AAPG Energy Minerals Division Mid-Continent Report

November, 2013

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(Kansas contribution)

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Kansas Coalbed Natural Gas

CBM constituted 12.3% of Kansas annual gas production in 2012 (down from 13% in 2011). 2012 CBM production for Kansas was approximately 35.66 billion cubic feet (BCF) (Figure 1). Prorated production based on the first 6 months of 2013 indicates that 2013 Kansas CBM production will be approximately 31.4 BCF. This represents a 4.4% drop from 2012.

2008 production (49.14 BCF) represents the peak of Kansas CBM production (Figure 1). CBM annual production declined 2.4% from 2008 to 2009, 10.7% from 2009 to 2010, 5.3% from 2010 to 2011, and 8.5% from 2011 to 2012. The number of wells reporting production during 2012 decreased by 543 wells from 2011 (Figure 1). The distribution of CBM production in Kansas is in Figure 2.

Cumulatively, approximately 383 BCF of natural gas in eastern Kansas has been produced since 2001, which is the year southeastern Kansas gas production started rising dramatically (see Figure 1). The overwhelming majority of southeastern Kansas gas being produced is now due to CBM. CBM production data for Kansas, and associated links, can be found on the KGS website: http://www.kgs.ku.edu/PRS/petroDB.html.

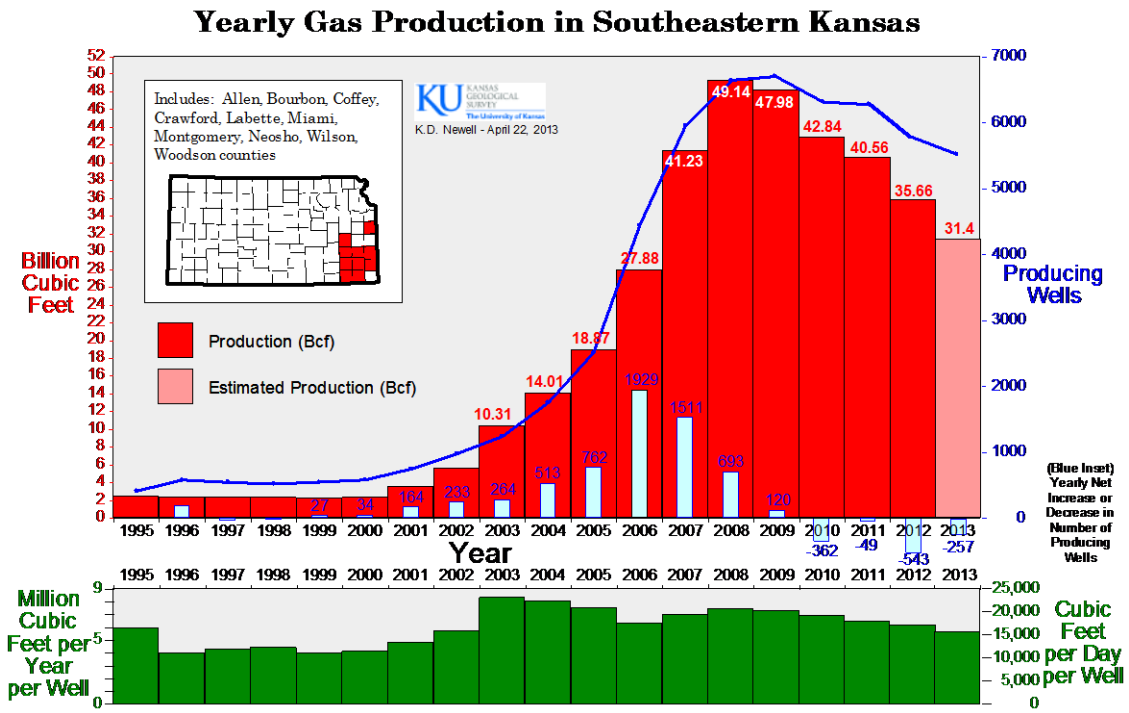


Figure 1 – Eastern Kansas Gas Production (overwhelmingly due to CBM) and the number of producing CBM wells reported annually (in blue), and total annual production divided by the total number of CBM wells (in green).

