EASTERN GAS SHALES PROGRAM

CORING AND LOGGING OF EGSP ILLINOIS NO. 5 WELL

WAYNE COUNTY, ILLINOIS

Final Report

Miles Wilhelm
LaVerne B. Cobb

November 1981

Work Performed for the Department of Energy
Under Contract DE-AC05-79MC98382

GRUY FEDERAL, INC.
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EXECUTIVE SUMMARY

The Eastern Gas Shales Project Illinois No. 5 well (Gordon T. Jenkins/Gruy Federal Simpson No.1) is located in southern Wayne County, Illinois. The site lies within the Fairfield sub-basin of the central part of the Illinois Basin.

The location was chosen for the purpose of gathering geological and petrophysical information on the gas bearing Devonian New Albany Shale in the Illinois Basin. The specific site was chosen at a location where a thick section of radioactive gas bearing shales was known to be present. Another factor in the selection of the well site is the presence of "synaeresis cracks" (Harvey, et al, 1977) and the possible presence of fractures due to local structures in the area. The presence of these fracture systems are believed to increase the potential for production from gas bearing shales. Essentially, the rationale for drilling the well at this site was to provide information valuable to the assessment of the New Albany Shale as an energy resource in a location having favorable geological conditions.

The well, spudded on September 16, 1979, was drilled as a cooperative operation between Mr. Gordon Jenkins and Gruy Federal, Inc., acting for the Department of Energy. Coring, under the direction of Gruy, began at a depth of 5010 feet on September 29, 1979. Two hundred and seventy-eight feet of formation was cored and recovered in six coring runs. Since several water bearing formations were encountered below the casing, drilling and coring operations could not be conducted using air drilling techniques; therefore conventional drilling mud was used. Although no serious problems were encountered, natural fractures occasionally caused the barrel to jam.

After coring was completed, drilling resumed until a depth of 5494 was reached. A suite of wet hole logs was then run. The well was neither completed nor tested for production in the New Albany as the operator did not wish to jeopardize the good quality (500 barrels per day) production proven in the uphole Warsaw Formation. Therefore, assessment of the well was made on geophysical log data and core data.

Geophysical log data and core data showed the area to have good potential. Log and cores both indicated the section of gas bearing radioactive black shale to be quite thick. Studies by the Illinois Geological Survey show the cores to contain substantial amounts of gas (0.16-2.4m^3 gas/m^3 shale) with a caloric content higher than most pipeline gas. Log and core data also confirmed the presence of natural fractures necessary for production. Although this study shows the Devonian had good potential for production in this part of Illinois, the resource will require production testing for a thorough evaluation.

INTRODUCTION AND RATIONALE

The Devonian Shales of the Appalachian, Illinois, and Michigan Basins (Fig. 1) have been under intensive study since the early 1970's as potential sources of large volumes of natural gas. Gruy Federal, Inc. (Gruy) of Houston was selected in 1979 by the U.S. Department of Energy (DOE) as a prime contractor for the evaluation of this unconventional gas source.

Historically, no gas production has come from Devonian shales in Illinois. They have been largely untested due to the high quality "pay" in other reservoirs. Mud logging units are seldom used in Illinois and operators show little interest in Devonian shales, hence gas shows may be largely overlooked.

Gruy, in a cooperative agreement with Mr. Gordon T. Jenkins, an independent oil producer, was allowed to utilize a well being drilled by Mr. Jenkins to obtain cores and logs of the Devonian New Albany Shales of the Illinois Basin. Coring and logging of this well, the Gordon T. Jenkins/Gruy Federal No. 1 Simpson (EGSP Illinois No. 5), in Wayne county, Illinois was undertaken to obtain information on the radioactive and nonradioactive Devonian New Albany Shales near the center of the Illinois Basin where the New Albany is thickest.

Regional studies indicate that black radioactive shale with high organic content occur in greatest abundance near the center of the Illinois Basin. Petrographic studies of New Albany shale samples north and south of the well location reveal the presence of "synaeresis cracks" (Harvey, et.al., 1977). The structural setting also suggests the possibility of fracturing, although there is no direct evidence from electric log data on the only two wells drilled through the shale in this area prior to EGSP Illinois No. 5. However, these two possible permeability sources within the New Albany in this area and in other anticlinal belts in the basin are believed to provide the greatest possibilities of economic occurrence of gas.

GEOLOGY

Geologic Setting

The site of EGSP Illinois No. 5 lies within the Fairfield sub-basin of the central part of the Illinois Basin, south and east of the southern end of the Clay City Anticlinal Belt (Fig. 2).

The specific location of the drilling site is 400 feet north and 300 feet east of the Southwest corner, SE1/4 SW1/4, Sec. 17, T3S, R8E (Fig. 3). The nearest deep control well is the A. J. Poorman No. 5 (NW1/4 SW1/4, Sec. 19, T3S, R8E), located about one mile to the southwest in the Mills Shoals Field of White County (Fig. 3). A shallower well (Fox No. 1) lies immediately to the north of the proposed site.

The stratigraphic column for south central Illinois shows the position of the New Albany Shale between the Borden Shale, Osage Series, of the Lower Mississippian and the Middle Devonian Dutch Creek Formation (Fig. 4).

The uppermost unit of the New Albany Shale is considered to be of Kinderhookian age (lowermost Mississippian, Fig. 4). Most of the shale, however, is Upper Devonian in age. Underlying the New Albany is the Dutch Creek Formation, predominantly a carbonate section but locally sandstone, which forms the top of the Middle Devonian in the Mills Shoals Field. The principal oil-producing units in this field are Mississippian sandstones and limestones and Middle Devonian carbonates.

Specifically, above the New Albany Shale are (in ascending order) the Chouteau, Springville Shale, Burlington, Keokuk, Warsaw, Salem, St. Louis, St. Genevieve, and Aux Vases Formation, all of Mississippian age. Below the New Albany, the Middle Devonian Dutch Creek Formation is also a prospective oil-producing unit. A drillstem test in the Jenkins No. 4 Poorman produced water with a show of oil, indicating that if structural elevation could be gained this sand should be oil-productive.

Characteristics of the New Albany Shale

According to Reinbold and others (1980), there are two main depocenters for Devonian New Albany shale in the Illinois Basin. Black shales of Grassy Creek-Middle Selmier and Blocher Members predominate in the center of the Illinois Basin where EGSP Illinois No. 5 was drilled. These black shales thin to the north and west. In the northwestern depocenter, greenish-gray shale and silt of Hannibal-Saverton, Sweetland Creek, Grassy Creek Members predominate.

The western depocenter which is located in southeastern Iowa and bordering west central Illinois, contains thicknesses of more than 300 feet. Greenish-gray, bioturbated shales and siltstones of the Hannibal-Saverton, Sweetland Creek, and Grassy Creek Members make up most of the New Albany here.

