Barnett Shale Symposium

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The Barnett Shale Play, Fort Worth Basin

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ABSTRACT

In terms of monthly production, the Newark East (Barnett Shale) field recently became the largest gas field in Texas. Production has grown from 80 MMCF/D in January 2000 to over 700 MMCF/D at present because of accelerated new-well drilling and old-well reworks/refracs. There are over 2.5 TCF of booked proven gas reserves in the field at present. Newark East field is located in the northern portion of the Fort Worth Basin, just north of the city of Fort Worth. The Mississippian Barnett rests on an extensive angular unconformity. The Barnett must be stimulated to achieve economic flow rates. Currently, wells are hydraulically fractured, but good frac barriers must be present directly above and below the Barnett for this stimulation technique to be successful. Hence, the stratigraphy above and below the Barnett is important to economic production from vertical wells. Recent horizontal drilling has shown great promise to expand the play outside the current economic limits of the play. The thermal history of the basin is an important reason for the success of the Barnett. The thermal history of the Fort Worth basin is directly related to the emplacement of the Ouachita system. Sections of the Barnett bordering the Ouachita front (regardless of depth) have the highest thermal maturity and, hence, the lowest BTU content of produced gas. In the late 1990s, work by Mitchell Energy had demonstrated the viability of water fracs in the Barnett play; this development has contributed to a huge acceleration in Barnett leasing and drilling activity during the past three years. Also in the late 1990s, Mitchell determined that the previous gas-in-place values for the Barnett were low by over a factor of three. There is approximately 150 BCF/mi2 of in-place gas in Newark East field. The realization that the primary completion was only recovering 7% of the gas in place per well spurred the current (and very successful) rework/refrac program underway in the field.

The success of the Barnett play may provide a model for prospecting for other large shale-reservoirs. Lessons learned from Mitchell's experience with the Barnett can be used to shorten the learning curve while evaluating other shale projects. For instance, relying on a poorly-determined estimate for gas-in-place (gas content) hindered the development of the Barnett; it wasn't until the true gas content was determined that Mitchell considered re-fracs, completions in the Upper Barnett, and even tighter downspacing. Another lesson from the Barnett is the understanding of the role of thermal history in prospecting for shale reservoirs.

Cardium Sand Play, Western Alberta Basin, Canada: Directional Drilling of a Fractured Reservoir in a Structurally Complex Setting

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ABSTRACT

An extremely interesting, challenging, and potentially rewarding gas play in the Upper Cretaceous Cardium Sand in the western Alberta Basin of Canada was undertaken by Conoco

Canada Ltd. in the early-1990s. It involved delineating the thin (10-30 m) Cardium sandstone in tight to overturned folds of the “Triangle Zone” at the leading edge of the deformed Rocky Mountain foreland using NE-SW oriented 2D seismic lines. Since the Cardium sandstone generally has low porosity and permeability in undeformed strata in this region, the key to significant gas production was to find and penetrate heavily fractured zones or to effectively frac tighter strata. Moreover, the thin nature of the Cardium required directional drilling to both stay in the sandstone over an extended stretch and to intersect the maximum number of fractures. The lessons learned from this exercise may be of interest to those currently drilling in the Barnett Shale, although there are, admittedly, some major differences between the two plays.

After several years of drilling with mixed success, it was concluded that one had to hit (and stay in) the zones of tight folding and high fracture density to achieve high gas flow rates. Attempts at fraccing originally mildly fractured backlimbs of tight folds, for instance, met with limited success. The optimal production zone was generally in or near the axial plane and steep to overturned forelimb of NW-SE trending folds, a target initially very difficult to pinpoint on seismic lines. This problem was gradually understood and overcome through time. It was also realized that the most productive fracture sets were not oriented perpendicular to Sh, the current minimum horizontal principal stress, but approximately parallel to it. Fracture system geometry was gradually understood using a combination of theoretical and field studies and detailed examinations of well cores and logs. Extensive field studies of heavily fractured Cardium folds were particularly helpful.