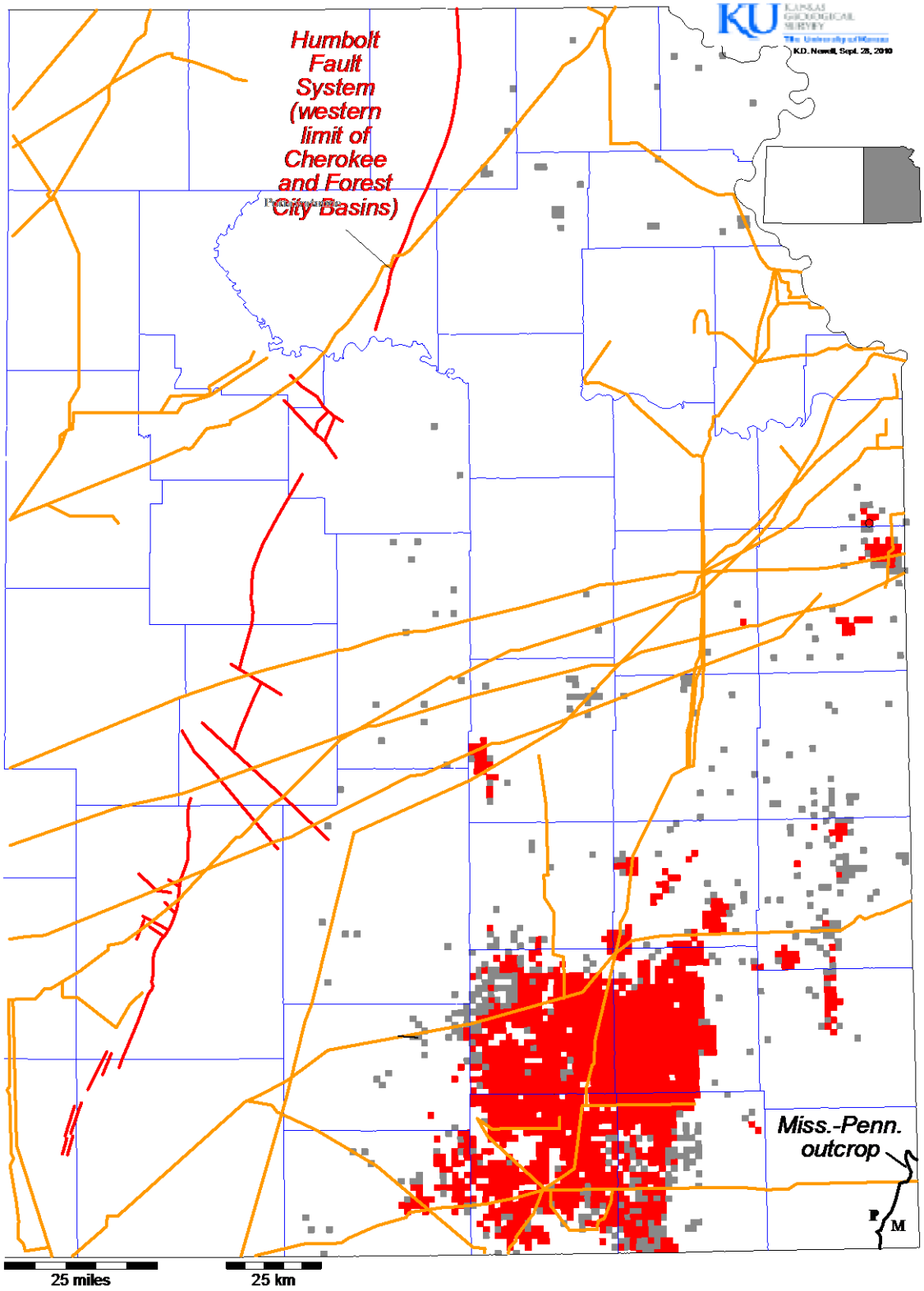

Humbolt Fault System (western limit of Cherokee and Forest City Basins)
Miss.-Penn. outcrop
P
M
25 miles
25 km

Figure 2 – Locations of sections (nominally 1 square mile) in eastern Kansas with record of CBM production (red) and sections with at least one well drilled for CBM, but with no production recorded (gray). Major gas pipelines are in orange (after Newell and Yoakum, 2010).