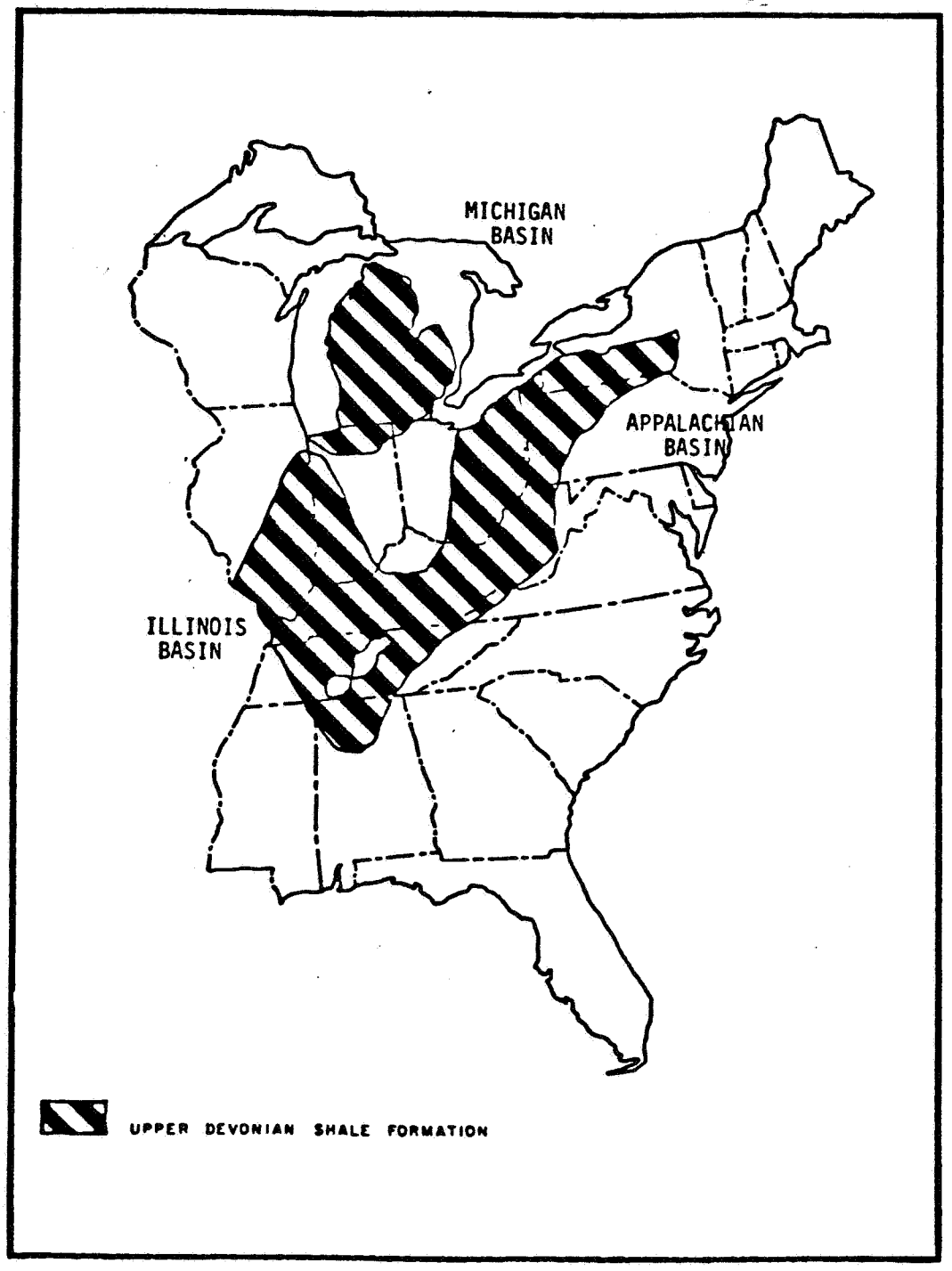


FIGURE 1 DEVONIAN SHALE BASIN. (AFTER FOSTER, 1975)

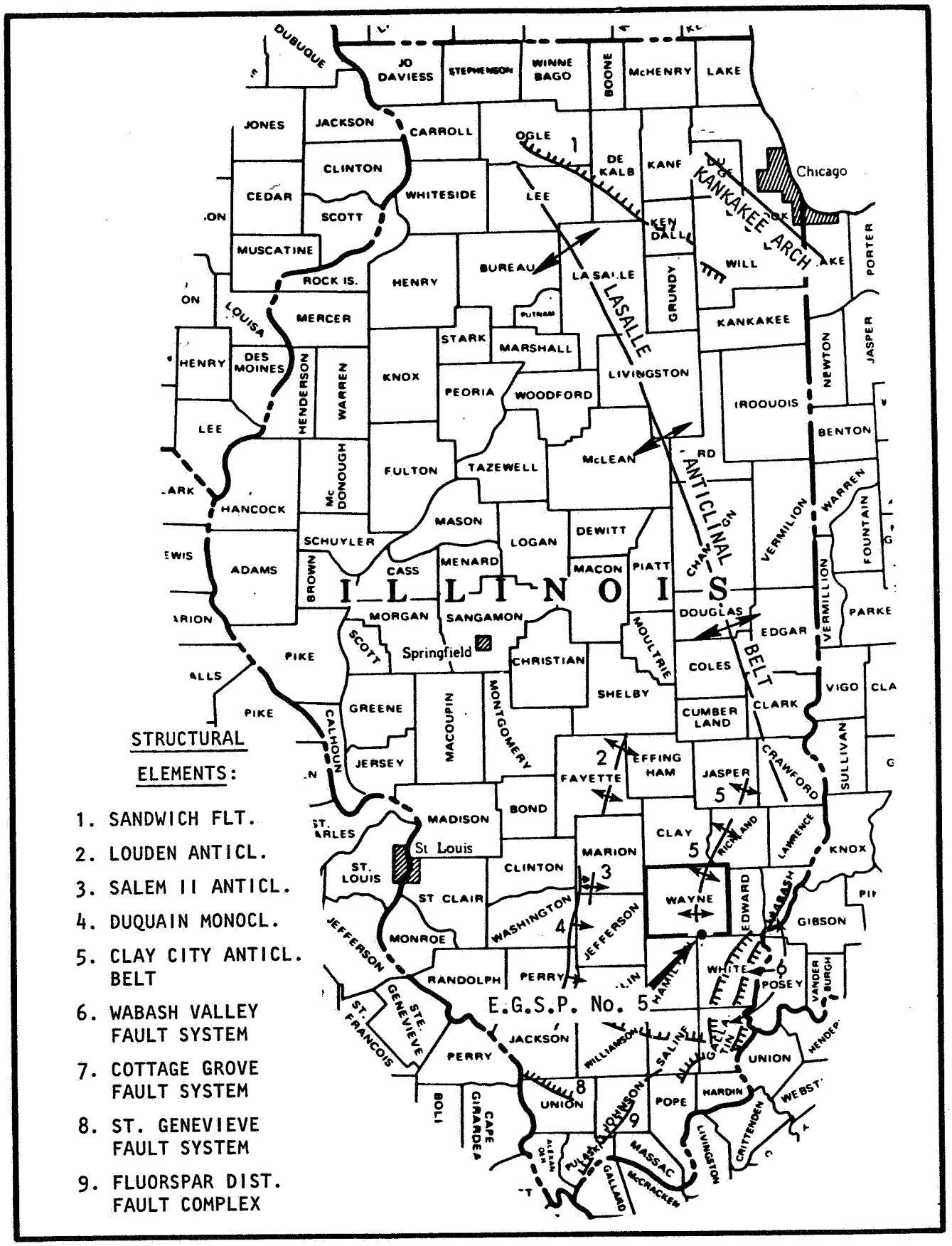


Figure 2.--Location of E.G.S.P. Illinois No. 5 core site in relation to major structures.

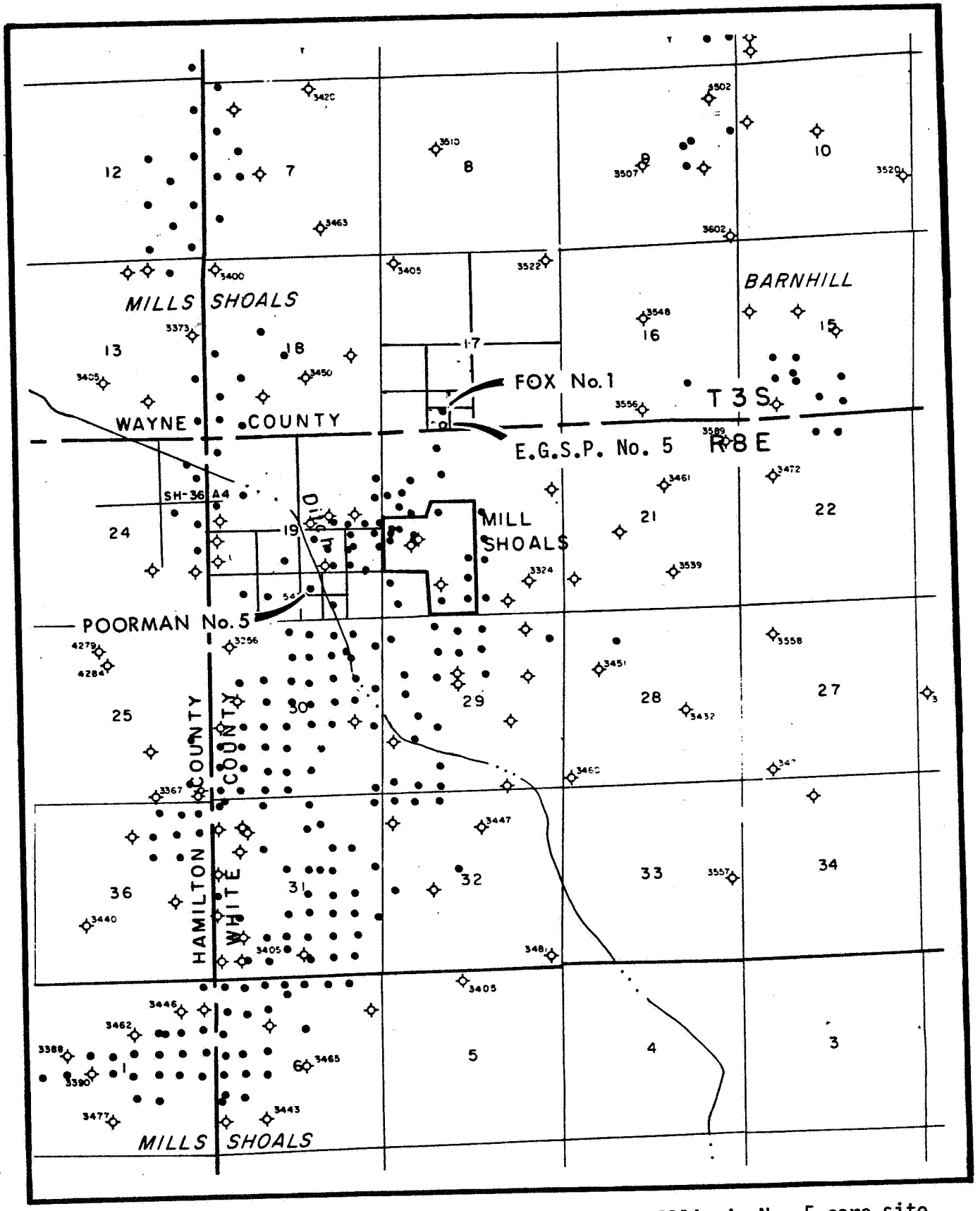


Figure 3.--Specific location of prospective E.G.S.P. Illinois No. 5 core site.

