	5,412-5,451	14	- - -	25	50	- -	- -	100	- - -	50	- -	2	2	X
June 6 - - - - -	5,451-5,526	27	- - -	- -	25	50	- -	- - -	- - -	- - -	- -	- -	- -	-
June 7 - - - - -	5,526-5,601	10	- - -	- -	- -	- -	- -	100	- - -	50	- -	- -	- -	-
June 8 - - - - -	5,601-5,669	25	- - -	50	50	- -	- -	- - -	- - -	- - -	- -	- -	- -	-
June 9 - - - - -	5,669-5,760	45	- - -	25	25	- -	- -	100	- - -	- - -	- -	- -	- -	-
June 10 - - - -	5,760-5,855	30	- - -	- -	- -	- -	- -	- - -	- - -	- - -	- -	- -	- -	-
June 11 - - - -	5,855-5,957	60	- - -	- -	- -	- -	- -	- - -	- - -	50	- -	- -	- -	-
June 12 - - - -	5,957-6,034	- - -	- - -	- -	- -	- -	- -	100	- - -	- - -	- -	- -	- -	-
June 14 - - - -	6,140-6,261	- - -	- - -	50	25	- -	- -	100	- - -	50	- -	- -	- -	-
June 15 - - - -	6,261-6,351	- - -	- - -	- -	25	50	- -	- - -	- - -	- - -	- -	- -	- -	-
June 16 - - - -	6,351-6,400	- - -	- - -	50	25	- -	- -	- - -	- - -	- - -	- -	- -	- -	-
June 18 - - - -	6,501-6,627	15	- - -	50	25	- -	- -	- - -	- - -	- - -	- -	- -	- -	-
June 19 - - - -	6,627-6,685	15	- - -	- -	- -	- -	- -	100	- - -	- - -	- -	- -	- -	-
June 20 - - - -	6,685-6,714	40	- - -	50	25	- -	- -	- - -	- - -	50	- -	- -	- -	-
June 21 - - - -	6,714-6,762	25	- - -	25	50	50	- -	- - -	- - -	- - -	- -	- -	- -	-
June 22 - - - -	6.762-6,800	X	- - -	- -	- -	- -	- -	- - -	- - -	- - -	- -	- -	- -	-

[1] A total of 10 pickup-truckloads of sawdust was used.
[X] Quantity unknown.

Table 3.--*Mud properties*

[Courtesy Indiana Farm Bureau Cooperative Association, Inc. and Magnet Cove Barium Corp.}

Depth (ft)	Mud in pits (bbl)	Mud in Hole (bbl)	Total mud in system (bbl)	Circulating pressure (psi)	Weight (lb per gal)	Funnel viscosity (qt)	Viscosity (centipoises)	Plastic viscosity (centipoises)	Yield point (lb per 100 sq ft)	Gel strength - - initial (g)	Gel strength - - 10 min (g)	pH--strip	Water loss (cc in 30 min)	Cake thickness (in.)	P- - mud (cc)	P- - mud filtrate (cc)	Chloride (ppm)	Calcium	Sulfate	Sand content (percent by volume)
771	350	64	414	400	9.7	42	20.0	15	10	0	2	10.0	8.4	2/32	0	0	400	Nil	Nil	1/8
830	350	64	414	400	9.7	53	25.0	15	10	0	5	10.0	8.2	2/32	0	0	500	Trace	Trace	1/8
1,100	1,100	88	1,180	450	9.1	40	17.5	9	5	0	1	10.0	9.8	2/32	0	0	500	Nil	Show	1/8
1,691	1,100	128	1,228	500	9.2	39	17.0	14	6	0	0	9.8	10.2	2/32	0	0	700	Nil	Show	Trace
2,036	1,100	200	1,300	500	9.1	40	16.0	12	5	0	0	9.5	8.2	2/32	0	0	800	Nil	Show	1/16
2,313	1,100	200	1,300	550	9.3	44	22.5	17	5	0	2	9.5	7.4	1/32	0	0	900	Nil	Show	1/8
2,601	1,100	208	1,308	550	9.3	42	20.0	17	5	0	0	10.5	7.8	2/32	0	0	800	Nil	Show	Trace
2,937	1,100	232	1,332	550	9.3	43	20.0	17	5	0	0	11.5	10.0	2/32	0	0	900	Nil	Show	1/8
- - - - -	1,100	264	1,364	550	9.1	40	16.0	13	5	0	0	9.5	6.6	2/32	0	0	900	Nil	Show	1/8
3,569	1,100	280	1,380	400	8.5	47	- - - -	- -	- -	5	10	8.5	16.4	2/32	0	0	1,000	Trace	Heavy	Nil
3,705	1,100	290	1,390	400	8.8	47	20.5	12	17	0	4	9.5	8.2	2/32	0	0	600	Nil	Show	1/8
4,040	1,100	320	1,420	400	8.8	47	22.5	13	9	0	5	10.5	9.2	2/32	0	0	900	Nil	Show	1/8
4,307	1,100	344	1,444	500	8.6	52	- - - -	- -	- -	0	5	9.5	10.0	2/32	0	0	500	Nil	Heavy	1/8
4,446	1,100	352	1,452	550	8.6	66	- - - -	- -	- -	0	15	9.5	7.4	2/32	0	0	400	Trace	Show	1/8
4,813	1,100	384	1,484	550	9.0	52	27.5	18	9	2	2	9.5	8.5	2/32	0	0	500	Nil	Show	1/8
5,005	1,100	400	1,500	650	8.9	40	13.5	10	7	0	2	9.5	8.2	2/32	0	0	500	Trace	Heavy	1/8
5,226	1,100	416	1,516	650	9.0	48	22.0	16	12	0	2	10.0	7.8	2/32	0	0	325	Nil	Show	1/8
5,655	1,100	447	1,548	- - -	8.9	48	24.0	14	7	1	4	9.5	7.8	2/32	0	0	500	Nil	Show	Trace
6,221	1,100	496	1,596	650	9.0	50	28.0	20	6	2	4	9.5	7.0	2/32	0	0	700	Nil	Show	Trace
6,611	1,100	528	1,628	800	9.0	45	23.0	16	5	2	8	9.5	7.8	2/32	0	0	650	Nil	Show	Trace
6,800	1,100	544	1,644	400	9.1	50	30.0	25	6	0	5	9.5	6.2	2/32	0	0	500	Nil	Show	Trace

Table 4.--*Bit record*

[Courtesy Indiana Farm Bureau Cooperative Association, Inc. and Hughes Tool Co.]