A related aspect of working in the Cardium sand play was the application of fracture mechanics over a wide scale range (7-8 orders of magnitude). Studies of the interaction and linkage of propagating extensional fractures suggests at least two disparate styles of overall fracture geometry depending on the relative magnitudes of regional and local (crack tip) differential stress. Fracture permeability can vary significantly based on which of the two stress fields dominates the fracture propagation and linkage history. Fracture systems that may superficially appear to be continuous (i.e., linked) may instead consist of a series of discontinuous fractures. This will clearly affect fluid flow in fractured reservoirs. Gross similarities in strike-slip and extensional fault/fracture systems will be pointed out and briefly discussed in the context of stress and strain interpretations.

The Barnett Shale Gas Play: A Giant Gas Field from an Unconventional Reservoir

Jeff Hall, Manager of Exploration/Exploitation, Central Division, Devon Energy Corporation

ABSTRACT

The Newark East Barnett Shale Field located within the Fort Worth Basin of North Texas has now developed into the largest gas field within the state of Texas. The field has produced 800 BCF of natural gas, over 220 BCF in 2002 alone, and is currently producing greater than 800 MMCF per day from over 2,350 wells. There are over 60 companies participating in the play with 55 rigs actively targeting the Barnett Shale.

The Newark East Field core area is now approaching full development on 40 acre spacing. The current field limits are being tested by wells targeting the Barnett Shale to the east and northeast into the deepest portion of the basin adjacent to the Muenster Arch, to the north toward the oil window and to the south into the Fort Worth metropolitan area. The largest challenge facing the Barnett play expansion lies to the west and southwest into western Wise, Parker and Johnson Counties where the underlying Ordovician tight limestone frac barriers, which are viewed as key to successful wells, are absent. Several wildcat wells have tested the Barnett to the south and west utilizing both vertical and horizontal technology with varied results.

Clearly the conventional technology developed within the core area will not be applicable to all of the expansion and exploration areas. A greater understanding of the Barnett Shale as a reservoir, as well as increased study of the frac barriers below, above and within the Barnett Shale are now necessary. Armed with this knowledge, completion technology can be developed to allow for the successful expansion of the play.

The Evolution of Technology in the Barnett Shale

Larry Buchanan and Loyd East, Halliburton

ABSTRACT

When the first well was drilled into the Barnett Shale reservoir in 1981 the data that was gathered provided information about the reservoir that led to early knowledge. That knowledge was applied to well Construction and Completion processes that utilized existing technology to optimize future well designs. Two things have changed dramatically since that time - the knowledge of the reservoir and the technology available. It is important to understand and evaluate these changes in order to leverage the new knowledge and technology for economic gain. To accomplish this a historical review of the Barnett Shale well construction and completion practices will be illustrated leading to state-of-the-art technology being applied today using current reservoir understanding.

Datamining and Analysis in the Barnett Shale using Drillinginfo

Martin B. Payne, Executive Vice President, Drillinginfo, Inc.

ABSTRACT

The Barnett Shale is an ideal trend for the utilization of datamining techniques. This is due to the blanket-type coverage of the interval as well as the large number of completions. Drillinginfo provides many map-based datasets as well as the applications necessary to convert those datasets into opportunities.

Fracture Mapping in the Barnett Shale

Kevin Fisher, Vice President of Business Development, Pinnacle Technologies

ABSTRACT

About 100 Barnett Shale hydraulic fracture treatments have been mapped over the past two years. Fracture mapping allows for direct measurement of the fracture treatment's contact with the reservoir: fracture orientation(s), height, length and total network size. Fracture mapping results have been used to determine well spacing, offset well locations, refrac candidate identification, staging strategies and real-time changes to fracture treatment design and execution in both horizontal and vertical wells. Fracture mapping technologies applicable to the Barnett will be presented and case histories shown illustrating the complexities of hydraulic fracture growth in the Barnett Shale.

The Expansion of the Barnett Shale Play in the Fort Worth Basin

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ABSTRACT

The Newark East Barnett Shale Field is the largest producing field in Texas. The discovery well was completed in 1982. The play began in southeastern Wise County and now has a production in eight (8) adjoining counties. A recent application has been filed in July 2003 to expand the "Tight Gas" classification to ten (10) counties.

Only 100 wells were completed in the first ten (10) years. Over 2,000 wells were completed in the second ten (10) years. The reason for the explosion in drilling the second ten (10) years was a combination of factors. The early fracs were using approximately 300,000 gallons of gel fluid and 300,000 pounds of frac sand. The frac jobs increased to 1,000,000 gallons of gel fluid and 1,000,000 pounds of sand, which doubled the initial productivity rates. In 1997, the frac design changed to 1,000,000 gallons of fresh water and only 100,000 pounds of sand with no change in deliverability. The change in frac design reduced the frac cost by 30% and at that time natural gas prices started to rise.