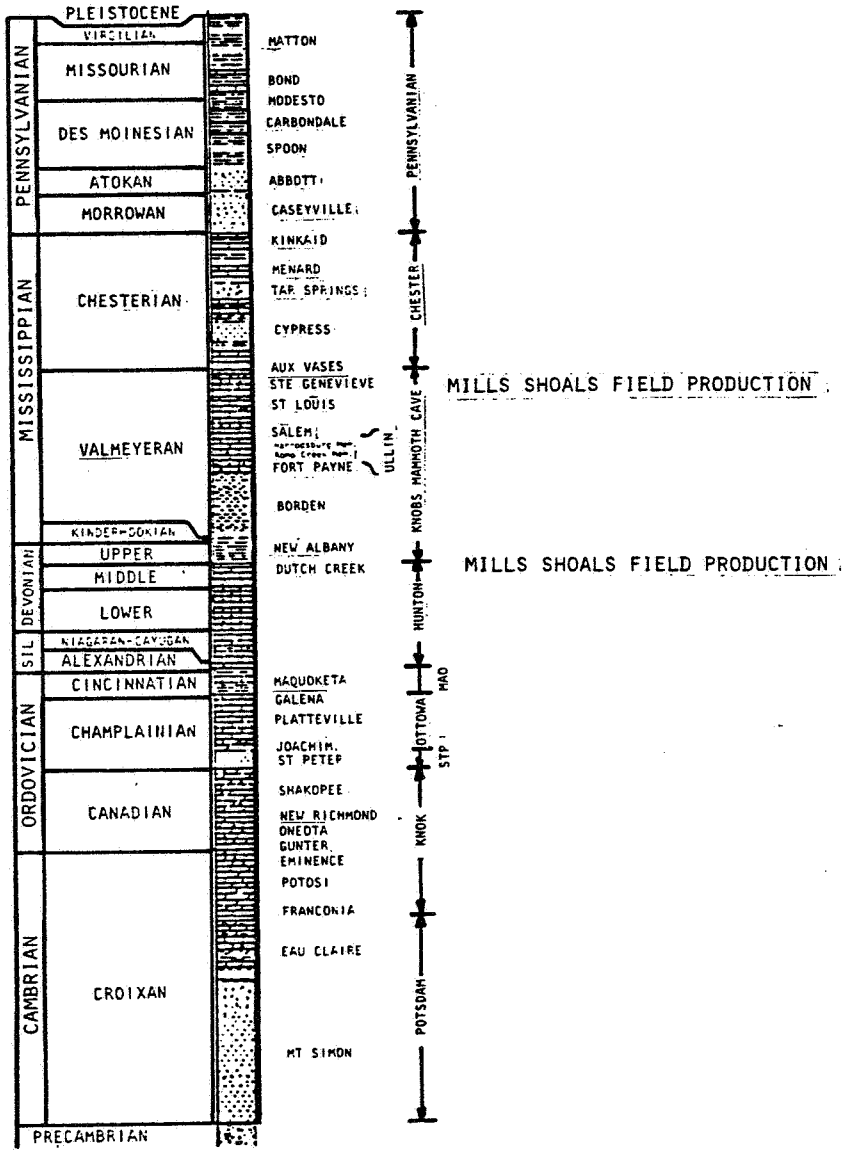


Figure 4.--Geologic column showing the stratigraphic position of the New Albany shale in the Illinois Basin (Willman, et al, 1975).

Black organic-rich radioactive shale beds of the Sweetland Creek, Grassy Creek and Saverton total less than 20 feet. Limestones, dolomites, and sandstone occur as very minor local constituents within this depocenter. The greenish-gray shales thin and occasionally grade laterally into black shales over the central thin area to the southeast.

The central thin which trends southwest to northeast in central Illinois has less than 100 feet of New Albany. From northwest to southeast, gray shales of the New Albany thin while black shales thicken. Limestone and dolostone, though still a minor constituent, occur in greater abundance here.

The New Albany Shale near the center of the Illinois Basin is composed of dark greenish-gray to olive-black and black shales with evidence of strong bioturbation (Reinbold and others, 1980; Harvey and others, 1977). Laminations characterize the shale here, the laminae varying from fine (2mm) to massive (>25mm). Silt laminae composed of illite clay and quartz are quite common. Minor mineral constituents are plagioclase, potassium feldspar, calcite, dolomite, and pyrite.

A striking aspect of the New Albany Shale is the presence of synaeresis joints--irregular polygonal systems of joints or cracks that are now filled with secondary minerals such as pyrite and calcite. These joints are linear and predominantly vertically oriented. They tend to be short (5 to 10 mm) and crooked. Harvey and others (1977) interpret the crooked pyrite-filled synaeresis joints to be an early diagenetic state in the history of the shale, asssociated with compaction processes but preceding the development of late-stage joints. Straighter, nearly vertical calcite-filled synaeresis joints are considered to have formed during post-compaction stages of diagenesis. The secondary mineralization within these synaeresis joints may provide permeable channels through the shale.

Although synaeresis produces some tension in sedimentary rocks, regional stresses may have some control over the orientation of the resulting cracks (Abramov, 1961). The proximity of the prospective site to the Clay City Anticlinal belt is believed to have an important bearing on the fracture and hence gas properties of the New Albany Shale.

Site Geology

Structure maps provided by the operator prior to drilling of EGSP Illinois No. 5, drawn on top of the Warsaw and Dutch Creek Formations (Figs. 5 and 6), indicate a low-relief anticlinal feature which trends northeast through the prospective well site.

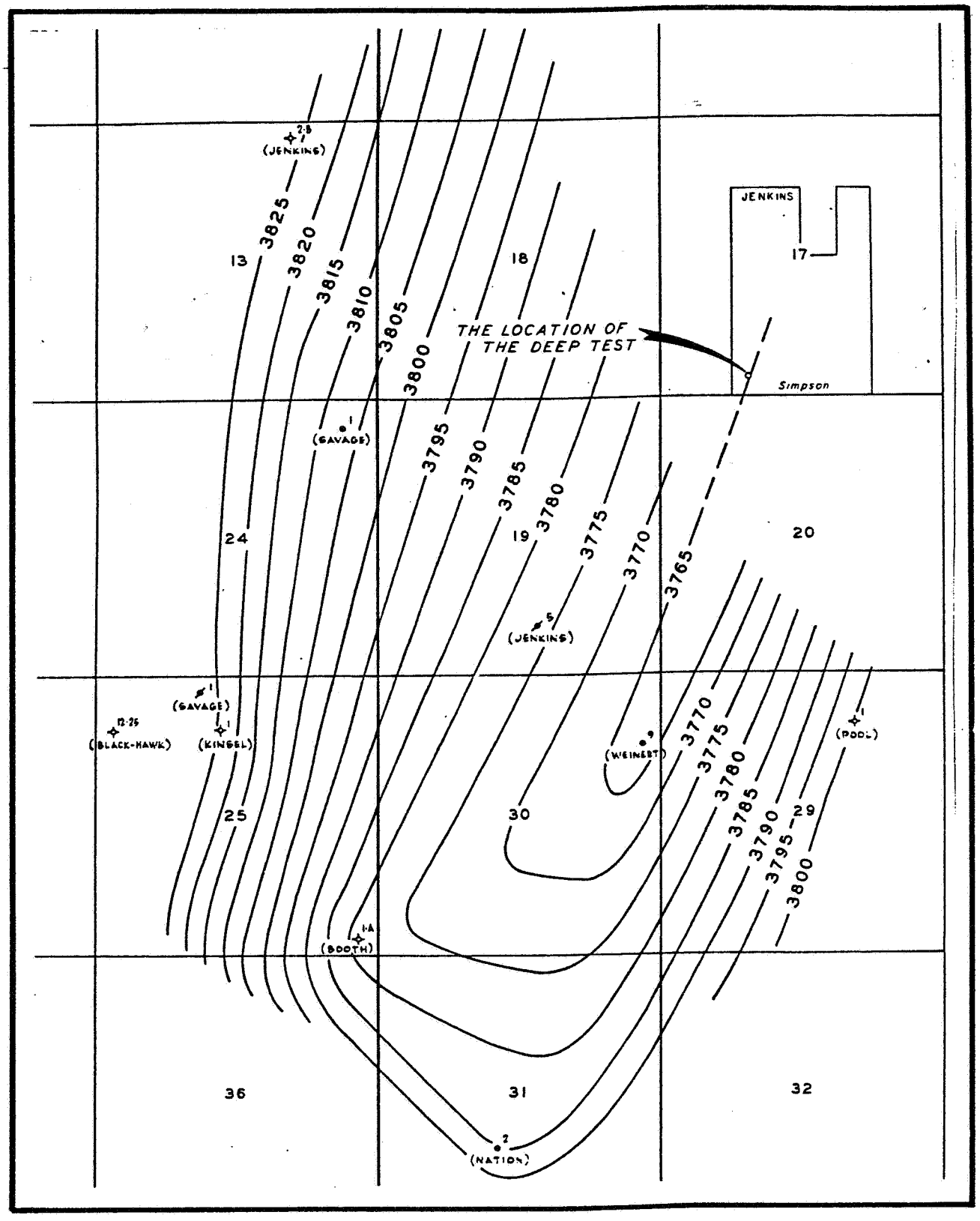


FIGURE 5 STRUCTURE AT TOP OF WARSAW FORMATION
(SUPPLIED BY OPERATOR, G.T. JENKINS)

Using electric logs from the Poorman No. 5 well for deep control and the Fox No. 1 (located a few hundred feet north of the prospective site) for shallower correlation, the prognosis for the principal formation tops to be encountered at the prospective site prior to drilling were as follows:

TABLE 1

PROGNOSIS FOR PRINCIPLE FORMATION TOPS

FORMATION	POORMAN NO. 5 KB = 386 ft.		SIMPSON (NEW SITE) KB = 392 ft. (est.)	
	Depth	Thickness	Depth	Thickness
St. Genevieve	-2892 (3386 KB)*	878	-2940 (3332 KB)* (Fox No. 1)	825
Warsaw	-3770 (4156 KB)*	774	-3765 (4157 KB)*	774
New Albany Shale	-4544 (4930 KB)*	270	-4539 (4930 KB)*	270
Lime Unit¶	-4814 (5200 KB)*	208	-4890 (5201 KB)§	208
Dutch Creek	-5022 (5408 KB)*		-5017 (5401 KB)*	

* E-log basis
¶ Limestone unit within the Albany Shale
§ Recommended coring interval -4498(4890 KB) to -4819 (5310 KB) = 420 ft.