No.	Size (in.)	Make	Type	Depth (ft)	Feet used	Hours used	Weight (in 1, 000 lb)	Rpm	Vertical deviation (in degrees)	Pump pressure	Pump spm	Pump liner (in.)
1 - - -	8 3/4	Hughes	OWS	648	578	26:03	--	75	0	400	60	7
2 - - -	8 3/4	Hughes	OWS	822	174	23:44	10	65	0	400	60	7
3 - - -	8 3/4	Hughes	W7	981	159	19:53	20	65	0	400	60	7
4 - - -	8 3/4	Hughes	W7	1,141	160	22:38	20	65	1/4	450	60	7
5 - - -	8 3/4	Hughes	W7	1,440	299	35:11	20	65	1/2	450	60	7
6 - - -	8 3/4	Hughes	W7	1,801	361	32:54	15	65	1	500	60	7
7 - - -	8 3/4	Hughes	W7	1,965	164	27:54	25	65	1	500	60	7
8 - - -	8 3/4	Hughes	W7	2,076	111	25:00	30	65	1	500	60	7
9 - - -	8 3/4	Hughes	W7	2,343	267	33:46	30	65	1	550	60	7
10 - - -	8 3/4	Hughes	W7	2,545	202	26:39	25	65	1	550	60	7
11 - - -	8 3/4	Hughes	W7	2,617	72	8:08	25	65	1	600	60	7
12 - - -	83/4	Hughes	W7R	2,736	119	21:34	25	65	1	600	60	7
13 - - -	8 3/4	Hughes	W7R	2,833	97	13:18	25	65	1	600	60	7
14 - - -	8 3/4	Hughes	W7R	2,912	79	17:20	30	65	1	600	60	7
15 - - -	8 3/4	Hughes	W7R	3,024	112	18:43	30	65	3/4	600	60	7
16 - - -	8 3/4	Hughes	W7	3,099	75	11:18	30	65	-----	600	--	7
17 - - -	8 3/4	Hughes	W7R	3,188	89	15:28	35	65	-----	600	--	7
18 - - -	8 3/4	Hughes	W7R	3,307	119	17:50	35	65	-----	650	--	7
19 - - -	8 3/4	Hughes	W7R	3,360	53	9:22	35	65	3	650	--	7
20 - - -	8 3/4	Hughes	W7R	3,395	35	9:14	35	65	3	650	--	7
21 - - -	8 3/4	Hughes	W7R	3,400	5	1:59	35	65	3	650	--	7
22 - - -	8 3/4	Hughes	RG1	3,559	159	36:29	15-35-40	40	2 1/2	600	--	6 1/4
23 - - -	8 3/4	Hughes	RG1	3,788	229	43:29	10-35	40	2 1/2	600	--	6 1/4
24 - - -	8 3/4	Hughes	W7R	3,805	17	4:57	25	40	2 1/2	600	--	6 1/4
25 - - -	8 3/4	Hughes	RG1	4,105	300	56:12	35	40	2	600	--	6 1/4
26 - - -	8 3/4	Hughes	RG1	4,435	330	65:21	40	40	1	650	--	6 1/4
27 - - -	8 3/4	Hughes	RG1	4,777	342	72:51	40	40	1	650	--	6 1/4
28 - - -	8 3/4	Hughes	W7R	4,813	36	10:30	40	40	1	650	--	6 1/4
29 - - -	8 3/4	Hughes	RG1	5,093	280	87:49	40	40	1	700	--	6 1/4
30 - - -	8 3/4	Hughes	RG1	5,413	320	86:41	40	40	1	750	--	6 1/4
31 - - -	8 3/4	Hughes	RG1	5,651	238	76:03	40	40	3/4	750	--	6 1/4
32 - - -	8 3/4	Hughes	RG1	5,972	321	73:02	40	40	3/4	750	--	6 1/4
33 - - -	8 3/4	Hughes	RG1	6,351	379	74:31	40	40	3/4	800	--	6 1/4
34 - - -	8 3/4	Hughes	RG1	6,685	334	71:30	40	40	3/4	850	--	-----
35 - - -	8 3/4	Hughes	RG1	6,800	115	52:13	--	--	-----	---	--	-----
					Total hours used------------	1,222:54						

Table 5.--*Deviation surveys*

[Compiled from drilling-time report and daily drilling report.]

Depth (ft)	Vertical deviation (in degrees)	Depth (ft)	Vertical deviation (in degrees)
310 - - -	1/2	3,388 - - -	3
490 - - -	0	3,405 - - -	2 3/4
700 - - -	1/4	3,447 - - -	3
792 - - -	1/4	3,468 - - -	3
822 - - -	1/4	3,500 - - -	2 3/4
846 - - -	1/4	3,534 - - -	2 1/2
910 - - -	1/4	3,568 - - -	2 1/2
1,091 - - -	0	3,629 - - -	2
1,301 - - -	3/4	3,690 - - -	2
1,330 - - -	1/2	3,749 - - -	2
1,451 - - -	1/2	3,872 - - -	2 1/2
1,632 - - -	1	3,933 - - -	2 1/2
1,752 - - -	1	3,994 - - -	2 1/2
1,896 - - -	1	4,055 - - -	2
2,048 - - -	1	4,147 - - -	1 3/4
2,171 - - -	1 1/4	4,237 - - -	1 1/4
2,343 - - -	1	4,356 - - -	1 3/4
2,563 - - -	1	4,505 - - -	1 1/2
2,812 - - -	1	4,717 - - -	1
3,024 - - -	3/4	4,872 - - -	1
3,305 - - -	2	5,651 - - -	3/4

STRATIGRAPHY

SAMPLE DESCRIPTION

The sample cuttings obtained from the deep test well in Lawrence County are of excellent quality, as a result of the effective mud program followed. A description of the samples is presented below, and a graphically plotted log, based on the sample description and correlated with the electric log, sonic log, and drilling-time log, is shown on plate 1. (Abbreviations used are explained at the end of the sample description.)

Permit 20871	Lawrence County
Indiana Farm Bureau Coop. Assoc., Inc.	Leesville Field
Brown, Luther No. 1	20-5N-2E
Completed 7-8-59	SE SE, 330 ft SL, 660 ft EL
D&A	Elevation 800 KB

0-	10	Skip	
10-	40	Surface	
40-	220	SD, lt gy, vf, mic, glauc, arg, sl calc; SLT (20%), lt gy, mic, glauc, sl calc	Borden
220-	310	SLT, lt gy, mic, glauc, sl calc	
310-	445	SD, It gy, vf, mic, glauc, arg, sl calc; SLT (10%), lt gy, mic, glauc, sl calc	
445-	480	SLT, lt gy, mic, glauc, sl calc; SD (30%), lt gy, vf, mic, glauc, arg, sl calc	
480-	505	SH, lt gy, mic, glauc, sl calc	
505-	525	SH, lt gy, mic, glauc, sl calc; SH (30%), brn, hd	
525-	555	SH, lt gy, plty, sft	
555-	590	SH, gngy, pity, sft	
590-	600	SH, gngy, plty, sft; SH (10%), brn, hd	
600-	625	SH, gngy, plty, sft	
625-	630	SH, gngy-mrn, plty, sft	
630-	645	SH, gngy, plty, sft	

645-	650	DOL, gntn, f xtln	Rockford 645 ft
650-	655	SH, blk	New Albany 650 ft
655-	660	SH, blk-gy	
660-	695	SH, blk	
695-	710	SH, blk-gngy	
710-	725	SH, blk	
725-	740	SH, blk-gngy	
740-	745	SH, blk-gngy; DOL (3016), gy-tn, vf xtln	
745-	755	SH, blk	
755-	760	SH, blk; DOL (20%), brn, of xtln, arg	
760-	770	SH, blk	
770-	775	LS, wh-tn, m-c xtln	Devonian limestone 770 ft
775-	795	LS, wh-gy-tn, mtld, m-c xtln	
795-	805	LS, tn-gy, f xtln	
805-	815	LS, tn-gy, m-c xtln, chty (wh)	
815-	820	LS, wh-tn, f xtln, chty (wh)	
820-	845	LS, wh-tn, f xtln	
845-	860	DOL, brn, f xtln	Geneva 845 ft
860-	875	DOL, brn, f xtln, spty oil stn	
875-	880	DOL, brn, f xtln, vug, oil stn; DOL (40%), lt gy, f xtln	Silurian 878 ft
880-	890	DOL, lt gy, f xtln, vug, spty oil stn	
890-	895	DOL, lt gy, f-m xtln, sue, vug, spty oil stn	
895-	910	DOL, lt gy, f-m xtln, suc, vug	
910-	970	DOL, wh-lt gy, f-m xtln, suc, vug, chty (wh-gy)	
970-1,	045	DOL, gngy, f xtln, v arg	
1,045-1,	070	LS, lt gy-pnktn, mtld, m-c xtln	
1,070-1,	085	LS, lt gy, f-m xtln, dol	
1,085-1,	090	LS, gngy-tn, f xtln, dol, arg	
1,090-1,	095	DOL, gy, f-m xtln	
1,095-1,	105	DOL, gy, f-m xtln, suc, vug	

