THE AUSTIN CHALK — AN OVERVIEW

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INTRODUCTION
The Upper Cretaceous Austin Chalk Trend as currently delineated in Texas Railroad Commission Districts One and Three extends from southern Maverick County, on the Rio Grande, northeastward some 325 miles through Madison County (Figure 1). In places the width of the trend approaches 40 miles, with an average width on the order of 20 miles. The trend covers parts of nineteen counties and encompasses over 4,000,000 acres.

Recorded Austin Chalk production in South Texas dates to the 1920s. However, early production was generally incidental to the exploration and development of deeper Cretaceous objectives, primarily the Edwards. Recognition
of the Austin Chalk as a primary target throughout much of the trend did not occur until the mid-1970s.

One notable exception is Pearsall Field, located by surface work in the South Texas counties of Frio, Zavala, La Salle and Dimmit. The Pearsall Austin Chalk Field was discovered in 1936 by the Amerada Corporation Openheimer No. 5 well, which potentialied 850 BOPD. However, after a robust development period, drilling in Pearsall Field tapered off, with 87 total wells having been drilled and 5303 MBO produced by 1950. The next 23 years saw only 40 additional Austin Chalk wells drilled in the field, with cumulative production through 1973 totaling 6368 MBO.

A second period of intense drilling activity in Pearsall Field commenced in the mid-1970s and resulted in the drilling of 1270 additional wells through 1981, with cumulative production standing at 40,589 MBO at year's end. By the late 1980s, a total of some 1600 wells had produced in excess of 60 MMBO from the Austin Chalk in Pearsall Field.

Oil was first produced in commercial quantities at Giddings Field, located in the upper coastal counties of Burleson, Lee, Bastrop and Fayette, in 1973. To date this field has produced over 185 MMBO from approximately 3000 wells.

The primary factors that spurred the exploration and development of the Austin Chalk commencing in the 1970s were advances in hydraulic fracturing technology, improved seismic technology and steadily escalating oil prices. By the mid 1980s, however, conventional exploration and drilling activity in the Austin Chalk Trend essentially ceased due to declining oil prices and generally disappointing producing characteristics. Average recoveries from vertical wells in Pearsall Field are variously calculated at from 30 to 38 MBO. Average recoveries from vertical wells in Giddings Field are in the 50 to 60 MBO range.

A new era of Austin Chalk activity had its beginning on October 22, 1984, when Exxon completed their Ehleret No. 7 well in Giddings Field from a horizontal borehole with a displacement of 285'. This well potentialied 149 BOPD, 95 MCFGPD and 21 BWPD. In the same year Oryx Energy experimented with horizontal drilling in Pearsall Field. Due to mechanical problems associated with refining horizontal drilling techniques, only 14 wells were drilled by eight operators through 1987. Nine of these wells were drilled in Giddings Field.

Although these initial 14 horizontal wells had an average displacement of only 617', the results were encouraging with an average I.P. of 143 BOPD and an anticipated ultimate recovery of 80,000 BO per well. Thirty-four horizontal wells were completed in 1988, and 1989 saw an additional 56 completions. In 1990 horizontal well completions in the Austin Chalk Trend totaled 548 wells. Per-month horizontal completions are now averaging 50 wells, and between 120 and 130 rigs have been active at any given time over the past three months. One-hundred-twenty-two horizontal wells were permitted in the trend in December, 1990.

THE AUSTIN CHALK

The Austin Chalk is a widespread Upper Cretaceous formation that underlies much of the Texas Gulf Coast and Central and East Texas. Deposition occurred on a low-energy shelf in a shallow, clear-water sea. There were periodic influxes of clastics, as the formation is interbedded with thin shale units and all sections of the chalk have some degree of clay content. The Austin Chalk is a very hard, dense, brittle, finely textured carbonate. Soft marl with limestone streaks is occasionally encountered. Pyrite, glauconite, volcanic ash and fossil fragments are often present. The rock matrix exhibits very low primary porosity, in the 3 to 9 percent range, with permeabilities normally less than 0.5 md and often below 0.1 md.

The thickness of the Austin Chalk varies both along strike and down-dip. Structural strike is northeast-southwest, with southeast dip into the Gulf Coast Basin at one to four degrees (100 to 400 feet per mile). The thinnest chalk, at about 200', is seen in the central portion of the trend in Gonzales and Wilson counties over the San Marcos Arch (Figure 2). In the extreme southwestern portion of the trend in Dimmit and Maverick Counties, where the chalk was deposited in the Maverick Basin, it attains a thickness in excess of 1100'. Throughout the remainder of the trend the chalk averages 300' to 500' in thickness. There is no apparent direct relationship between the thickness of the Austin Chalk and the quality of production.

The best Austin Chalk production occurs between the depths of 4500' and 9500' along the entire trend. The chalk's porosity and permeability loss is directly related to depth of burial; therefore, above 4500' higher matrix porosity and permeability requires conventional anticlinal or fault traps to effect accumulation. Also, water content is greater in the...
up-dip chalk. Below 9500', most production has been either gas or high GOR oil. This, coupled with higher drilling costs, has discouraged many operators from pursuing the down-dip play.

