AAPG Search and Discovery Article #90023©2002 AAPG Southwest Section Meeting, Ruidoso, New Mexico, June 6-8, 2002 (2003)

INTEGRATING SYNSEDIMENTARY TECTONICS WITH SEQUENCE STRATIGRAPHY TO UNDERSTAND THE DEVELOPMENT OF THE FORT WORTH BASIN

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Abstract

The Fort Worth Basin formed during Early and Middle Pennsylvanian due to the oblique collision of the Afro-South American and North American plates. This tectonic activity not only affected deposition at that time but also affected the underlying formations. Depositional environments changed from shelf carbonates to shallow marine to deep marine then back to shallow marine during basin development. Eustatic cycles combined with tectonic activity have complicated mapping efforts and led to many misunderstandings about the basin. Much of the basin center is unexplored and has potential for enormous gas reserves. Reservoir mapping of just the basin-centered tight gas sediments indicate natural gas reserves in the tens of TCF.

A four-hundred-foot throw reverse fault extends through southern Parker County with openhole logs indicating a repeat section in the Barnett Shale. This tectonic activity has the potential to have created "sweet spots" in the Barnett Shale. Eustatically controlled deposition of Lower Atoka sediments along with penecontemporaneous tectonic activities created exploration targets in unexplored areas of the basin. An understanding of faulting and fracturing is necessary to interpret potential permeability enhancement and hydrocarbon traps in the Ellenburger and Marble Falls. Due to a lack of drilling, very little is known about these formations. Sediment deposition during the Strawn was primarily controlled by eustatic cycles and just adds to the many productive formations that may be encountered when exploring in the Fort Worth Basin.

Introduction

The Fort Worth Basin of North Central Texas is considered a mature basin by many involved in oil and gas exploration. This is true for some parts of the basin, but very little exploration and drilling have been conducted in the central part of the basin for deeper sediments. It is believed the basin center is an excellent target for future exploration and development. Oil and/or gas have been discovered and produced in Ellenburger, Barnett Shale, Marble Falls, Atoka and Strawn sediments throughout the basin. A generalized stratigraphic column has been developed for the Fort Worth Basin, but there is much confusion and debate about formation nomenclature in the basin (Figure 1).

The basin developed primarily during the Early and Middle Pennsylvanian in front of the advancing Ouachita Foldbelt (Walper, 1982). The Afro-South American and North American plates experienced an oblique collision, with the Black Warrior Basin developing during early Morrowan time and the Marfa Basin developing during Late Pennsylvanian and Early Permian times (Figure 2). The Muenster Arch was the first structural element to form and served as a sediment source during the Early Atoka. An additional sediment source was the Ouachita Foldbelt with the Bend Arch severing as the hinge line when the basin down warped. The final structural element to form was the Llano Uplift, which brought the basin formations to their present dip (Figure 3).

test well confirmed the sand development, and gas shows from the mud logs confirmed gas potential of the field. The zone is now behind pipe while the Barnett Shale is being tested in the well.

Atoka Basin-Centered Tight Gas Sands

Smithwick

During the Smithwick the basin center first filled with deep-water black marine shales. These shales serve as hydrocarbon source rocks along with the Barnett Shale. Turbidite deposits then started developing and filling the basin (Pranter and Grayson, 1990). These sediments are exposed within the Colorado River Valley in the southern part of the Fort Worth Basin (Heller and Dickerson, 1985). The gross thickness of these sediments exceeds three thousand feet in the study area and is thicker near the leading edge of the Ouachita thrust belt.

Several of these submarine ramp (fan) progradational and retrogradational events took place during this deposition. Three principal progradational "cycles" are recognized in the surface exposures based on transitions from distal ramp through proximal ramp into prodelta slope facies associations (Pranter and Grayson, 1990).

These deeper marine turbidite deposits are classic basin-centered gas sands. Characteristic of a turbidite deposit, the reservoir sandstone consists of thick packages of fine-grained, thin lentils interbedded with thinner beds of shale as indicated by SP curves (Bloomer, 1991). They are also under-pressured and of low permeability.

The resisitivity values on openhole logs tend to be lower than other deposits due to the irreducible water saturation of these very fine-grained rocks (Hilchie, 1987). Productive zones in these tight gas sands usually have 18 or greater ohms on the induction log in the cleaner sand sections. A number of these tight gas sands were completed in the late 1970s and early 1980s with very mixed results. Most of these completions were uneconomic, and very little interest has been shown since that time. After a study of other tight gas sands in the continental United States, the author believes the tight gas sands of the Forth Worth Basin deserve additional consideration.

Davis

The deposition of the Davis is shallow marine and more extensive in the northern part of the Fort Worth Basin. The Davis Sandstone was one of the subject formations in a low-permeability-sandstone gas reservoir study in the continental United State conducted by the Bureau of Economic Geology and the Gas Research Institute (Dutton and others, 1993). The transition between the Smithwick and Davis is little understood in the Fort Worth Basin and will not be addressed in this paper.