1,105-1,120	DOL, gy, f-m xtln	
1,120-1,125	DOL, gy, f-m xtln, suc, vug	
1,125-1,130	Skip	
1,130-1,135	DOL,gy, f -m xtln, v chty (wh-gy)	
1,135-1,145	DOL, brn, f-m xtln, suc, chty (wh-gy)	
1,145-1,155	LS, brn-gy, f-m xtln, arg, fos	Cincinnatian 1, 145 ft
1,155-1,160	DOL, gngy, f xtln	
1,160-1,170	LS, brn-gy, f xtln, arg, fos	
1,170-1,205	LS, wh-gy, f-c xtln, arg	
1,205-1,215	SH, gy-blk, hd, calc; LS (40%), brn-gy, mtld, f-m xtln, arg, fos	
1,215-1,220	LS, wh-gngy, mtld, f -m xtln, arg, fos; SH (40%), It gy, calc	
1,220-1,285	SH, gy, calc; LS (40%), wh-gy, mtld, f-c xtln, arg, fos	
1,285-1,290	SH, gy, calc	
1,290-1,300	LS, wh-gy, mtld, f-c xtln, arg, fos; SH (40%), gy, calc	
1,300-1,340	SH, gy, calc; LS (10%), brn-gy, mtld, f-c xtln, arg, fos	
1,340-1,345	SH, gy, calc	
1,345-1,350	SH, gy, calc; LS (10%), brn-gy, mtld, f-c xtln, arg, fos	
1,350-1,360	SH, gy, calc; LS (40%), brn-gy, mtld, f-c xtln, arg, fos	
1,360-1,415	LS, wh-gy, mtld, m-c xtln, arg, fos; SH (20%), gy, calc	
1,415-1,440	SH, gy, calc; LS (10%), wh-gy, mtld, f-m xtln, arg, fos	
1,440-1,460	LS, wh-gy, mtld, m-c xtln, arg, fos; SH (40%), gy, calc	

1,460-1,480	SH, gy, calc; LS (20%), wh-gy, mtld, m-c xtln, arg, fos	
1,480-1,495	SH, gy, calc	
1,495-1,505	LS, wh-gy, mtld, f-c xtln, arg, fos; SH (40%), gy, calc	
1,505-1,540	SH, gy, calc; LS (10%), wh-gy, mtld, f-c xtln, arg, fos	
1,540-1,705	SH, gy, calc	
1,705-1,720	SH, gy, calc; LS (10%), wh-gy-brn, mtld, f-c xtln	
1,720-1,755	SH, gy, calc	
1,755-1,760	SH, gy, calc; LS (10%), wh-tn, c xtln	Trenton 1,759 ft
1,760-1,790	LS, wh-tn, c xtln, carb prtgs	
1,790-1,800	LS, wh-brn, c xtln, chty (bl-brn), carb prtgs	
1,800-1,810	LS, wh-tn, c xtln	
1,810-1,815	LS, wh-brn, c xtln, carb prtgs	
1,815-1,840	LS, wh-tn, c xtln, carb prtgs	
1,840-1,845	LS, wh-tn, c xtln; LS (40%), tn-brn, lith; BENT (1%)	Black River 1,843 ft
1,845-1,865	LS, tn-brn, lith, chty (wh-brn)	
1,865-1,870	LS, brngy, lith	
1,870-1,895	LS, tn-brn, lith	
1,895-1,900	LS, brngy, lith, chty (gy)	
1,900-1,910	LS, tn-brn, lith	
1,910-1,915	LS, brngy, lith	
1,915-1,920	LS, tn-brn, lith, chty (gy)	
1,920-1,925	LS, brngy, lith	
1,925-1,945	LS, tn-brn, lith	
1,945-1,950	LS, brngy, lith	
1,950-1,965	LS, tn-brn, lith	
1,965-1,970	LS, brngy, lith	
1,970-1,995	LS, tn-brn, lith	
1,995-2,000	LS, tn-orn, lith, fos, chty (gy)	
2,000-2,050	LS, tn-brn, lith; DOL (20%), tn-brn, f xtln	

2,050-2,060	LS, tn, f xtln; DOL (5%), tn-brn, f xtln	
2,060-2,140	LS, tn-brn, lith; DOL (10%), tn-brn, f xtln	
2,140-2,185	LS, brngy, lith; DOL (5%), tn-brn, f xtln	
2,185-2,210	LS, gy-brn, lith	
2,210-2,235	LS, tn-brn, lith; DOL (20%), tn-brn, f xtln	
2,235-2,250	DOL, tn-brn, f xtln; LS (20%), tn-brn, lith	
2,250-2,285	LS, brngy, lith	
2,285-2,290	Skip	
2,290-2,295	LS, brngy, lith	
2,295-2,310	DOL, tn, of xtln; SH (40%), gy, calc	Chazyan 2, 295 ft
2,310-2,320	DOL, tn, of xtln; SH (20%), gy	
2,320-2,325	DOL, lt gy, vf-f xtln	
2,325-2,335	LS, gy-gngy, f xtln, slty	
2,335-2,340	LS, gy, f xtln, arg	
2,340-2,345	LS, lt gy, f xtln, arg	
2,345-2,355	LS, gygn, f xtln, arg	
2,355-2,360	SH, blk-gngy, calc; SD (10%), wh, f-m, ang-rnd, fr	
2,360-2,365	DOL, wh-tn, of xtln, v chty (wh-brn, ool)	Knox 2, 360 ft
2,365-2,385	DOL, wh-tn, of xtln, sl chty (wh-brn, ool)	
2,385-2,390	DOL, wh-tn, f xtln, aren, chty (wh)	
2,390-2,415	DOL, wh-tn, of xtln, chty (wh)	
2,415-2,455	DOL, wh-tn, f xtln, chty (wh)	
2,455-2,465	DOL, tn, m-c xtln; SD (20%), wh, f-c, ang-rnd (frstd), fr-uncon	
2,465-2,505	SD, wh, f-c, ang-rnd (frstd), fr-uncon	
2,505-2,510	SD, wh, m, ang, fr; DOL (40%), wh, vf-f xtln	
2,510-2,520	SD, wh, m-c, ang, fr-uncon	

2,520-2,525	SD, wh, m-c, ang, fr-uncon; DOL (20%), wh, vf-f xtln
2,525-2,530	SD, wh, m-c, ang, fr-uncon
2,530-2,535	SD, wh, m-c, ang, fr-uncon; DOL (40%), gngy, f xtln
2,535-2,540	SD, wh, m-c, ang, fr-uncon
2,540-2,560	DOL, wh-tn, of xtln; SD (20%), wh, m, ang, fr-uncon; SH (10%), gygn
2,560-2,605	SD, wh, m-c, ang-rnd (frstd), fr-uncon
2,605-2,610	DOL, tn, m-c xtln; SD (40%), wh, m-c, ang-rnd (frstd), fr-uncon
2,610-2,625	DOL, wh-tn, vf-f xtln, chty (wh)
2,625-2,635	DOL, brn, f xtln
2,635-2,660	DOL, wh-tn, of xtln; SD (40%), wh, m-c, ang-rnd (frstd), fr-uncon
2,660-2,670	SD, wh, m-c, ang-rnd (frstd), fr-uncon
2,670-2,675	SD, wh, m-c, ang-rnd (frstd), fr-uncon; DOL (30%), tn, m-c xtln, v chty (wh-brn, ool)
2,675-2,680	DOL, tn, m xtln, v chty (wh-brn, ool); SD (10%), wh, m-c, ang-rnd (frstd), fr-uncon
2,680-2,705	DOL, tn-gy, f xtln, chty (wh-brn, ool); SD (10%), wh, f-m, ang-rnd (frstd), fr-uncon; SH (5%), gn, calc
2,705-2,715	SD, wh, m-c, ang-rnd (frstd), fr-uncon; DOL (10%), wh-tn, m-xtln, chty (wh); SH (10%), gy-tn, bent
2,715-2,725	DOL, tn, f xtln, chty (wh)
2,725-2,745	DOL, wh-tn, of xtln, v chty (wh-brn, ool)
2,745-2,755	DOL, wh-tn, f xtln, chty (wh); SD (20%), wh, m-c, ang-rnd (frstd), fr-uncon

