The Barnett Shale

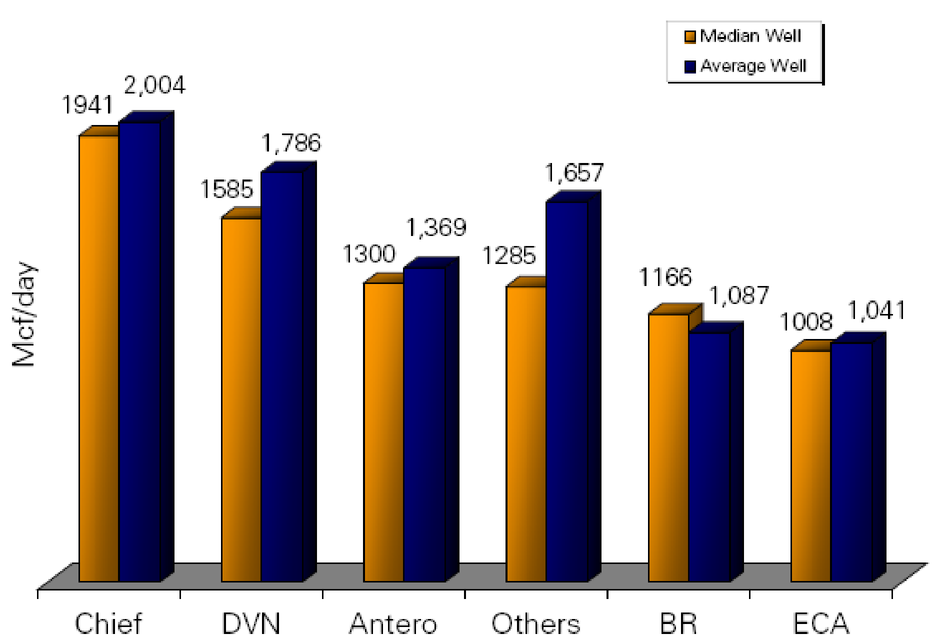
Introduction
The Barnett Shale play is currently one of the most prolific onshore gas plays in the country. Much of the growth in the past decade has been driven by the development of new fracture stimulation technologies needed to produce gas in the very low permeability mudstones.

Mitchell Energy began exploration of the Barnett Shale in Wise County in 1985. This established the core area for the play in Wise, Denton, and Tarrant counties. The full extent of the Barnett Shale resources is distributed across a larger geographic area that includes Parker, Hood, and Johnson counties. In this six-county area, more than 90% of the 7,931 wells drilled into the Barnett Shale have been completed since 2000.

The USGS estimates the mean gas resources at 26.7 Tcf (trillion cubic feet) and ultimate producible resources between 3 and 40 Tcf. The Texas Railroad Commission estimates 250 Tcf for total gas in place (not all of it recoverable). The play is currently producing gas at a rate of about 0.5 Tcf/year.

As of January, 2008, there are 6600 wells producing gas from the Barnett Shale in the six counties listed above. Approximately 150 operators are active in the play. Devon Energy is by far the most important player in terms of production. Significant skill is required by operators to produce from the Barnett Shale and some operators are more successful than others.

Figure 19. 2004 Horizontal Well Performance by Company – Peak Monthly Production



Land Leasing

The Railroad Commission of Texas regulates drilling in the state. Texas is not a forced pool state. If a homeowner does not lease their mineral rights and their acreage is inside a unit as designated and filed by an exploration company, the company **can** drill without leasing their mineral rights. That homeowner becomes a 100% working interest partner for those few acres that he/she owns within the unit. They get royalties only if a well drilled beneath their property produces. The surface location could not be on their property. As a working interest partner, they are responsible for their share of drilling and completion costs, although they are not usually billed for them. The homeowner would not receive any money until the well recovers all costs--that is, until the costs for all working interest partners are paid back by the well. Some companies won't create units like this but it is completely legal. It is to the benefit of the oil companies to lease as much of the unit as they can.

As a homeowner, you can look at this two ways. You can join with your neighbors and negotiate a group leasing bonus and royalty (usually 25%) or gamble that the well will pay off in some reasonable period of time and you'll end up with more than that percentage. It's important to note that companies drill many wells that never pay out, even in mature plays.

Reserves and Production

Per well reserves are relatively low compared to conventional gas plays. Play success is sensitive to gas price which has reached record highs in 2008 at more than $9.50/Mcf (thousand cubic feet). A large drop in gas price will stop the viability of the play. There seems to be some agreement that the gas price needs to stay above $4/Mcf for the play to stay viable in the long term. For horizontal wells, the peak monthly production averages 1520 Mcf/day.

Declines in production have averaged 55% in year 1, 25% in year 2, 15% in year 3, and 10% thereafter. The rate of decline may be slowing with newer technology. Reserves per well have averaged 2.4 Bcf (billion cubic feet, or 109 cubic feet) gross, calculated from an average decline curve using a 30-year well life. For most gas wells, the upper Barnett yields 20 to 25% of the total production, with the lower Barnett delivering 75 to 80%.

Wells to the west of us, along Hwy 377 have highly variable production rates but probably average a little less than 1.5 million cubic feet per day initial production. EnCana has the most well pads near us and is the only operator in Trophy Club.

Geology

The Barnett Shale is the source, reservoir, and trap for the hydrocarbons, with a natural permeability in the microdarcy to nanodarcy range and porosity in the 0.5 to 6% range.

This is extremely low for a reservoir expected to produce hydrocarbons and explains why the reservoir needs to be artificially fractured in order to produce gas. The Barnett Shale has been described as a fine grained, black organic shale. It is considered the source rock for several other oil and/or gas conventional reservoirs in the Fort Worth Basin where gas has been produced since the 1950's.

The Barnett Shale is a marine basinal deposit of Mississippian age, deposited under mostly anoxic conditions in a calm back-arc basin just before the formation of the Ouachita thrust foldbelt. It lies unconformably on the Ordovician limestones of the Viola-Simpson formations and dolomites of the Ellenburger Group and is overlain by the carbonates and shales of the Pennsylvanian-age Marble Falls Group.

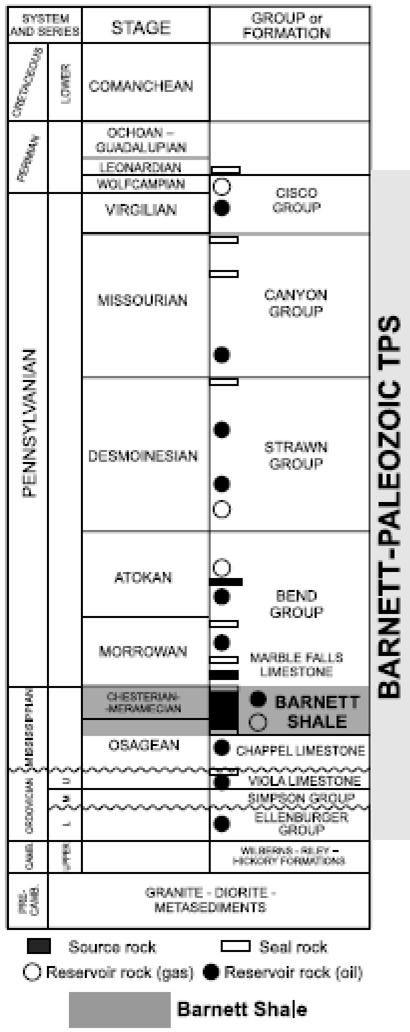


Figure 5. Generalized stratigraphic section of the Bend arch – Fort Worth Basin showing the distribution of source, reservoir, and seal rocks of the Barnett-Paleozoic total petroleum system (TPS).