Now in the 21st year of development, over 100 horizontal wells have been drilled or permitted in the first nine (9) months of the year 2003, as compared to the five (5) in the first twenty (20) years.

Horizontal wells appear to be the potential wave of the future. The knowledge gained from the micro seismic mapping of the fracture treatment is beneficial. Insight gained from 3-D seismic identifying faults, karsts and caves has added a new dimension to the play. The expansion area of the play will be concentrated south and west of the core area where the Barnett is thinner and overlying the possible water bearing Ellenberger. The industry faces new challenges in the next twenty (20) years of development to exploit the 10-20 TCF potential of the Barnett Shale in the Fort Worth Basin.

Gas Marketing 101: Market Challenges Presented by the Barnett Shale

Ridge McMichael, President, McMichael Resources

ABSTRACT

A discussion of the factors which drive gas prices in general, and North Texas markets in particular, with special emphasis on factors to consider in the Barnett Shale play.

Horizontal Drilling in the Barnett: Detailed Structural Analysis and its Impact on Our Understanding of the Reservoir

Tim Dean, Terra Domain Consulting

ABSTRACT

Over the past year highly successful horizontal drilling programs have effectively converted the Barnett Shale unconventional gas play into a horizontal play. Detailed structural analysis of Barnett Shale has provided important insight into the significance of karst collapse related faulting and other risks and opportunities associated with horizontal drilling. Potential methods of avoiding or mitigating water infiltration problems will be discussed as well as the future potential of enhanced recovery methods using horizontal wells.

Reservoir Characterization a Mississippian age Shale: The Barnett Shale Play of North Central Texas

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ABSTRACT

The Barnett Shale gas and oil play of North Central Texas currently has over 1000+ wells completed and producing gas and in some cases condensate from the Barnett shale. There are also a handful of pumping oil wells.

Because of the complexities of this reservoir/source rock (porosity less than 6 pu, perm less than a micro-darcie, and open and closed fractures to name a few), conventional log analysis, completion, and stimulation cannot be used. In late 1999, a reservoir model was developed to evaluate the Barnett Shale. This model characterizes the reservoir rock in terms of pay thickness, hydrocarbon type, porosity, perm, natural fractures, and other rock properties. With this information, a forecast of hydrocarbon production is made. This forecast can then be used as a benchmark of a well’s productivity to help determine the effectiveness of its completion. Additional benefits are designing more effective completions and picking offset well locations.

This process has been used on 300+ wells and this presentation will highlight some of the results. Included in this presentation will be reservoir model that includes geological and petrophysical characteristics.

Geologic and Production Characteristics Utilized in Assessing the Barnett Shale Continuous (Unconventional) Gas Accumulation, Barnett-Paleozoic Total Petroleum System, Fort Worth Basin, Texas

Richard M. Pollastro, U.S. Geological Survey, Denver, Colorado

The organic-rich Barnett Shale (Mississippian) is the primary source rock for oil and gas that is produced from numerous conventional clastic- and carbonate-rock petroleum reservoirs of Paleozoic age in the Bend arch–Fort Worth Basin area, Texas. In this area, the Barnett Shale is also the source and reservoir for the tight, siliceous continuous (unconventional) shale-gas accumulation within the Barnett. Based on this information, a Barnett-Paleozoic Total Petroleum System was identified that includes mature Barnett Shale source rock, all known oil and gas accumulations, and an area hypothesized to contain undiscovered oil and gas accumulations (Pollastro and others, 2003) (Figures 1 and 2).

Mapping of the Barnett Shale from subsurface well logs and well database queries combined with geochemical measurements conducted by the U.S. Geological Survey (USGS) and others demonstrates that thermally mature, organic-rich Barnett Shale is present over most of the Bend arch and Fort Worth Basin area. In the Bend arch-Fort Worth Basin area, the northern, eastern, and southeastern extent of the Barnett is controlled by structural fronts of the Red River arch, Muenster arch, and Ouachita thrust front, respectively. The western margin is an erosional limit or facies change along the Eastern shelf and Concho platform (Figures 1, 2, and 3). Adjacent to the Muenster arch, the Barnett Shale is more than 1,000 ft thick and interbedded with thick limestones. Westward, the Barnett thins rapidly over the Mississippian-age Chappel Limestone shelf to only a few tens of feet (Figure 2c).