2,755-2,850	SD, wh, m-c, ang-rnd (frstd), fr-uncon
2,850-2,860	DOL, wh, m-c xtln, ool; SD (20%), wh, f-m, ang, fr
2,860-2,870	SD, wh, f-m, ang, fr-uncon
2,870-2,885	DOL, wh-tn, f-c xtln
2,885-2,915	DOL, tn, f -m xtln, chty (wh, ool)
2,915-2,920	DOL, brn, f xtln
2,920-2,935	DOL, tn, f-m xtln, chty (wh)
2,935-2,960	DOL, tn, f xtln, aren, chty (wh)
2,960-2,970	DOL, brn, m-c xtln, chty (wh)
2,970-2,990	DOL, tn, f xtln, chty (wh)
2,990-3,010	DOL, tn-brn, m-c xtln, chty (brn)
3,010-3,050	DOL, wh-tn, f xtln, chty (wh)
3,050-3,105	DOL, tn-brn, m-c xtln, chty (wh)
3,105-3,140	DOL, tn, f xtln, chty (wh)
3,140-3,150	DOL, tn, m-c xtln, chty (wh)
3,150-3,170	DOL, tn-gy, vf-f xtln, chty (wh)
3,170-3,180	DOL, tn, m-c xtln, chty (wh)
3,180-3,185	DOL, brn, c xtln, chty (wh)
3,185-3,205	DOL, tngy, f xtln, chty (wh)
3,205-3,360	DOL, wh-tn, m-c xtln, chty (wh)
3,360-3,365	DOL, gytn, c xtln, chty (wh)
3,365-3,380	DOL, tn-brn, c xtln, chty (wh)
3,380-3,405	DOL, tn, f-c xtln, chty (wh)
3,405-3,420	DOL, tn-brn, f xtln, chty (wh, ool)
3,420-3,435	DOL, tn, c xtln, chty (wh, ool); QTZ (3%), lrg free xtals
3,435-3,465	DOL, tn, m-c xtln, chty (wh, ool); QTZ (10%), lrg free xtals

3,465-3,490	DOL, tn-brn, f-m xtln
3,490-3,495	DOL, brn, f xtln
3,495-3,535	DOL, tn, f -m xtln, chty (wh); QTZ (5%), lrg free xtals
3,535-3,545	DOL, tn-gy, f xtln, chty (wh); SH (5%), gy; QTZ (5%), lrg free xtals
3,545-3,565	DOL, tn-brn-gy, m-c xtln, chty (wh-blk); QTZ (25%), lrg free xtals
3,565-3,580	DOL, tn, f-c xtln, chty (wh); QTZ (3%), lrg free xtals
3,580-3,615	DOL, tn-brn, f-m xtln, chty (wh); QTZ (1%), lrg free xtals
3,615-3,645	DOL, tn, f-c xtln, chty (wh); QTZ (10%), lrg free xtals
3,645-3,670	DOL, tn-gytn, f-m xtln, chty (wh); QTZ (5%), lrg free xtals
3,670-3,825	DOL, tn-brn, m xtln, chty (wh); QTZ (1%), lrg free xtals
3,825-3,865	DOL, tn-brn, m-c xtln; QTZ (1%), lrg free xtals
3,865-3,870	Skip
3,870-3,920	DOL, tn-brn, m-c xtln; QTZ (1%), lrg free xtals
3,920-4,100	DOL, tn-brn, f-c xtln
4,100-4,130	DOL, brn, m-c xtln
4,130-4,180	DOL, tn-brn, f-c xtln
4,180-4,265	DOL, tn-brn, c xtln
4,265-4,275	DOL, tn, m-c xtln; QTZ (3%), lrg free xtals
4,275-4,285	DOL, brn, f xtln; BENT (3%)
4,285-4,300	DOL, brn, f-c xtln
4,300-4,305	DOL, brn, f-c xtln; BENT (1%)
4,305-4,360	DOL, tn-brn, m-c xtln
4,360-4,385	DOL, tn-lt gy, c xtln
4,385-4,440	DOL, tn, f-m xtln
4,440-4,490	DOL, wh-tn, f xtln
4,490-4,515	DOL, brn, f-m xtln
4,515-4,525	DOL, brn, f-m xtln, ool

4,525-4,530	DOL, wh-brn, f xtln	
4,530-4,540	DOL, brn-gybrn, f xtln	
4,540-4,675	DOL, brn, f-m xtln	
4,675-4,705	DOL, tn-brn-gybrn, f-c xtln, glauc; SH (10%), gy	Eau Claire 4,675 ft
4,705-4,740	DOL, tn-brn, f-m xtln, glauc, ool; SH (5%), gy	
4,740-4,765	DOL, tn-brn, f xtln, glauc	
4,765-4,780	DOL, tn-brn, f xtln, glauc, ool	
4,780-4,785	DOL, tn-brn, f xtln, glauc, ool; SH (10%), gy; BENT (1%)	
4,785-4,815	DOL, tn-brn, f xtln, glauc, ool; SH (10%), gy, mic	
4,815-4,850	SLT, tn-gy, hd, calc, glauc; SH (30%), gy-gngy-mrn, mic	
4,850-4,915	SH, mrn-gy, mic; SLT (40%), gy, hd, calc, glauc; DOL (5%), tn, m xtln	
4,915-4,970	SH, mrn-gy, mic; SLT (20%), gy, hd, calc, glauc	
4,970-5,055	SH, mrn-gy, mic; SLT (40%), tn-gy, hd, calc, glauc	
5,055-5,095	DOL, wh-brn, mtld, f-m xtln, ool; SH (40%), mrn-gy-gn, mic	
5,095-5,115	SH, mrn-gy, mic; SLT (10%), gy, hd, calc, glauc; DOL (5%), tn-brn, f xtln	
5,115-5,145	SH, mrn-gy-gn, mic; SLT (40%), tn-gy, hd, calc, glauc	
5,145-5,150	LS, red, m-c xtln, fos; SH (40%), mrn-gy, mic	
5,150-5,195	SH, mrn-gy-blk, mic; SLT (20%), tn-gy, hd, calc, glauc	
5,195-5,310	SH, mrn-gy-blk-gn, mic; SLT (40%), tn-gy, hd, calc, glauc	
5,310-5,365	SH, mrn-gy-blk-gn, mic; SLT (20%), tn-gy, hd, calc, glauc	

5,365-5,384	SH, mrn-gy-blk, mic; SD (30%), wh, f-m, ang-rnd, well cmtd-fr, glauc; SLT (5%), tn, hd, glauc	Mt. Simon 5,365 ft
5,384-5,400	SD, wh, m, ang, well cmtd-fr; SH (30%), mrn-gy-blk, mic	
5,400-5,405	SD, tn, f, hd, calc, glauc	
5,405-5,455	SH, mrn-gy-blk, mic; SLT (10%), tn-gy, hd, calc, glauc	
5,455-5,485	SD, wh-tn, f-m, ang-rnd, well cmtd-fr, glauc; SH (30%), mrn-gy-blk, mic	
5,485-5,515	SH, mrn-gy-blk, mic; SD (30%), wh-tn, f-m, ang, well cmtd-fr; SLT (5%), tn-gy, hd, calc, glauc	
5,515-5,520	SD, red, f-m, ang-rnd, well cmtd-fr, feld; SH (30%), mrn-gy-blk, mic	
5,520-5,530	SD, wh, f-m, ang-rnd, fr; SH (40%), mrn-gy-blk, mic	
5,530-5,545	SD, dk red, vf-f, well cmtd, mic, ark; SH (40%), mrn-gy-blk, mic	
5,545-5,602	SD, wh, f-c, ang-rnd (frstd), well cmtd-fr; SH (20%), mrn-gy-blk, mic	
5,602-5,685	SH, mrn-gy-blk, mic, glauc; SD (40%), wh, f-c, ang-rnd (frstd), well cmtd-fr	
5,685-5,870	SD, wh, f-vc, ang-rnd (frstd), well cmtd-fr; SH (30%), mrn-gy-blk, mic, sl glauc; SLT (5%), gy, hd, calc, glauc	
5,870-5,915	SH, mrn-gy-blk, mic; SD (30%), wh, f-vc, ang-rnd (frstd), well cmtd-fr; SLT (5%), gy, hd, calc, glauc	

