THE IDENTIFICATION OF NATURAL FRACTURES AND THEIR ORIENTATIONS IN THE SPRABERRY/DEAN FORMATIONS IN WEST TEXAS

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ABSTRACT

Recent improvements in the Borehole Televiewer logging field have enabled oil operators to determine the presence of natural fractures and their orientations in the Spraberry and Dean Formations. Running modern open hole logs over the Spraberry and Dean zones is rarely done when these zones are the primary target zone of a well. However, the need for determining the natural fracture direction is important to the oil operator so he can optimize his offset locations with respect to the trend of the natural fracture system. Defining the trend of the fracture system is particularly important since many Spraberry/Dean wells are drilled on 40 acre spacing and are candidates for waterflood projects in many areas.

The following examples document the utility of the Borehole Televiewer in both evaluating the subject formations for hydrocarbon production and optimizing the hydraulic fracture stimulation design for achieving maximum oil production.

INTRODUCTION

The Spraberry and Dean formations have been a major drilling objective in West Texas for many years, beginning on a large scale since the early 1950's. The Spraberry and Dean formations are found in a ten county area on the eastern side of the Midland Basin in West Texas, Figure 1. The Spraberry formation was first identified in the Seaboard Oil Company's A.J. Spraberry No. 1, Dawson County, on March 21, 1944. It was found to be primarily sandstone, interbedded with shaly limestones between the sandstone layers. Extensive testing between 6400'-7300' proved this as a dry hole. Oil shows in what was later to be named the Spraberry zone had been encountered earlier at the Gulf Oil Company's No. 1 Dean, ten miles north of Seaboard Oil Company's well. However, the blanket nature of the sand was not suspected until it had been drilled at the No. 1 Spraberry and at that time, the formation was named. The first producer from the Spraberry was the Seaboard Oil Company's Southeast Lea No. 2, Dawson County, Texas, completed January 22, 1949. This well was drilled to the Ellenberger formation, T.D. 11,060'. The well was plugged back to the Spraberry and completed for 319 BOPD between 6430'-6700'. From this beginning, the Spraberry boom developed into one of the biggest and fastest growing projects in the development of Texas oil plays.

As stated earlier, the Spraberry Trend which in many wells also includes producers from the Dean sand just below the lower Spraberry, grew to 766 completed wells and up to 175 rigs running along the Trend by December 31, 1951.[1] To date there have been thousands of producers from this fractured sandstone reservoir which have produced millions of barrels of oil. Specifically, 9.4 billion barrels of oil have been found in place in the Spraberry/Dean Trend; however, it is estimated that only 6 percent of that figure will be recovered.[4] The North Ackerly Dean Field developed as offsets from the wells stated above. Almost forty years later, the Spraberry/Dean Trend is a mature play that in many areas is under extensive waterfloods.

The Spraberry/Dean formations occur in the lower Leonard section and are generally restricted to the Midland Basin province of the Permian Basin, Figure 1a. The lithology of the Spraberry and Dean formations consist of well developed sandstone bodies that can usually be correlated. Other sand lenses are developed with intervening argillaceous limestones and shales that cannot be correlated consistently. In the Spraberry/Dean formations, vertical fractures are found in a semi-consistent trend, meaning some fields have fractures in both zones and some fields only have fractures in one zone. The effective porosity ranges between 2 to 19 percent and permeability varies from .2 to 3.4 md.[3] The usual thickness of these sand beds are 2 to 3 feet bounded by the layers of shale and limestone. Early studies of the Spraberry/Dean formations suggest that the oil occurs mainly in the intensive fracture system. Recent studies conclude that only 1 or 2 percent of the oil comes from the fractures. The bulk of the oil is trapped in the matrix porosity and the vertical fractures serve as flow paths to the wellbore.[5]

CONCEPTS and METHODS

In the earlier years of development, operators perforated intervals covering 200-300 feet, then gave the wells a hydrafrac treatment with some hydrochloric acid. Pumping crude oil or kerosine was tried without success. Pumping hydrafrac gel fluids with high viscosities enabled the fractures to be widened and extended by suspending specially graded sand into the fractures. This enlarging of the fractures allowed the high rates of production which varied from 150 to 600 BOPD with very little water.

Over the years, depleted pressures, high water production and lower oil production forced the operators to seek alternative ways to concentrate the perforations and treatments in the best zones for oil production. The lithological conditions of the Spraberry/Dean wells required a log that gave precise bed boundaries and indicated the productive porosity. The first Gamma Ray/Neutron logs, Figure 2, were primarily correlation devices.[6] Today, many operators still use the Gamma Ray/Neutron as their only log, relying on direct correlation to offset wells and known oil shows as the main method for selecting perforations. Occasionally, an operator will run a suite of open hole logs to find flooded zones and possible new producing intervals. In mature fields that are candidates for water floods, well spacing and fracture orientation are very important for determing positioning for injector wells and producing wells. The average fracture orientation from a five county study shows the fracture direction ranges from 025°/205° to 050°/230° direction.[2,4] The counties in this study were several counties to the south in the Spraberry/Dean Trend so the operator wanted to determine the fracture direction in the N.E. Ackerly Dean Unit (N.E. ADU). The Borehole Televiewer (BHTV), now known as the Circumferential Acoustic Scanning Tool,(CAST) allows the oil operator a modern way of determining the fracture orientation and fracture development.

The North Ackerly Dean Field has been under waterflood since the middle 1970's by Mobil and Conoco, Figure 3. Plains Petroleum's acreage is surrounded by these companies wells and is being drained and flooded by their waterflood projects.

In the anticipated waterflood project in Dawson County, Texas, Figure 4, the oil operator considered fracture orientation a primary concern for placing injector wells. The ability of the CAST to image 360° of the borehole gave the operator confidence that major fracture systems would be clearly defined. Additionally, the oil operator wanted to run a full suite of modern open hole logs including Gamma Ray/Dual Spaced Neutron/Spectral Density Logs and Dual Laterolog-Micro Guard Logs. The Dual Spaced Neutron/Spectral Density Log, Figure 5, shows the lithology and porosity of the Upper Spraberry beginning at 7045'. The Gamma Ray and Neutron curves are similar to the 30 to 40 year old logs. The Spectral Density Curve helps define effective porosity and the Pe curve shows how close the beds of sand, shale and limestone are layered. The Dual Laterolog-Micro Guard Log, Figure 6, beginning at 7045' shows the typical log characteristics of the Spraberry/Dean formations. The three resistivity curves are stacked showing little or no permeability. The resistivities range from 2 ohms to 200 ohms depending on porosity and lithology. These log profiles are typical of the Spraberry/Dean formations which range from 1400' to 1800' thick. Throughout the Spraberry section of this well very little indications of fracturing can be detected.