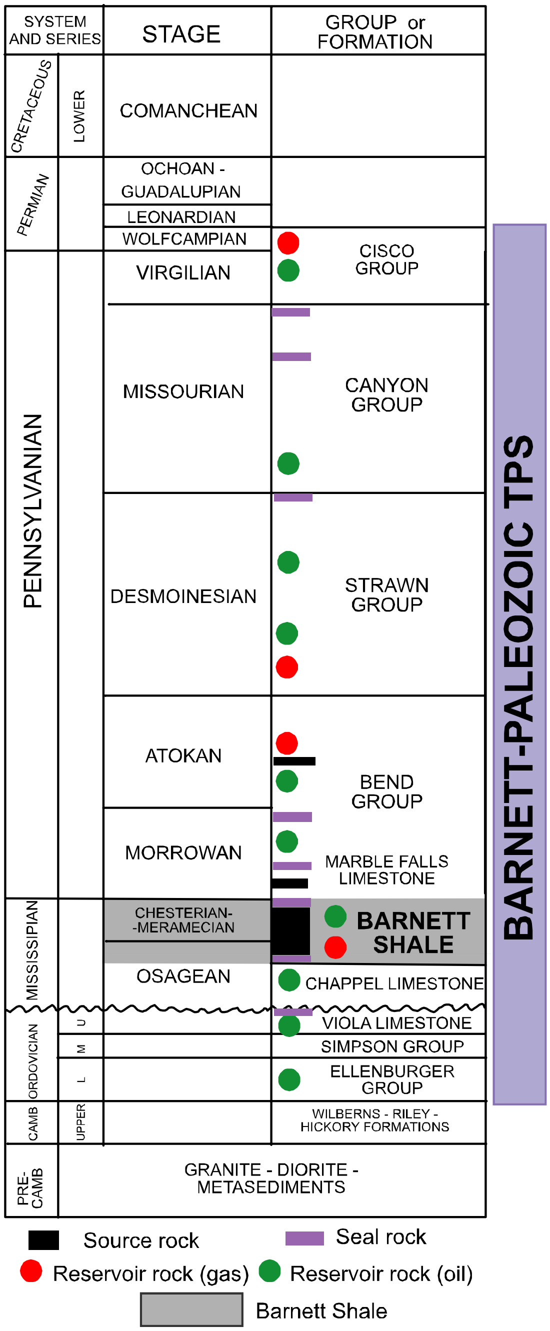

Figure 1. – Generalized subsurface stratigraphic section modified from Lindberg (1987) of the Bend Arch-Fort Worth Basin Province showing the distribution of source rock, reservoir rock and seal rocks of the Barnett-Paleozoic Total Petroleum System (TPS).

Vitrinite reflectance (Ro) measurements show poor correlation with present-day burial depth. Contouring of similar Ro values from the Barnett Shale and typing of produced hydrocarbons indicates significant uplift and erosion, and that the Barnett Shale thermal history was strongly influenced by elevated heating along the Ouachita thrust front and Mineral Wells-Newark East fault system. In these areas, vitrinite iso-reflectance lines are oriented perpendicular to the

Ouachita thrust front, bend westward along the Mineral Wells fault system, or cross cut the present basin axis. The lower thermal maturity limit of the gas “window” for Barnett Shale sourced gas is defined where Ro values approximate 1.1% (Jarvie and others, in press).

Of particular importance is the giant gas accumulation within the continuous (unconventional) fractured shale reservoir of the Barnett Shale. Cumulative gas production from the Barnett through mid-2003, mostly from the greater Newark East field, was about 0.7 trillion cubic feet of gas (TCFG) with proven reserves booked at more than 2.5 TCFG (Bowker, 2003). Moreover, recent estimates of the technically recoverable gas in the Barnett Shale play are between about 7 and 20 TCFG (Kuskraa and others, 1998; Petroleum News, 2003).