Most CBM in southeastern Kansas is from Middle and Upper Pennsylvanian high-volatile B and A rank bituminous coals. Almost all wells are vertical and have multiple completions.

To date (October 2013), 7836 wells have been reported spudded for CBM in eastern Kansas (Figure 3). The peak for drilling was in 2006, and drilling has languished since 2008. The drastic price decline for natural gas since the last half of 2008 and the economic slowdown in the USA continues to affect gas drilling in Kansas.

As of data reported to the state through October 2013, 147 wells were drilled in 2011 in Kansas for CBM and 71 were drilled in 2012. The following companies were the most active according to CBM wells spudded in 2012:

- PostRock Energy, LLC (*once Quest*) (37 wells)
- Cherokee Wells, LLC (31 wells)
- Layne Energy Operating, LLC (1 well)
- GatewayResources U.S.A., Inc. (1 well)
- LR Energy, Inc. (1 well)

Only 3 new CBM wells have been so far reported through the first 6 months of the year 2013. Several operators are now changing their business model and are reviewing data from their CBM wells with effort directed to find previously overlooked or ignored oil accumulations.

PostRock Energy, LLC recorded the greatest CBM production in Kansas in 2012 (~15.3 BCF). Dart Cherokee Basin Operating Co. (~6.3 BCF), and Layne Energy Operating (~4.7 BCF) followed.