The top of the Dean Formation starts at 8468'. Continuing down the open hole logs, Figures 7 and 8, evidence of fracturing can be seen on the Dual Laterolog from 8563' to 8574'. This spiking is caused by the Micro Guard pad losing contact with the borehole wall as it goes across a fracture. This fracturing is not observed on the Spectral Density log because the Density pad does not cross the vertical fractures. The direction of these fractures cannot be determined from the porosity or resistivity logs. However, in Figure 8a, the CAST clearly shows the reason that the Micro Guard Log shows the sharp spikes between 8563' and 8568'; heavy fractures are clearly shown at this interval. The Micro Guard does identify fractures if the pad traverses the fracture, but the CAST identifies fractures and shows their orientation. From the top of the Dean, small indications of vertical fractures are beginning to appear on the CAST. These traces can be followed on down the CAST where massive vertical fractures are developed from 8525' to 8610'. An example of these fractures is shown on Figures 9 and 10. By studying the CAST, the relative bearing of the fractures intersecting the borehole can be determined. In this interval the fractures are intersecting the borehole in an east to west direction. This information can then be plotted in polar form to graphically display the fracture trends, Figure 11. Each radial on the polar summary represents a fracture found at a certain level. This polar summary was tabulated from 8525' to 8580'.

The operator decided to selectively perforate and treat the interval from 8490' to 8660' in two stages. The first stage from 8558' to 8600', and the second stage, from 8490' to 8546'. The Halliburton Logging Services Tracerscan Log, Figures 12 and 13, summarizes the treatment of each zone and shows the effectiveness of the two. Although the massive fracturing was not evident in the lower interval, significant oil shows were found in this zone. Thus the operator figured a good hydraulic fracture treatment of 34,000 pounds of sand would create a fracture system for oil flow to the wellbore. Then in the second stage, a treatment of 102,000 pounds of sand was pumped. The first stage was tagged with 15 mci of Scandium 46 and the second stage was tagged with 46 mci of Iridium 192. As shown in the Tracerscan log, the majority of the treatment went into the fractures generated by the hydraulic frac treatment in the lower interval. Although more natural fractures were found in the upper interval and more hydraulic horsepower and sand was used to treat the upper zone, the treatment broke into the lower zones fracture system.

This well initially produced 80 BOPD with very little water. Six months later, oil production has fallen to 20 BOPD and 35 BOWD. In retrospect, the operator concluded that a better well could have been made if the two zones were treated together in one massive hydraulic frac treatment. Because of this production decline the operator is planning to make this well a water injection well and based on the orientation of the fractures, drill one more water injector approximately 2000' to the northwest. These two injectors will help flood the producing intervals and extend the production of this operator's wells in the Northeast Ackerly Dean Unit, Figure 14. Plains Petroleum also has Dean production approximately 4 to 5 miles north of the N.E. ADU No. 1-6 discussed here and was planning to drill two new production wells in late 1989 on that acreage. Because of their well spacing, well positioning with other operator's waterfloods and the fracture orientation determined by running the CAST on the N.E. ADU No. 1-6, the operator cancelled plans to drill these two wells. At current prices, cancelling the two wells to the north represents a savings of at least $800,000 to Plains Petroleum.

CONCLUSIONS:

The method described above satisfied the oil operator's basic question of fracture orientation in the N.E. Ackerly Dean Unit. Also, some oil operators have drilled horizontal holes in the Spraberry Trend. Identifying the fracture direction is a critical factor in determining which direction to drill horizontally to maximize hitting the vertical fractures. This fracture information is now easily attainable by running the CAST. Fracture information from the CAST can be an important part of selecting perforations and zones to be hydraulically fractured. As more fields in the Spraberry/Dean Trend are waterflooded or put under CO_2 injection projects, the use of the CAST should be an important logging consideration.

R E F E R E N C E S

1) Ira Rinehart's 1952 Yearbook, Rinehart Oil News, 1952.

2) Bulletin of the American Association of Petroleum Geologists, A.J. Eardley.

3) SPE 17280 Optimizing Hydraulic Fracture Length in the Spraberry Trend, Robert E. Barba, 1988.

4) Bureau of Economic Geology, RI 171 Heterogeneous Deep-Sea Fan Reservoirs, Shackelford and Preston Waterflood Units, Spraberry Trend, West Texas, Noel Tyler and J.C. Gholston, 1988.

5) Bureau of Economic Geology, RI 172 Geological Characterization of Permian Submarine Fan Reservoirs of the Driver Waterflood Unit, Spraberry Trend, Midland Basin, Texas, E.H. Guevara, 1988.

6) Petroleum Review, Dawson and Martin Counties, Texas Robert L. Phifer, 1957.