Engineering Characteristics

An evaluation of other tight sand formations around the country has led the author to conclude that most of the gas production problems have been due to formation damage. These low permeability sands were completed with methods that were designed for higher permeability, normal-pressured rocks and have tended to cause permeability reduction instead of permeability enhancement.

A few gas wells in the area were completed with methods different from those used on most other wells in the basin. Several of the wells completed in these basin-centered tight gas sands show identical decline curves that vary only with the thickness of the deposits, and all are in different zones. Two of these wells were only stimulated with a nitrogen-assisted acid water treatment with the other being a very large gel frac. The large gel fracs have not been a successful treatment for most of these formations.

These more productive wells have all produced an average of 10 MMCF of gas per foot of clean sand. The basin-centered tight gas sands of the Fort Worth Basin have a net clean sand

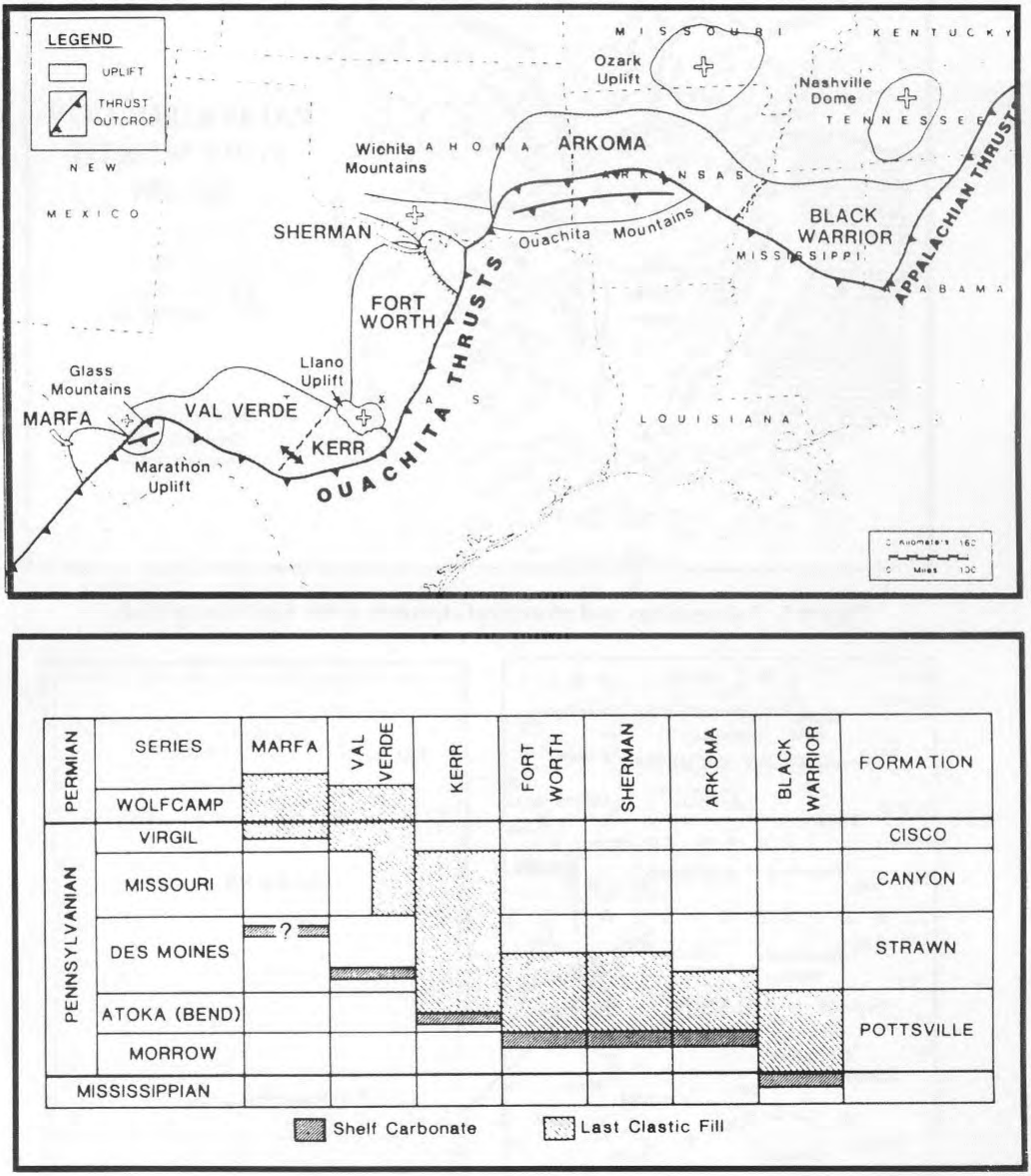

Figure 2. Basin development related to the Ouachita Foldbelt. (From Meckel, Smith & Wells 1992)