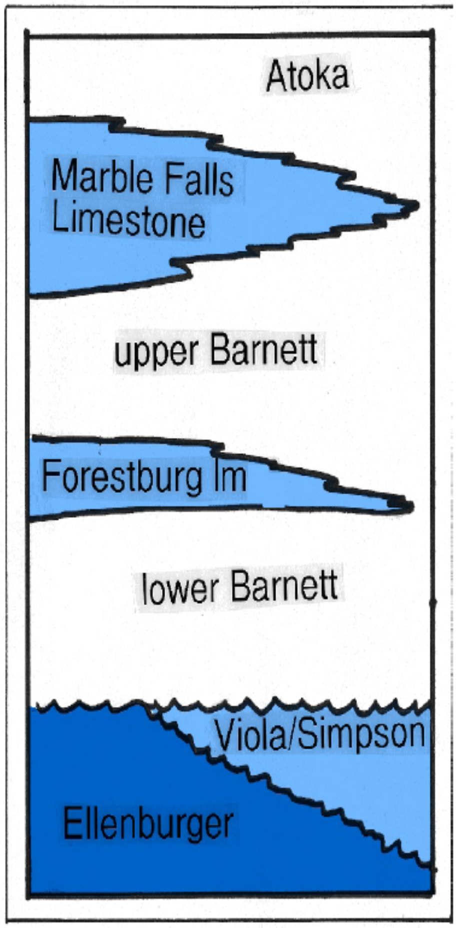


Figure 5. A section of the stratigraphic column in the northern portion of the Fort Worth basin.

The core area is constrained on its northeast boundary by the Muenster Arch, immediately beyond which no Barnett has been found; is bounded to the east by the Ouachita thrust foldbelt (old, eroded, and buried mountain range) east of which there is little chance of Barnett presence; on its southwest boundary by the Viola Limestone pinch-out; on its northwest boundary by the northern limit of the dry gas window; and to the north by the uplifted Muenster and Red River Arches.

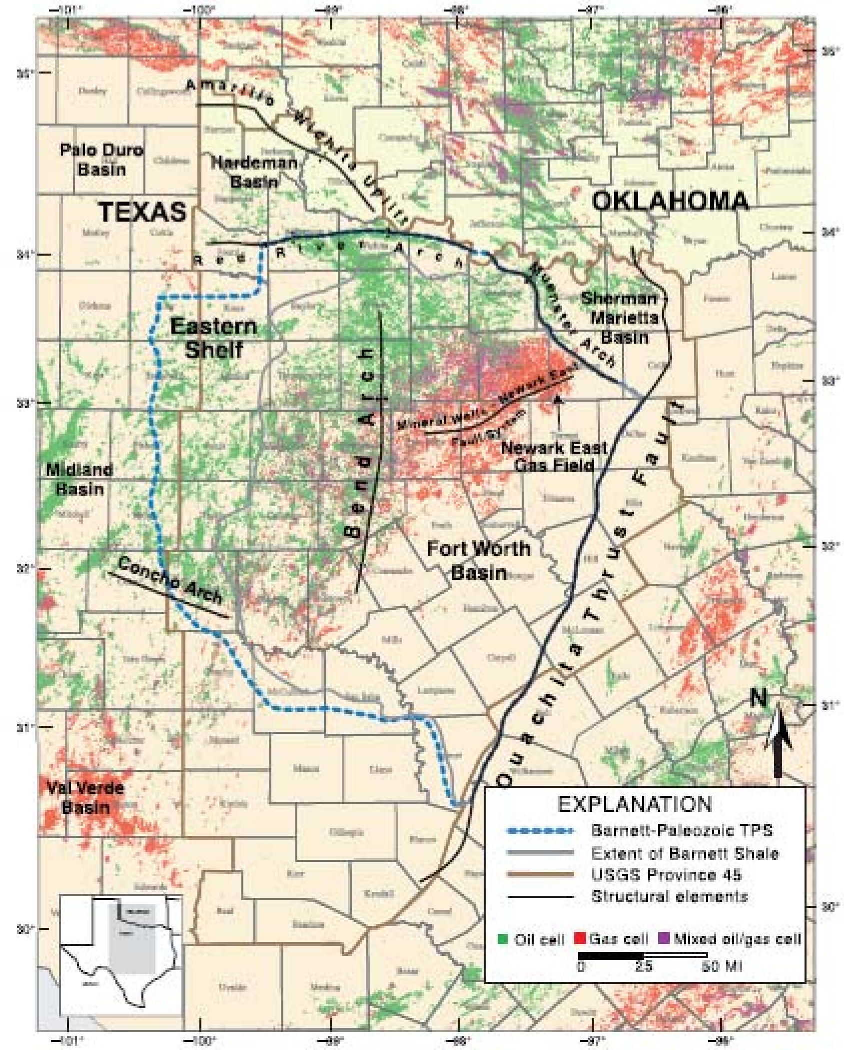
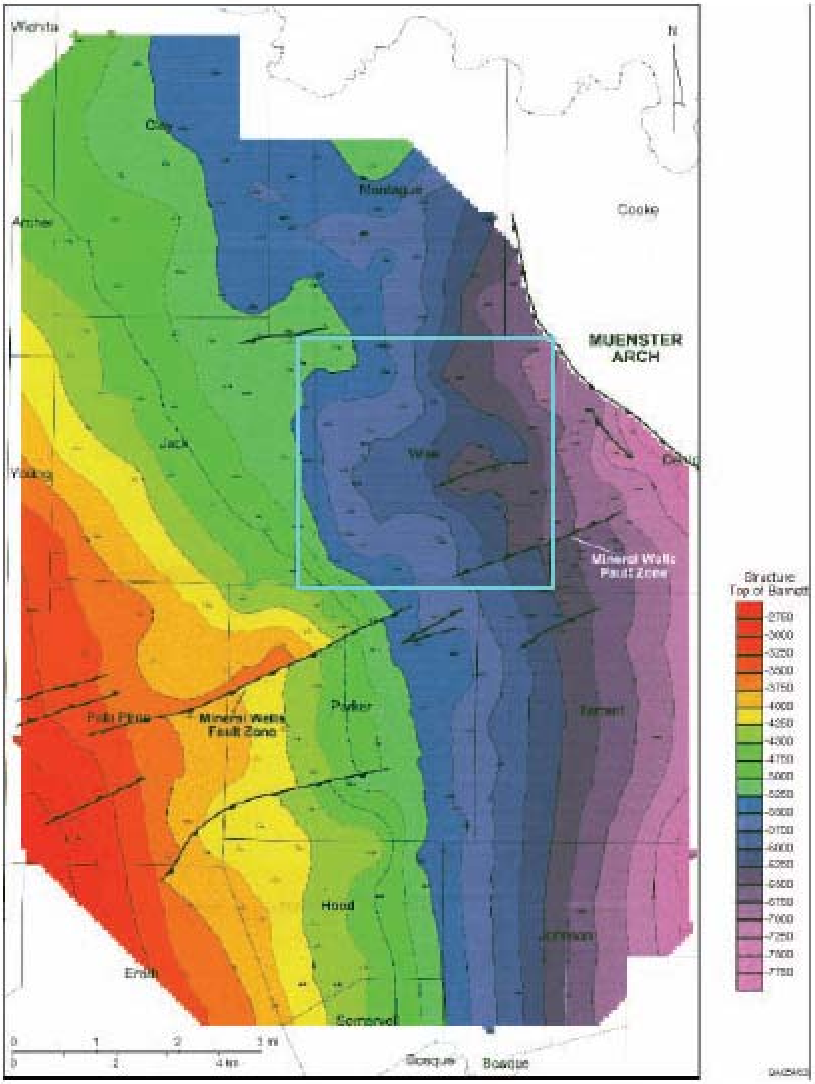


Figure 3. Map showing oil-, gas-, and mixed oil-and-gas–production cells in north-central Texas and southwestern Oklahoma, boundary of the U.S. Geological Survey Bend arch–Fort Worth Basin province 045, boundary of Barnett-Paleozoic total petroleum system (TPS), geographic extent of Barnett Shale, major structural elements, and location of Newark East field. Cells are equal to 0.25 mi^2 (0.64 km^2). The data are from IHS Energy well production database (IHS Energy, 2003).