5,915-5,945	SH, mrn-gy-blk, mic; SD (10%), wh, m-c, ang-rnd (frstd), well cmtd-fr; SLT (5%), gy, hd, calc, glauc
5,945-5,955	SH, mrn-gy-blk, mic; SD (40%), red, m-vc, ang-rnd (frstd), fr, feld; SLT (5%), gy, hd, calc, glauc
5,955-6,005	SD, wh, f-c, ang-rnd (frstd), well cmtd-fr; SH (30%), mrn-gy-blk, mic; SLT (5%), gy, hd, calc, glauc
6,005-6,095	SD, wh-red, f-c, ang-rnd (frstd), fr-uncon, feld; SH (5%), mrn-gy-blk, mic
6,095-6,125	SD, wh, f-c, ang-rnd (frstd), fr-uncon; SH (10%), mrn-gy-blk, mic
6,125-6,135	SD, wh-pnk, f-c, ang-rnd (frstd), fr-uncon; SH (5%), mrn-gy-blk, mic
6,135-6,145	SD, red, f-c, ang-rnd (frstd), fr-uncon, feld; SH (5%), mrn-gy-blk, mic
6,145-6,215	SD, wh, f-c, ang-rnd (frstd), fr-uncon; SH (5%), mrn-gy-blk, mic
6,215-6,300	SD, wh-red, m-c, ang-rnd (frstd), fr-uncon, feld; SH (5%), mrn-gy-blk, mic
6,300-6,310	SD, wh-red, c, rnd (frstd), uncon
6,310-6,350	SD, wh-red, m-c, ang-rnd (frstd), fr-uncon, feld; SH (20%), mrn-gy-blk, mic
*6,350-6,490	SD, pnk-dk red, f-m, ang-subang, well cmtd-fr, ark; SH (10%), mrn-gy-blk, mic
6,490-6,500	DOL, wh-red, f xtln, arg; SH (20%), mrn-gy, mic
6,500-6,530	SD, wh-yel-red (cotd), c-vc, ang-rnd (frstd), fr-uncon; SH (5%), mrn-gy, mic

6,530-6,550	SD, wh, c-vc, ang-rnd (frstd), fr-uncon; SH (5%), mrn-gy, mic	
6,550-6,595	SD, wh-yel-red (cotd), c-vc, ang-rnd (frstd), fr-uncon; SH (5%), mrn-gy, mic	
6,595-6,600	SH, mrn-gy, mic; SD (30%), wh-red, f-vc, ang-rnd (frstd), fr-uncon	
6,600-6,610	SH, mrn-gy, mic	
6,610-6,625	SH, mrn-gy, mic; SD (30%), wh-red (cotd), c-vc, ang-rnd (frstd), fr-uncon	
6,625-6,635	SD, wh-red (cotd), c-vc, ang-rnd (frstd), fr-uncon; SH (40%), mrn-gy, mic	
6,635-6,640	SD, wh-red (cotd), c-vc, ang-subang, fr-uncon; SH (20%), mrn-gy, mic	
6,640-6,650	SH, mrn-gy, mic; BSLT (10%), red-gn, mtld	
6,650-6,735	BSLT, red-gn-gy, mtld	Precambrian 6,650 ft
6,735-6,740	BSLT, red-gn-gy, mtld; FELD (20%), orge	
6,740-6,775	BSLT, gygn	
6,775-6,785	BSLT, red-gn-gy, mtld	
6,785-6,800	BSLT, gygn-gn	
6,800-6,806	BSLT, gngy	
6,806	Total depth	

*A pronounced change in velocity character (Biggs, Blakely, and Rudman, 1960) and some basic petrologic change (Seymour S. Greenberg, oral communication) at 6,350 feet suggest that the sediments between 6,350 feet and 6,650 feet may be a part of the basement complex. These sediments are probably equivalent to the Red Clastics, which Gutstadt (1958) included in the Mt. Simon Sandstone.

Explanation of Abbreviations

ang - angular
aren - arenaceous
arg - argillaceous
ark - arkosic (more than 25% feldspar)
BENT - bentonite
bent - bentonitic
bl - blue
blk - black
brn - brown
brngy - brownish-gray
BSLT - basalt
c - coarse
calc - calcareous
carb - carbonaceous
chty - cherty
cmtd - cemented
cotd - coated
D&A -dry and abandoned
dk - dark
DOL -dolomite
dol - dolomitic
EL -east line
f - fine
FELD - feldspar
feld - feldspathic (5-25% feldspar)
fos - fossiliferous
fr - friable
frstd - frosted
glauc - glauconitic
gn - green
gngy - greenish-gray
gntn - greenish-tan
gy - gray
gybrn - grayish-brown
gygn - grayish-green
gytn - grayish-tan
hd - hard
KB - Kelly bushing
lith - lithographic
lrg - large
LS - limestone
lt - light
m - medium
mic - micaceous
mrn - maroon
mtld - mottled
ool - oolitic
orge - orange
pity - platy
pnk - pink
pnktn - pinkish-tan
prtgs - partings
QTZ - quartz
rnd - rounded
SD - sandstone
sft - soft
SH - shale
SL - south line
sl - slightly
SLT - siltstone
slty - silty
spty - spotty
stn - stain
Subang - subangular
suc - sucrosic
to - tan
tngy - tannish-gray
uncon- unconsolidated
v - very
vc - very coarse
of - fine
vug - vuggy
wh - white
xtln - crystalline
xtls - crystals
yel - yellow

LOWER ORDOVICIAN AND CAMBRIAN STRATIORAPHIC UNITS IN INDIANA

Important new stratigraphic knowledge gained from the deep test well in Lawrence County is limited to the rock section below the top of the Knox Dolomite, and comments on lithology in this report are restricted to the Knox-Eau Claire-Mt. Simon section. Likewise, thickness maps presented in this report are restricted to stratigraphic units within the lower Ordovician and Cambrian section.

Gutstadt (1958) prepared a comprehensive report on the Cambrian and Ordovician in Indiana. Gutstadt's report included detailed lithologic descriptions for the Knox, Eau Claire, and Mt. Simon. To recite the general lighologic character of these formations here would be a duplication of Gutstadt's work. However, two lithologic units that have not been recognized heretofore as distinctive rock units were found in the lower Ordovician and Cambrian section of the Farm Bureau No. 1 Brown well and are worthy of comment. The first of these is the 415-foot dominantly sandstone section that lies 95 feet below the top of the Knox (sample description and pl. 1). This thick sandstone section has been penetrated in wells in Jennings and Decatur Counties to the east, but in these wells it lies directly beneath the Glenwood Shale and thus occupies a stratigraphic position normal for the St. Peter Sandstone--a circumstance that has caused some geologists to identify it as St. Peter Sandstone. This sandstone in the Knox is not present in the extreme eastern part of Indiana. As an unconformable relationship presumably exists between the Knox and the overlying Chazy, the absence of this Knox sandstone in the extreme eastern part of Indiana is probably due to gradual overlap from west to east by the Chazy. Overlap of the sandstone by the impermeable Glenwood (Chazyan) might reasonably be considered as a favorable circumstance for the entrapment of oil.

The second lithologic unit worthy of comment is the upper 640 feet of section assigned to the Mt. Simon Sandstone (sample description and pl. 1). Whereas the Mt. Simon is usually regarded as a formation of nearly pure sandstone, this section is approximately half shale and siltstone. Shale and siltstone are characteristic lithologies of the Eau Claire. On the other hand, much of the sandstone in the section is medium and coarse grained--sandstone of a type characteristic of the Mt. Simon. This section of mixed lithologies is assigned, somewhat arbitrarily, to the Mt. Simon.

Gutstadt (1958) had available only scanty control for the compilation of isopach maps of the Knox, Eau Claire, and Mt. Simon formations. Control for compilation of such maps is still limited, but it is not so limited as it was at the time of Gutstadt's study. Since Gutstadt's maps were compiled, deep test wells drilled in Indiana, in addition to the deep test in Lawrence County, include 2 Mt. Simon tests in Jay and Vermillion Counties, 4 Eau Claire tests in Fountain, Lagrange, Randolph, and Steuben Counties, and 16 Knox tests. Some of these wells are critically located for the compilation of isopach maps of stratigraphic units within the lower Ordovician and Cambrian section. Thus, thickness maps of various stratigraphic units within this section are presented in this report.

In compiling the thickness maps it was necessary to establish formational contacts between the Chazy and Knox, between the Knox and Eau Claire, between the Eau Claire and Mt. Simon, and between the Mt. Simon and Precambrian. With the exception of the Knox Eau Claire contact, the writer is in agreement, for the most part, with the contacts picked by Gutstadt.

