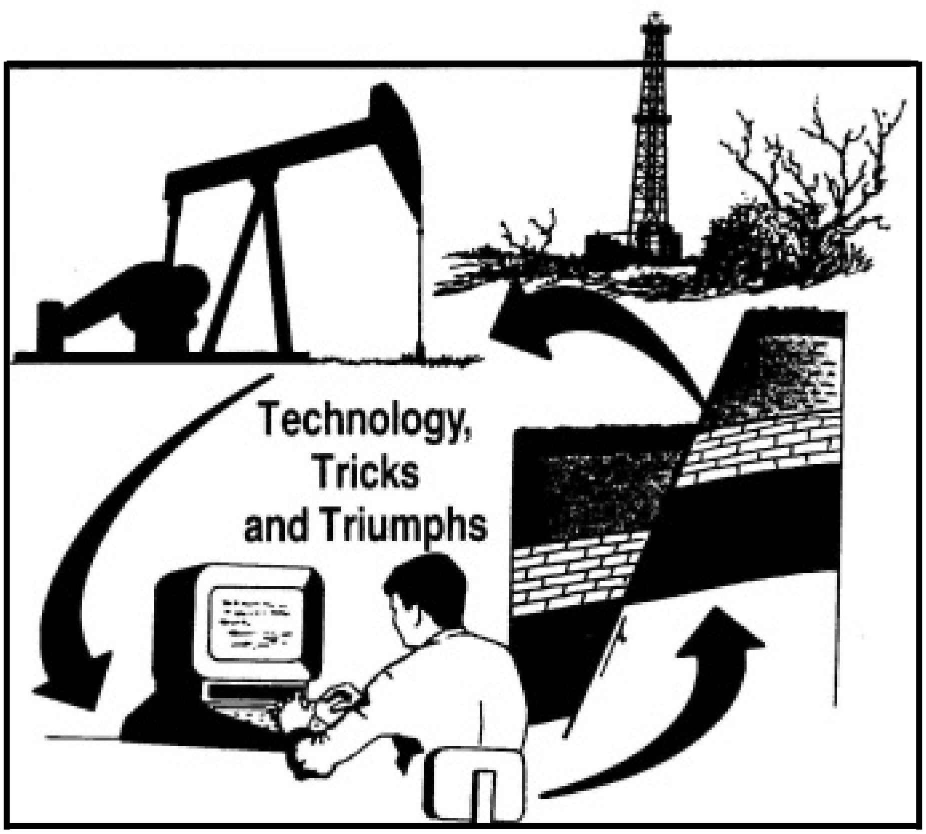
SOUTHWEST SECTION OF AAPG

1987 Convention Transactions with Abstracts

DALLAS, TEXAS

Edited by Thomas C. Kamin,
Wayne M. Ahr, and
Dwight "Skip" Roberts



Sponsored by Dallas Geological Society

Canyon (pennsylvanian) Sand Prospecting in Nolan County, Texas Using an Electrotelluric Survey Method

Robert B. Lanter and Michael R. Birkos
Geophysics International Co.
Dallas, Texas

The Upper Pennsylvanian section of the Eastern Shelf is composed of a number of productive sands that were deposited in fluvial/deltaic systems. Conventional exploration for these sands involves using existing well control. Drillsites are then picked by extrapolating the sand continuity in conjunction with sand deposition models from fully developed fields.

Electrotelluric surveying, a method using a passive surface detector of electrotelluric radiation, was employed in the Lake Trammel (West Canyon) field to define the limits of locally productive Canyon sand. With existing well control for calibrating the instrument, the electrotelluric response for the prospective sand was ascertained. Electrotelluric response refers to character changes in the surface electrical field caused by conductivity interfaces beneath the surface. A number of electrotelluric survey points were then taken across the field. Sand extent was determined by correlation of the electrotelluric response patterns from calibration wells to the various survey points. Two well locations surveyed exhibited a potentially commercial thickness of sand, and hydrocarbon continuity with calibration wells. Electrotelluric data from the third well location served to condemn this site, because of sand thinning, lack of hydrocarbon continuity with the calibration wells, and possible loss of trap.

Upon completion of the survey, the two locations were drilled. The accuracy of the electrotelluric survey, with respect to sand presence and thickness, was confirmed. While there was no guarantee that a commercial amount of hydrocarbons would be produced, the electrotelluric survey proved effective in evaluating potential reservoir distribution from the surface. Drilling a location with a low probability of success was also prevented.

Introduction

The Pennsylvanian section in the Eastern shelf of north-central Texas contains a number of locally productive sands. Most of these sands were deposited in fluvial-deltaic channel systems, and sand distribution is typically erratic. The reservoir trapping mechanism is primarily stratigraphic. Structure becomes a factor when dealing with a single continuous reservoir.

Today, more than ever, the economic viability of finding and exploiting these reservoirs lies in risk reduction. Even when a productive sand is located, selecting an offset location is largely speculative.