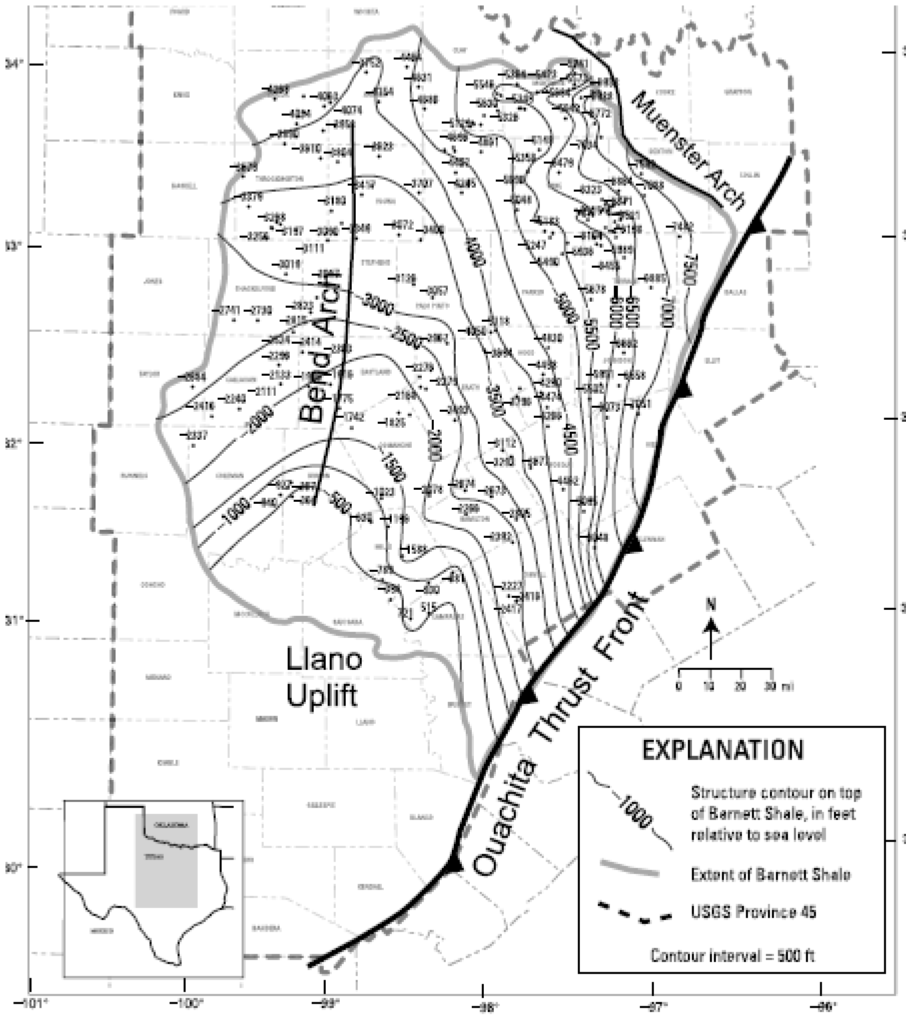
The Barnett Shale dips gently toward the core area and the Muenster Arch from the south where it crops out and to the west where it thins considerably. The bottom of the formation reaches a maximum depth of ~8,500 ft (subsea) in the NE confines of its extent.

The depth to the top of the Barnett ranges from about ~4,500 ft in northwestern Jack County to about ~2,500 ft in southwest Palo Pinto County to about ~3,500 ft in northern Hamilton County to about ~6,000 ft in western McLennan County to about 7,000 to 8,000 ft in the Dallas-Fort Worth area.

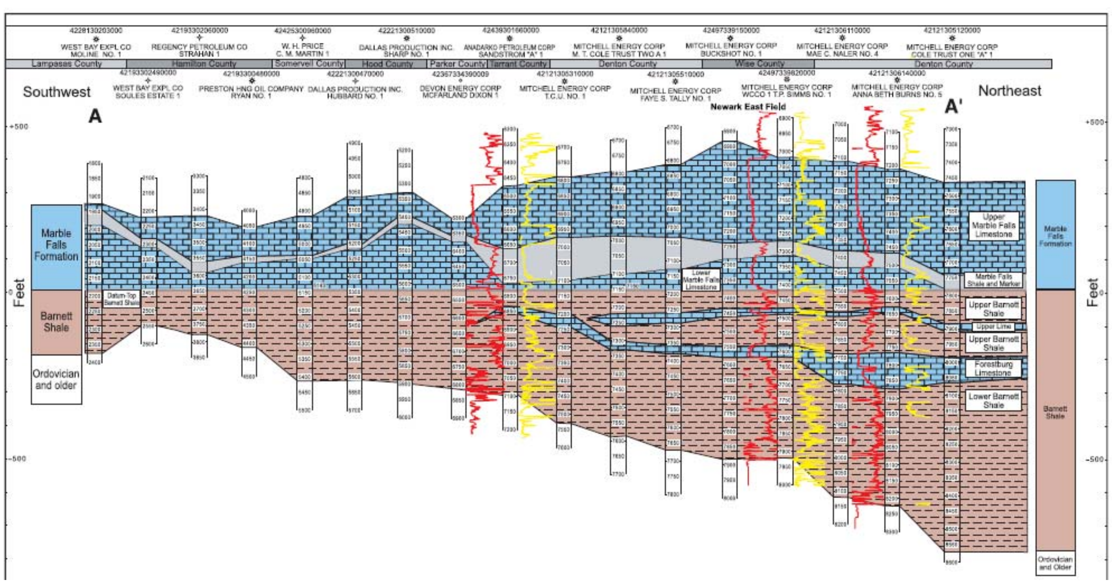


Courtesy of T. Hentz, BEG; Units are subsea feet; blue square represents Wise County