Reservoir development in the Austin Chalk below 4500' is almost wholly the result of fracturing. Although some matrix porosity and permeability may be encountered, commercial production cannot be established or maintained in the absence of fractures. The fractures approach being vertical and the overwhelming consensus is that the fracture systems tend to parallel regional strike, i.e., northeast-southwest.

The cause of the fracturing is directly related to the tectonics responsible for creating the Gulf Coast Basin, specifically: (1) downwarping as a result of the burden of younger Tertiary sediments, (2) localized uplifts such as the Pearsall Anticline and the Chittim Arch and (3) faulting. Downwarping had the effect of stretching the Austin, and in response to this tension it fractured. The focus of these tensional forces would have been on the Upper Cretaceous hinge-line and it seems likely that the defined Austin Chalk Trend delineates this hinge-line. Similarly, localized uplifts created tensional forces resulting in fracturing. Fractures associated with faulting are, for the most part, found on the downthrown side of the faults and within grabens. Where the chalk had been sufficiently stressed, fractures will always be present.

The degree of fracturing in the Austin Chalk is neither uniform nor predictable, and fractures are not always continuous vertically throughout the entire chalk section. In fact, evidence suggests that fractures within individual chalk beds tend to terminate where the thickness of an intervening marl bed is as little as one-tenth the thickness of the surrounding chalk beds. For the most part fracture intensity appears to be highest in the upper and lower third of the chalk and there is unquestionably a direct relationship between the brittleness of the chalk and fracture intensity.

Fractures do not appear to communicate in a dip direction, as evidenced by the occurrence of gas down-dip to oil production and highly variable fluid ratios in adjacent wells. There is, however, ample evidence of communication along strike. Good initial production can be anticipated and a stabilized level of production at an economically attractive rate is probable where the fracture systems are numerous and extensive or where swarms of micro-fractures or some matrix porosity is found. However, due to the variable nature of this fractured reservoir, even the best producing areas have a few poor wells scattered in with the good wells. It would therefore be a mistake to condemn an area on the basis of just one or two penetrations.

The Eagle Ford Shale section separates the Austin Chalk and the Buda. It is a brittle, often micaceous and fossiliferous black shale which ranges in thickness from less than 100' in the southwestern end of the trend to in excess of...
METHODS OF EXPLORATION

Since hydrocarbon accumulation in the Austin Chalk below 4500' is not in conventional anticlinal or fault traps, methods generally used for prospect definition are not applicable. The problem is to define areas with sufficient fracturing to sustain commercial production. Prior to the mid-1970s and the extensive drilling in the Pearsall and Giddings Fields, the best tool was data from scout tickets and drilling records on wells drilled looking for deeper objectives. In drilling through the Austin Chalk and Buda, many wells encountered lost circulation or experienced a kick with oil on the pits, which is direct evidence of the presence of fractures. Other clues are reports of cores with fractures and drill-stem tests that had some oil recovery with good shut-in pressures.

Examination of production records is also a valuable exploration tool in that numerous deep tests were plugged back and completed in the Austin Chalk or Buda after failing to establish production in deeper zones. Although most of these were one- or two-well fields and had rather dismal production histories, it must be remembered that these wells did not have the benefit of modern completion techniques and that generally the operators believed that they were dealing with "bailout" production at best.

Structure and isopach mapping, and the preparation of dip-oriented cross sections, are valuable exploration tools. They help define localized downwarping, minor structures that could cause tension fracturing, and faulting. In areas where a significant number of completions have been effected, the presentation of initial potentials and cumulative production in contoured map form offers direct evidence of the presence and orientation of zones of fracturing. However, one must be cautious in utilizing this data. Operators have been known to exaggerate their well's potential for various nefarious reasons. Also, areas containing a large number of vertical wells that produced relatively large volumes of oil should be avoided, as it is probable that the fractures have already been drained.

Examination of electric log resistivities in the Austin Chalk appears to offer at least some indication of the content of the matrix or the fracture zones. Although this subject has not been addressed to any great extent in the literature, evaluation of numerous electrical logs indicates that resistivities of less than 10 to 20 ohms imply that the zone is shaly and/or water-bearing. Resistivities in excess of 40 to 50 ohms imply an extremely dense chalk and often a high gas content. It therefore appears that the best oil production will come from zones where the resistivities fall in the 20- to 40-ohm range.

All of the methods of exploration discussed above are viable, and it is wise to take advantage of all of the data available in selecting areas where significant fracturing is most likely to exist. However, since the late 1970s we have seen the emergence and refinement of seismic as a modern exploration tool for identifying fractures and, in some instances, hydrocarbon-bearing fractures.

HORIZONTAL DRILLING

It is evident that a vertical wellbore in the Austin Chalk can drain only a limited area. However, drilling horizontally with a dip orientation has the potential to connect multiple vertical fracture systems with a single wellbore, resulting in drainage of a larger area and in higher producing rates. The development and application of horizontal drilling technology within the last two years has proved this approach to be valid, and horizontal drilling is now the standard operating procedure throughout the Austin Chalk Trend.