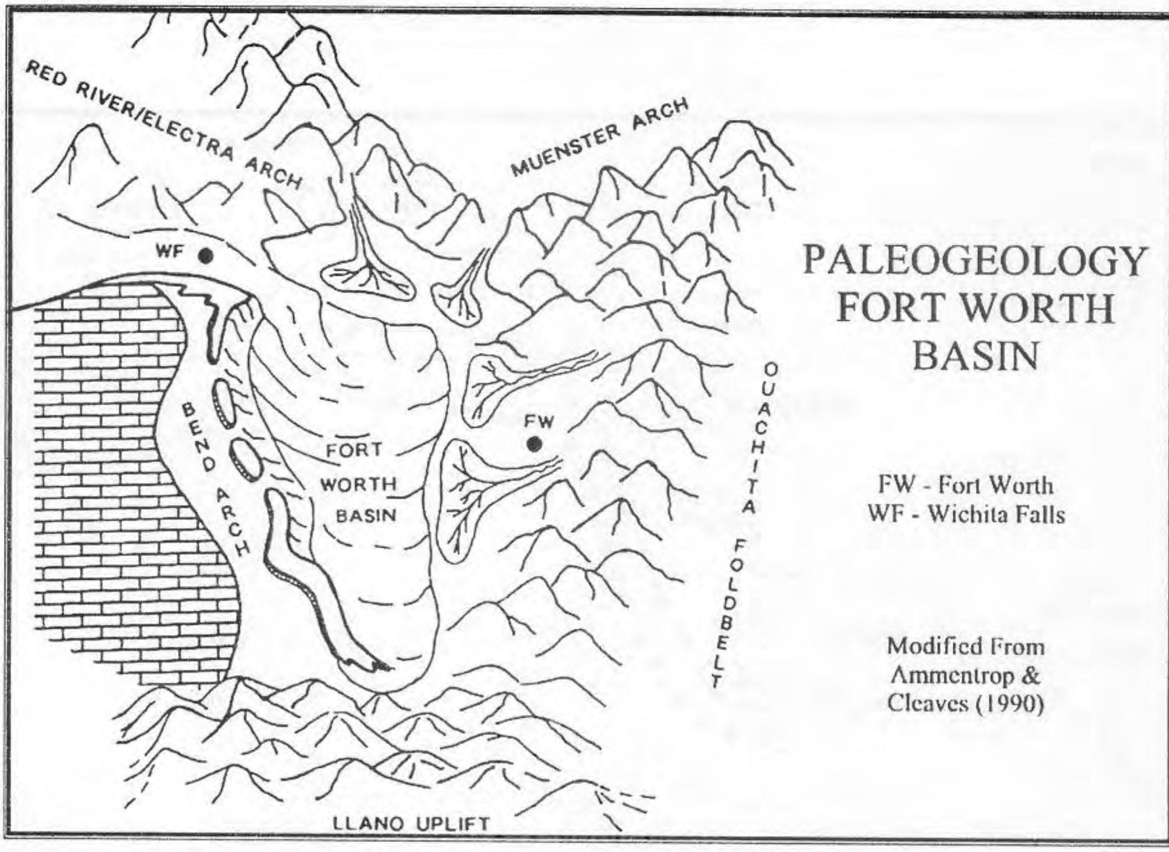

Figure 3. Paleogeology and structural elements of the Fort Worth Basin

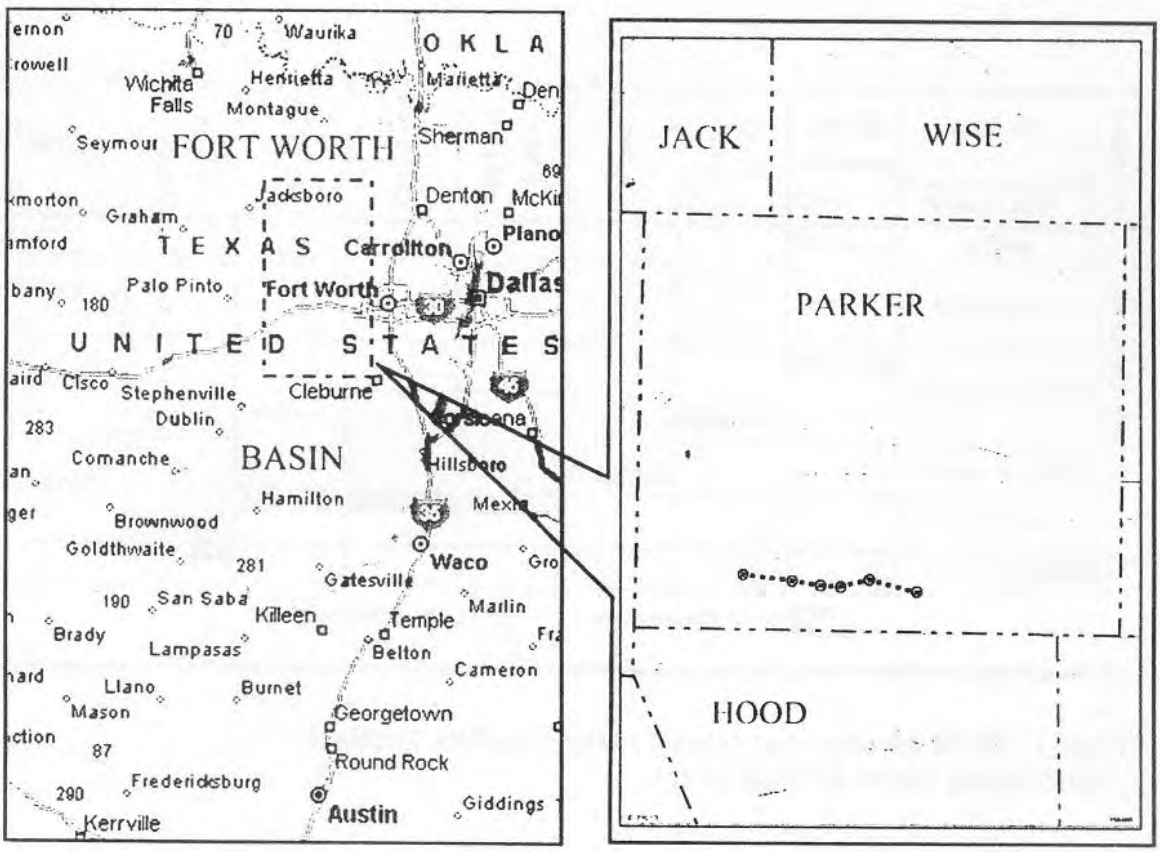

Figure 4. Location map for the Fort Worth Basin and cross-section.