A unique approach to exploration involves a passive geophysical method. This method employs an instrument that transduces electro telluric radiation (as a component of the electrical field at the earth's surface) into an audible signal. A specific relationship between the frequency of the electrical field and the depth of origin of the electrotelluric wave front generally allows for accurate (±20 ft) depth determination. The character changes of the audible signal are qualitatively graphed against depth. This data presentation format is referred to as an electrotelluric response log.

The effect on the surface electrical field by conductivity interfaces at depth (the character changes in the audible signal) are noted by deviations from a baseline on the log. Correlation with conventional logs allows for the interpretation of the deviations as they relate to changes in lithology, porosity, or fluid content, or any combination of the three. Hydrocarbons and salt water impart different distortions to the audible signal. Discrimination between the two fluids is usually possible when both are present.

The information is site specific, in that the electrotelluric radiation being evaluated emanates from directly below the instrument. A survey is accomplished by generating electrotelluric response logs at various points on the surface. The distribution of the survey stations is entirely dependent on the objectives of the survey.

Field Procedure

Lake Trammel (West Canyon) field produces from the Canyon (Pennsylvanian) "A" sand interval, and was the site of the electrotelluric survey (Figure 1). The objective of the survey was to determine the lateral extent of the pay sand at three possible drill sites (Figure 2). At the onset of the survey, electro telluric response patterns for the sand and the fluid distortion pattern for hydrocarbons and water contacts were ascertained at the Frymire # 4-80, # 5-80, and # 6-80 producing wells.

The calibration procedure of the electrotelluric instrument is accomplished by generating an electrotelluric response log prior to review of the subsurface information (usually a suite of conventional logs). When the instrument operator is correctly interpreting the electrotelluric signal and the signal itself is of adequate quality, there will be an obvious correlation between the conventional logs and the electro telluric data. When no such correlation exists, the survey does not proceed until the problem is resolved.

Figures 3, 4, and 5 are correlations of the electro telluric response logs with the dual induction logs of the Frymire # 4-80, # 5-80, and # 6-80 producing wells. The electrotelluric response pattern associated with the pay sand was consistent with downhole information, in depth, thickness and fluid content. Following the calibrations, several data points were taken across the field to evaluate the three proposed locations (Figure 6).

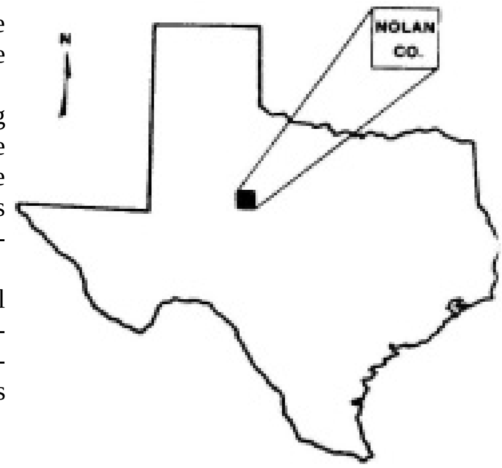


Figure* 1. *Geographic location of Lake Trammel field, Nolan County, Texas.