In selecting areas for leasing and locations for horizontal wells, three main characteristics are sought: (1) evidence of hydrocarbon accumulation, (2) indications of multiple fracture systems and (3) the absence of significant drainage from existing vertical wells. In a hot trend play such as the Austin Chalk evaluating acreage using high resolution seismic data is generally impractical. Therefore, all of the subsurface, older CDP seismic, test and production data available should be utilized to identify the most promising areas and acreage. When possible large, contiguous acreage blocks should be acquired. Such blocks, particularly if oriented in a dip direction, permit an effective seismic program, the placement of wells at optimum locations and the ability to achieve maximum horizontal displacement.
Logically there should be a direct relationship between horizontal displacement, initial flow rates and ultimate recoveries; i.e., longer laterals will intersect more fracture systems and therefore result in better wells. There does not, however, appear to be a clear-cut consensus as to the optimum horizontal displacement based on wells permitted, drilling, testing or completing in Texas Railroad Commission Districts One and Three. The Petroleum Information Reports of January 21 and 24, 1991 published the status of 553 horizontal wells that fall in one of these categories, and a breakdown of proposed or actual horizontal displacements shows the following:

<table>
<thead>
<tr>
<th>Displacement</th>
<th>Number of Wells</th>
<th>Percent of Wells</th>
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<tbody>
<tr>
<td>999' or less</td>
<td>7</td>
<td>1.3</td>
</tr>
<tr>
<td>1000' to 1999'</td>
<td>54</td>
<td>9.8</td>
</tr>
<tr>
<td>2000' to 2999'</td>
<td>143</td>
<td>25.8</td>
</tr>
<tr>
<td>3000' to 3999'</td>
<td>205</td>
<td>37.0</td>
</tr>
<tr>
<td>4000' to 4999'</td>
<td>132</td>
<td>23.9</td>
</tr>
<tr>
<td>5000' or greater</td>
<td>12</td>
<td>2.2</td>
</tr>
</tbody>
</table>

However, improved seismic technology, a better understanding of reservoir mechanics, moderately acceptable oil prices and the application of horizontal drilling techniques have combined to make this the play of the "90's in the Texas Gulf Coast. Further, the potential to apply horizontal drilling techniques to other fractured reservoirs is obvious. It is very likely that the near-term future of the trend promises to be robust in the absence of a precipitous decline in the price of oil.

Thus we see that although 86.7% of the currently permitted or active wells in Districts One and Three have proposed or actual horizontal displacements of between 2000' and 4999', only 37% of these wells fall in the slightly favored displacement range of 3000' to 3999'. Reportedly, one major operator is presently planning horizontal displacements in excess of 4000' for all their wells. The questions of what the ultimate recovery will be from the average horizontal well and how much more oil the average horizontal well will recover vs. a comparable vertical well remain largely unanswered. Studies by Oryx indicate that a horizontal well will recover three to five times more oil than a comparable vertical well. However, there are good operators and poor operators, good areas and poor areas. There are so many variables that influence recoveries that any estimate of what the averages will be, based on the limited historical data presently available, would be misleading. In a trend covering at least 6500 square miles in which thousands of wells will ultimately be drilled, averages really have limited meaning. The generally rapid payoffs and apparent favorable economics of horizontal drilling, however, have encouraged no less than 184 operators to be active at the present time in Texas Railroad Commission Districts One and Three.

The application of sound horizontal drilling and completion techniques is extremely critical to a successful horizontal drilling venture. Although an in-depth discussion of these techniques is beyond the scope of this paper, it is important to mention two aspects of planning and drilling the horizontal borehole.

First, the operator must identify the zone or zones within the chalk that he wishes to evaluate with the horizontal borehole. Ideally, this decision is made subsequent to the drilling of a vertical or angled hole through the chalk and a careful examination of the local chalk stratigraphy.

The production history of vertical wells in close proximity to the planned horizontal well, if such exist, may also provide clues to the chalk zones most likely to be fractured. With rare exception, the hardest, cleanest, most brittle chalk intervals will exhibit the highest fracture intensity. Having identified the zone or zones to be evaluated, the prudent operator should try to maximize the amount of horizontal penetration in these targeted zones.

As noted above, there is some degree of clay content throughout the Austin Chalk. These clays are frequently fresh-water sensitive. As the clays are drilled into fine cuttings and distributed throughout the drilling fluid system, they can be carried into the fractures by normal invasion mechanics. If the drilling fluid is fresh water and if the fluid and cuttings are allowed to remain in the fractures, the clays may swell and reduce the permeability of the fractures, possibly plugging them completely. It is therefore imperative that during drilling operations the well be allowed to flow to a degree sufficient to flush the cuttings from the fracture systems. Also, the use of NaCl brine-based drilling fluid can greatly prevent the swelling of such clays.

**SUMMARY**

The Austin Chalk is an Upper Cretaceous carbonate reservoir rock known for its high initial producing rates, precipitous decline curves, erratic production histories and unpredictable ultimate recoveries. These characteristics have historically been impediments to the exploration for and development of the formation.

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