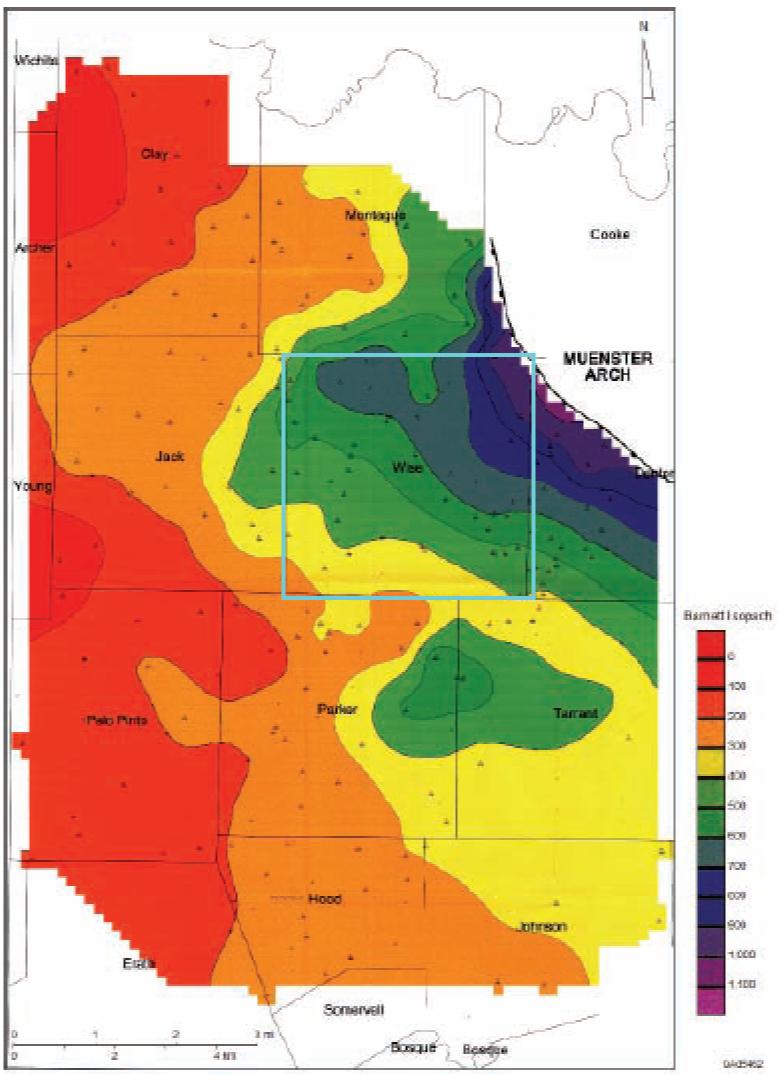
Figure 4 Top of the Barnett Shale (northeastern area of full Barnett Shale extent)



e 15. Structure contour map on top of Barnett Shale, Bend arch–Fort Worth Basin as interpreted from well logs. Contour l equals 500 ft (152 m).



The thickest and most productive section is the Lower Barnett. Formation thickness is in the 30-to 50-ft range on the Llano Uplift and increases to almost 1,000 ft farther north in the core area. However, this 1000-ft thickness includes the entire Barnett section, including interspersed limestones. In the northeastern and structurally deepest part of the Fort Worth Basin adjacent to the Muenster arch, the formation is more than 1000 ft (305 m) thick and interbedded with thick limestone units; westward, it thins rapidly over the Mississippian Chappel shelf to only a few tens of feet.



Courtesy of T. Hentz, BEG; Units are feet; blue square represents Wise County

Figure 5 Barnett Shale isopachs (northeastern area of full Barnett Shale extent)

Most gas cells are found along the northeastern part of the basin or along the Ouachita thrust front. These areas are located in the deeper and more thermally mature parts of the basin. Oil cells are concentrated to the north and west, where thermal-maturity levels are lower. Mixed oil and gas cells occur mostly in transition zones between oil and gas cell concentrations.

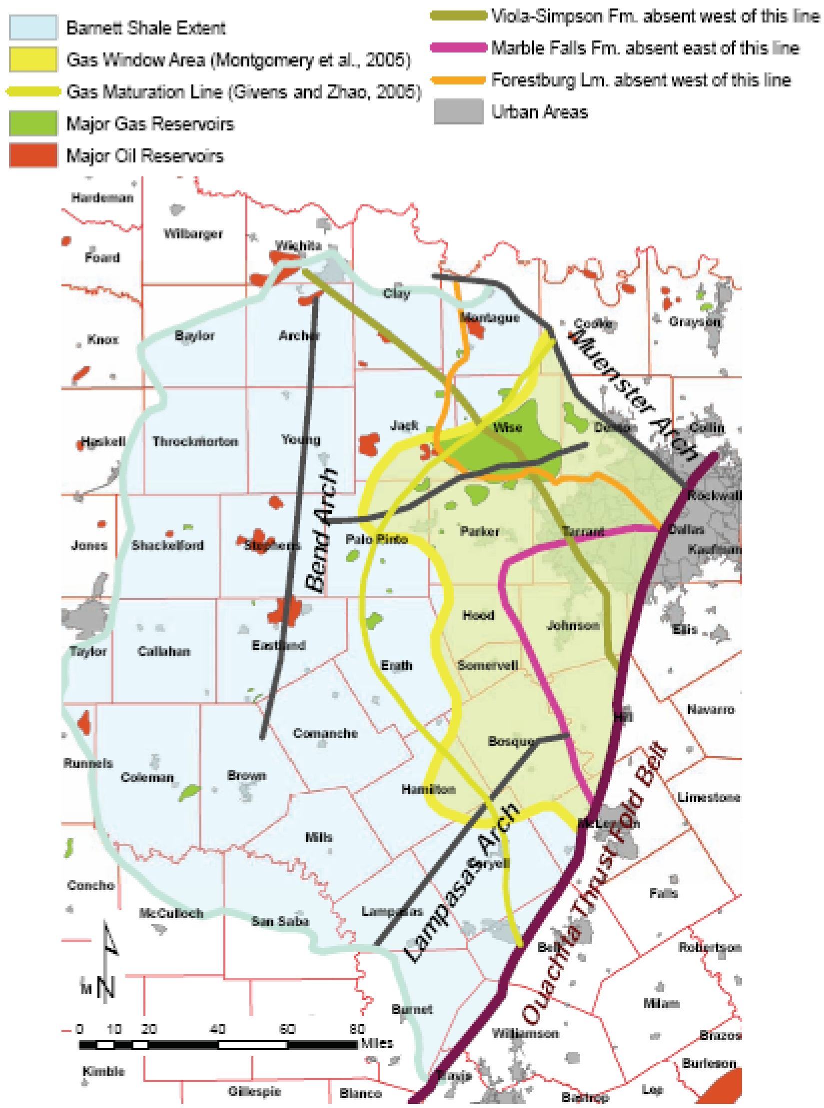
Fracture Technology
The play is currently driven by technology rather than by geology. Fracture technology is responsible for the current success in the Barnett shale play. This technology uses large amounts of water in a short period of time to develop a gas well. The concept is to enhance natural or create induced fractures by injecting fluids at pressures greater than the strength of the rock. Addition of sand or other material to the fluid is needed to keep the induced fractures open once the fluid has been removed and the pressure has subsided.

Most Barnett wells are horizontal wells with one or more horizontal legs extending into the target section. The legs may extend more than a mile from the surface location of the well. A typical vertical completion in the Barnett consumes approximately 1.2 million gallons of fresh water while a typical horizontal well completion requires 3.0 to 3.5 million gallons of fresh water. Horizontal wells are more expensive to drill and develop but have better performance and larger production volumes because more of the well bore is in contact with the reservoir. Salt water cannot be used to fracture the reservoir because saltwater significantly increases the potential for scale deposition in the formation, tubing, casing, and surface equipment, therefore inhibiting gas production. Saltwater also significantly increases the potential for corrosion on the tubing, casing, and surface equipment, potentially shortening the life of a well. In addition, chemicals needed to carry out a good fracture job do not perform as well in saltwater.