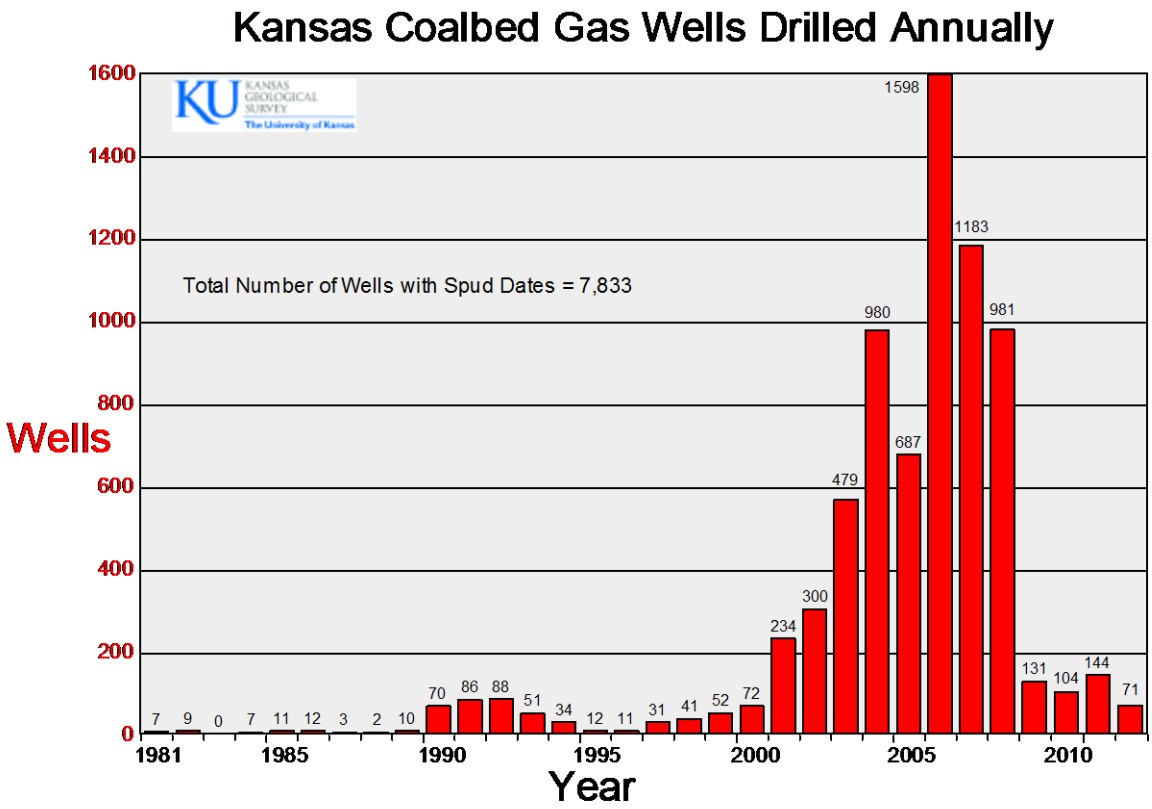


Figure 3 – CBM wells (dry and producing) drilled in Kansas.

The Kansas Geological Survey continues to partner with industry to pursue additional CBM-related research. Ongoing research has focused on the gas content of coals and shales, the isotope chemistry and composition of produced gases, and production characteristics. The Kansas Geological Survey has received grants from industry participants several times to core scientific test holes and recover coals and shales for desorption studies, utilizing the Survey wireline drilling rig and desorption laboratory. Other research partnerships are always welcomed.

Kansas Coal

Kansas coal production for 2012 totaled 18,823 short tons. Of this total, 15,865 tons were produced from two permit areas at the Phoenix Coal Company Garland Mine in southeastern Bourbon County. The coal produced was primarily Mineral coal, with Croweburg being a secondary target. The remaining 2,958 tons was produced by the Mulberry Limestone Quarry Company in sec. 02-T.29S.-R.25E. in

northeastern Crawford County. At this locality, the Mulky coal is mined as partial interburden between the underlying Breezy Hill Limestone and the overlying Fort Scott Limestone.

Kansas coal in recent years is used mainly as a blending fuel with western coal from Wyoming for local power generation in eastern Kansas and western Missouri. During 2012, Empire Electric Company's Asbury power plant (Asbury, MO) blended 7.3% local coals with 86.8% Powder River Basin coal.

Proposed Coal-Fired Power Plant in Kansas

In August 2012, the Kansas Supreme Court heard arguments regarding a brief filed by Earthjustice, which represented the Sierra Club of Kansas. The litigation was regarding a permit issued by the Kansas Department of Health and Environment (KDHE) for a proposed 895-megawatt coal-fired plant to be operated by Hays, KS-based Sunflower Electric Power Corp. in southwestern Kansas, near the town of Holcomb. The plant has the capacity to power approximately 500,000 homes, and Tri-State Transmission and Generation Association Inc. of Westminster, CO would get 75% of the power for customers in Colorado.

The Sierra Club seeked to block construction of the power plant, alleging that the permit issued by the KDHE did not comply with the Clean Air Act. Conversely, KDHE and Sunflower Electric maintained the permit met all state and federal requirements.

The court issued a decision in early October 2013 and overturned the project's permit, stating that KDHE failed to apply Environmental Protection Agency regulations on pollution emissions that had become effective several months before the permit had been issued. The court thus sent the case back to KDHE, telling the agency that the permit must comply with one-hour emission limits for nitrogen dioxide and sulfur dioxide.

In a separate lawsuit, in late January, 2012, U.S. District Court Judge Emmett Sullivan in Washington, D.C. handed down a ruling that the Rural Utilities Service of the federal government, which was financially supporting the Sunflower project, failed to consider environmental impacts of the plant. The Rural Utilities Service was directed not to issue any approvals or consents related to the construction of the power plant until a new Environmental Impact Statement was completed.

Even though the proposed project has been the center of legal disputes for over 6 years, Sunflower Electric maintained that the company would “continue to take the steps necessary to preserve and advance the project”. Counsel representing the Sierra Club said after the recent Kansas Supreme Court ruling, "That plant is no closer to being built than in 2007. In fact, in terms of legality, it is much less likely to be built now."