In placing the Knox-Eau Claire contact in wells, the writer has placed more emphasis on glauconite as a defining characteristic of the Eau Claire than did Gutstadt. For many of the deep test wells the writer is in agreement with Gutstadt on the position of the top of the Eau Claire. For wells in northwestern Indiana, however, the writer has placed the top of the Eau Claire, based on the conspicuous occurrence of glauconite, at a higher stratigraphic position than did Gutstadt. The top of the Eau Claire in northwestern Indiana as picked by the writer corresponds closely to the top of the Franconia Formation of northern Illinois. To place the top of the Eau Claire in northwestern Indiana in this manner is to place it at the correlative position of the top of the Eau Claire in other areas of Indiana as picked by Gutstadt (1958) and the writer. In figure 3, which shows the thickness of the Eau Claire, and in figure 5, which shows the composite thickness of the Eau Claire and the Mt. Simon, the Franconia Formation and the underlying Galesville Sandstone are included in the units mapped.

For thickness of various mappable stratigraphic units within the Knox-Eau Claire-Mt. Simon section, the reader is referred to figures 2 through 6. For structure on top of this section the reader is referred to figure 7.

The deep test well in Lawrence County has added materially to the limited data available in Indiana on the lower Ordovician and Cambrian. The excellent records on this well make it a guidepost for future study of this basal Paleozoic rock section.

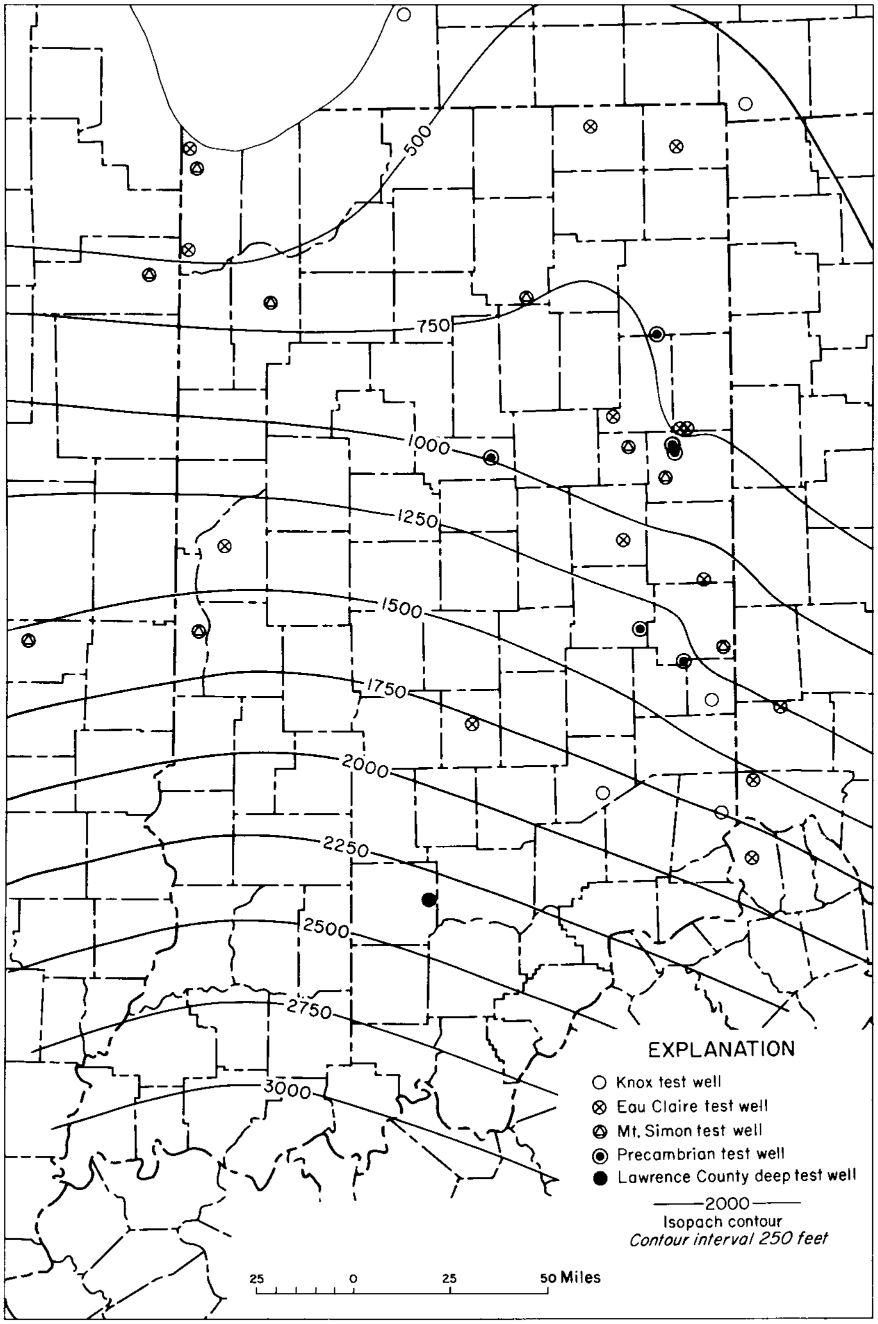


Figure 2. --Map showing thickness of Knox Dolomite in Indiana.

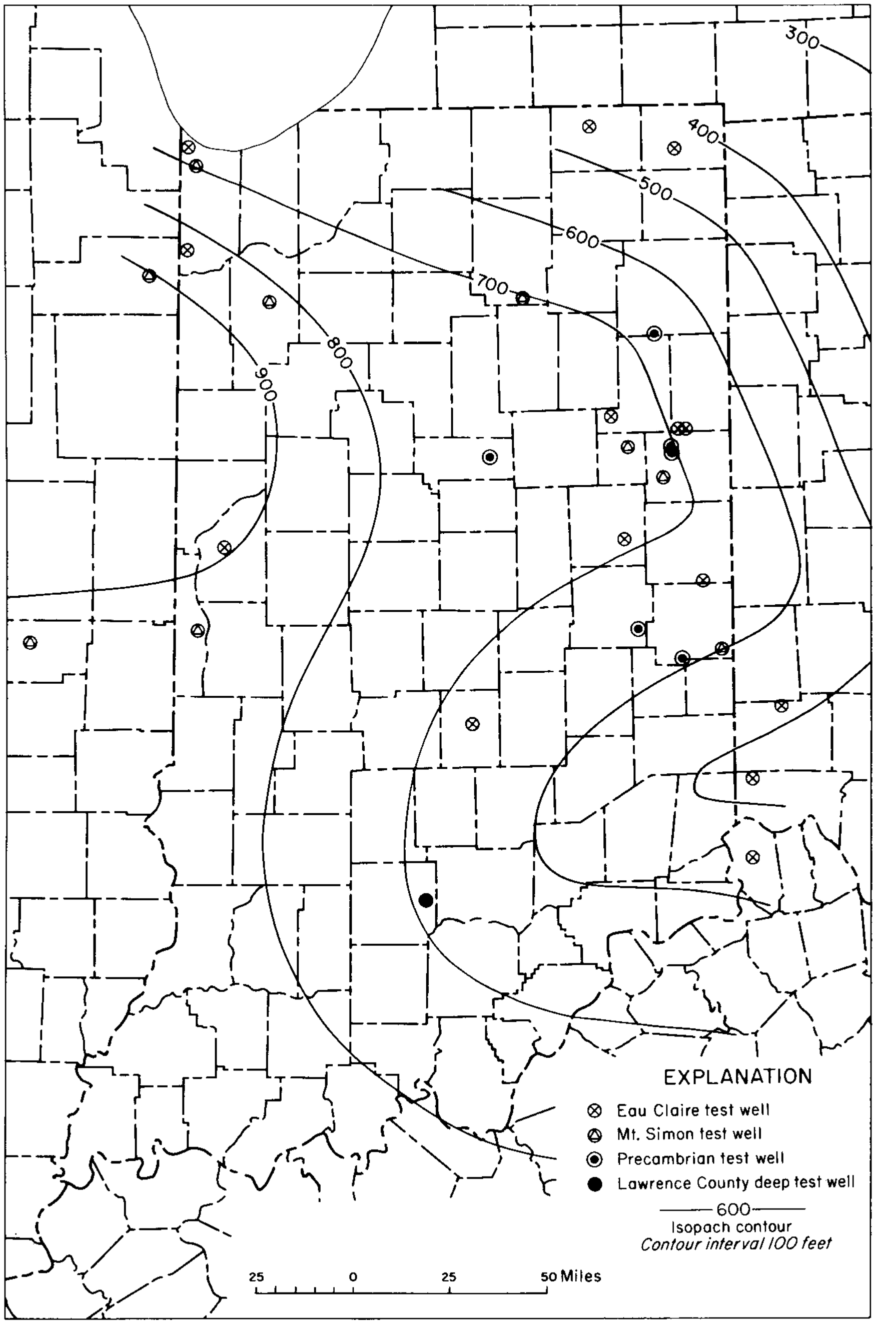


Figure 3. --Map showing thickness of Eau Claire Formation in Indiana.