Not assessed by the USGS in 1995 (Gautier and others, 1995), the Barnett Shale play is now considered one of the most significant domestic onshore gas plays. Using the USGS total petroleum system assessment unit methodology, undiscovered Barnett Shale gas was assessed in September 2003 using the Forspan methodology for continuous resources (Schmoker, 1999; 2002) by (1) mapping critical geologic and geochemical conditions to define assessment units with future gas potential, and (2) by defining distributions of drainage area (cell size), estimated ultimate recovery (EUR), and estimating success ratios. Two gas assessment units (AU) were defined and assessed for the Barnett Shale continuous accumulation: 1) a Greater Newark East Frac-Barrier Continuous Barnett Shale Gas AU, and 2) an Extended Continuous Barnett Shale Gas AU. Volumes, statistical analysis, and final USGS approval of undiscovered technically recoverable gas in the

Barnett Shale continuous accumulation is incomplete and scheduled for release in early 2004.

The boundaries of the Greater Newark East Frac-Barrier Continuous Barnett Shale Gas AU define a geographic area where thick, organic-rich, siliceous Barnett Shale is within the gas window, and is overlain and underlain by impermeable limestone barriers (Marble Falls and Viola Limestones, respectively), which confine induced fractures during well completion and improve gas recovery (Figure 3). The northern boundary of this assessment unit is the lower limit of the thermal window for gas generation approximating a Ro of 1.1%. The western boundary is the limit of the underlying Ordovician Viola Limestone. The southern boundary of the Greater Newark East Frac-Barrier Continuous Barnett Shale Gas AU is the southeast pinchout and absence of overlying Pennsylvanian Marble Falls Limestone. In this assessment unit, exploration and production is established from about 2,000 wells that produce gas from the Barnett Shale.

