FRAC TURE EVALUATION IN THE AUSTIN CHALK

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INTRODUCTION

The application of horizontal drilling technology to the Austin Chalk in South Texas has ignited yet another drilling boom in this Upper Cretaceous fractured-limestone reservoir. There are presently over 100 rigs drilling for the Chalk in South Texas, representing over ten percent of all drilling rigs in the U.S. This activity, which began in earnest in 1990, is fueled by results such as the following (reported by TIPRO for the first 224 horizontal wells):

- 3% dry
- 75% potentiaded over 100 BOPD
- 10% potentiated over 1000 BOPD

The drilling is mainly driven by independents, although the AAPG reports that three major players (Oryx, UPRC and Meridian) each have 200,000 acres or more under lease. New records for lateral extent and initial production rates are regularly reported in the media.

Horizontal drilling not only greatly improves the odds of making a well in a vertically-fractured reservoir, but also allows intersection of more than one fractured interval or “swarm”. By drilling perpendicular to fracture trend, several separate reservoirs can be tapped.

THE AUSTIN CHALK TREND

The active Chalk drilling trend stretches northeasterly from the Rio Grande to the Giddings area and can be divided into three primary areas of activity: Pearsall, Mid-trend (Wilson-Gonzales) and Giddings. Each play is somewhat different. The Pearsall area (where the first Chalk production was discovered in 1936) has had the most impressive results to date. The fractures in this area are more evenly spaced and less fault-related. In the “sweet spots” a horizontal well with a long lateral reach (up to 5000’ or more) will literally cross thousands of individual fractures. In the Giddings area, the fractures are more fault related and therefore usually more widely spaced. In the recently developed Midtrend area, there seems to be more deep seated faulting leading to concerns about possible Edwards water (and even hydrogen sulfide).

In all three areas the key to making a well in this tight limestone is the fracturing system. The Chalk itself is a dense, somewhat chalky limestone with many marly zones, or “shale beds” as they are commonly called. The matrix itself has low porosity (six to nine percent) and very low permeability (measured in hundredths of a millidarcy). This matrix is usually oil saturated. In fact, the Chalk probably “sourced” itself along with the underlying carbonaceous, calcareous Eagleford Shale. This matrix feeds the fracture systems, but the only way to get commercial production from the Chalk is through the fracture systems.

The Fracture Systems

The fracture systems in the Austin Chalk are made up of remarkably consistent, nearly vertical fractures. These fractures normally dip toward the coast (southeast) at 75 to 88 degrees, although fractures dipping away from the coast (northwest) are not uncommon. Aperture widths vary from less than one hundredth of a millimeter to large enough to detect with the drilling bit. Typical apertures vary from one to 0.01 millimeters for productive fractures. These extensional fractures parallel the basin margin and trend roughly northeast-southwest with variations of ±15 degrees (north 45 ± 15 degrees east to south 45 degrees ±15 degrees west). In a particular area, however, whatever the azimuth of the fracture trend is, it will usually not vary much. (Some variation with structure has been observed in long lateral reach wells.)

Key Questions About Fractures

Two important questions about fractures of obvious commercial importance are:

1. What is the average spacing between fracture “swarms”?
2. How far do they extend vertically and horizontally?

The spacing between fracture swarms varies from being virtually continuous (i.e. one or more per foot) for hundreds of feet to being virtually undetected in some dry holes. A certain periodicity in fracture-swarm spacing often seems to exist; sometimes it is on a 20-foot cycle, sometimes it is on a 200-foot cycle, etc. Fractal techniques may provide insight, but at this point the only practical way to assess this spacing is to evaluate fracture identification logs in the immediate area.

The jury is still out on the question of the vertical extent of the fractures. Obviously they do not extend from the Lower to the Upper Chalk because vertical production isolation has been proven in many areas. Known cases of nonproductive horizontal intervals above and/or below production intervals in “horizontal twin” completions also support this conclusion. On the other hand, fractures have been observed cutting across the shaly (marly) zones on logs and in outcrop. Furthermore, in most productive Chalk intervals there are numerous shale beds or marls (as often...
as every foot or so) and the oil volumes produced could not possibly come from only one, or even several of these thin fractured intervals. There are some indications that the ash beds often found in the Upper Chalk may act as pressure and/or fluid barriers. Fracture intensity, however, seems to show little relationship to these marker zones.

The questions of the lateral extent of the fractures is also of great interest. Production rates and cumulative production totals strongly suggest large drainage areas. This large lateral extent is especially apparent when the overall fracture porosity values of less than one percent are taken into consideration in reservoir calculations.