Risks to Production
It is important to keep the induced fractures contained within the Barnett Shale but this is balanced against an operator's desire to fracture as much of the reservoir as possible. Production is related to the area of the reservoir that is fractured and the length of the fractures that are created. Where it is present, the dense Viola Limestone that underlies part of the Barnett Shale formation can absorb some of the fractures without jeopardizing production of the well. However, if fractures penetrate into the water-saturated Ellenburger limestone below or the Marble Falls limestone above, excess water is drawn into the Barnett because of the high permeability of the surrounding limestone formations. This can potentially doom a well. The solution to undesirable penetrating fractures put forward by operators is to use horizontal wells and multiple, simultaneous, and carefully sized fracture jobs in the same well bore.

Those consequences also explain the general reluctance of operators to drill next to a fault. The induced fractures could access the fault and potentially connect the water-rich formations to the newly drilled well bore.

In large areas underneath the Barnett Shale, dolomites of the Ellenburger Formation commonly are paleokarsts—that is, cave-collapse cavities. Many of the resulting sags do impact the Barnett Shale. Barnett Shale horizontal wells drilled through the faults of these collapse features could encounter weak zones prone to water flow and directly link the Ellenburger to the borehole. The paleokarst features are common, and could explain many early well failures. 3D seismic programs have allowed the oil companies to identify the karsted areas and mitigate this risk.



*Note: Forestburg limit modified from Givens and Zhao (2005); all others modified from Montgomery et al. (2005); major oil and gas reservoirs from Galloway et al. (1983) and Kosters et al. (1989). The Major Gas and Oil Reservoirs refer to non-Barnett production

Figure 3 Relevant geologic features associated with the Barnett Shale

As with most deeply buried formations, the Barnett Shale is naturally fractured. In the core area of Barnett production, fractures trend NW-SE. They are generally closed by calcite but it is speculated that they can be reactivated during a fracture job. Induced fractures have a NE-SW strike.

Well Spacing

The usual well spacing for vertical wells is 1 well per 40 acres. Spacing between horizontal wells is a function of the shape of the induced fractures. Ketter et al. (2006)

suggested that spacing between laterals should be at least 1.5 times the fracture height, which they estimate typically in the 300- to 400-ft range (that is, spacing of at least 450 to 600 ft).

Homeowner Concerns in Tarrant County

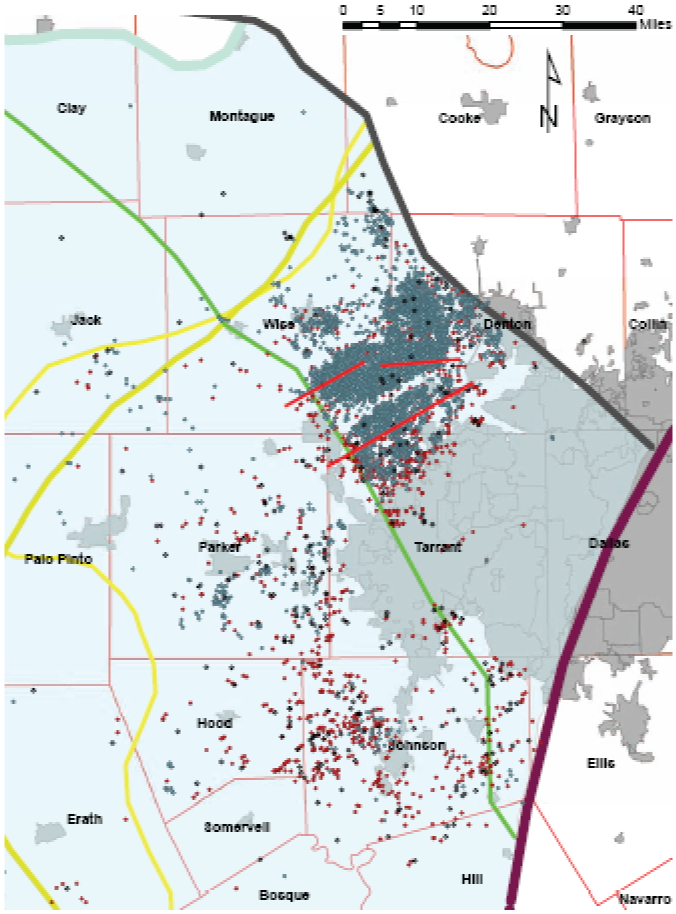
The Barnett Shale in northeast Tarrant County is near its deepest and thickest extent. The top of the Barnett shale is expected to be between 7500 and 8000 feet below sea level and greater than 1000 ft thick. The Viola limestone should be present below the Barnett Shale acting as protection from the underlying karsted Ellenburger formation. The hydrocarbons in this area should be dry gas and the maturity in the area should be high enough to generate significant production.

According to the Texas Railroad Commission, 526 drilling permits, nearly all for horizontal wells in the Barnett Shale, were issued for Tarrant County since January 1, 2008. The issuing of a permit does not guarantee that a well will be drilled, but given the high level of activity in the Barnett Shale play, it is a good bet that companies intend to drill and complete these wells. In order to drill a well, an exploration company needs to lease the mineral rights of a minimum number of contiguous acres, called a unit. For these wells, units vary between 120 and 300 acres. The size of the unit dictates the number and length of the laterals that can be drilled into the target reservoir. In the urban part of the Barnett Shale play, the density of homes and businesses on the unit are also an important factor.

One of the primary concerns expressed by home owners this area are the large amounts of fresh water needed for the drilling that either need to be produced from water wells in the area or trucked in from local reservoirs.