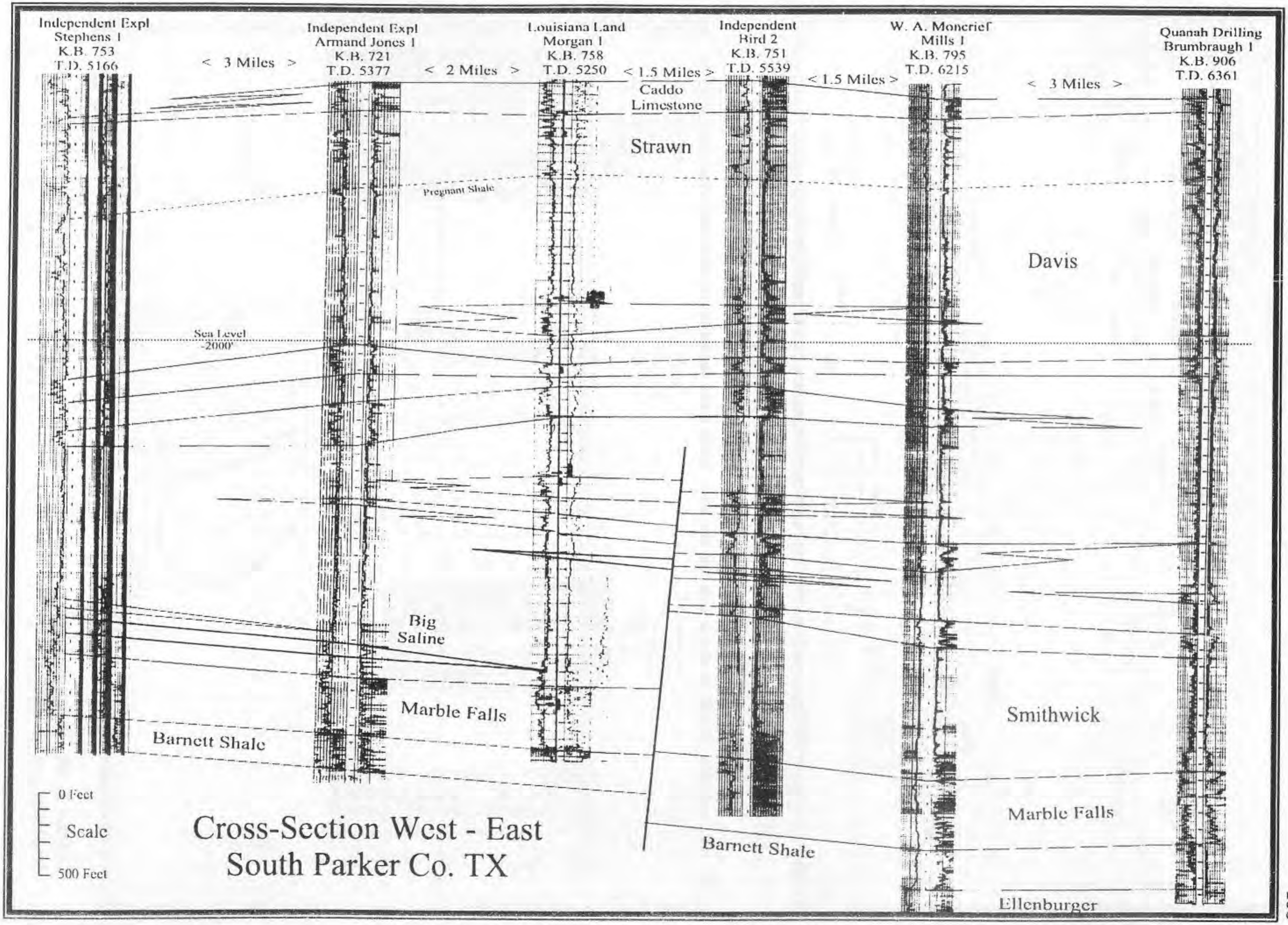

Figure 5. Cross-section for southern Parker County