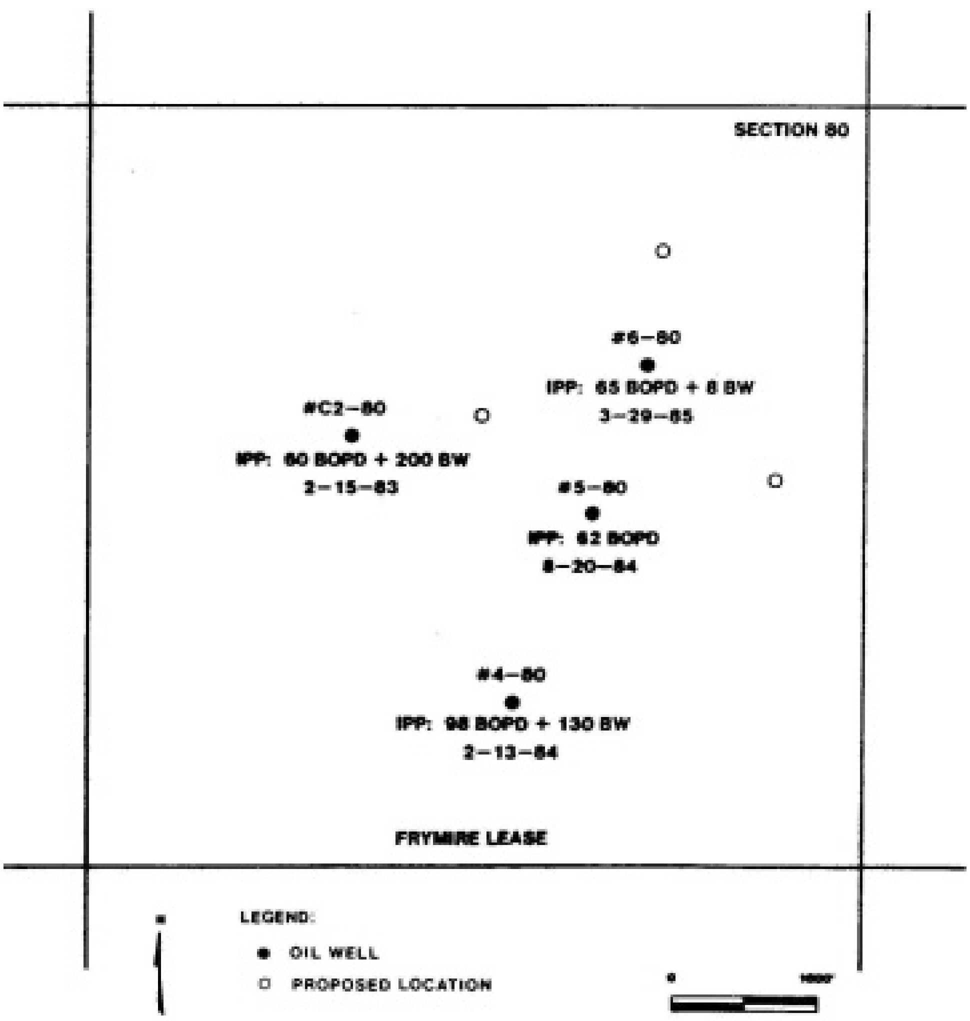


Figure* 2. *Base map of existing wells and proposed locations in Frymire lease electrotelluric survey.

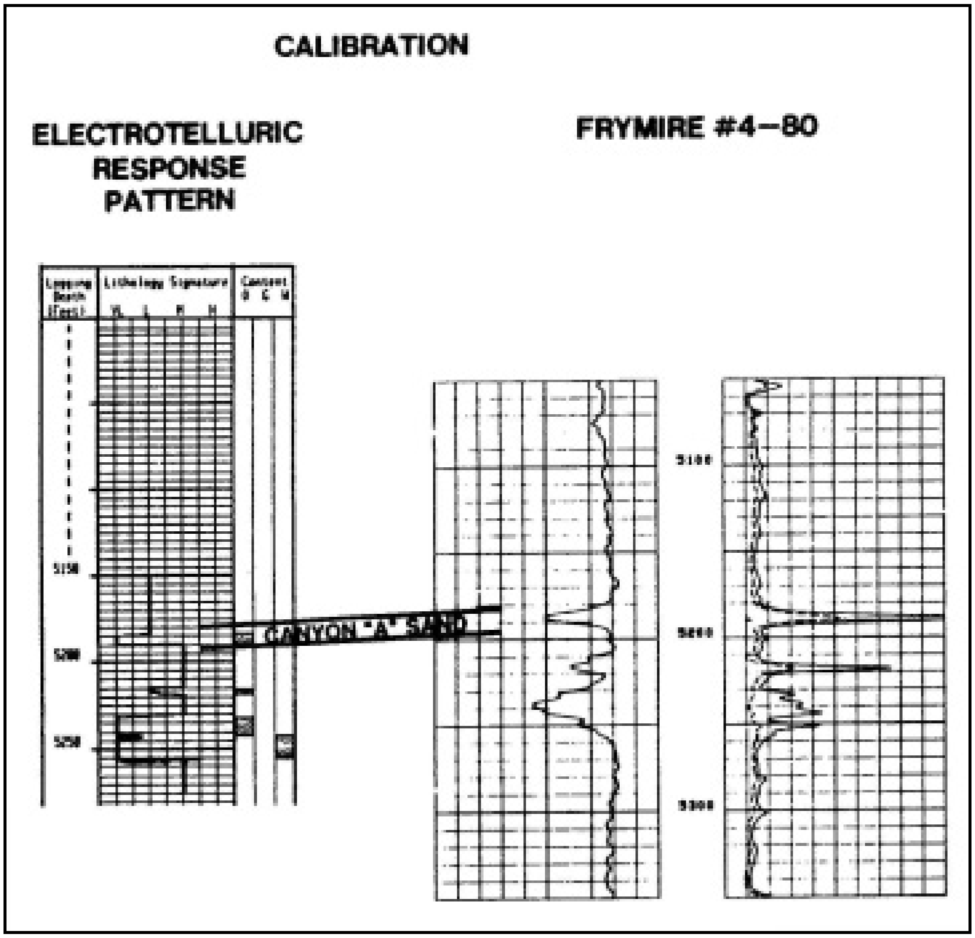


Figure 3. *Correlation of electrotelluric response pattern and dual induction log from Frymire # 4-80 well.*