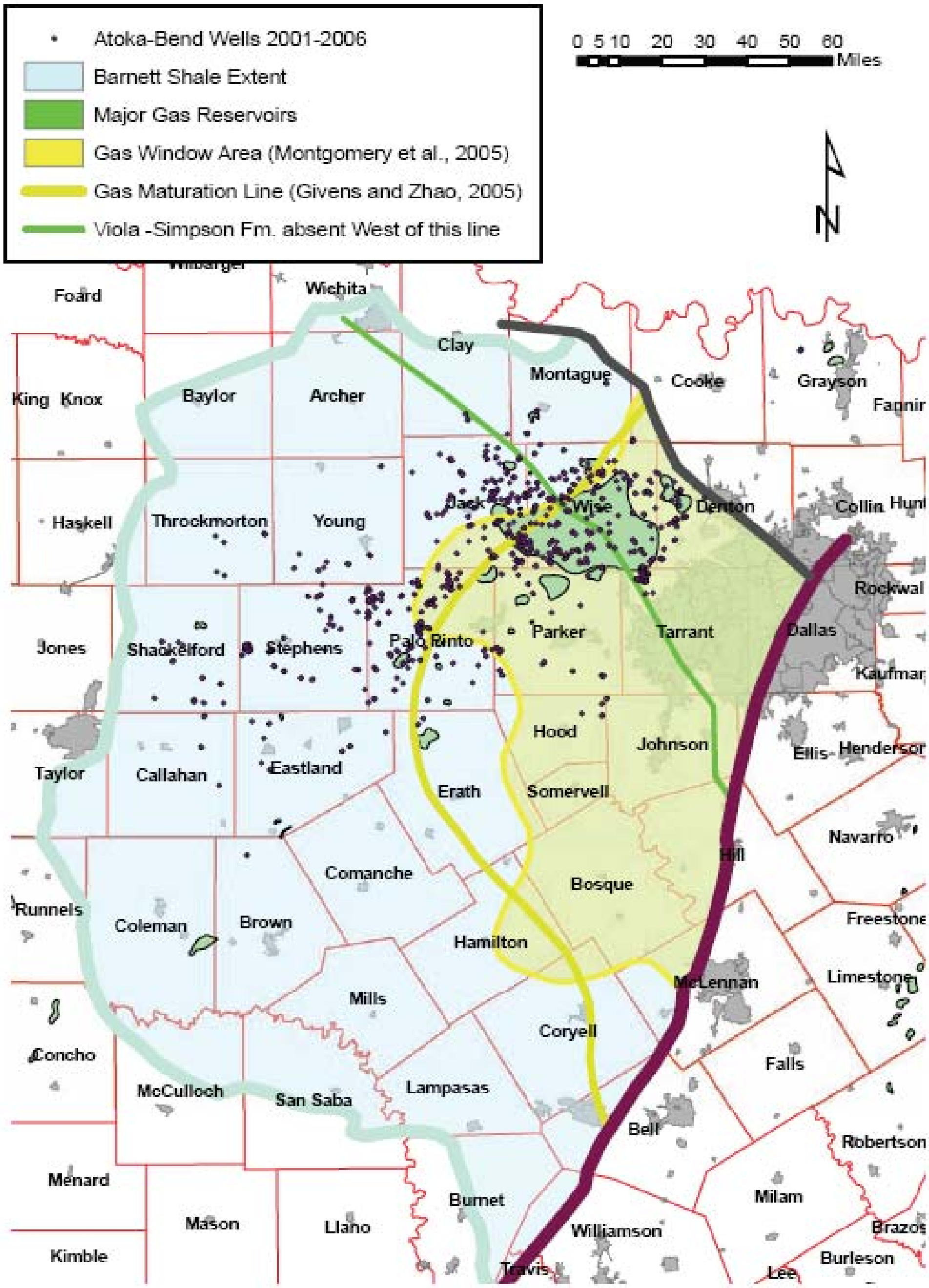
The experience of the operators will determine the success and level of production of any wells in the area. Some operators are clearly better at producing gas in this type of play than others.

Drilling in northeast Tarrant County has been slowed primarily due to the population in the area. It is much more difficult for oil companies to operate in densely populated areas and manage the concerns of numerous landowners within each lease. The potential production in the area will encourage the oil companies to work with the land owners as long as the price of gas remains high.



Core area is clearly delimited between the Muenster Arch and the Viola Simpson pinch-out (green line). The vast majority of the wells drilled to date are within the gas window (2 versions shown with yellow lines) and in rural areas. Blue dots represent vertical wells whereas red dots represent horizontal wells. Non-colored dots represent those wells where directional information is not available. Known faults are shown by red lines. Well locations courtesy of drillinginfo.com.

Figure 6 Barnett Shale well location



gure 19 Recent (2001–2006) well completion in the Atoka/Bend Conglomerate of the Fort Worth Basin

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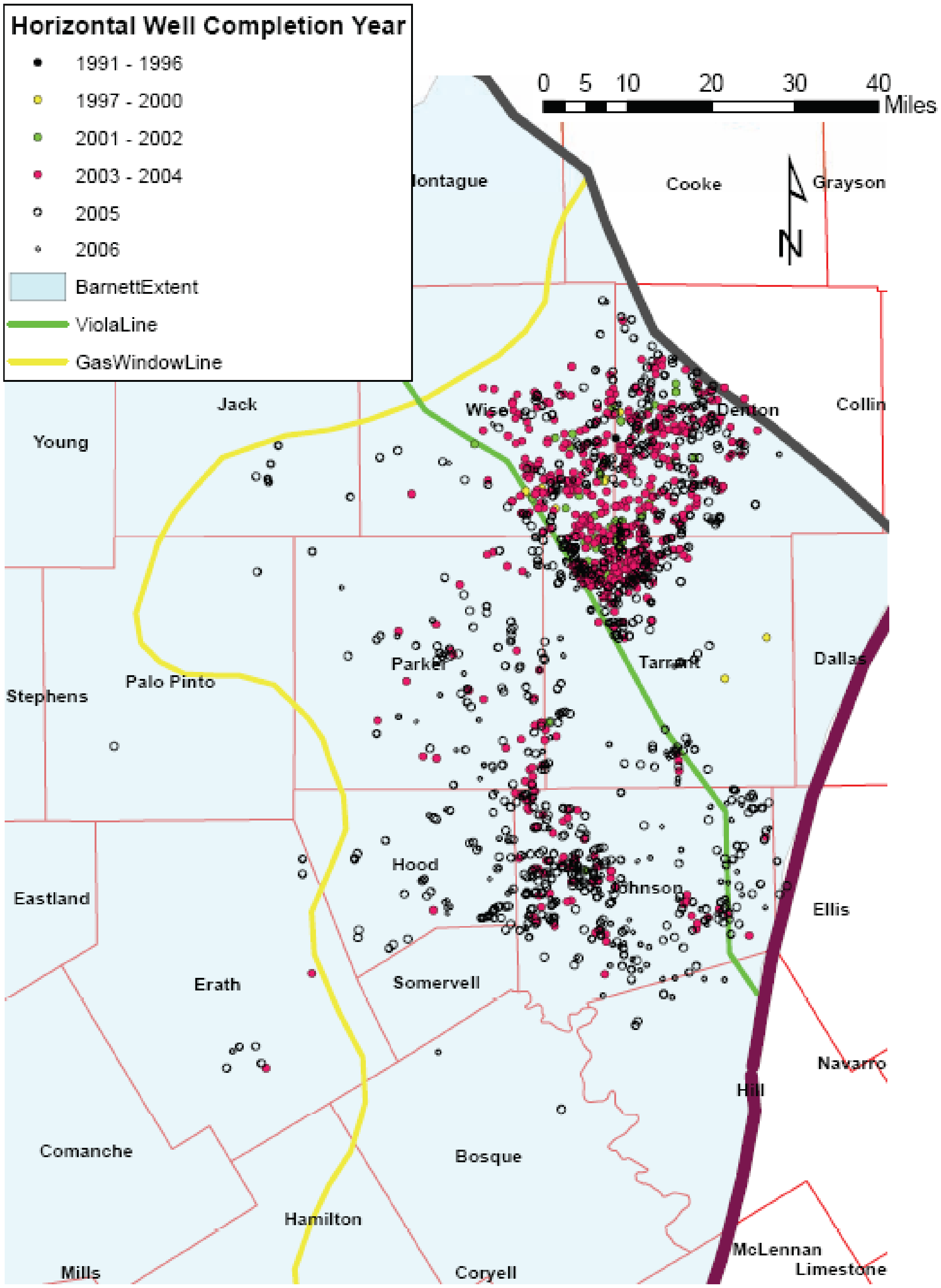