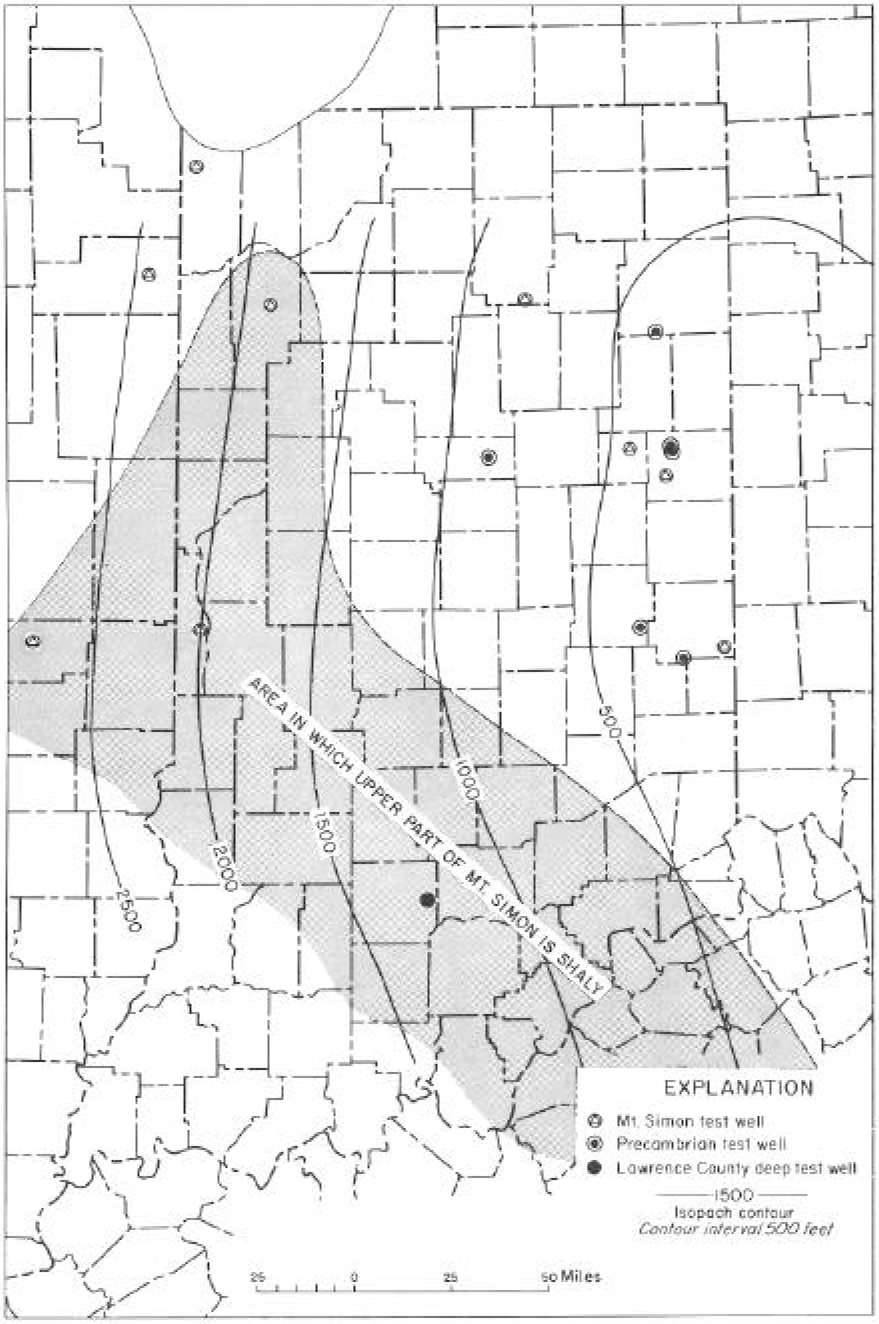


Figure 4. --Map showing thickness of Mt. Simon Sandstone in Indiana.

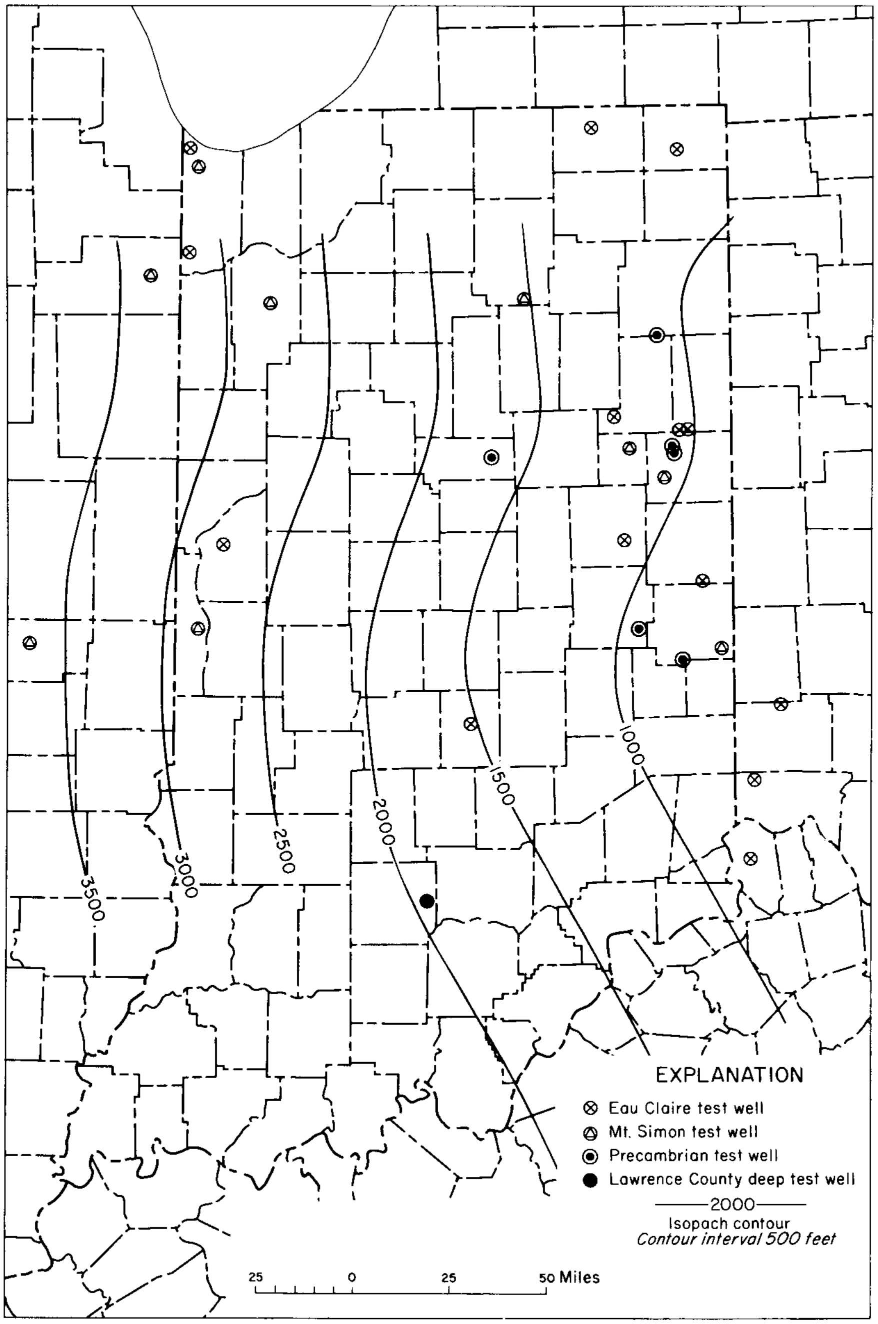


Figure 5. --Map showing thickness of Eau Claire Formation and Mt. Simon Sandstone in Indiana.