TABLE 2

SUMMARY OF CORED INTERVALS

Core No.	Cored Interval (depth)	Core Recovered (feet)	Geology
1	5010 - 5043	43	Springville Shale 5031' Chouteau Limestone 5041' New Albany Shale
2	5043 - 5096	53	5058' Upper Grassy Creek Shale Member
3	5096 - 5136	41	
4	5136 - 5178	42	
5	5178 - 5238	60	5184' Sweetland Creek Shale Member
6	5238 - 5288	50	5252' Blocher Shale Member 5278' Lingle Limestone

DRILLING AND CORING OPERATIONS

EGSP Illinois No. 5 - Well Location

The specific location of the EGSP. Illinois No. 5 drilling site is 400 feet north and 300 feet east of the southwest corner, SE1/4 SW1/4 SW1/4, Sec. 17, T3S, R8E (Fig. 3). The nearest deep control well is the A. J. Poorman No. 5, (NW1/4 SW1/4 Sec. 19, T3S, R8E), located about one mile to the southwest in the Mills Shoals Field of White County as shown on location map Figure 1. A shallower well (Fox No. 1) lies immediately to the north of the proposed site.

Drilling, Coring and Logging

After setting 8-5/8-inch surface casing at 150 feet, a 7-7/8 inch-"button" bit was used to deepen the hole to the core point at 5010 feet, attained on September 29, 1979. Although air drilling techniques would have been preferred in coring the shale, the presence of numerous water-bearing zones in higher strata precluded this approach. Hence, conventional mud was used as the drilling fluid.

A total of 278 feet of oriented core was obtained in this interval from 5010 to 5288 feet. This was accomplished in six coring runs during the period from September 30, 1979 through October 4, 1979, using a Christensen 7-27/32-inch type C-4 diamond bit and a 60 foot long 6-1/4-inch x 3-1/2-inch core barrel (Table 2). The average penetration rate was about 3.5 feet per hour. All the core cut was recovered. Length of recovered core was longer or shorter than cored intervals due to jamming of fractured core intervals in the core barrel.

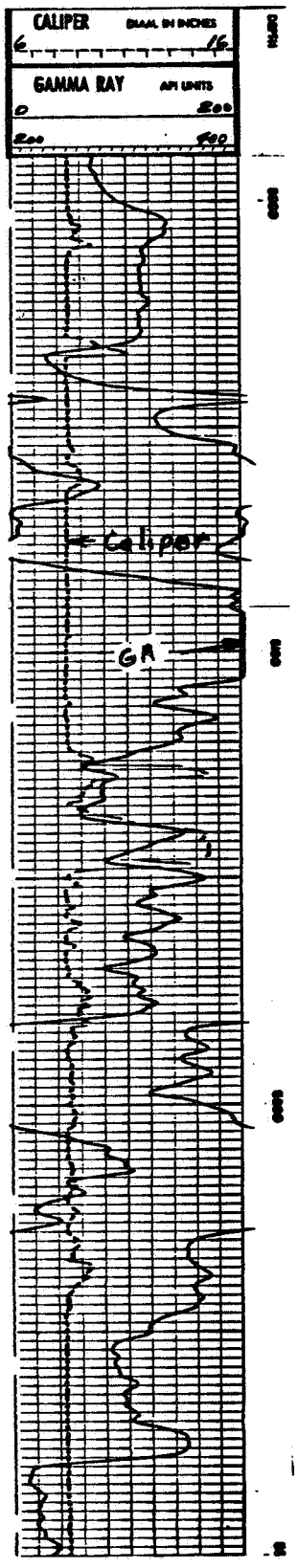
Difficulty was encountered in removing the plastic liner, containing Core No. 4 from 5136 to 5178 feet, from the inner core barrel and in extruding the core from the liner. Small sharp fragments of shale were found lodged between the inner barrel and the plastic liner, wedging the plastic liner within the inner barrel. In order to remove the liner, it was necessary for five men, using a thick walled piece of tubing, to ram the liner out of the core barrel. Although this resulted in triple telescoping of about 10 inches of liner, the core was not damaged. The core was then cut into six foot sections to facilitate removal of core from the plastic barrel. Some of the core slid out with ease. However, most of the core was extruded only by the use of a fabricated core extruder. In extreme cases, a circular power saw was used to cut partially through the liner which was then snapped open with a chisel.

The other main difficulty encountered while coring was a zone of "lost circulation" in a highly fractured zone of the Grassy Creek zone. After the last core was retrieved, drilling with a 7-7/8-inch bit was resumed until a total depth of 5494 feet was reached. No test was made of the New Albany as the well was completed for production from a higher interval.

As the hole was fluid-filled, only the following wet hole logs were run by Schlumberger:

- Gamma Ray (GR)
- Compensated Neutron (CNL)
- Formation Density Compensated (FDC)
- Caliper
- Dual Induction Laterolog (DIL)
- Borehole Compensated Sonic (BHC)
- Variable Density (VDL)
- Fracture Identification Log (FIL)
- Coriband (computer analysis of complex reservoirs)

Figure 7, a section of the gamma ray log from this well, shows the location of lithologic units. High radioactive zones are evident at depths of 5041.5-5043, 5057-5068, 5086-5187 and 5205-5228 feet.



Formation Tops

Depth, ft	Formation
	Springville Shale
5031	Chouteau Limestone
5041	New Albany Shale, Hannibal-Saverton
5058	Upper Grassy Creek shale member
5184	Sweetland Creek shale member
5252	Blocher shale member
5278	Lingle Limestone

Figure 7.--Gamma ray curve and formation tops.

CORE ANALYSIS

The top of the upper Devonian New Albany shale was encountered at 5047 feet DIL, while the Lingle Limestone was encountered at 5278 feet. Approximately 231 feet of New Albany Shale was measured at this site. Core recovery was 100%.

Core Descriptions

A lithologic description of each core follows:

Core 1: From 5010 to 5031.5 feet, core consisted of dark greenish-black Springville Shale. From 5031.5 to 5041.5 feet, the core consisted of fossiliferous bedded, argillaceous, light to dark green Choteau Limestone. From 5041.5 to 5043 feet, the core consisted of dark greenish-black New Albany Shale. Several vertical fractures occurred from 5010 to 5043 feet. On the gamma ray log, this section is identified by moderate radioactivity in the Springville Shale, a drop in radioactivity at the top of the Choteau Limestone, and a large increase in radioactivity at the top of the New Albany Shale (Fig. 7).

Core 2: From 5043 to 5097 feet, the core consisted of dark green to black, slightly calcareous shales with pyrite nodules throughout. A large number of vertical fractures were encountered from 5044.7 to 5088.8 feet. The core was rubbelized from 5093 to 5097 feet. Radioactivity high enough to run on the highest backup scale was encountered in this section (Fig. 7).

Core 3: From 5096 to 5136 feet, the core consisted of very dark brown to black, noncalcareous to occasionally slightly calcareous shale. A fair number of vertical factures could be seen in the cores. The bottom of the core was rubbelized. The gamma ray curve continued to run on the highest backup scale throughout this section (Fig. 7).

Core 4: From 5136 to 5178 feet, the core consisted of dark brown shale, occasional pyrite laminae and some pyrite blebs. Some gas bubbles were noticed when the core was first wet, though no distinct gas zones were evident. A number of vertical fractures were encountered and the lower part of the core was badly rubbelized. Again, the gamma ray log continued to stay on the highest backup scale (Fig. 7).

Core 5: From 5178 to 5238 feet, the core consisted of brownish-black to gray-green fossiliferous shale, with dolomitic streaks and pyrite. Numerous vertical, multiplanar and petal fractures were noticed here. The Sweetland Creek Member was encountered at 5178 feet. The top of the Sweetland Creek was marked by a reduction in the gamma ray curve (Fig. 7).

Core 6: From 5238 to 5288 feet, the core consisted mainly of dark brown, greenish-black to black shale. Pyrite occurred as inclusions and bands. The core was noncalcareous above 5246 feet and calcareous below. Several sand lenses were encountered below 5250 feet. At 5252 feet, the Blocher Shale Member was encountered, and at 5275 feet, the Lingle Limestone, marking the bottom of the New Albany Shale. Several vertical fractures occurred in the shale but none occurred in the Lingle Limestone. The top of the Blocher Shale Member and the top of the Lingle Limestone were marked by a drop in the gamma ray curve at the top of both (Fig 7).