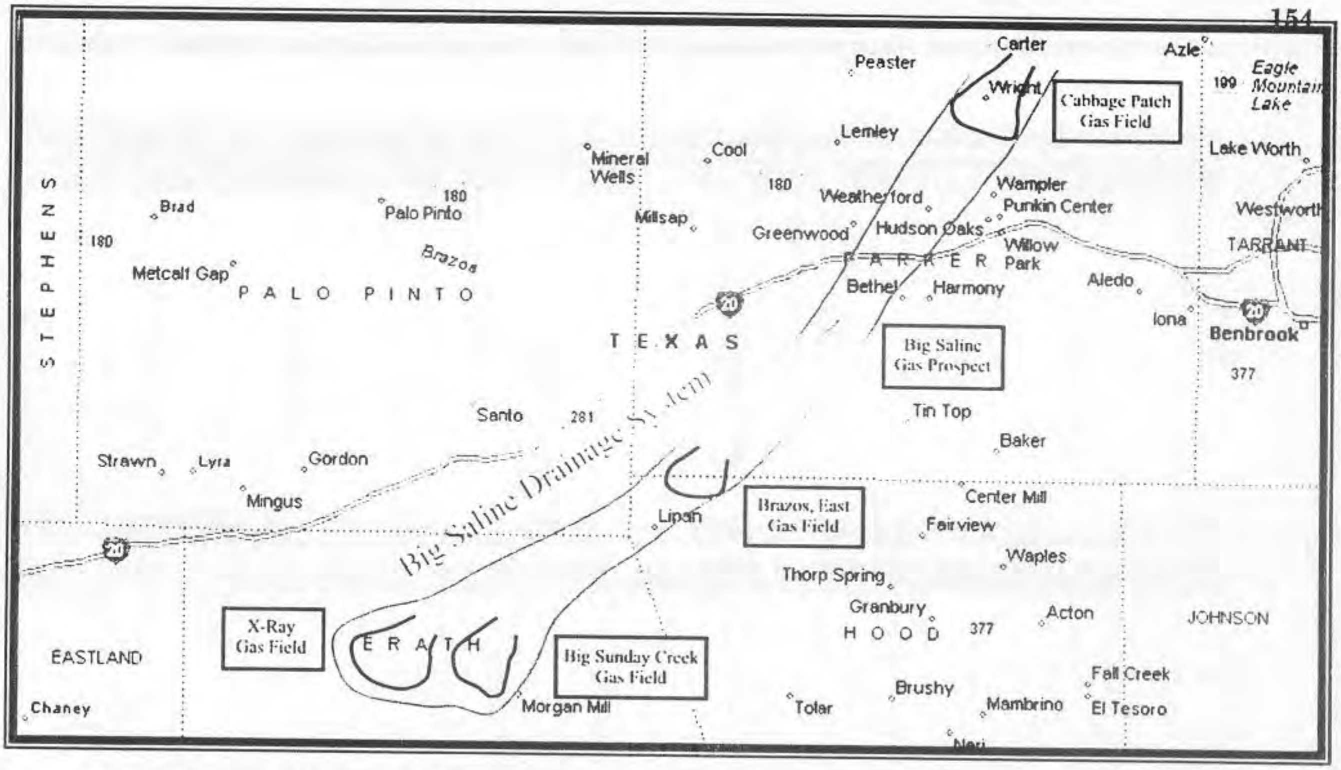

Figure 6. Big Saline gas fields of the Fort Worth Basin.