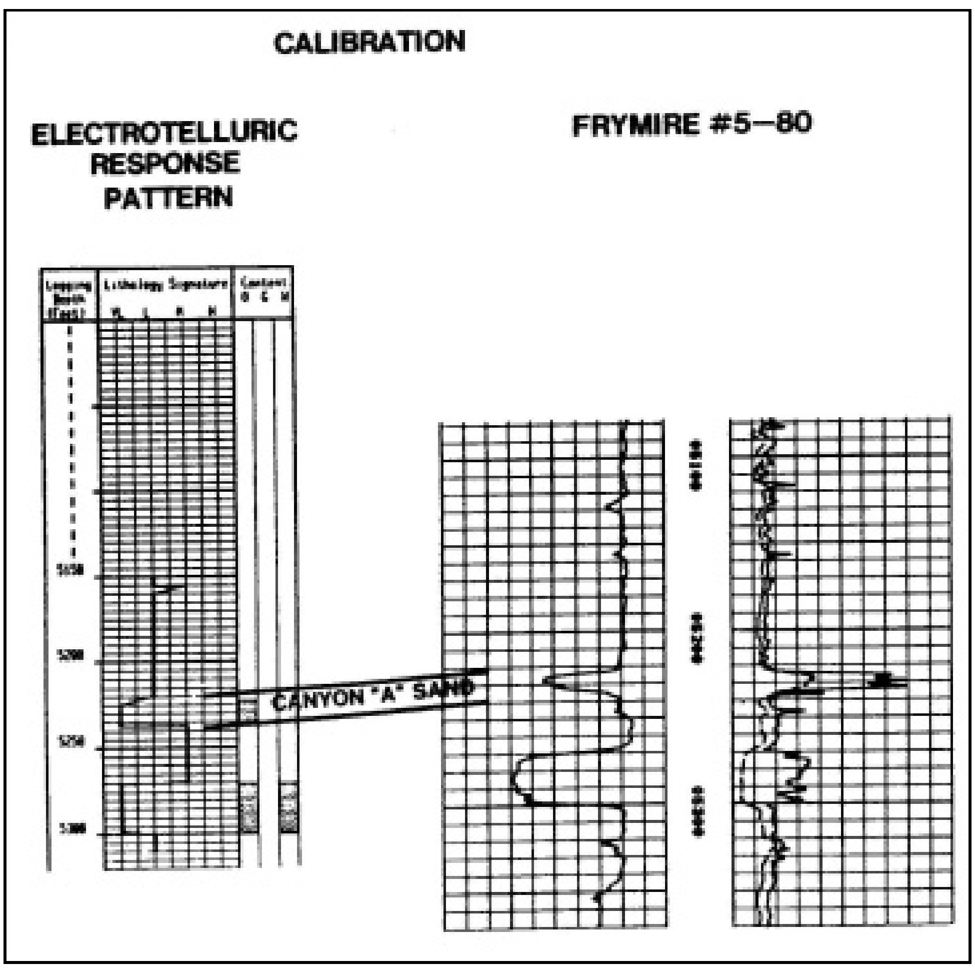


Figure 4. *Correlation of electrotelluric response pattern and dual induction log from Frymire # 5-80 well.*

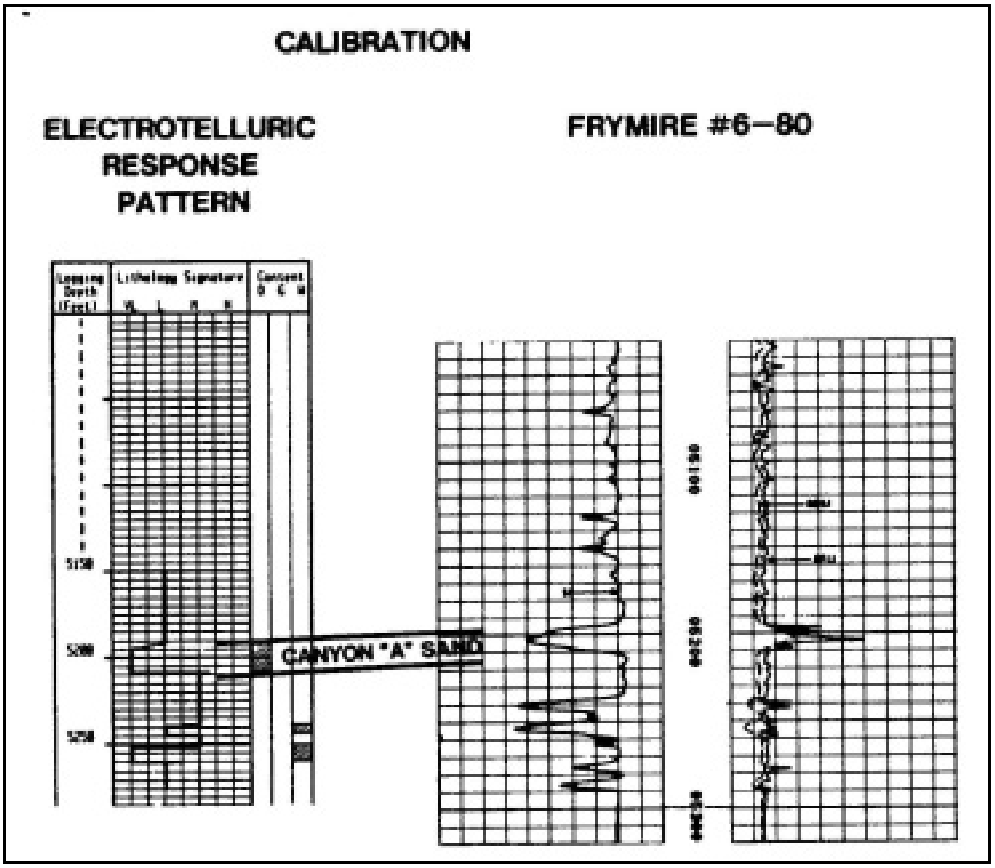


Figure **5.** ***Correlation of electrotelluric response pattern and dual induction log from Frymire # 6-80 well.***