Off-Gas Analysis

Sixty-six samples taken at approximately 1 meter intervals were used for off-gas analysis by Dickerson and Chou, 1979, of the Illinois Geologic Survey. The quantity of gas obtained from 34 day tests of the samples ranged from .16 to 2.4m^3 gas per m^3 of shale, and averaged about 1m^3 per m^3 of shale. The composition of the off-gases were fairly consistent with average values of about 65 percent C_1, 20 percent C_2, 12 percent C_3, 3 percent C_4 and higher. Composition of the off gases as determined by Dickerson and Chou, has a caloric content somewhat higher than most pipeline gases.

Because of the time span involved between cutting the cores and placement in the sealed canister (4-6 hours), actual in-situ gas content is somewhat higher.

LOG ANALYSIS

Indications of fractures were seen on every log that was run. Specifically, on the resistivity log (Fig. 8) from 5128 to 5142 feet. The spiking and displaced position of the shallow and medium induction curves with respect to the deep induction imply that there are fractures filled with a highly resistive substance (gas, most likely) within the depth of investigation of the tool.

On the fracture identification log (Fig. 9), strong indications of a formation fracture system are seen from 5122 to 5148 feet and lesser indications from 5164 to 5166 feet and from 5234 to 5242 feet (Fig. 10). This is also a resistivity device and, as may be seen when the fracture is encountered, the resistivities on opposing electrodes are different. Furthermore, the recorded rotation of the tool indicated by the solid line in the left hand track seems to stop at 160°-340° with a reversal between 260°-220°. This implies that the hole is elongated and the tool is tracking as illustrated in Figure 11. From the differential caliper curve on the far right, it can be determined that the elongation is in a direction which is approximately N70°E.

Other evidence of fractures from logs can be seen on the CNL-FDC log (Fig. 12), also gamma ray (Fig. 7). Throughout the entire shale interval, there is a strong positive compensation even where the hole is determined to be relatively gauge. This is strongly suggestive of fracture porosity near the bore hole. Density logs measure the electron density of reservoir rocks by bombarding the formation with gamma rays and measuring the amount returning to the counter after a short time interval by Compton scattering. The depth of investigation of this instrument is quite shallow. It is adversely affected by irregularities of the borehole and mud cake thickness. Corrections for borehole effects are made by the use of two counters, one long and the other short spaced. When the two counting rates do not indicate the same density, the density recorded is corrected by adjusting it in a manner consistent with mud cake or wash out effects. The amount of correction applied is recorded on one track of the density log. A sharp positive correction when the caliper log has not indicated a washed out hole has been found to be indicative of a fracture.

The caliper log with borehole compensated sonic log (Fig. 13) gives indication of weakness from 5120 to 5150 feet. The hole is very washed out. This hole was cut with a diamond core bit and only slightly enlarged by reaming afterwards. The conventional diamond bit by design cuts a very smooth borehole. The wash out here is indicative of a very weak zone in the formation which, in the Devonian Shale, is probably a fractured interval.

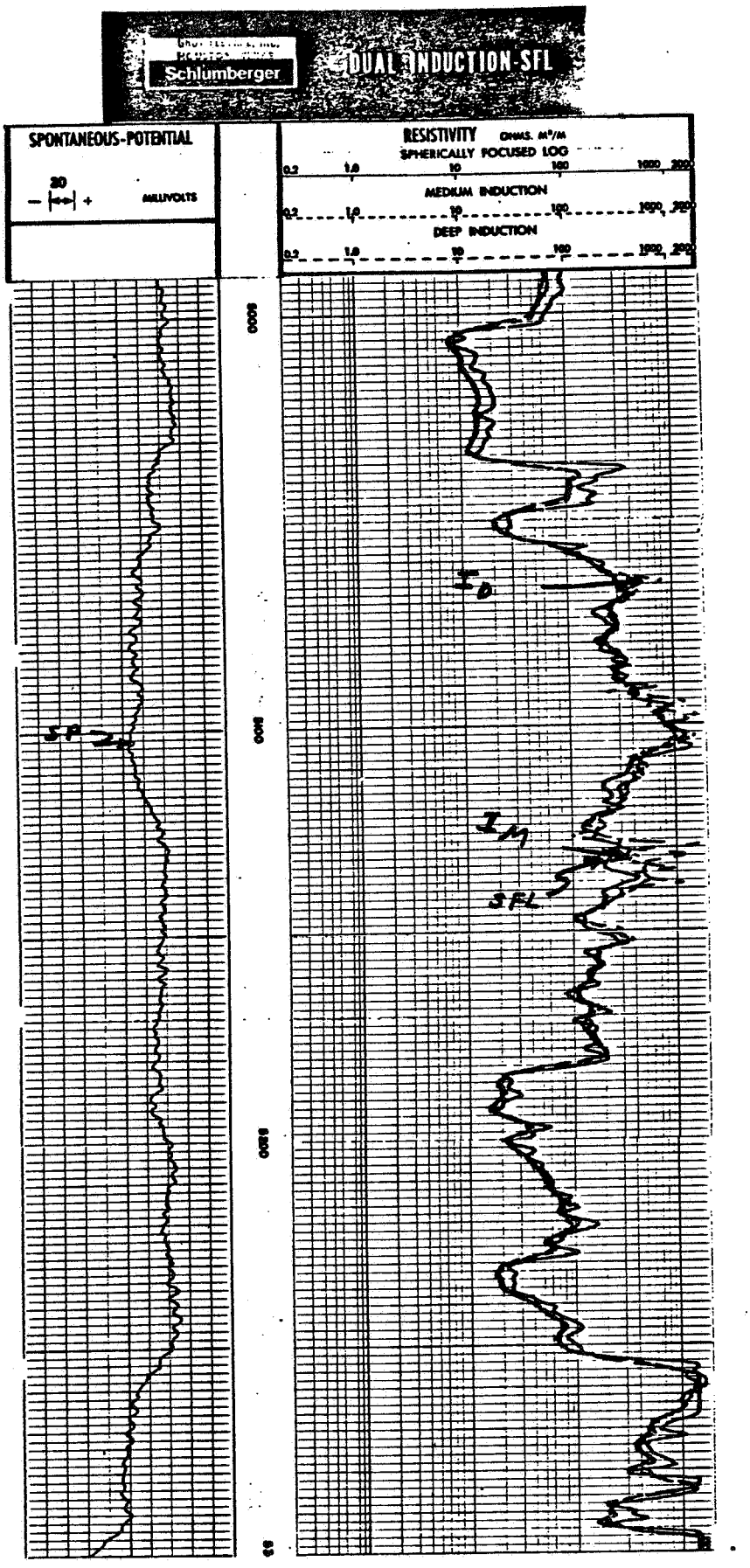


Figure 8.--Dual induction--SFL and S.P.