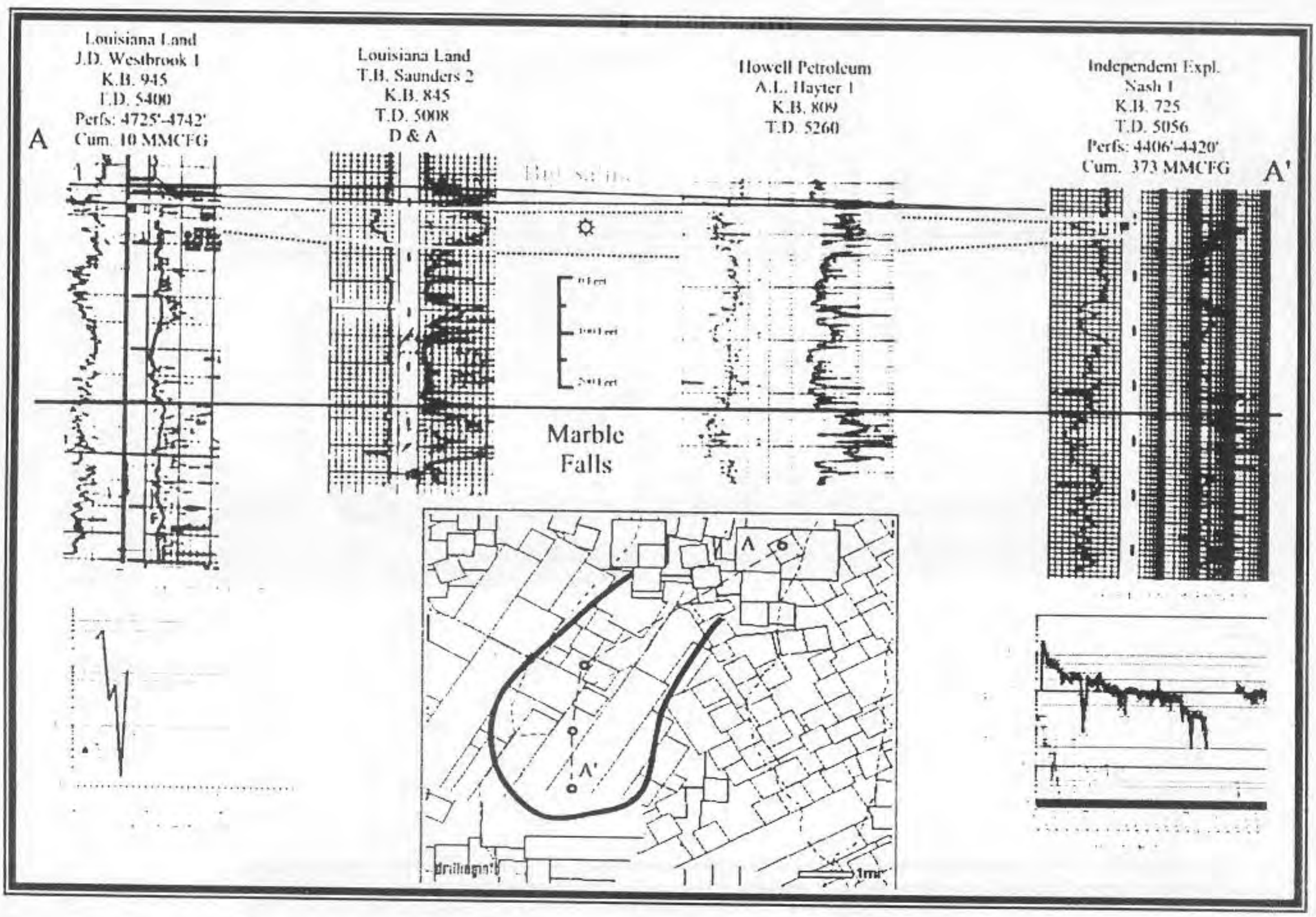

Figure 7. Big Saline gas prospect develpomented from dry hole logs and gas production from the gas field edge.

thickness in excess of 150 feet and are around 4,000 feet deep. This gives the potential for gas production in excess of a BCF of gas for wells less than 5,000 deep. This is very economic at today's gas prices.

The basin-centered tight gas sands of the Davis Sand alone could conservatively contain 20 TCF of natural gas in place. "Such reserve numbers are staggering in terms of future potential" (Meckel, Smith, and Wells, 1992).

Tectonic Effects on Underlying Formations

Ellenburger

Sediments of the Ordovician Ellenburger Group are the oldest sediments that produce in the basin. Few wells have penetrated the Ellenburger in the basin center, and production is very limited from these sediments. It is interesting to note that the first commercial well in Parker County was an Ellenburger oil well (Herkommer and Denke, 1982). Tectonics during the Atoka created faults and fractures in the Ellenburger, making possible structural traps for hydrocarbons and also possibly enhancing formation permeability. It is believed that a better understanding of area tectonics and exploration strategies will make the Ellenburger a target for future exploration.

The Bureau of Economic Geology completed a study of the Boonsville Gas Field in the northern part of the Fort Worth Basin. They ran a 3-D seismic survey across a study area and discovered karst collapsing in the Ellenburger, which developed after Strawn time. Longhorn Caverns are of Ordovician age and located just south of the Fort Worth Basin. Karsting of the Ordovician seems to be extensive, and these karst collapses create fractures in the overlying rocks.