Horizontal Wells and the Mississippian Limestone Play

Although about 765 horizontal wells have been drilled in Kansas over several decades, 2010 marked the beginning of a new era in drilling where staged massive hydrofracturing was extensively utilized in long-reach horizontal wells. Most horizontal wells since 2010 have been drilled to access poorly drained reservoir compartments and low-permeable oil zones in Mississippian carbonates in southern Kansas, particularly in the tier of counties immediately north of the Oklahoma state line. This new engineering and geological play is dubbed the Mississippian Lime(stone) Play, or MLP.

The most prolific of all the MLP wells to date is the SandRidge Bernice #1-17H well in sec. 17-T.35S.-R.07W. in Harper County just north of the Oklahoma state line. Peak production of this well was 849 bbls/day and 1603 mcf/day in its 5th month of production in December 2011. In 23 months (production reported through June 2013), the well has produced 199,106 bbls of oil and 912,145 mcf of natural gas. Production for June 2013 from Bernice #1-17H was 1048 bbls (35 bbls/day) and 9646 mcf (322 mcf/day) of natural gas. This well remains the most prolific MLP horizontal well to date in terms of greatest monthly production and greatest cumulative production.

The number of intents-to-drill, which are posted on the website of the Kansas Corporation Commission, can provide an up-to-date monitoring of the types of wells that are soon to be drilled in Kansas. The number of horizontal wells in the southern part of the state gradually increased in 2011 and has gradually declined since mid-2012 (Figure 4). Some companies, including Chesapeake Energy, Shell Oil Gulf of Mexico, and Apache Oil, gained acreage positions in Kansas, but then stated after initial drilling that that they would not pursue the play any more in the state. SandRidge Energy (Oklahoma City, OK) and Woolsey Petroleum (Wichita, KS) continue to be active in the play, as are several other independents from Oklahoma, Texas, Kansas, and Colorado.

As of mid-October 2013 (and since May 2011), 694 intents-to-drill for horizontal wells have been permitted, and as of the June 2013 (the most recent publication of production data) 256 MLP horizontal wells (and 6 additional horizontal wells targeting other formations) have reported production (Figures 5, 6). Production from these wells constituted 7.7% of Kansas oil and gas production as of June 2013

(Figure 6). The other 92.3% of Kansas oil and gas production is produced from 48,298 oil wells and 24,118 gas wells.

The 262 modern horizontal wells in Kansas in June 2013 produced 262,426 bbls of oil and 2,075,303 mcf of natural gas. Overall gas-oil ratio for that month was 7.91 mcf/bbl. Cumulative production for these wells is 3,008,949 bbls and 22,966,739 mcf of natural gas (GOR = 7.63 mcf/bbl). Operators for these 262 wells are:

PRODUCING WELLS	COMPANY
164	SandRidge Energy
31	Shell Gulf of Mexico
12	Woolsey Operating
9	Tug Hill Operating
7	Osage Resources
39	(other companies, none with more than 6 wells)