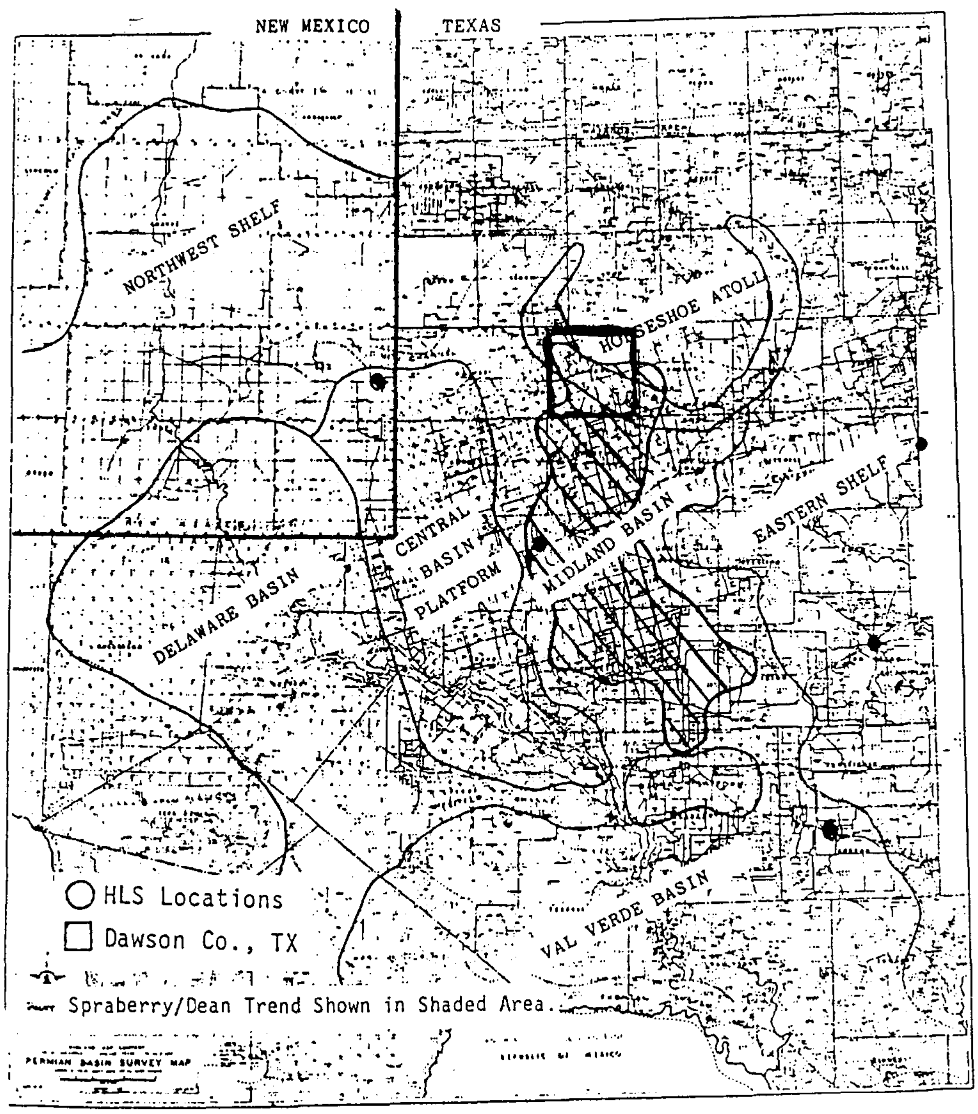

Figure 1 - Major oil and gas areas of the Permian Basin

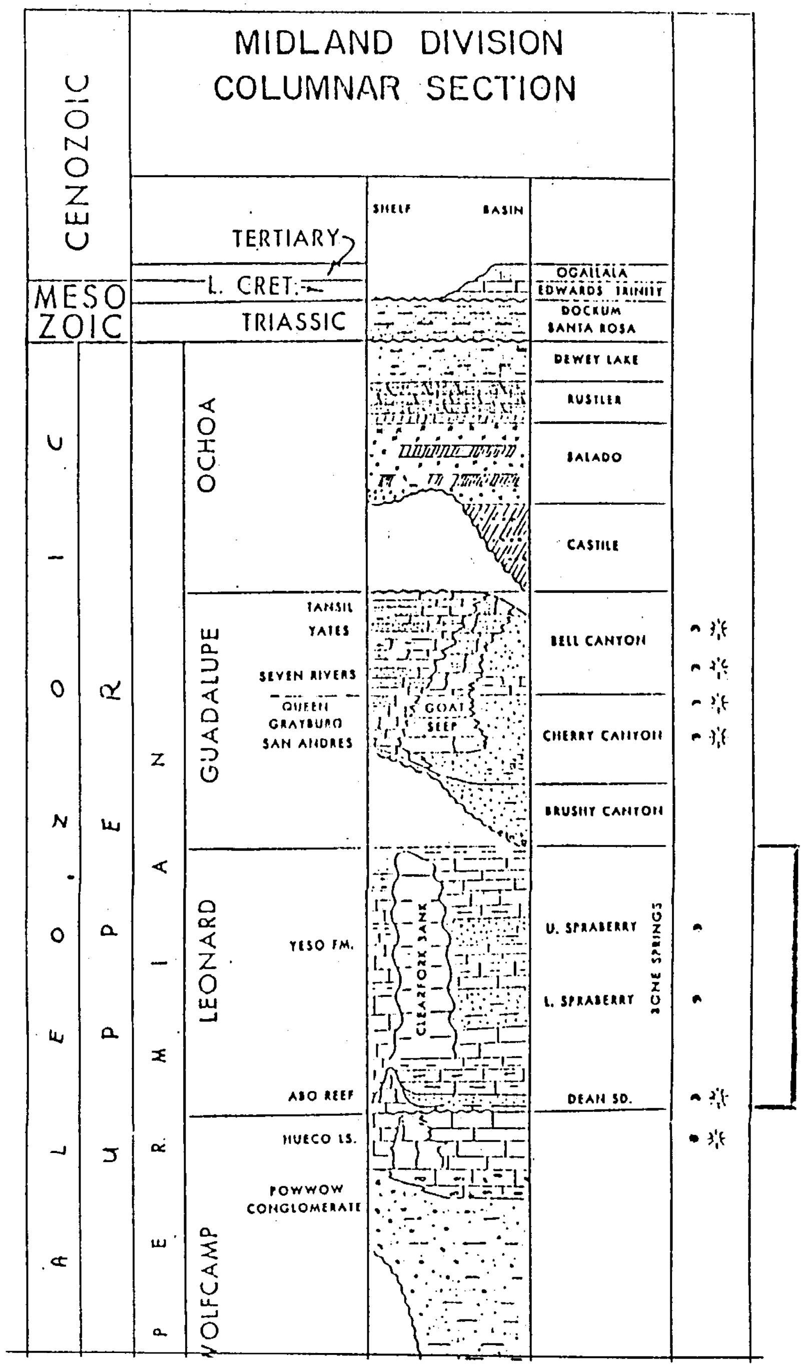

Figure 1a - Columnar section

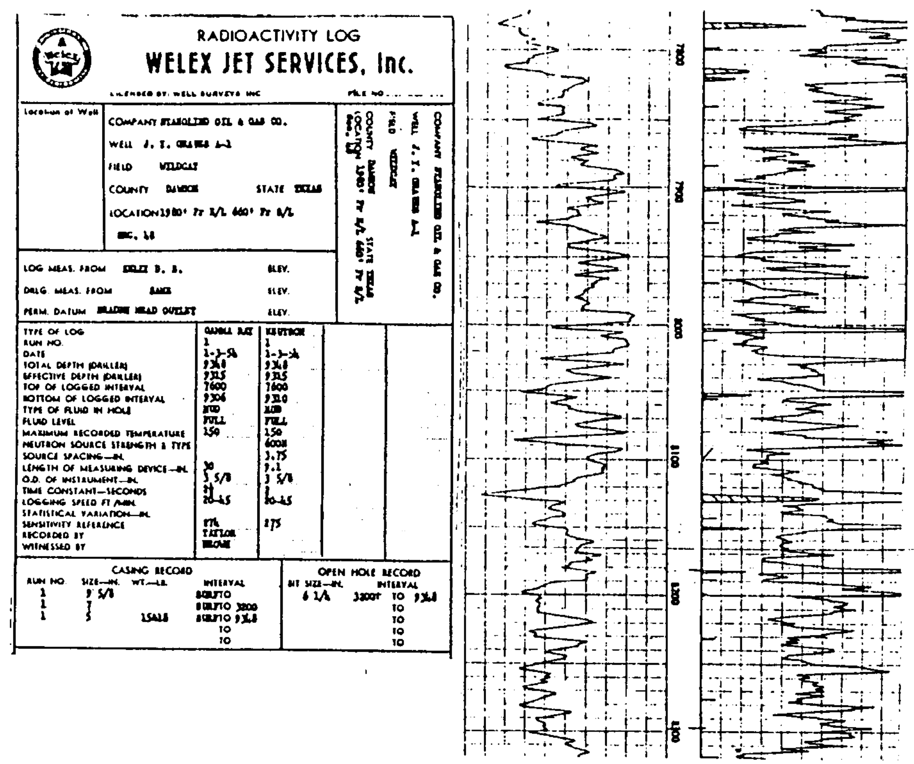

Figure 2 - Pay section (8180'-8298') of discovery well, Ackerly (Dean Sand) Field