The Big Saline Limestone produces gas in a well adjacent to a karst collapse in the Cabbage Patch gas field of northern Parker County. It is the author's opinion that this production is due to permeability enhancement caused by the collapse. No other well produces gas in the area or shows porosity in the Big Saline Limestone.

Barnett Shale

The Mississippian Barnett Shale is the most active exploration and development target in the basin at the present time. The advancement of completion technology, such as water fracs, has been the single most important factor in Barnett Shale economic success to date. Exploration and development are expanding from Wise and Denton counties to other parts of the basin. Leasing has been extensive in Tarrant, Eastern Parker, Johnson and Hood counties. The Barnett Shale thickness ranges from about 200 feet in the west to more than 300 feet in east Parker County (Figure 8).

Two sets of faults have been mapped in South Parker County (Figure 9). The core area of the Newark, East (Barnett Shale) is also bounded by faults. The Barnett Shale has not been tested in this area of Parker County yet. The Viola Limestone is not beneath the Barnett Shale in most of Parker County, and this has deterred drilling up until now. Wells in eastern Parker County are beginning to show Barnett Shale promise, which do not have the Viola Limestone.

Faulting and fracturing are very important factors contributing to the economic success of Barnett Shale. As the faulting patterns are better understood in the basin, potential new target areas will emerge for exploration and development. Karst collapses in the underlying Ellenburger also have the potential to have created extensive "sweet spots" for Barnett Shale production.

Marble Falls

During the end of the Mississippian and beginning of the Pennsylvanian, sediments are primarily shelf carbonates and are identified as the Marble Falls formation. The Marble Falls has proven to be productive for natural gas in the basin, and it is expected that additional gas fields will be discovered and developed during

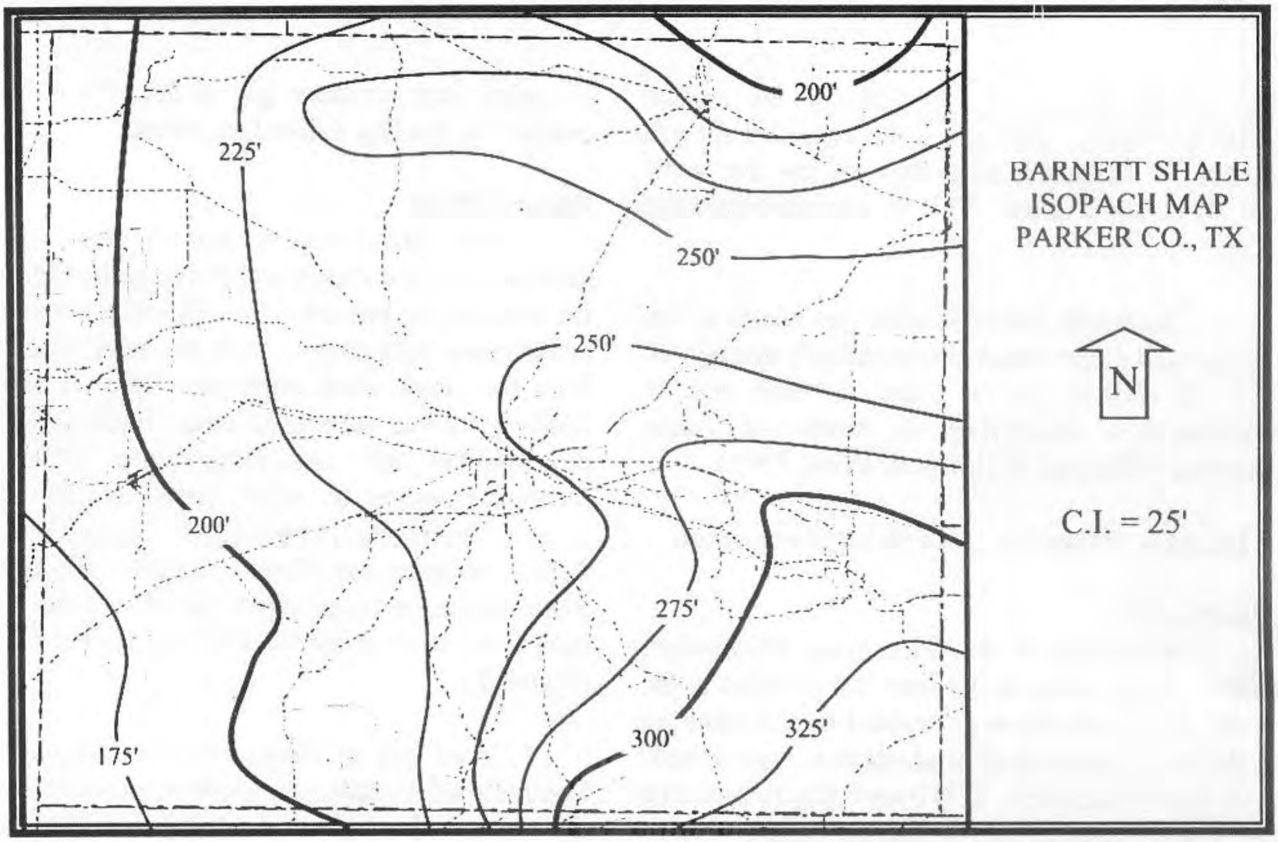

Figure 8. Isopach map of the Barnett Shale in Parker County.