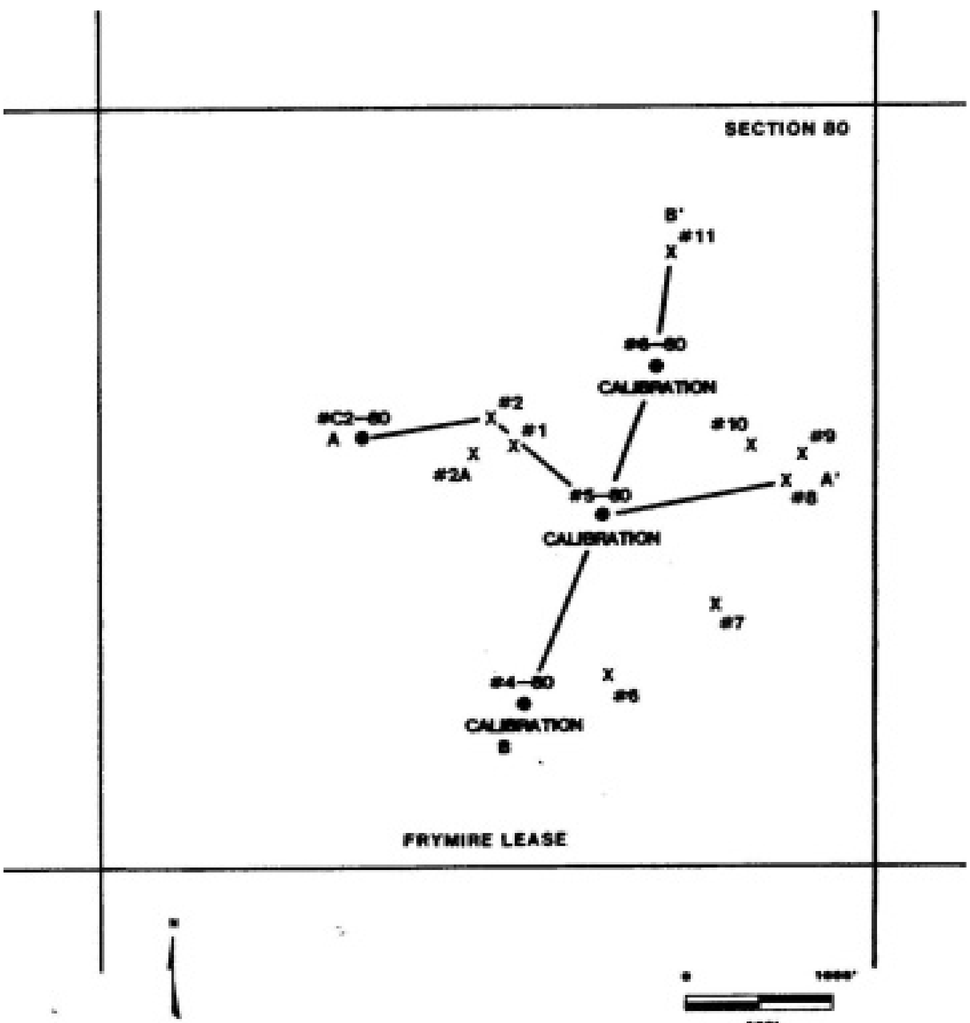


Figure **6.** ***Base map of calibration wells, electrotelluric data points, and cross section orientations.***