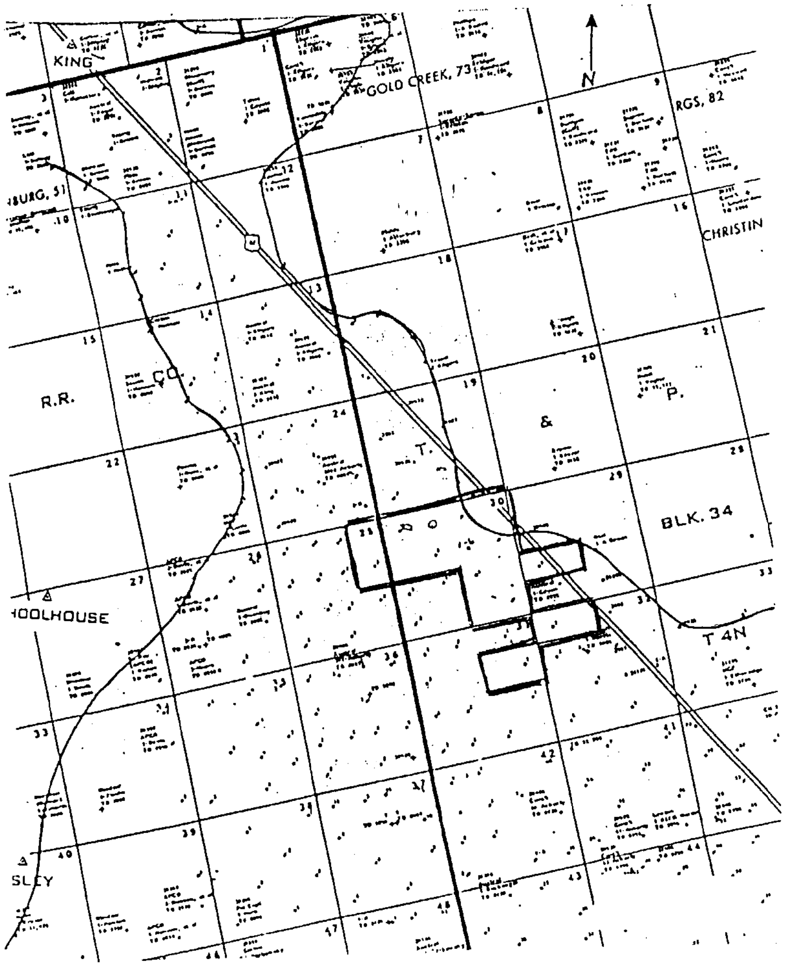

Figure 3 - Northeast Ackerly Dean Field Dawson County, Texas

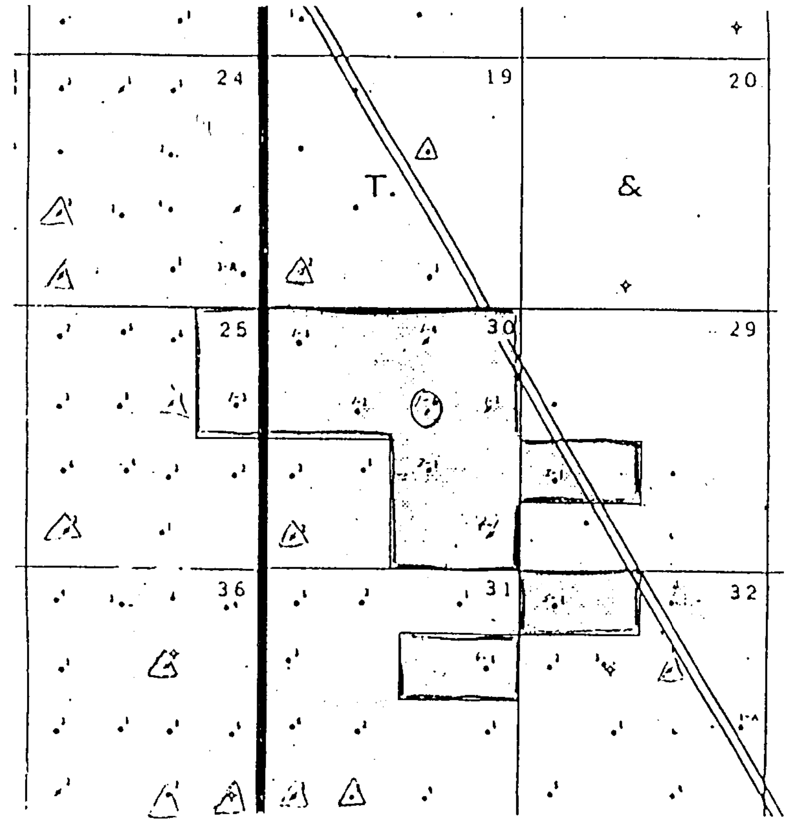

Figure 4 - Area waterflood wells and Plains Petroleum's acreage in N.E. ADU, Dawson County, Texas