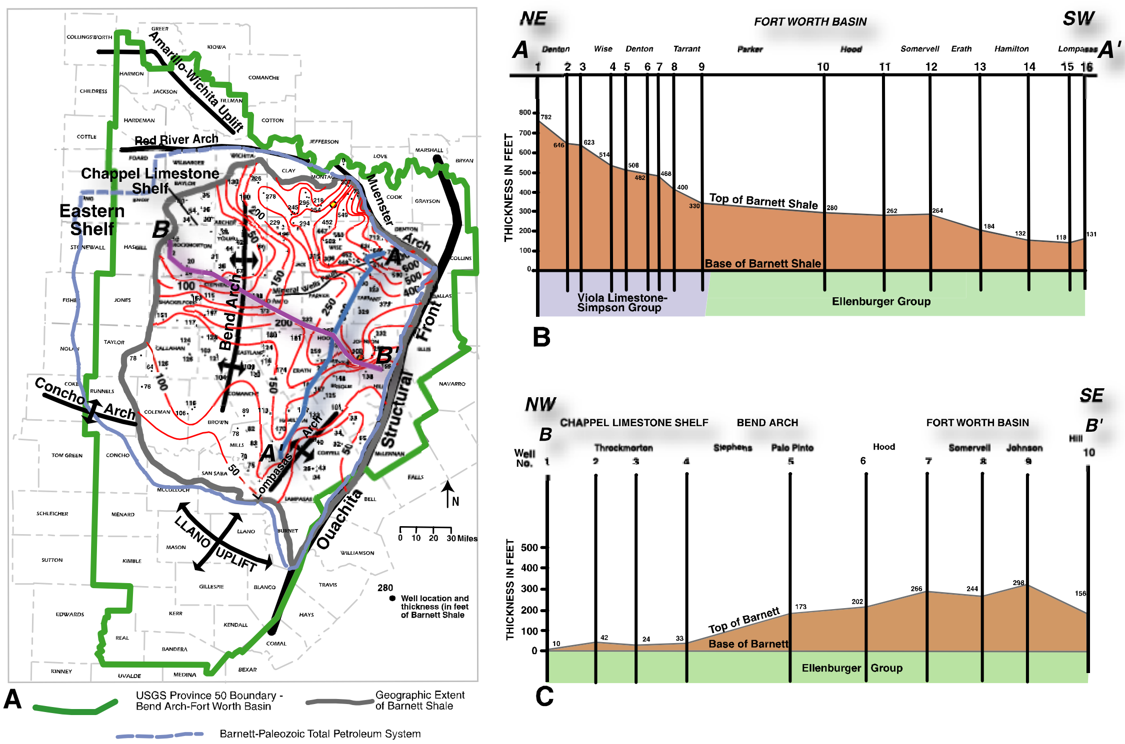

Figure 2. (A) Map of U.S. Geological Survey Province 50, Bend Arch-Fort Worth Basin, showing major tectonic features, geographic extent of the Barnett-Paleozoic Total Petroleum System, extent of Barnett Shale, thickness of Barnett Shale from wells and generalized regional isopach of Barnett Shale, and lines of well log cross sections A-A' and B-B'. Contour intervals for isopach map are 50 ft from 0 to 300 ft, and 100 ft from 300 to 1,000 ft. (B) Generalized northeast-southwest well log cross section A-A' showing thickness of Barnett Shale. C) Generalized northwest-southeast well log cross section B-B' showing thickness of Barnett Shale.

The boundaries of an adjacent Extended Continuous Barnett Shale Gas AU defines a geographic area where the Barnett Shale is within the thermal window for gas generation (Ro>1.1%), contains at least 100 ft of Barnett Shale, and where at least one impermeable limestone barrier is absent (Figure 3). Exploration and development within the Extended Continuous Barnett Shale Gas AU is limited to only tens of producing wells, and completion and production practices are currently experimental or not fully established. Thus, assessment of undiscovered gas in this area is expressed with greater uncertainty than in the Greater Newark East Frac-Barrier Continuous Barnett Shale Gas AU.

Cell size and EUR distribution for each of the Barnett Shale assessment units are defined by evaluating the performance of existing vertical producing wells: 1) with single or multiple completions, and 2) by historical discovery thirds. Only a few horizontal wells completed in the Barnett Shale are listed in our database and these wells have only minimal production history; therefore, horizontal wells were not evaluated in our study. Because about 75 percent of Barnett Shale gas wells have been producing since January 2000 (Figure 4), there is still considerable uncertainty about the EUR distribution of vertical wells.

The Greater Newark East Frac-Barrier Continuous Barnett Shale Gas AU covers a mean area of about 995,000 acres (Figure 3). Area per cell of untested cells was estimated as follows: minimum of 10 acres, mode of 40 acres, maximum of 110 acres, and a calculated mean of about 53 acres; uncertainty of the mean ranges from 40 to 60 acres. About 90 percent of the area is untested and the mean future success ratio is estimated at 86 percent to produce a well of minimum volume of 0.02 billion cubic feet of gas (bcfg). The EUR distribution for this assessment unit is estimated as follows: minimum of 0.02 bcfg; median of 0.7 bcfg, maximum of 10 bcfg, and a calculated mean of 1.01 bcfg.