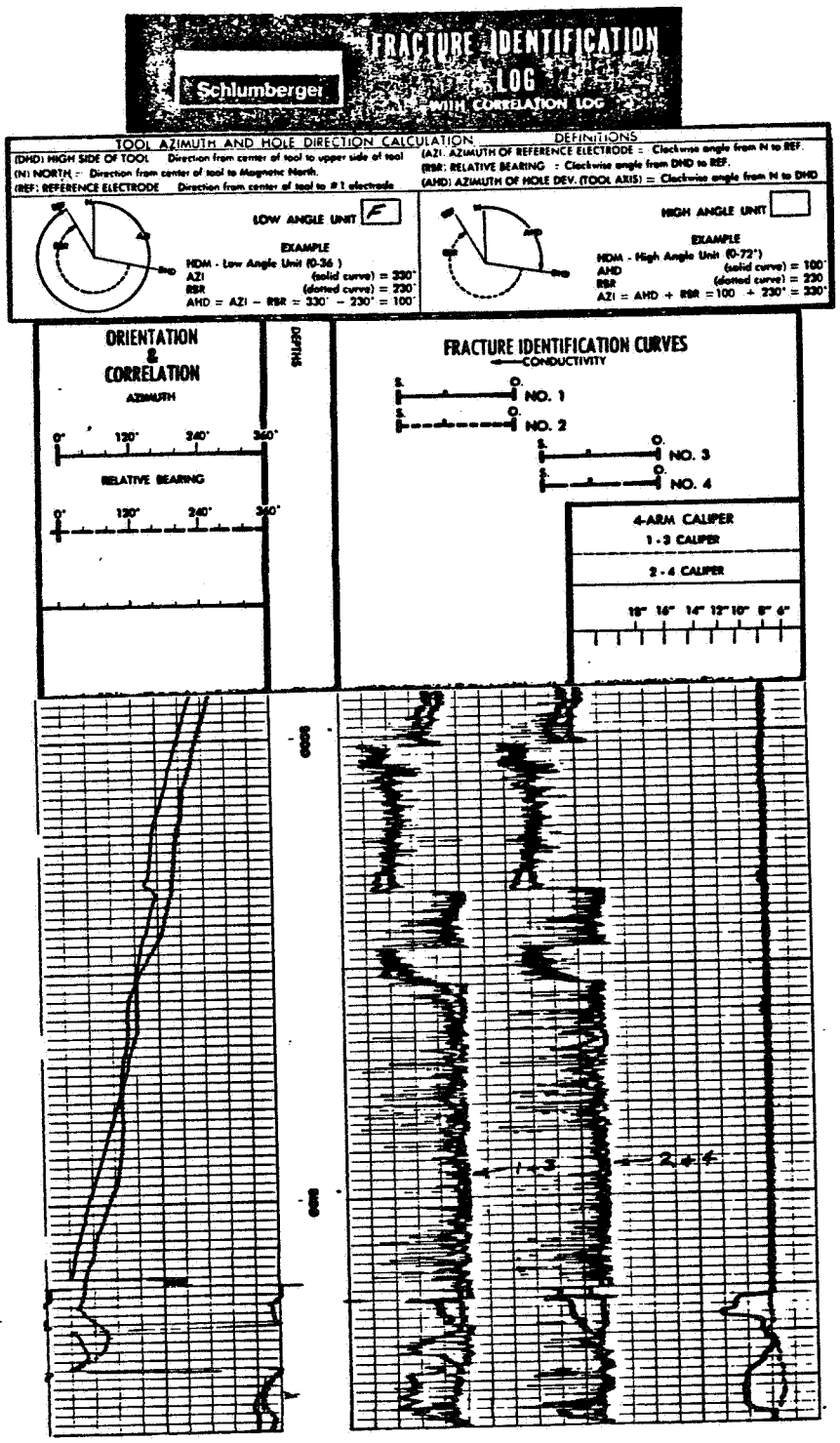


Figure 9.--Fracture identification log.

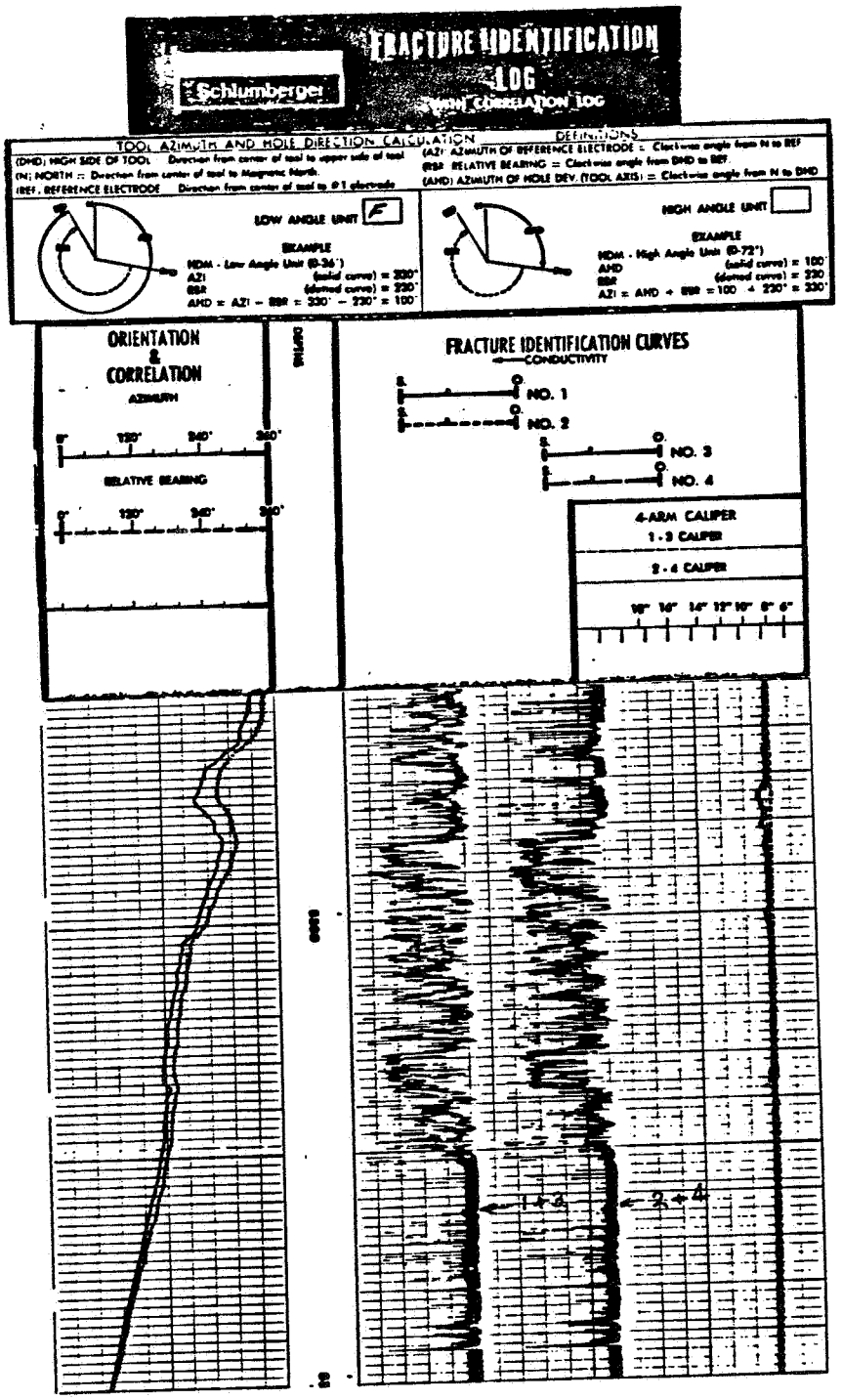


Figure 10.--Fracture identification log.

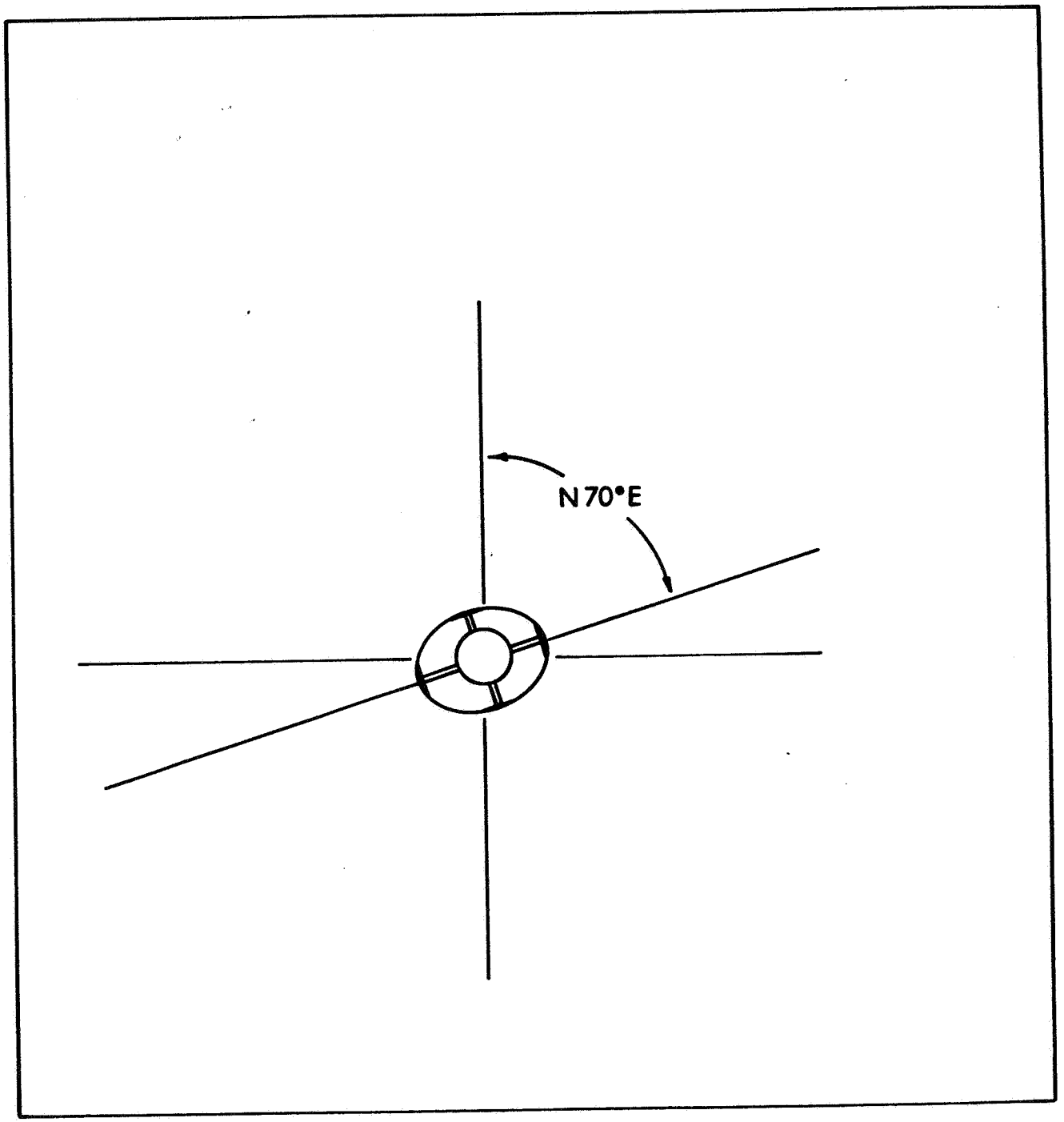


Figure 11.--Tracking orientation of caliper in elongated hole.