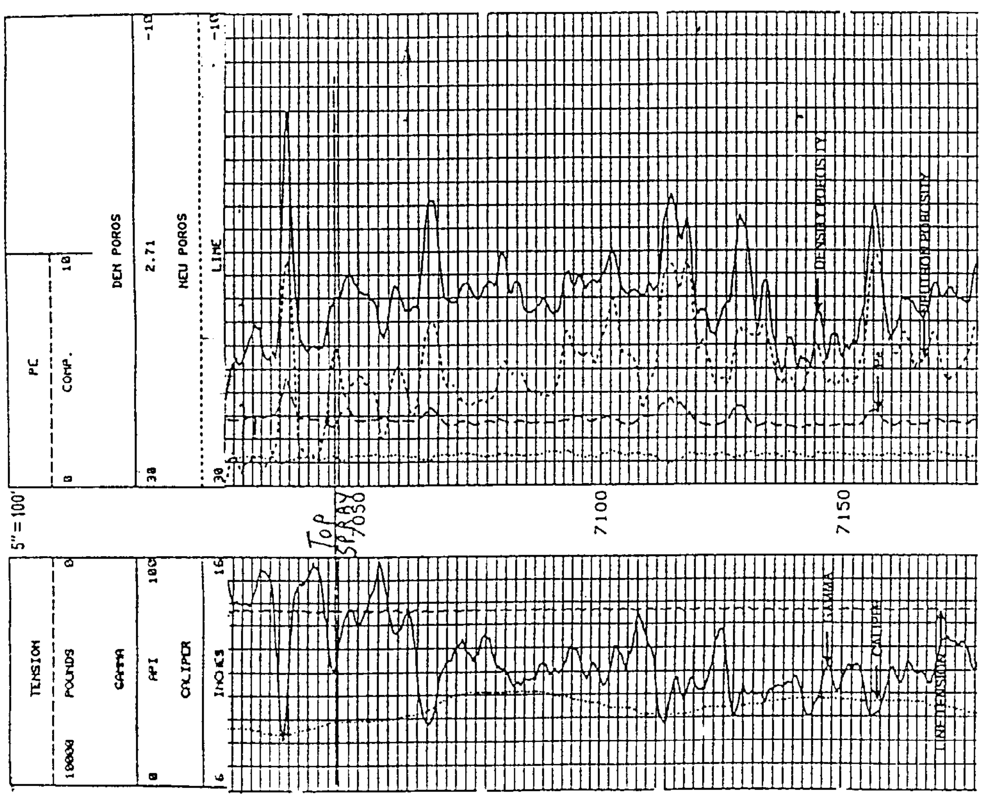

Figure 5 - Spraberry–GR/DSN/SDL

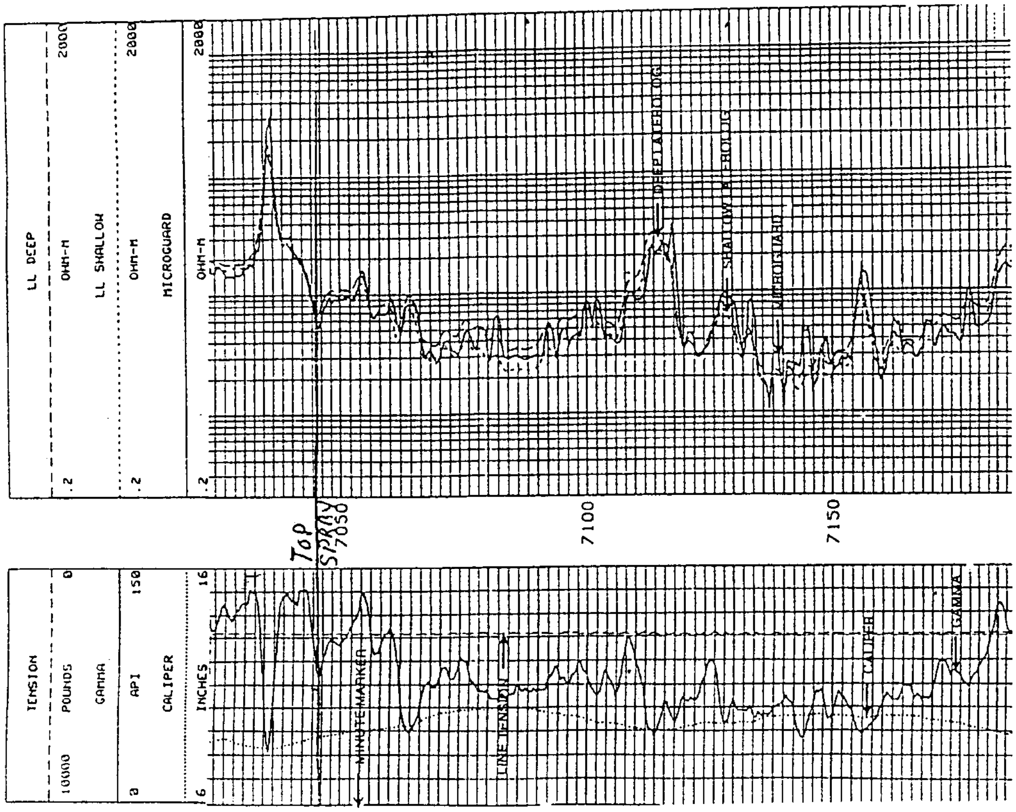

Figure 6 - Spraberry–GR/DLL-MG

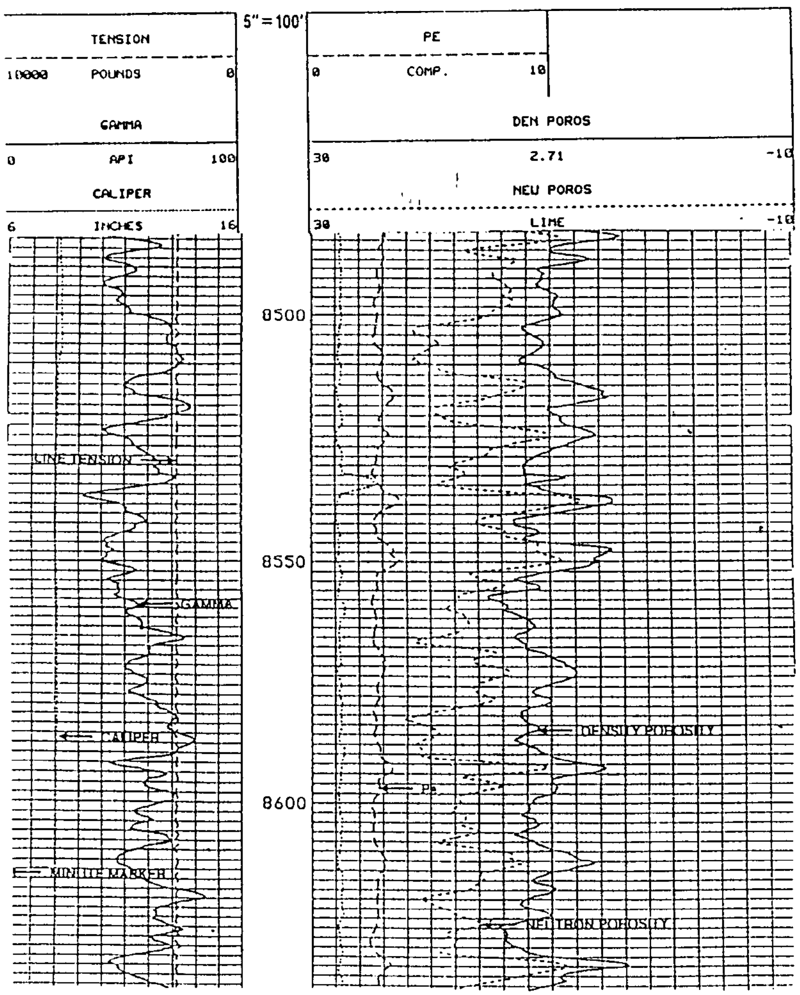

Figure 7 - Dean–GR/DSN/SDL