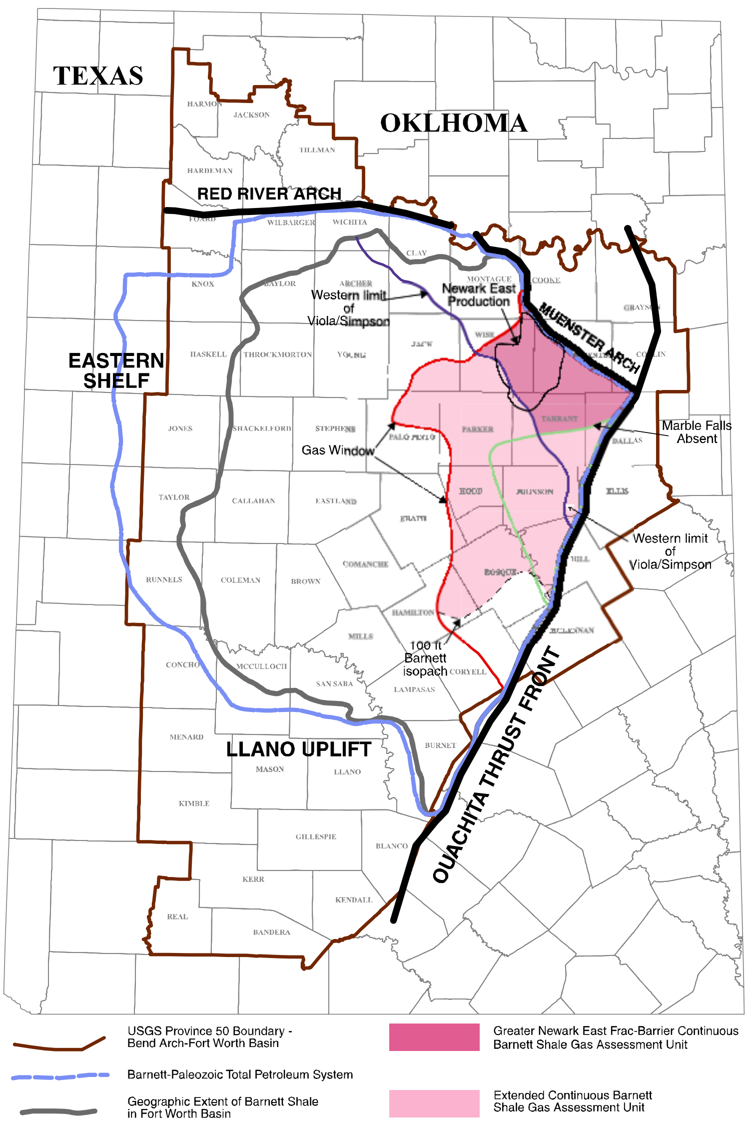

Figure 3. Map of U.S. Geological Survey Province 50, Bend Arch-Fort Worth Basin, showing major tectonic features, geographic extent of the Barnett-Paleozoic Total Petroleum System, extent of Barnett Shale, gas window, western limit of Viola Limestone-Simpson Group, area where Marble Falls Limestone is absent, Greater Newark East Frac-Barrier Continuous Barnett

Shale Gas Assessment Unit, Extended Continuous Barnett Shale Gas Assessment Unit, and area of greater Newark East field gas production.

Similarly, the Extended Continuous Barnett Shale Gas AU covers a mean area of about 3,000,000 acres. Area per cell of untested cells was estimated as follows: minimum of 10 acres, mode of

40 acres, maximum of 110 acres, and a calculated mean of about 53 acres; however, uncertainty of the mean is greater (35 to 65 acres) than in the previous assessment unit. Greater than 99 percent of the area is untested and the mean future success ratio was estimated at 68 percent to produce a well of minimum volume. The EUR distribution for this assessment unit is estimated as follows: minimum of 0.02 bcfg; median of 0.2 bcfg, maximum of 5 bcfg, and a calculated mean of 0.34 bcfg.

Much uncertainty exists in calculating the gas resources of this giant continuous accumulation based on EUR, cell size, and untested areas because of the following: 1) this is a newly defined and recently developed gas resource with very large potential, 2) most producing vertical wells in the Barnett Shale are concentrated in the core area of Newark East field and have been completed only within recent years (Figure 4), and thus have short production histories; 3) horizontal wells are minimal, and also have only short production histories; 4) technology and completion practices are evolving rapidly in the Barnett Shale play, and 5) much of the area within each assessment unit is unexplored and untested in the Barnett. For these reasons, it will be necessary for the USGS to conduct periodic assessments of the giant Barnett Shale continuous gas resource and update our assessments as new resources are developed reflecting changing perceptions of the Barnett resource base.

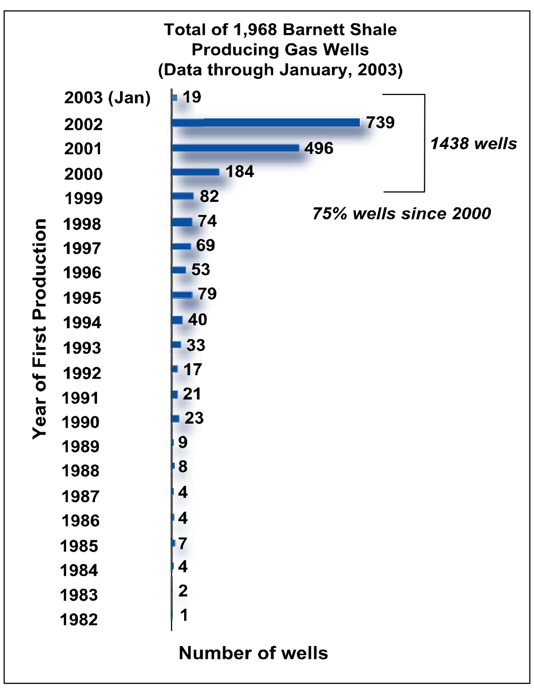

Figure 4. Histogram showing number of producing Barnett Shale gas wells versus first year of production. Data derived from HIS Energy, U.S. Production data (2003).

Acknowledgments

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