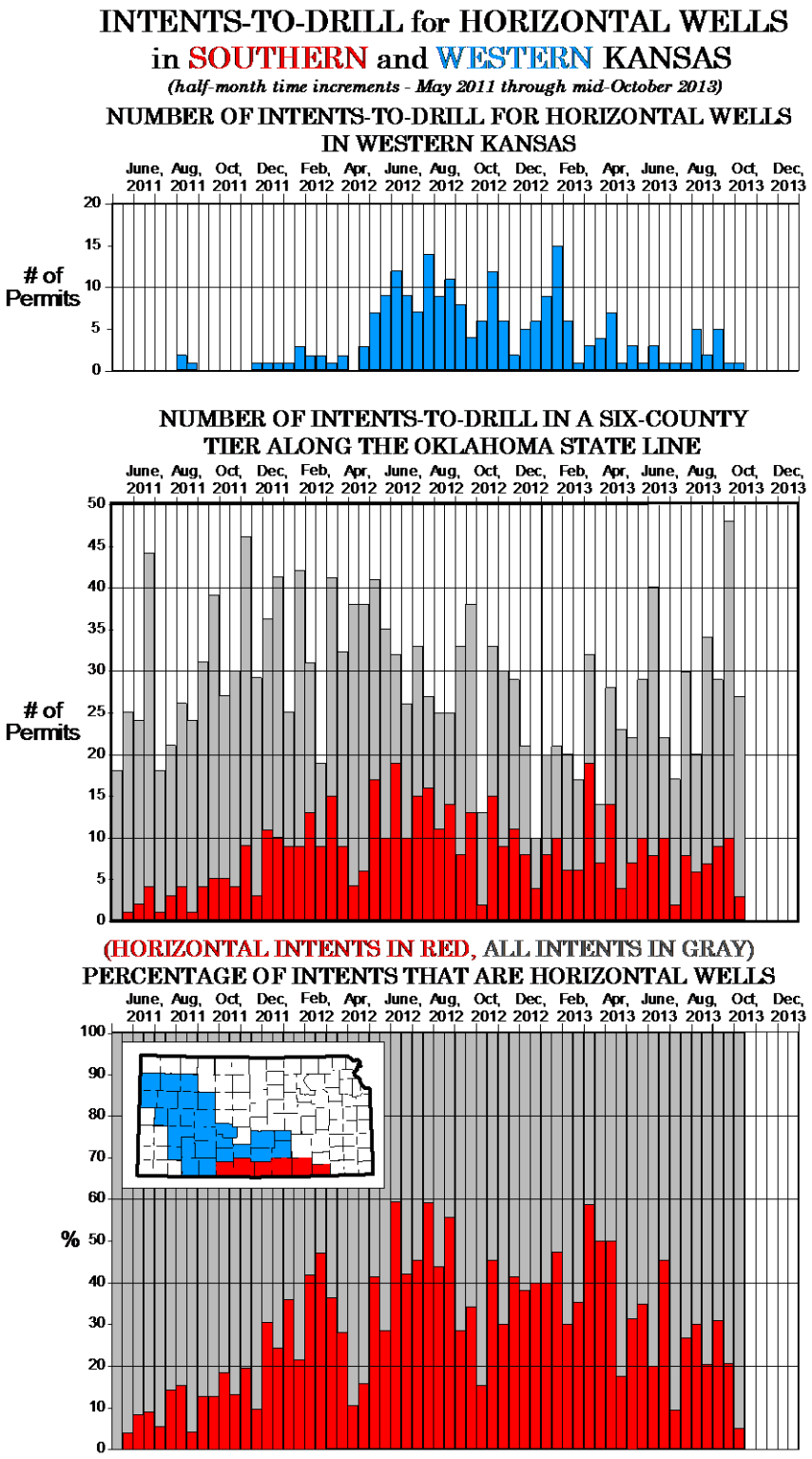


Figure 4 – Intents to drill for Kansas counties immediately north of the Oklahoma state line (in red), and western Kansas (in blue).

Horizontal Wells in Kansas (post-2009)