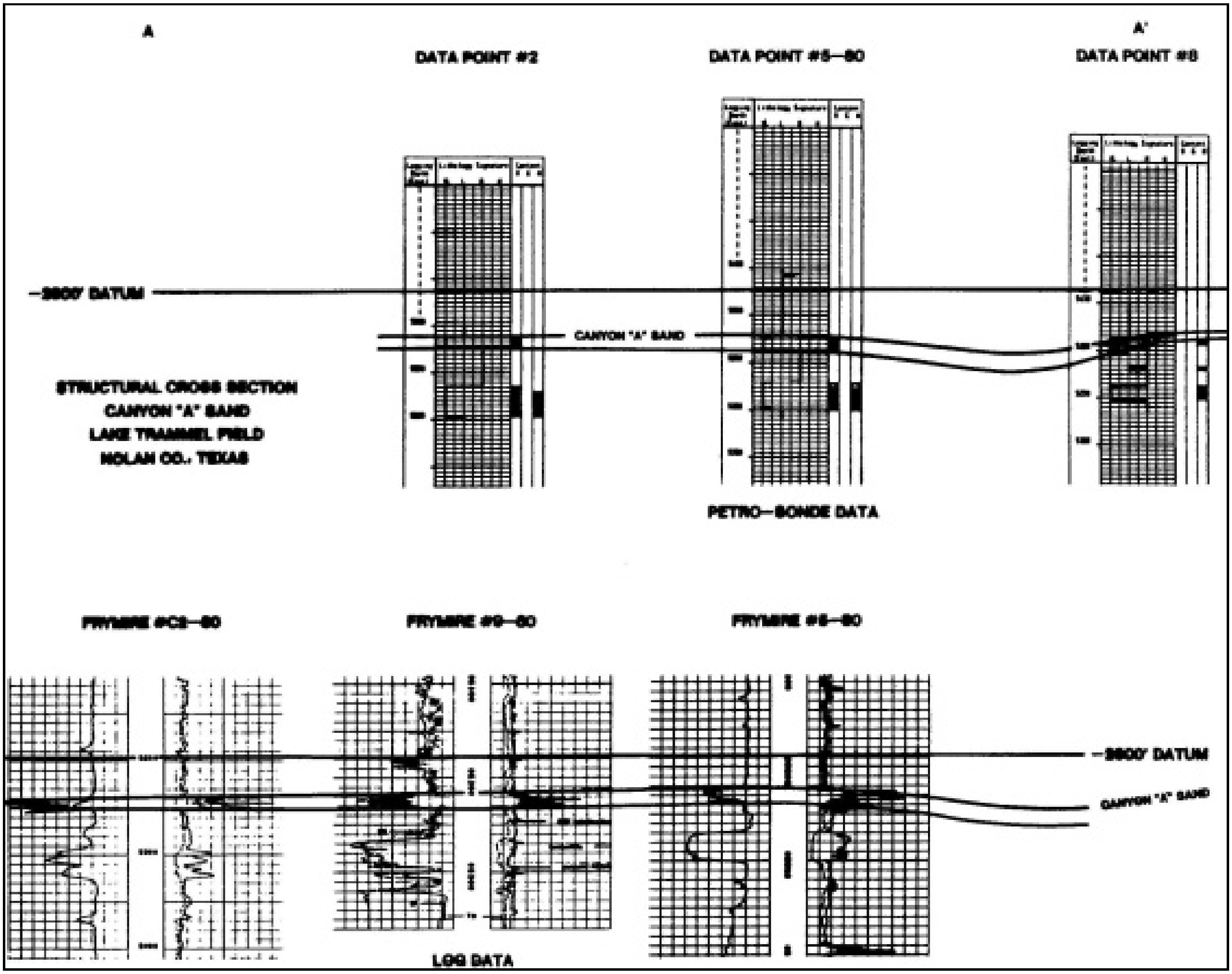


Figure 7. Interpreted sand distribution and structure from electrotelluric calibration and data points # 2 and # 11 (upper). Structural cross section of calibration dual induction log (# 5-80 well), # C2-8O well, and subsequently drilled # 9-80 well.

Data Interpretation

The interpretation of electrotelluric survey data indicated that the Canyon "A" sand was continuous across the west drillsite (data point # 2 in A-A' cross section of Figure 7). The Canyon "A" sand was known to be silty in the C2-80 well, but the electrotelluric response pattern at data point 1# 2 was comparable to the calibration pattern exhibited at the *1#* 5-80 well. From the *1#* 5-80 well west to data point 1# 2, the Canyon "A" sand appeared to be structurally flat and of uniform thickness. Also, hydrocarbon content was detected at both the *1#* 5-80 well and data point # 2.

The survey data also suggested that the Canyon "A" sand was continuous across the east drill site (data point *1#* 8 in A-A' cross section of Figure 7). Sand thickness at data point # 8 appeared comparable to the # 4-80 well, but somewhat thinner, compared with the *1#* 5-80 well. Structurally, the Canyon "A" sand at data point 1# 8 was relatively flat compared with the 1# 5-80 well, but the existing well control suggested that a re-entrant (structural low) was probable between the two points. Further, hydrocarbons were detected at the calibration 1# 5-80 well, while only water was detected at data point 1# 8. The fluid discontinuity taken together with the probable re-entrant served to condemn data point 1# 8 as a high-risk drillsite.