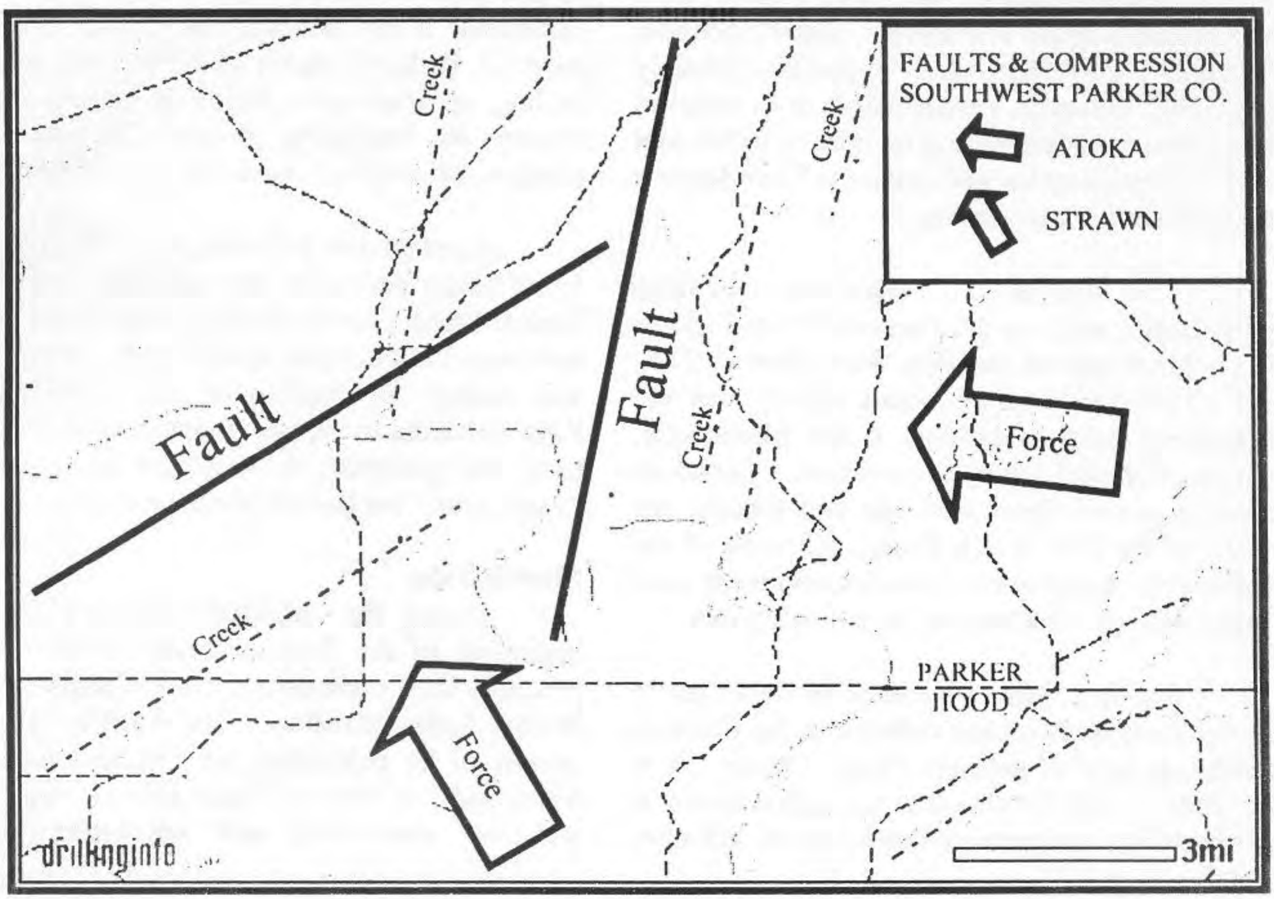

Figure 9. Fault locations and direction of compressional forces in southern Parker County.

exploration of the underlying Barnett Shale. The Marble Falls consists of a variety of depositional environments with very little being published about the Marble Falls of the basin. Faulting and fracturing is present in the Marble Falls and has the potential to have created horizontal drilling targets in the thicker limestone deposits of the basin.

Conclusions

The Fort Worth Basin has enormous future natural gas potential from a variety of different formations. With present-day higher natural gas prices, it is expected that exploration and development will increase in the Fort Worth Basin. Modern geologic interpretations along with improved drilling and completion techniques are going to be necessary to successfully develop these reserves. Combining the success and expansion of the Barnett Shale gas development with the potential of other formations makes the Fort Basin a very important and exciting exploration province for the future.

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