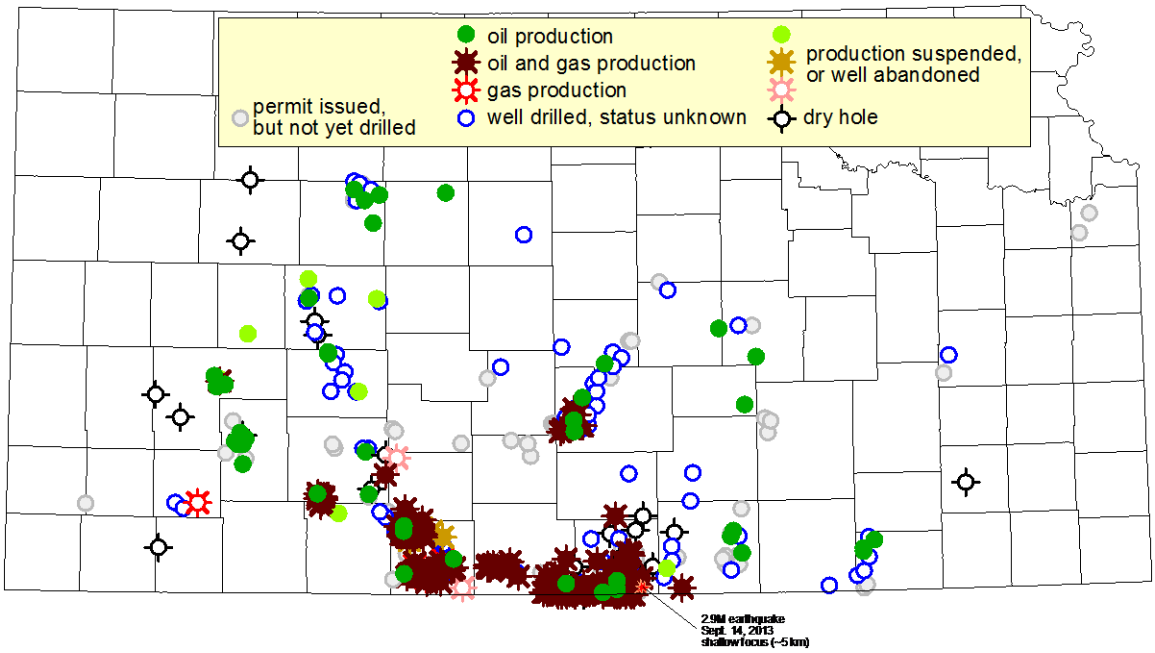


Figure 5 – Modern horizontal wells in Kansas. Most horizontal wells in the southern tier of counties in the state are targeting the Mississippian.