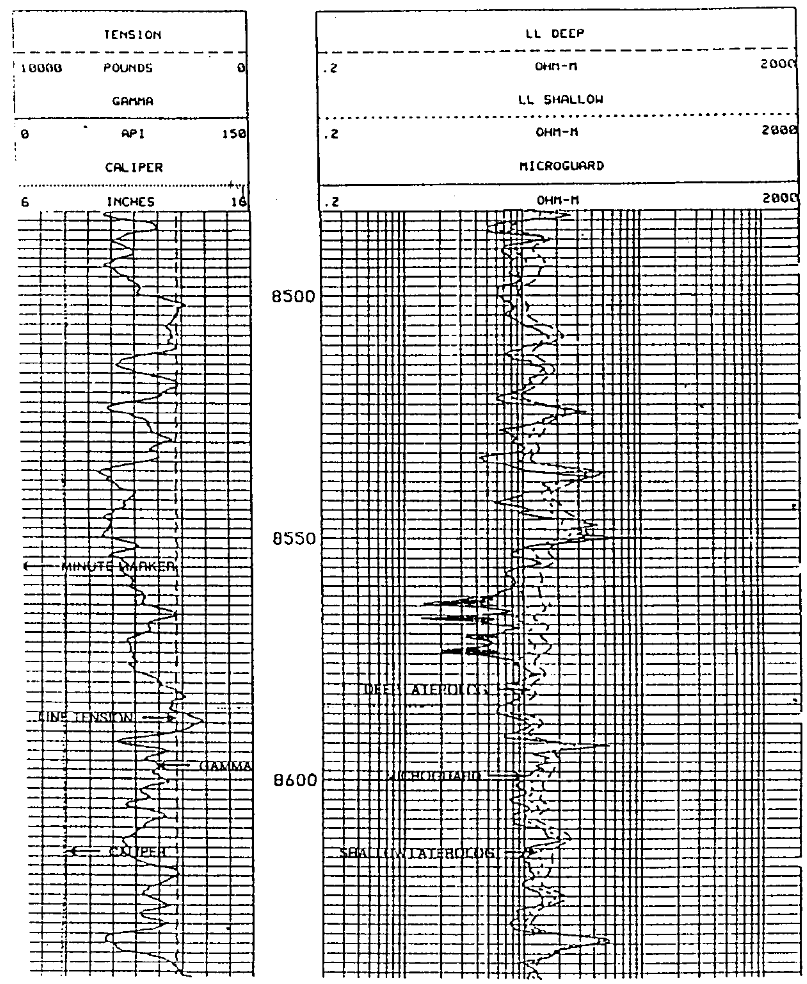

Figure 8 - Dean–GR/DLL-MG

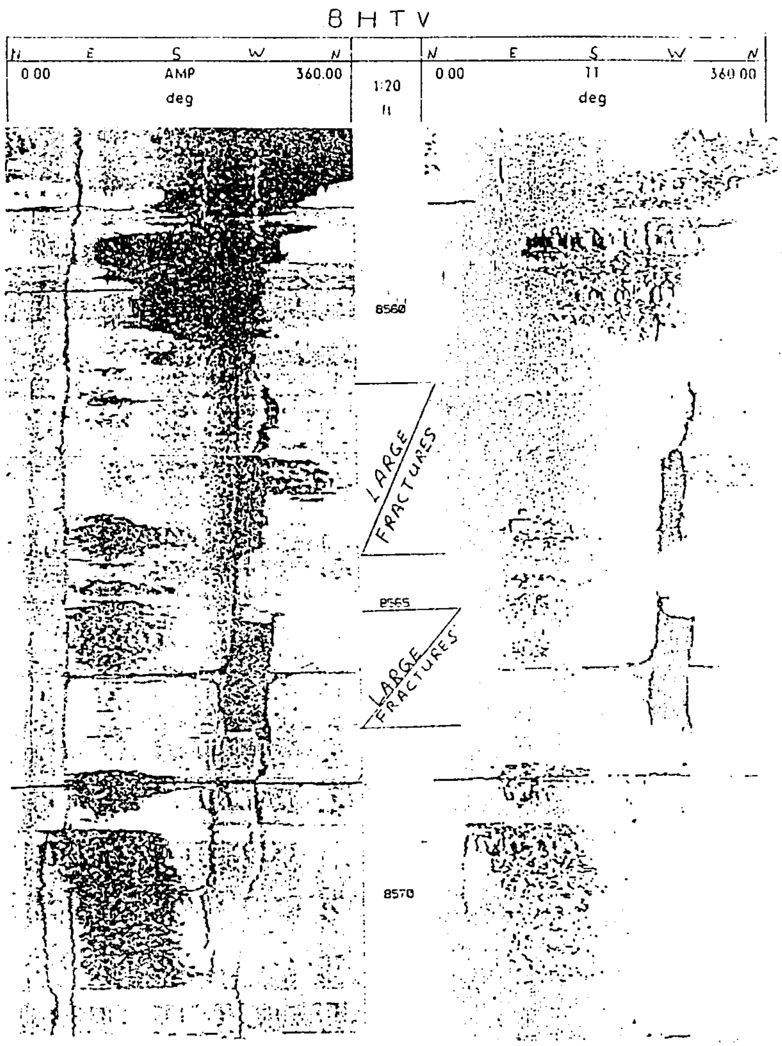

Figure 8a-CAST log of Fig. 8

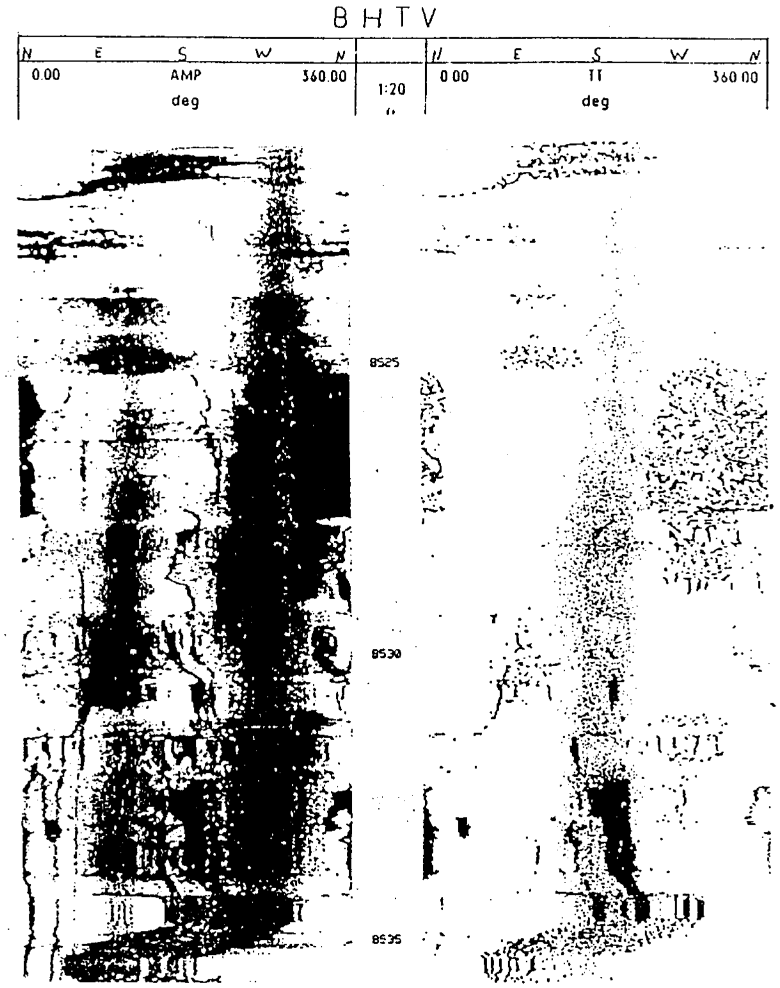

Figure 9 - Example of fracture from a CAST log