Data from the north drill site (data point 1# 11 in B-B' cross section of Figure 8), suggested that sand thickness was nearly equal to that of the calibration # 6-80 well. The sand appeared somewhat higher, structurally, when compared with the #6-80 well, and

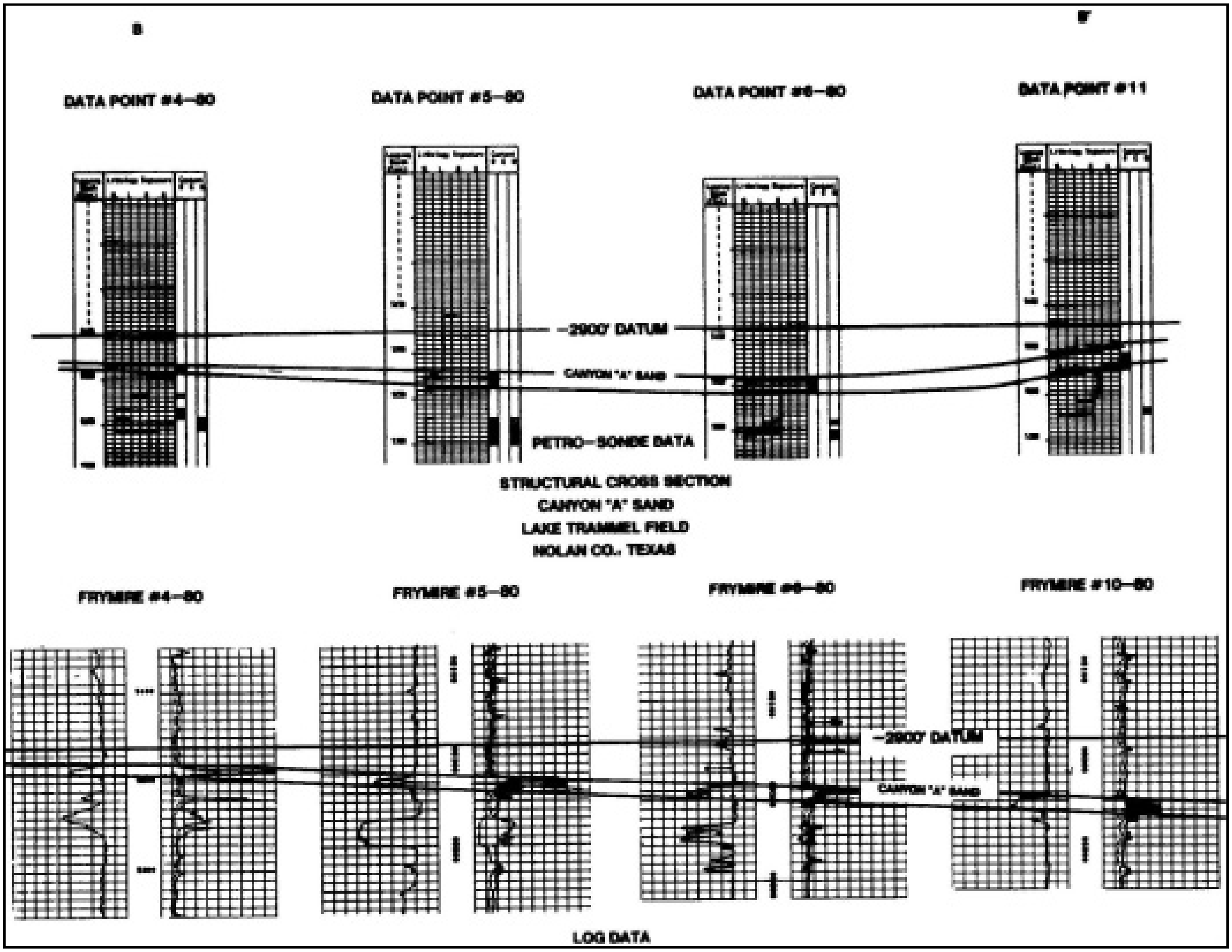


Figure 8. Interpreted sand distribution and structure from electrotelluric calibrations and data point # 11 (upper). Structural cross section of calibration dual induction logs (# 4-80, # 5-80, and # 6-80 wells), and data point # 11 (# 10-80 well) which was drilled following the electro telluric survey.