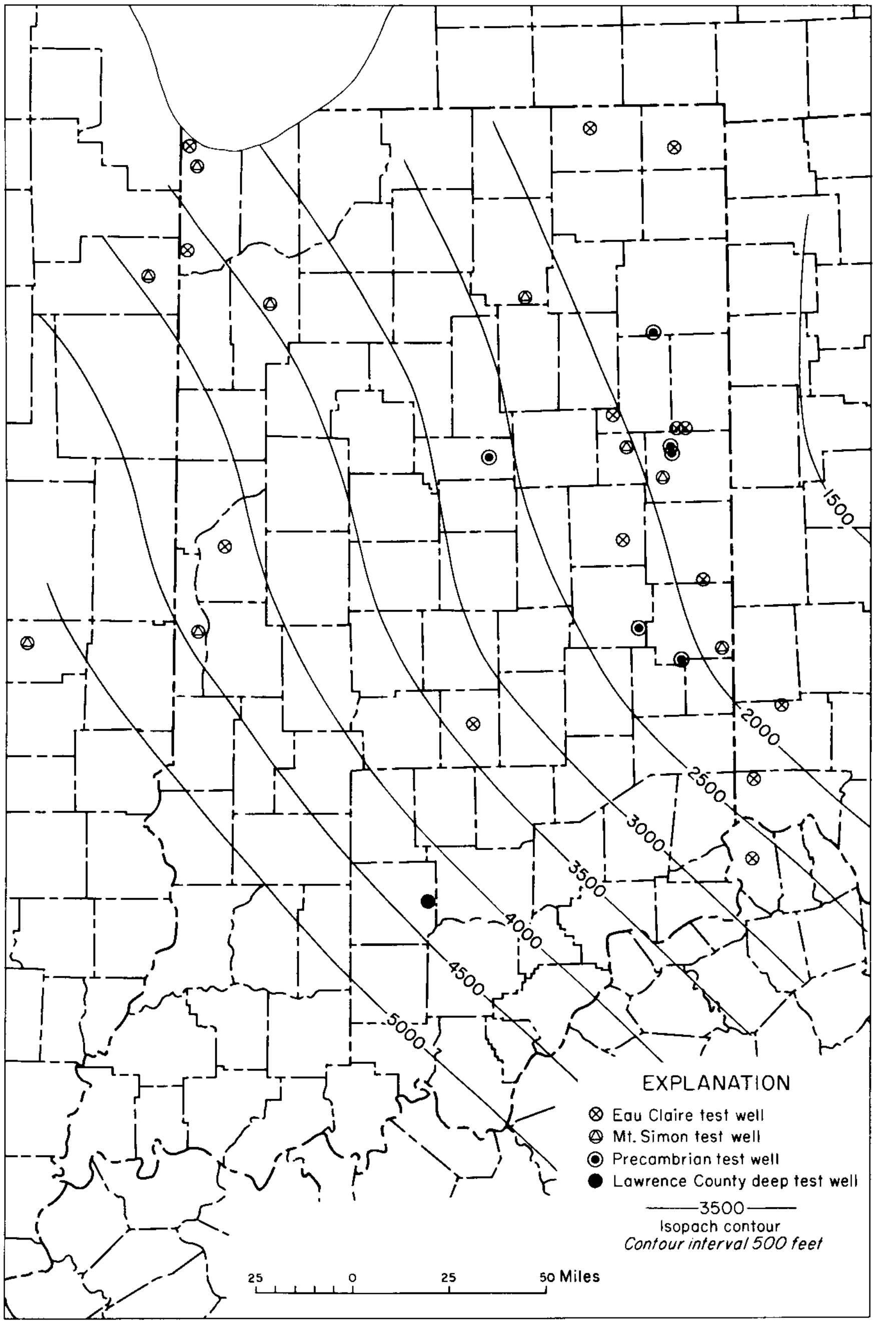


Figure 6. --Map showing composite thickness of Knox Dolomite, Eau Claire Formation, and Mt. Simon Sandstone in Indiana.

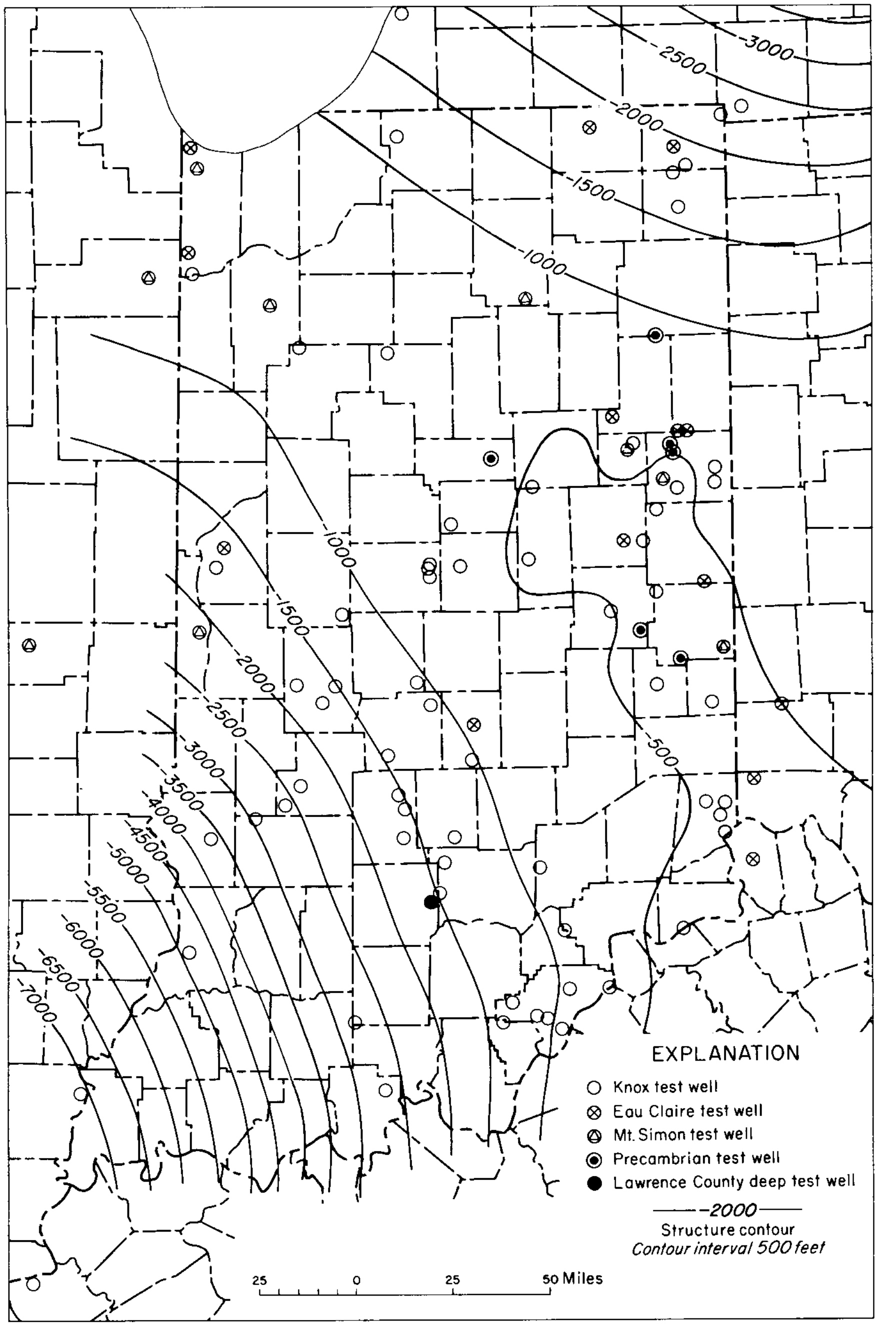


Figure 7. --Map showing structure on top of Knox Dolomite in Indiana.

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