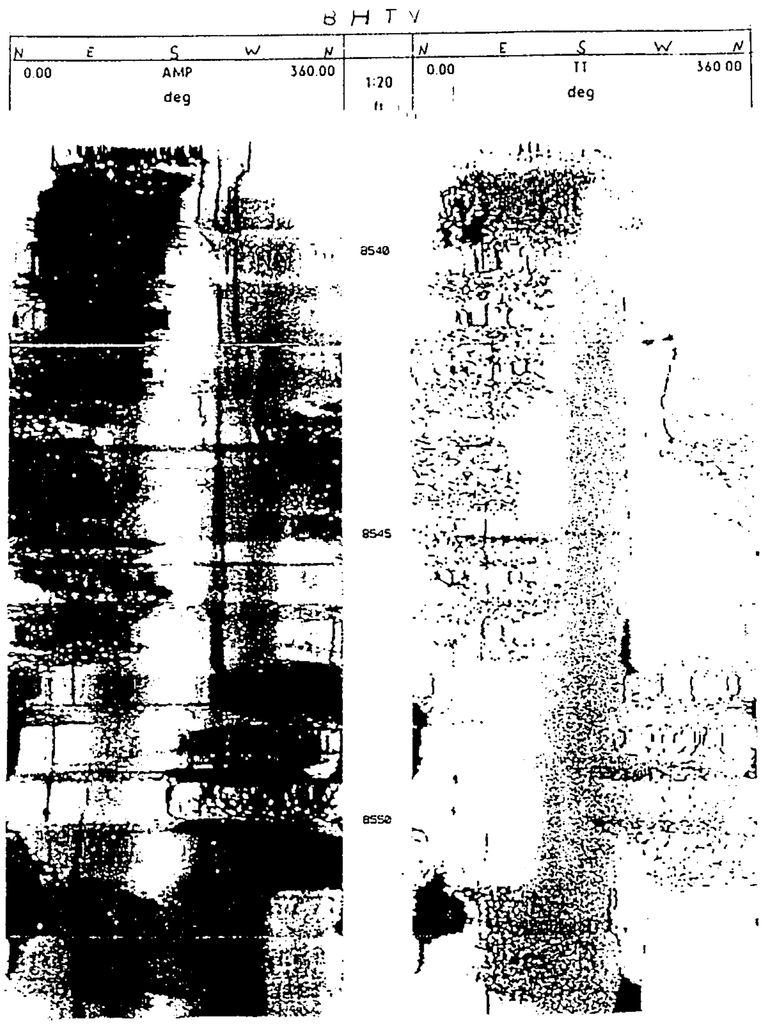

Figure 10 - Example of fracture from a CAST log

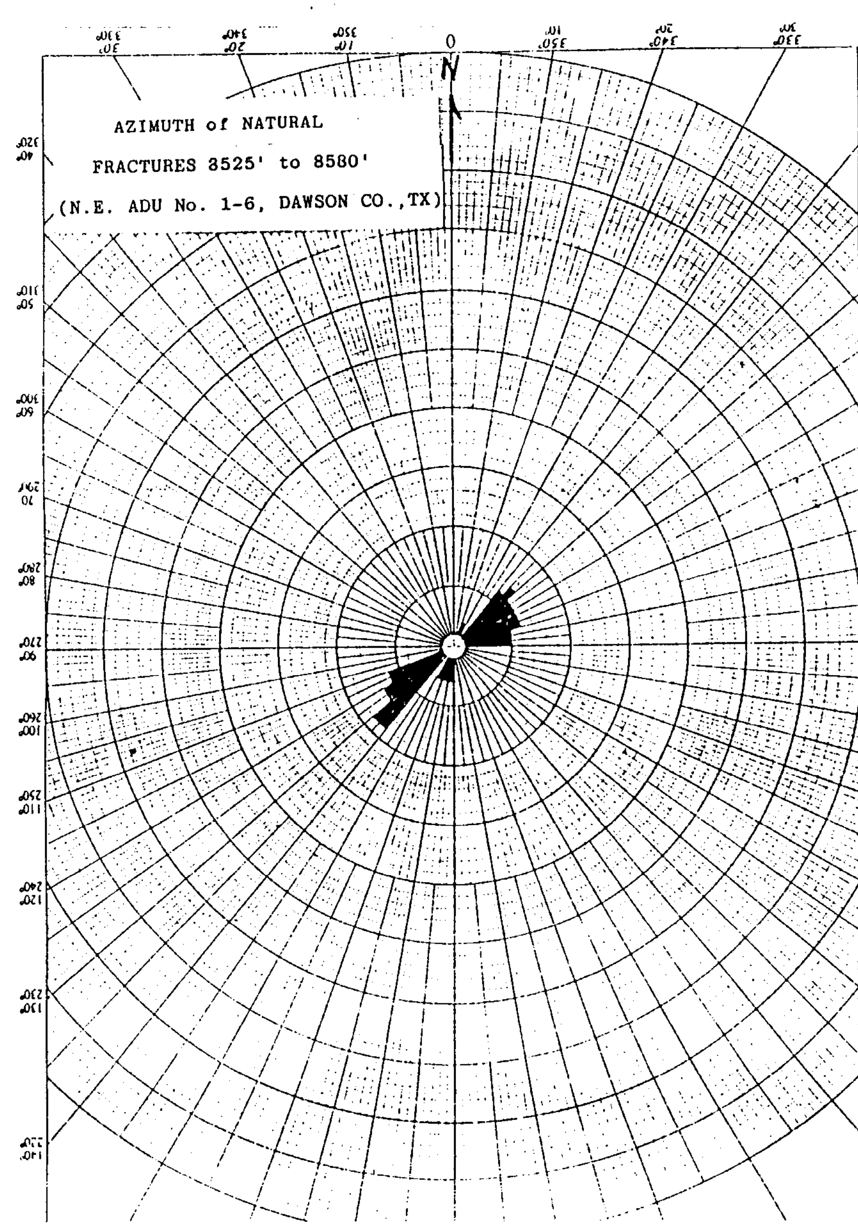

Figure 11

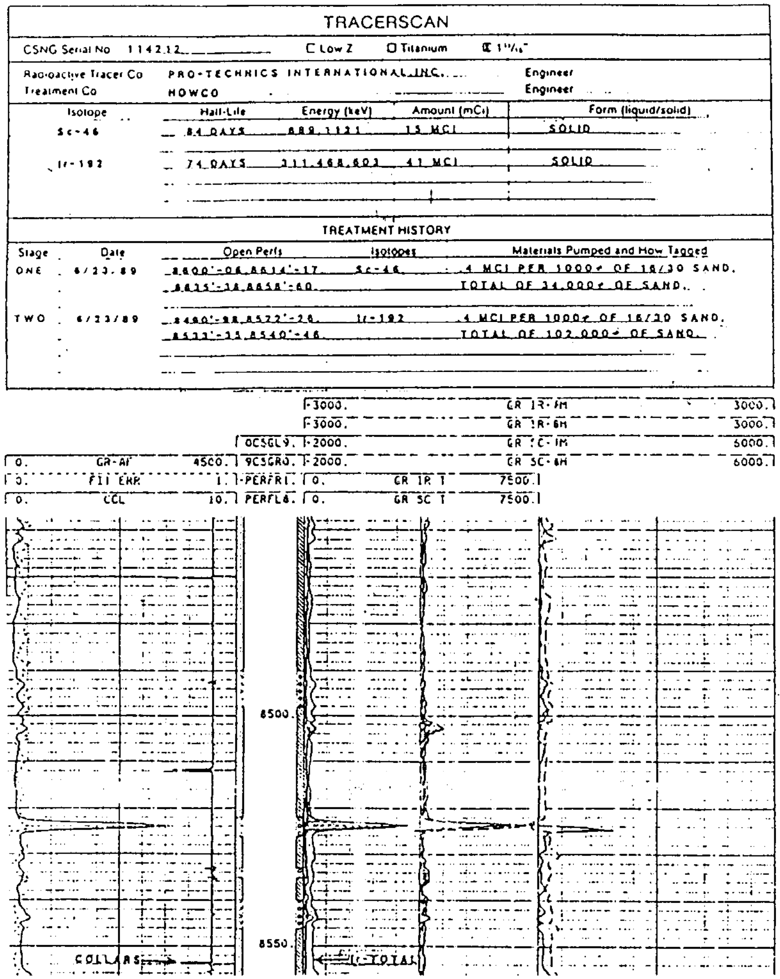