Figure 8 Spatial and temporal distribution of horizontal wells

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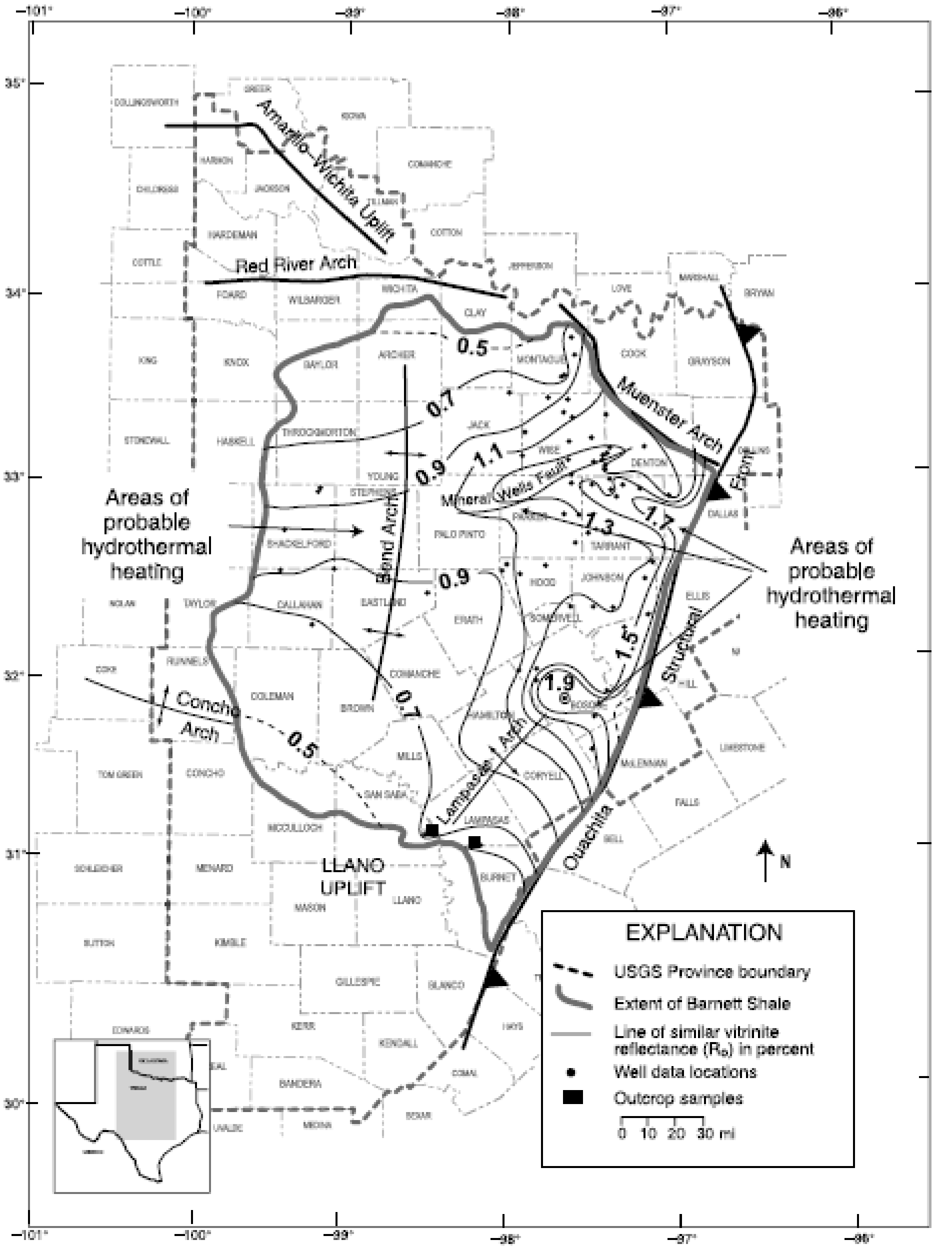
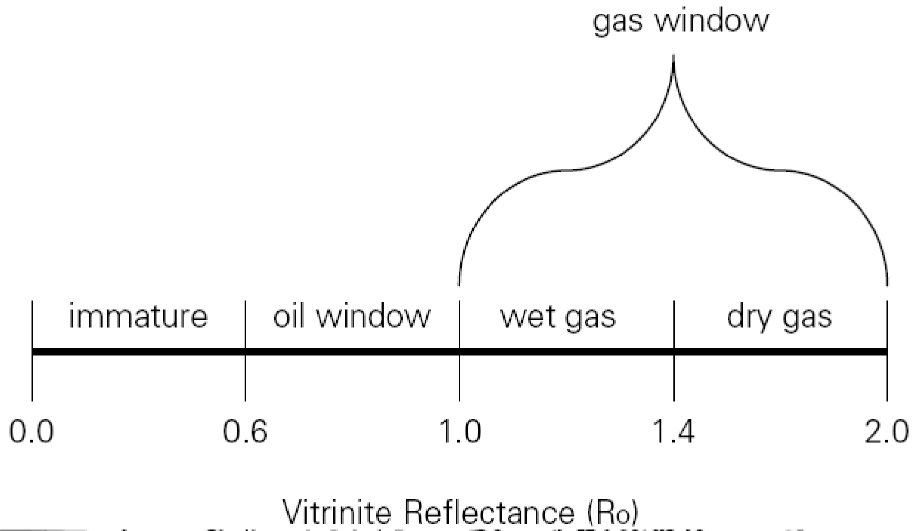


Figure 12. Map shows lines of equal thermal maturity as determined from mean vitrinite reflectance (R_o) of Barnett Shale. Based on data from Humble Geochemical Services, Humble, Texas. Areas of probable high hydrothermal heating and anomalously high R_o are also indicated (arrows).



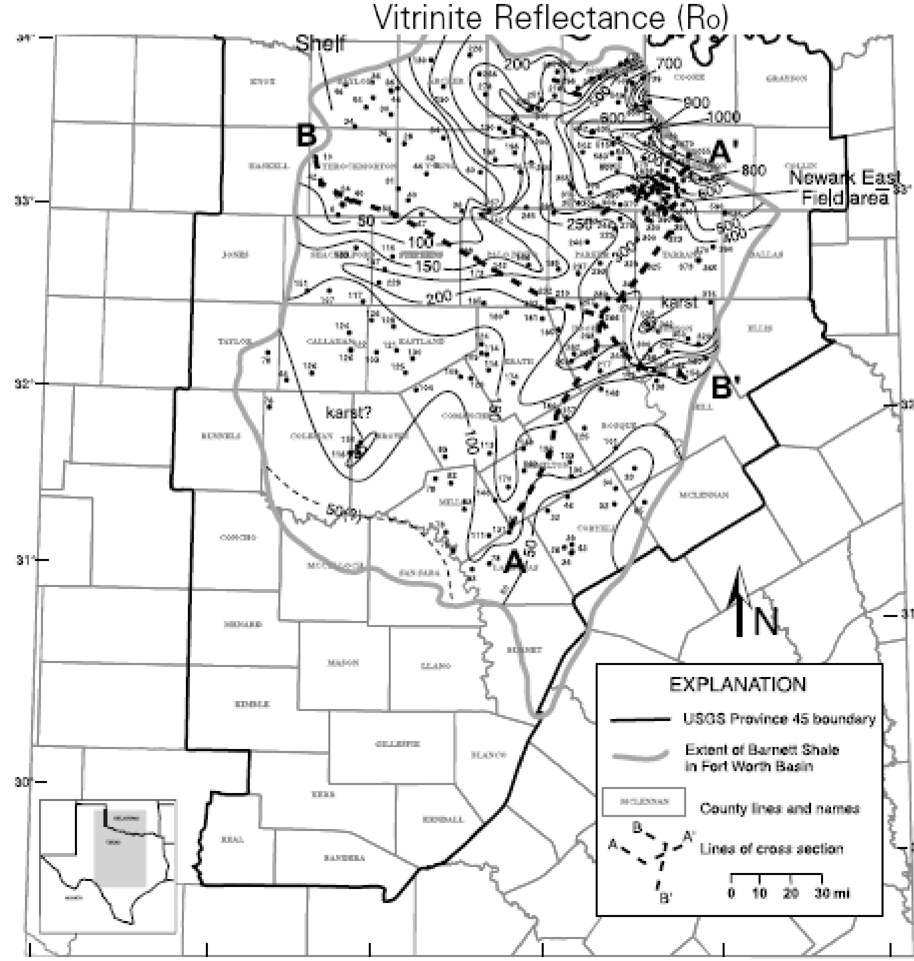


Figure 6. Map showing regional extent of Barnett Shale, thickness of Barnett Shale in selected wells, generalized regional isopachs of Barnett Shale, and lines of well-log cross sections AA′ of Figure 9 and BB′ of Figure 10. Contour intervals are 50 ft (15 m) for thicknesses from 0 to 300 ft (0 to 91 m) and 100 ft (30 m) for thicknesses from 300 to 1000 ft (91 to 305 m). Modified from Pollastro (2003).