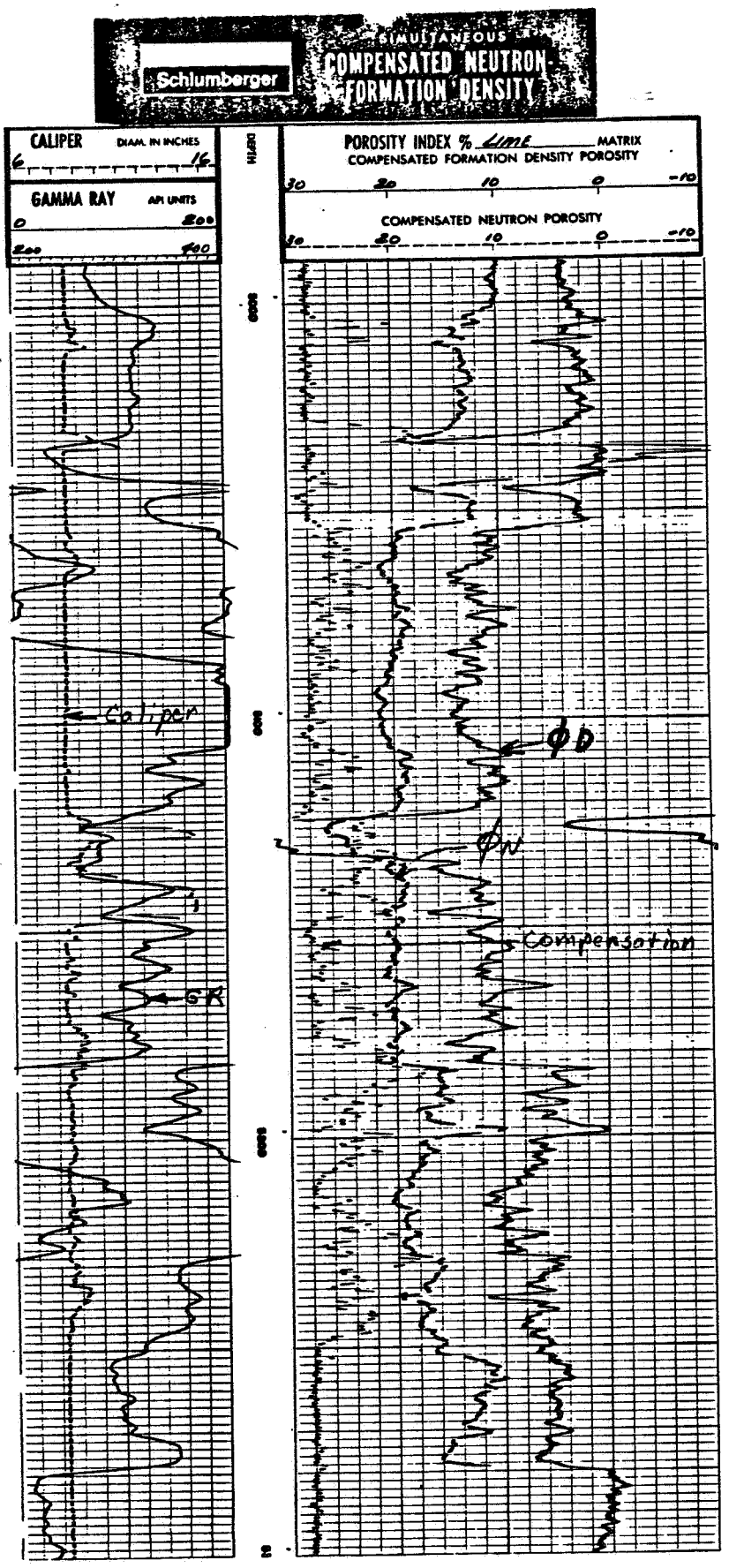


Figure 12.--Compensated neutron log, formation density log, and gamma ray with caliper curve.

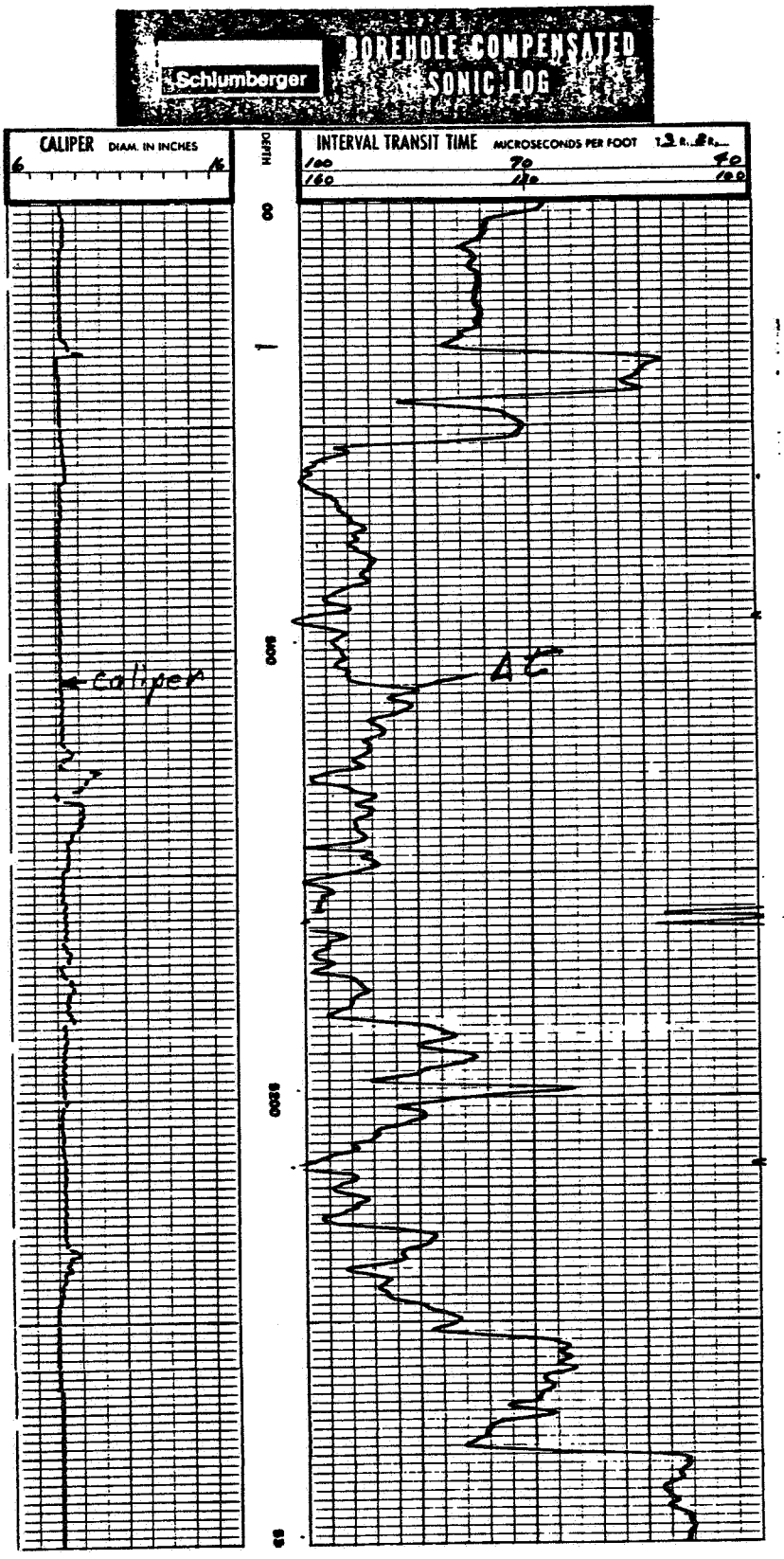


Figure 13.--Borehole compensated sonic log.

The conventional sonic log (Fig.13) shows some cycle skipping at 5146, 5162 and 5198 feet. Cycle skipping occurs when the acoustic impulse is so mitigated that the arrival of a wave is not recorded within the gate time of the instrument. So the wave is recorded as an early arrival on the next cycle. Sound waves travel through the formation as compressional waves and shear waves. Fluids have no shear strength and, hence, cannot support shear wave transmission. Also, at any interface between substances of varying acoustic impedance, some energy will be reflected. For these reasons, sonic log cycle skipping on conventional sonic logs have found utility in fracture detection.

The elongation of the hole implied by the fracture identification log indicates preferred directions of fracture consistent with structural deformation. The polygonal fracture patterns produced by synaeresis should have no preferred fracture orientation.

GEOLOGIC INTERPRETATIONS

The formations encountered in the EGSP Illinois No. 5 were found to be 50 feet lower than expected, as shown in the following table:

TABLE 3

PREDICTED AND ENCOUNTERED DEPTHS OF FORMATION TOPS

FORMATION	FORMATION DEPTHS FROM PROGNOSIS KB = 392 ft. (est.) Depth, ft.	FORMATION DEPTHS ENCOUNTERED THIS WELL KB = 392 ft. (est.) Depth, ft.
St. Genevieve	-2940 (3332 KB)	-2990 (3382 KB)
Warsaw	-3765 (4157 KB)	-3815 (4207 KB)
New Albany Shale	-4539 (4930 KB)	-4589 (4980 KB)
Lime Unit	-4890 (5201 KB)	-4940 (5251 KB)
Dutch Creek	-5017 (5401 KB)	-5067 (5451 KB)

As a result of these findings, a reinterpretation of the local structure shown in Figures 5 and 6 was made. The additional information, shown on structure contour maps on the top of the Warsau Formation (Fig. 14) and the top of the Dutch Creek Formation (Fig. 15) indicate a closed anticline. These maps show the general alignment of the structure near Illinois No. 5 to be parallel to the NE-SW trending axis of the Clay City Anticlinal Belt.