Figure 12 - Tracerscan log

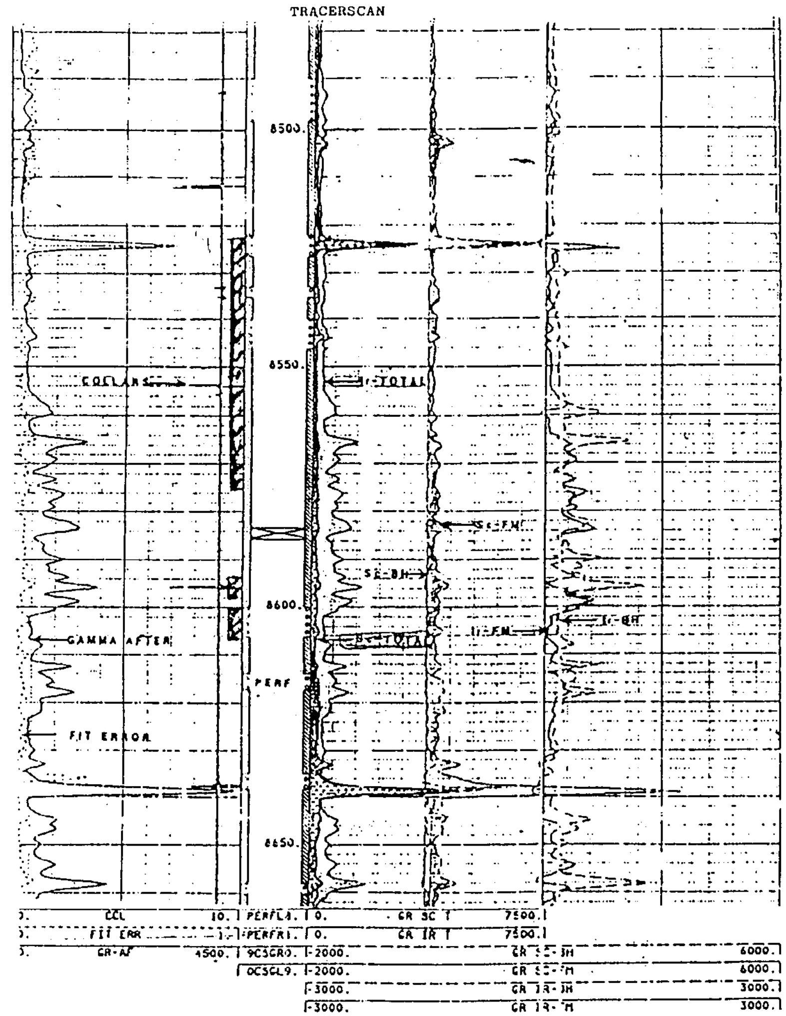

Figure 13 - Tracerscan log

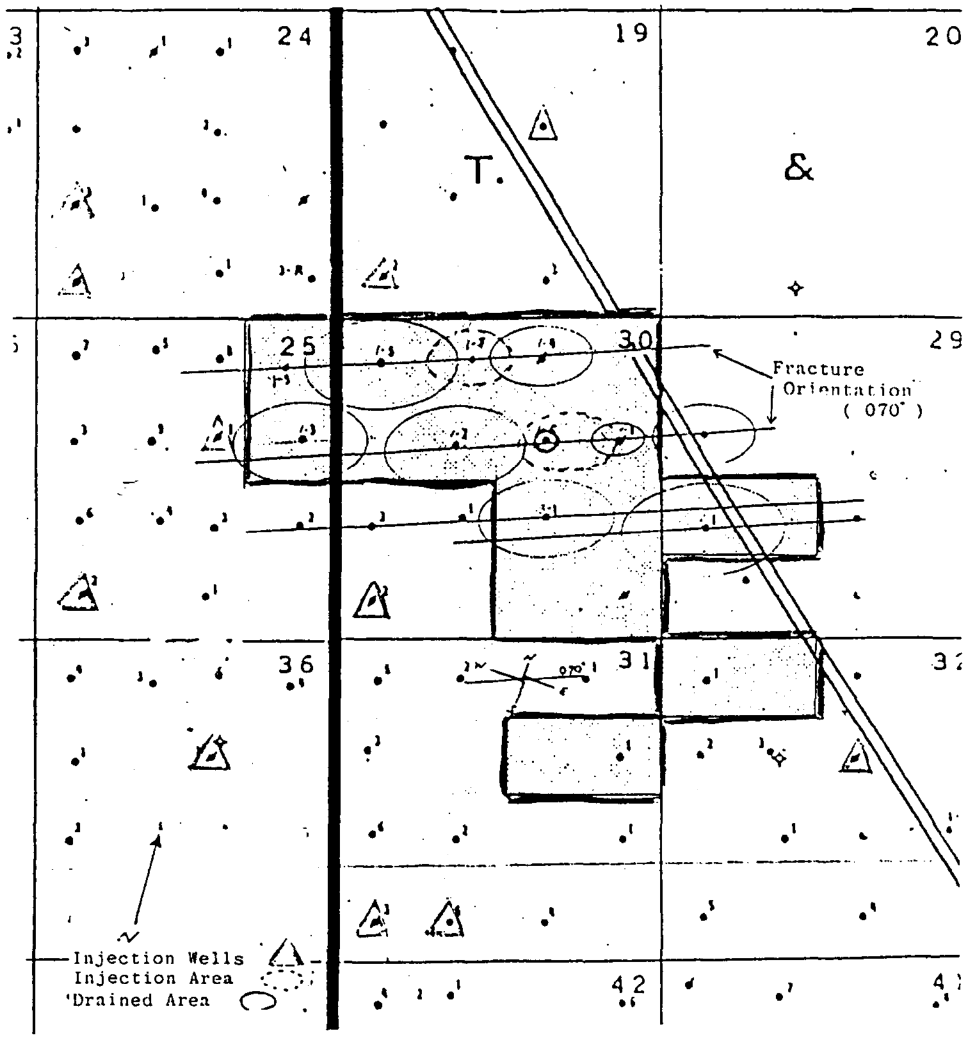

Figure 14 - Fracture orientation–Spraberry/Dean
N.E. Ackerly Unit, Dawson County