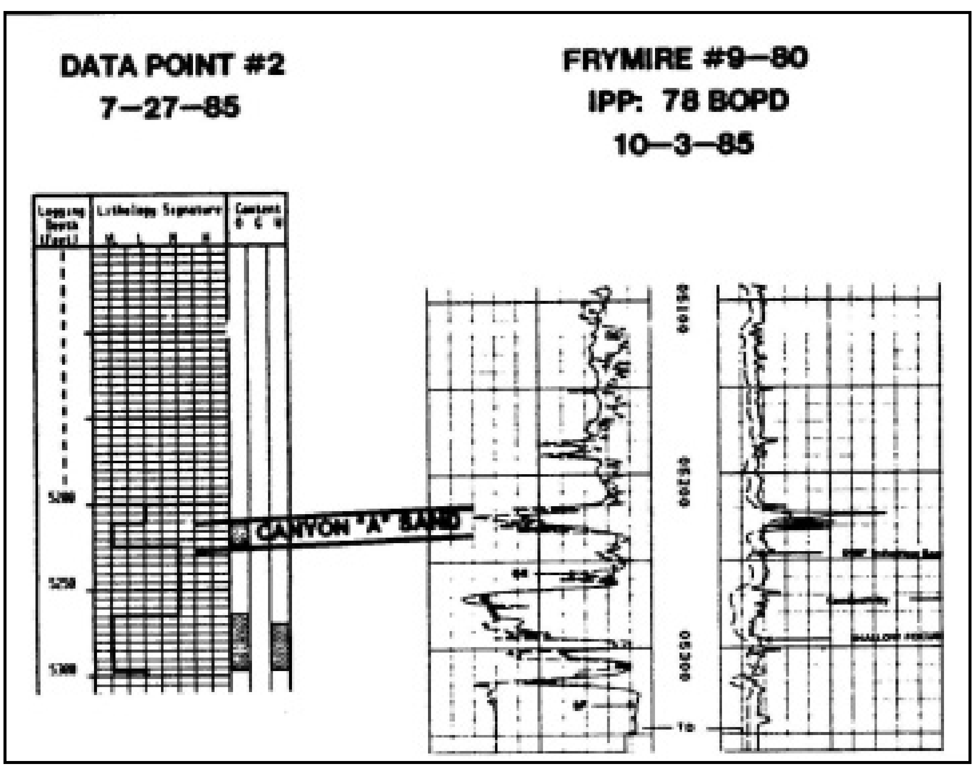


Figure 9. Correlation of # 9-80 dual induction log and electro telluric response pattern.

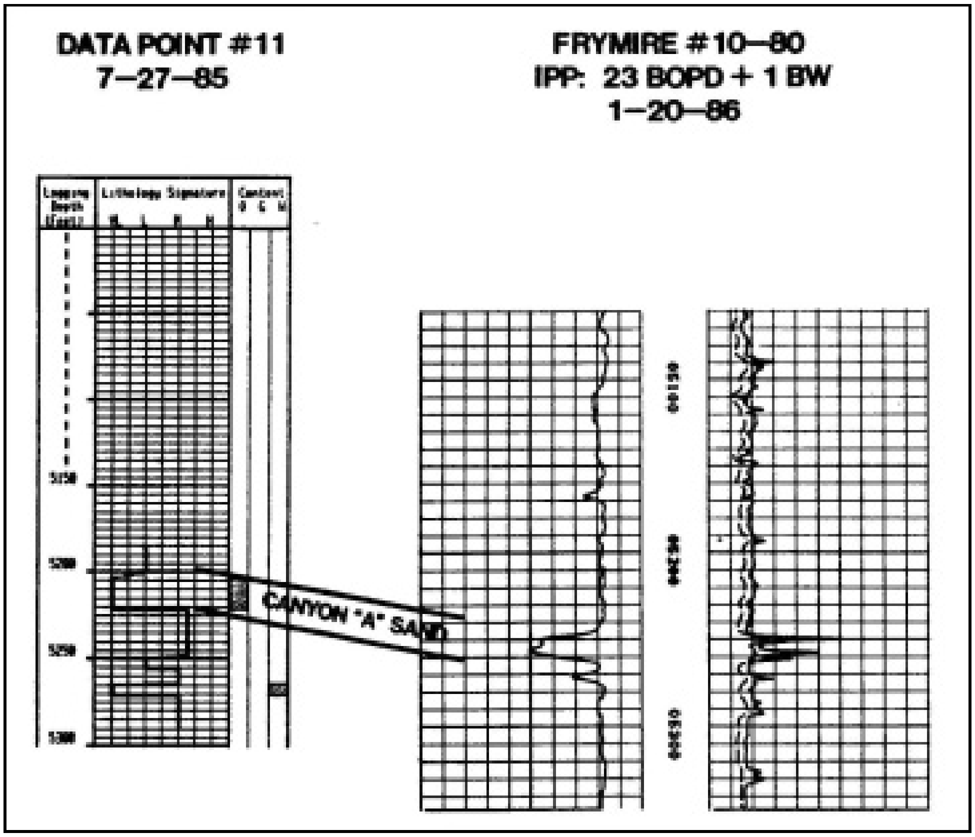


Figure 10. Correlation of # 10-80 dual induction log and electrotelluric response pattern.

Conclusion

Following the survey, the proposed east offset location was abandoned, and the west and north offset locations were drilled (Figure 2). Correlations of downhole logs with the electrotelluric data are presented in Figures 9 and 10. In the west offset well (Frymire 9-SO), the sand presence, thickness, depth, and fluid content interpretations from the electrotelluric data proved to be extremely accurate. In the north offset well (Frymire 10-SO), the sand presence and thickness interpretations were also accurate, but the sand was 30 ft lower, structurally, than the electrotelluric data indicated.

It is important to note that the depth-frequency relationship is built into the electrotelluric instrument as a constant. Accordingly, actual depths will vary within a range (usually ± 20 ft) from electrotelluric data depths, because the depth-frequency relationship is somewhat variable. Therefore, it is advisable to structure electrotelluric surveys emphasizing the presence and thickness of potential reservoirs, as opposed to determining their absolute depth.

Depth errors notwithstanding, the detection and delineation of a 12 ft sand at 5200 ft represents a significant breakthrough in risk reduction in hydrocarbon exploration.