Drilling, stimulation, and production experience indicates very limited communication in the updip (NW) or downdip (SE) direction, but very good communication (up to a mile or more) along trend (i.e. NE or SW). Further drillstem and production testing is needed to resolve these questions. Ironically, it will probably be the landowners and lawyers who force the issue.

### Log Evaluation

All of these questions would seem to beg for answers and yet in a play that has yielded some of the best flow rates in the lower 48, “no cores, no tests, and no logs” is all too often the standard operating procedure.

Many types of conventional logging devices have been run in the Chalk. In horizontal holes they can be run on drill pipe or on coiled tubing.

Resistivity devices such as induction and lateral tools are used for correlation and can identify the thicker ash and shale beds. Traditional minimum resistivity cut off values (usually six ohms or more) are used to identify so-called “pay zones”, yet some of the most resistive zones (such as the Two Fingers) have often proven to be devoid of fractures. Thin shale beds below the resolution of these traditional resistivity devices further complicate the issue. Other measurements such as the SP are usually quite nondescript. The GR (gamma ray) will identify the thicker, highly radioactive ash beds. The GR will also give a feel for overall shaliness which should influence the fracturability of the rock, but once again the numerous thin shaly beds are a problem. Porosity devices report a monotonously consistent six to nine percent porosity (with a range of as little as three percent to as much as 12 percent porosity). Traditional water saturation calculations are of little practical use. Acoustical-type measurements such as traditional sonics and the newer full-wave-train analysis logs have the advantage of being compatible with seismic, which is a primary exploration tool in the Chalk (along with “close-ology”).

Wireline formation tests and sidewall cores have been only marginally useful in the Chalk. The newly-introduced mechanical coring tool offers exciting possibilities, but it will not presently operate in horizontal holes.

### Fracture Detection

Fracture detection is the key to evaluating an Austin Chalk well. Other questions such as pressures and fluid types must also be addressed, but without good fracturing, very little or no production is possible from this very low-permeability, high-reserve formation.

Historically, telltale indicators such as “nervousness” on the SP, the caliper, the short normal, and/or the density short spacing curves has been used to attempt to identify fractured zones. At best these have been able to detect only the extensively fractured (and often brecciated) zones. The introduction of a dipmeter technique known as the Fracture Identification Log (or FIL*) improved matters considerably, but often doubts remained.

### Imaging Devices

The introduction of imaging devices allowed fractures to be “seen” and thus positively identified.

Acoustical imaging devices such as the Borehole Televiewer (or BHTV) have been around for quite some time. The more recent (1986) commercial introduction of microresistivity image devices such as the Formation MicroScanner* (FMS) tool have revolutionized our ability to detect and evaluate fractures.

Each of these two basic types of imaging devices has its advantages and disadvantages. The acoustical devices give full (360 degrees) coverage and will operate in any mud system provided mud weight is not too high. Its dis-
advantages are that it must be well centralized (a major problem in horizontal holes), that it is degraded by solids in heavy muds and emulsion interfaces in oil based mud sytems, and that it has less vertical resolution than the microresistivity devices. The microresistivity devices have the advantage of better vertical resolution (and hence sensitivity to fractures) and ability to evaluate fracture aperture width and hence permeability. Microresistivity devices have the disadvantages of not having full borehole coverage and being severely degraded by oil based muds. If fuller coverage with these devices is needed, multiple passes can be run, or the newly introduced eight-pad tool (which has very high availability at present) can be utilized.

A fundamental consideration in choosing between the two types of imaging devices is the amount of contrast between the feature you are trying to identify and the surrounding matrix. In the case of fractures in the Austin Chalk the resistivity contrast between the fluid-filled fractures and the chalk matrix is at least one order (ten to one) and often two orders (100 to one) of magnitude. For example, you are often comparing fractures filled with water of 0.1 ohms resistivity to the chalk matrix itself which may have ten ohms of flushed resistivity or more. On the other hand, the acoustical contrast between the fractures and the matrix is much smaller (only two to three times). The acoustical devices such as the BHTV actually rely heavily on borehole rugosity to detect anomalies such as splayed fractures and washouts, etc.

Experience has shown that both types of imaging devices will identify the best fractures such as those with aperture widths greater than one millimeter. Somewhere between one and 0.1 millimeter, however, the acoustical devices lose the ability to resolve open fractures. Somewhere below 0.01 millimeter (also probably the lower limits of effective fracture permeability) the microresistivity devices also lose the ability to resolve fracturing. Many of the other techniques will identify the “super fractures” with one centimeter in width or more.

Additionally, the FMS has the unique ability to accurately evaluate fracture aperture or width. These values have been found to match those found in horizontal and vertical cores taken in Chalk. A knowledge of fracture spacing and aperture allows the computation of fracture porosity and permeability. This in turn can be used to calculate flow rates. Experience to date indicates an excellent correlation between these predicted production rates and actual results.