The structural interpretation, as shown, strongly suggests the presence of structurally derived fractures in the area around the EGSP. Illinois No. 5 well.

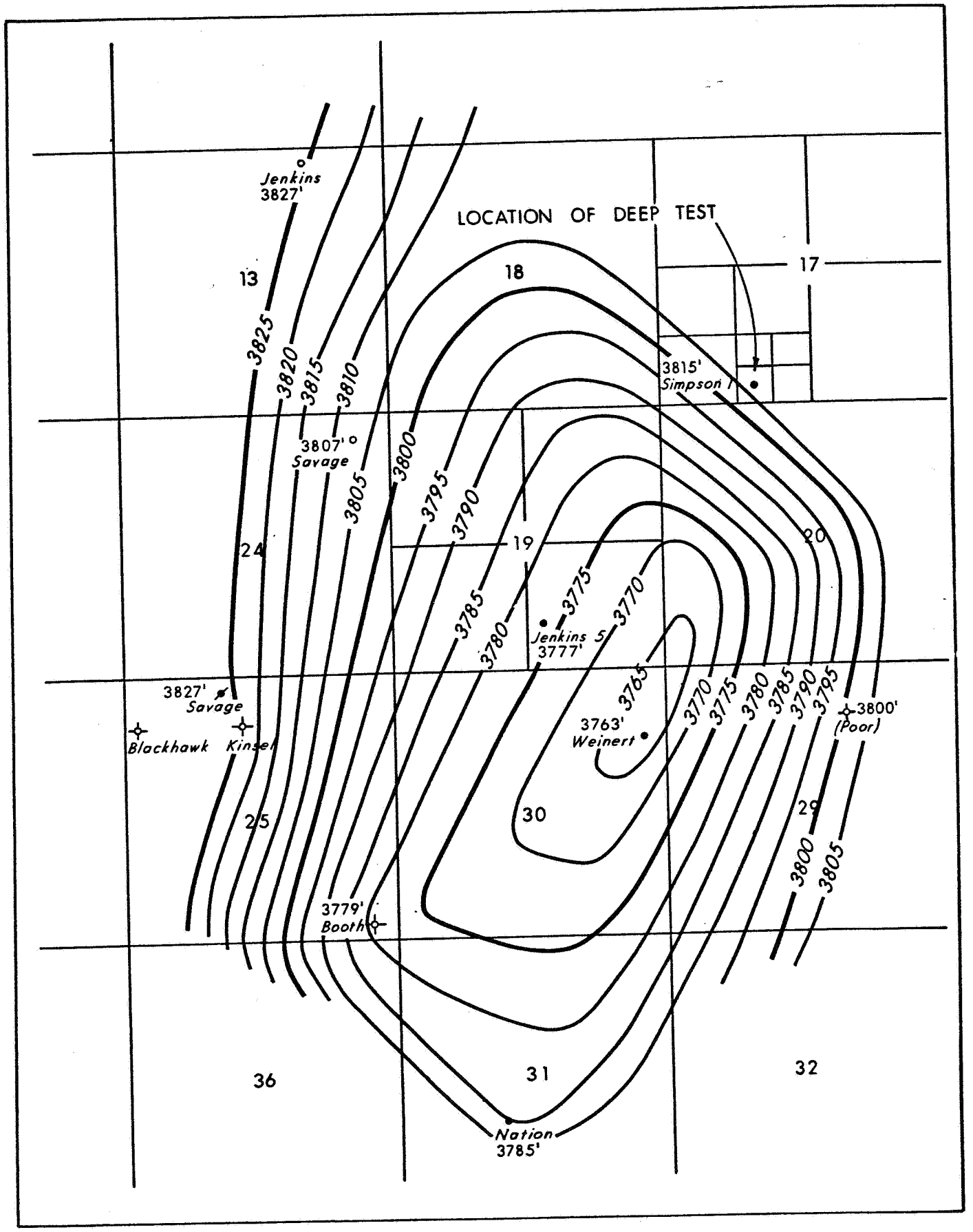


Figure 14.--Interpreted structure at top of Warsaw formation.

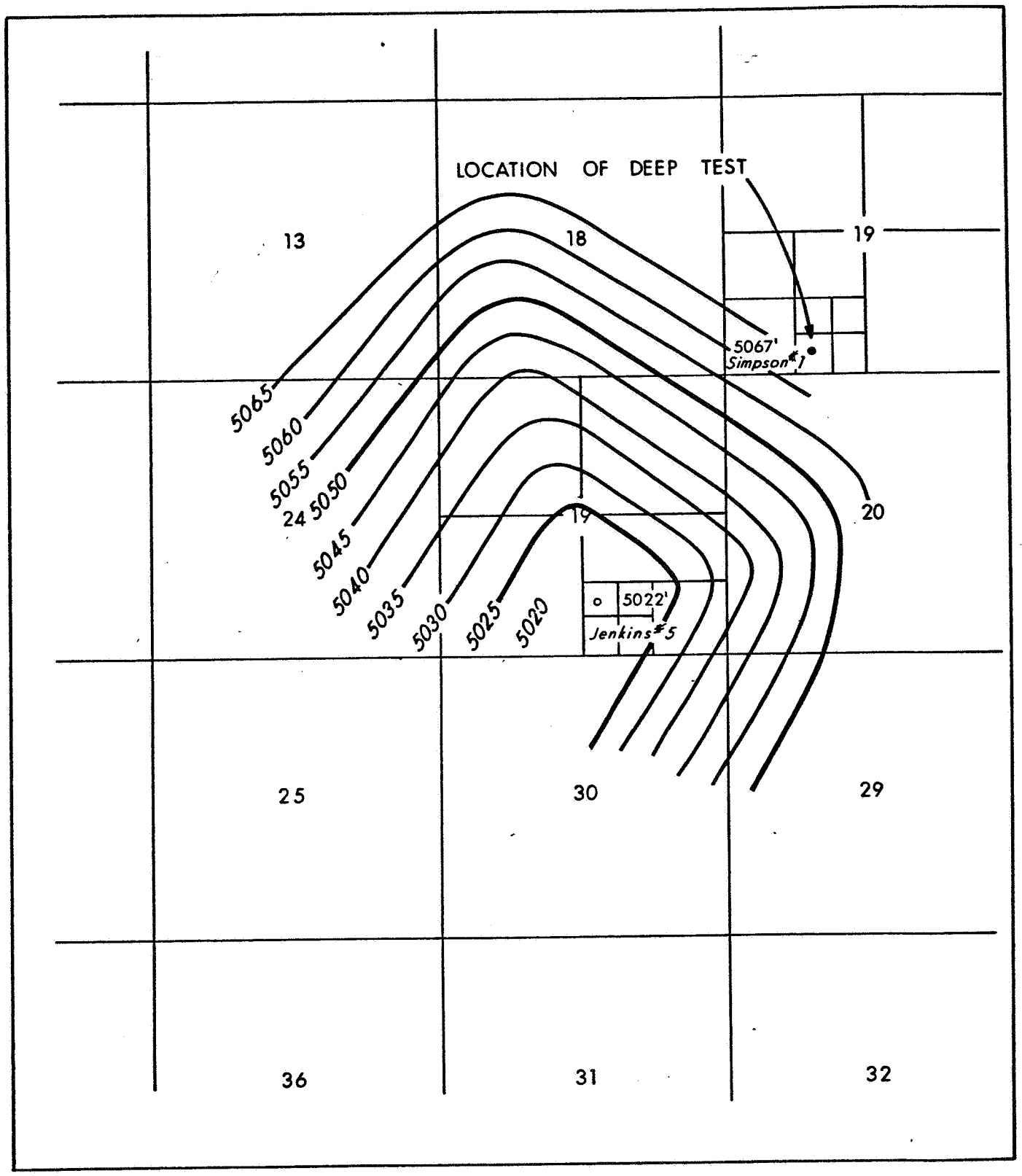


Figure 15.--Interpreted structure at top of Dutch Creek formation.

SUMMARY AND CONCLUSIONS

The New Albany Shale in Illinois has never been considered a gas producer. This is because the New Albany Shale has been overlooked in lieu of more commercial hydrocarbon occurrances in other formations.

The site of the EGSP Illinois No. 5 was selected as conditions for potential commercial gas production such as high organic kerogen content, adequate thickness, natural fracture systems (diagenetic and structural), should be present.

Two hundred thirty-one feet of New Albany Shale was cored at this site. Inspection of the cores showed high organic kerogen content, adequate thickness and fractures to be present. The geophysical logs run for this well confirmed the presence of high radioactivity, hydrocarbons and in-situ fracture systems.

Off-gas analysis of the cores, performed by the Illinois Geological Survey, showed them as having the highest gas content of any Devonian wells sampled in Illinois.

Although the New Albany was not tested by the operator, as he was assured of good oil production from a higher formation, core and log data show the New Albany has potential to be productive in this area. Production testing is needed in the area to determine if the New Albany is truly commercially productive.

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