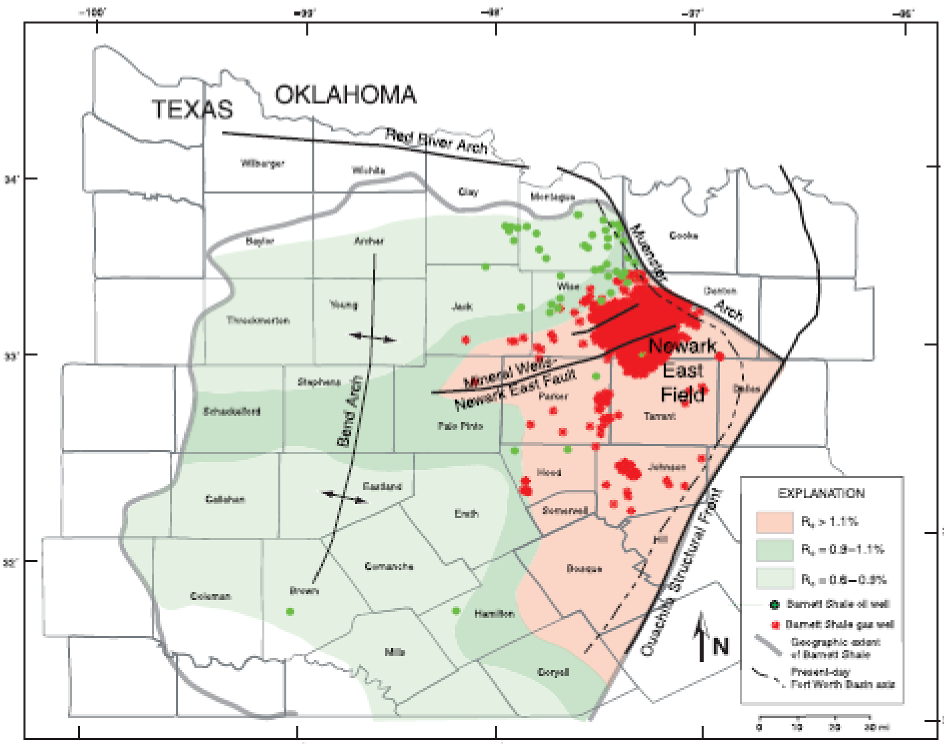
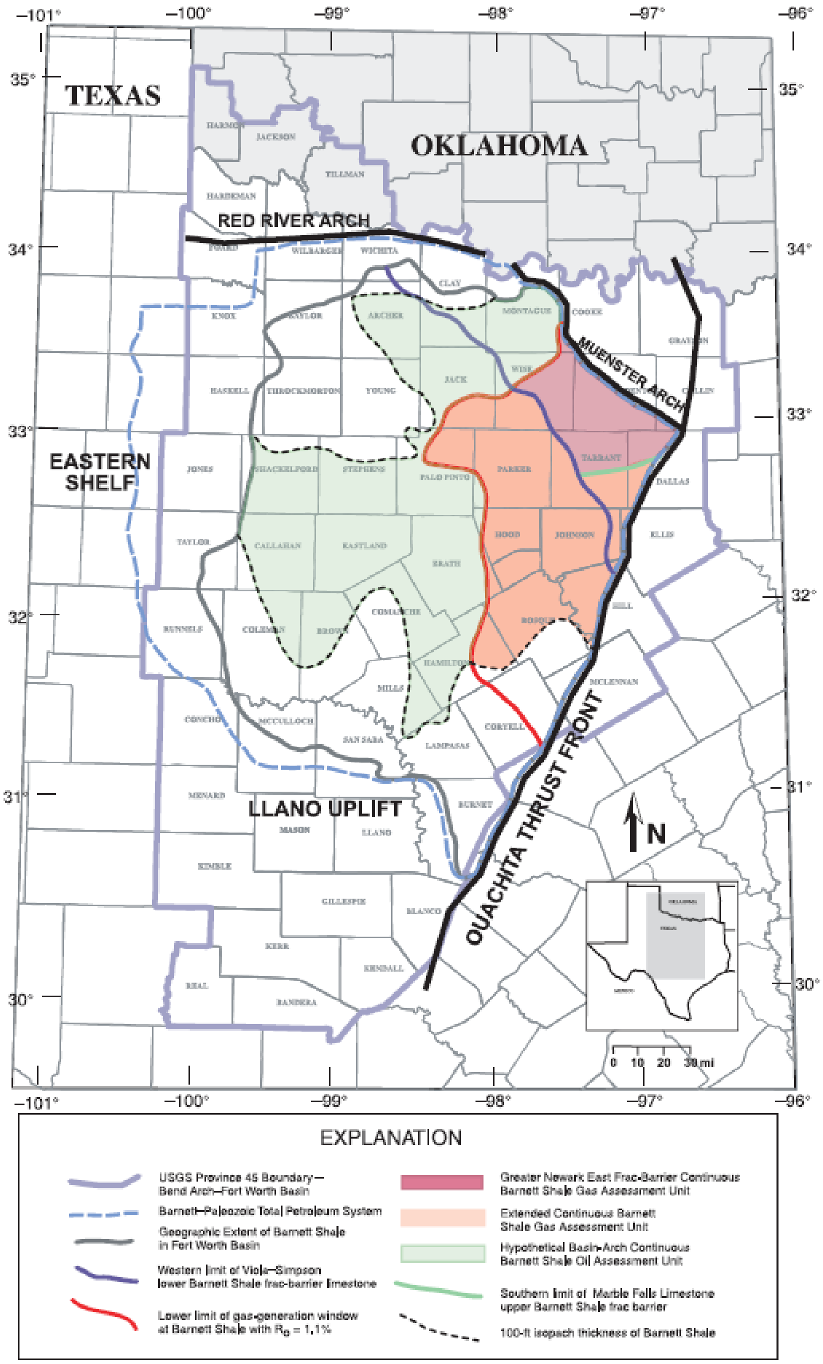


Figure 18. Relation between oil and gas production from Barnett Shale in Fort Worth Basin, Texas, versus oil- and gas-generation windows as determined from mean vitrinite reflectance (R_o) (see Figure 12). Derivative of data from 2900 wells as reported by IHS Energy (2003).

Figure 19. Map of U.S. Geological Survey Bend arch–Fort Worth Basin province 45 showing the composite of critical tectonic elements and stratigraphic and thermal-maturity boundaries used in the assessment of Barnett Shale. Also shown is the geographic extent of the Barnett-Paleozoic TPS.



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