A further consideration of fracture evaluation is the problem of tool pulls. This is always a potential problem especially when logging in highly deviated or horizontal holes. The problem is not completely understood, but apparently in addition to the normal tool pulls, sliding friction on the drill pipe can cause decelerations and accelerations at the end of the drill pipe where the logging devices are conveyed for tough logging conditions. This results in “apparent pulls” on the logs. This type of hole problem affects all logs but is especially apparent on the imaging-type devices. Recent software improvements have eliminated most of these “pulls” on the Formation MicroScanner logs.

The Formation MicroScanner* (FMS) Tool

As the tool of choice for fracture identification and evaluation, the microresistivity imaging devices need a bit of description.

The FMS is a dipmeter-type device with all the standard capabilities of a modern dipmeter, such as borehole and tool orientation, borehole geometry with two pairs of calipers, structural and stratigraphic computation, etc. Additionally, it has the ability to produce images. The standard tool ratings of 350° F and 10,000 psi apply. Minimum hole size is six inches and maximum is 21 inches. A slim hole tool with a minimum hole size of 4-3/4 inches is now available in South Texas. A variety of FMS presentations are available to suit the operator’s needs.

EXAMPLES

Vertical Holes

Examples from vertical holes (see Figure 1) show the vertical depth of the fracturing, the orientation or trend of the fractures, and the presence of faulting, as well as structural dip and lithologic variation. The study of ash beds and shales and their relationship to the fracturing, is an example of the increased understanding of these fractured reservoirs that can be achieved by fully evaluating fractures in the vertical (as well as horizontal) dimension.

Pilot Holes

Increasingly, operators are realizing the advantages of optimizing the picking of their horizontal targets by drilling a
straight (or deviated) pilot hole through the Chalk and then logging to determine the best fractured intervals (or "sweet spots"). The fracture trend, the structural dip, the faults, etc. can be taken into account to properly engineer the hole to encounter the optimum zones in the best position and at the best hole angle. This approach has proven particularly valuable in avoiding getting the bit "hung up" in the ash beds. While drilling "nearly horizontally," the operator will often drift slowly down (or up) with structural dip in order to stay in the best interval. They may later drop down to other prospective zones if the first zone is not doing as well as hoped and some even drill downward through the rest of the prospective Chalk at the end of their drainhole.

**Horizontal Holes**

The FMS can be conveyed on drill pipe to bottom and logged going either up or down. This operation will usually take from 12 to 24 hours (depending on the interval logged) and is reliably and routinely performed using Tough Logging Conditions (TLC*) equipment which is locally available.

In horizontal holes (see Figure 2) the fractures can be counted and evaluated for aperture width. Fracture count and aperture width are the two major values needed for calculating fracture porosity and permeability. Comparisons of these values to those from horizontal cores as well as comparisons to production results have been very encouraging.

Other Horizontal Evaluation Techniques

Other evaluation techniques such as Thermal Decay Tool (TDT*) devices (which can be run through pipe), shear and Stoneley sonic wavetrain analysis logs, and others have been calibrated versus the FMS and have shown good potential. Production logging, oxygen activation surveying, (done with the TDT) and drill stem testing have been done in horizontal holes in the Chalk to evaluate pressures and fluids. More work of this kind is needed.

**CONCLUSION**

The ability to count most if not all open natural fractures in the Austin Chalk has been proven. The ability to evaluate those fractures for aperture width, and hence productivity, has been verified by core and production. The question remains however, why so many horizontal operators are willing to have little or no concrete information about where their reserves actually are when these proven fracture evaluation techniques are routinely available today. True, drilling breaks and mud logs can give you good information, but many productive fractures are missed this way. Furthermore, after the first strong kick or lost circulation zone is drilled, the mud logs lose their ability to detect fractures altogether.

Admittedly, it's hard to argue with success, but if an operator is going to commingle zones (that potentially can take or make thousands of barrels of fluids - mud, oil, and/or water), wouldn't it be prudent to at least know at what
measured depth the productive intervals are? Without proper evaluation, if a well is making 500 barrels a day, who is to say whether it is producing to its maximum potential or whether it might be able to make 1000 barrels per day and need selective stimulation? Worse yet, maybe the well actually is producing 1000 barrels per day but is cross flowing from one fracture system into another and the oil is being lost, perhaps forever.

The technology exists to successfully and economically drill and evaluate the fractured Austin Chalk. Only time will tell whether the euphoria of the initial successes will lead to the inefficient exploitation of this tremendous resource and bring to a premature end the latest Austin Chalk boom.

*Trademarks of Schlumberger