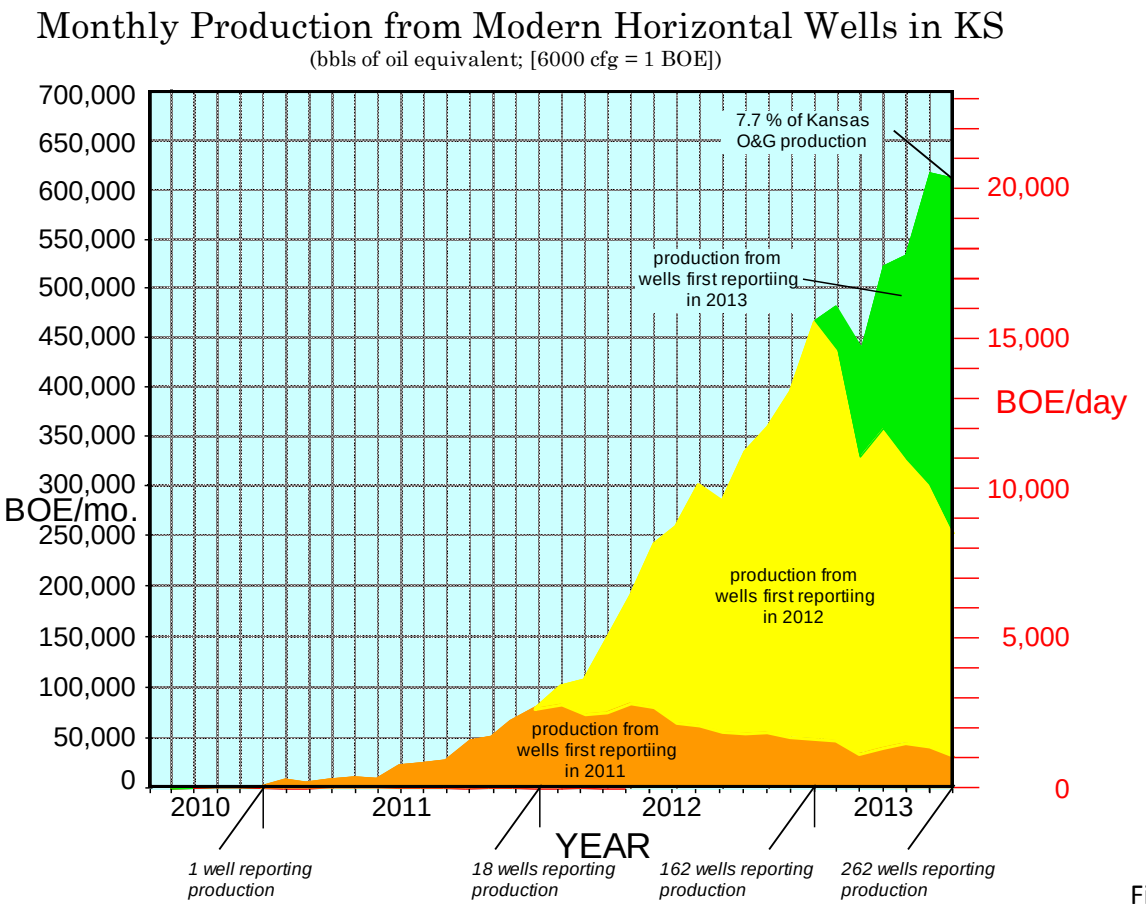


Figure 6 – Production from horizontal wells in the Mississippian Limestone Play in Kansas. 262 wells, 256 of which target the MLP, reported production as of June 2013.

References Cited

Newell, K.D., Watney, W.L., and Gerlach, P., in review, An overview and preliminary economic assessment of horizontal wells drilled in the Mississippian Limestone Play in Kansas, 2010-2012: Kansas Geological Society, Bulletin.

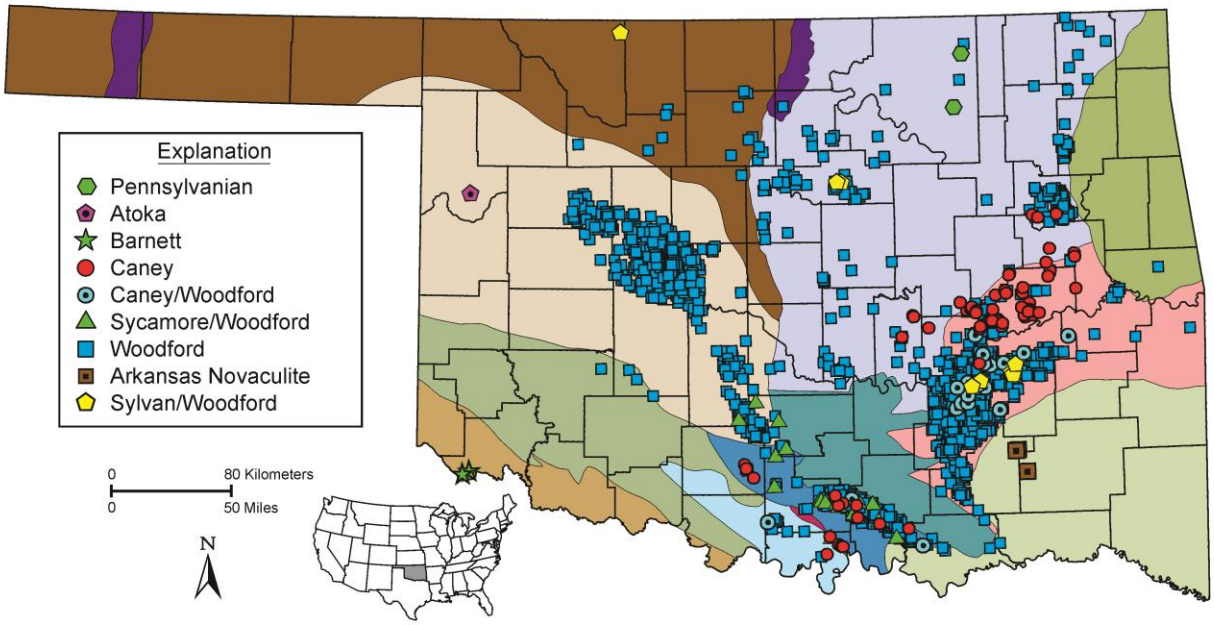
Newell, K.D., and Yoakum, R.L., 2010, Kansas coalbed methane play, *in* Merriam, D.F. (ed.), New Plays and Ways: Kansas Geological Society (Wichita, KS), Kansas Oil and Gas Fields, v. VI, p. 105-128.

Oklahoma Update for Shale Gas/Oil and Coal-Related Projects
By Brian Cardott (Oklahoma Geological Survey)

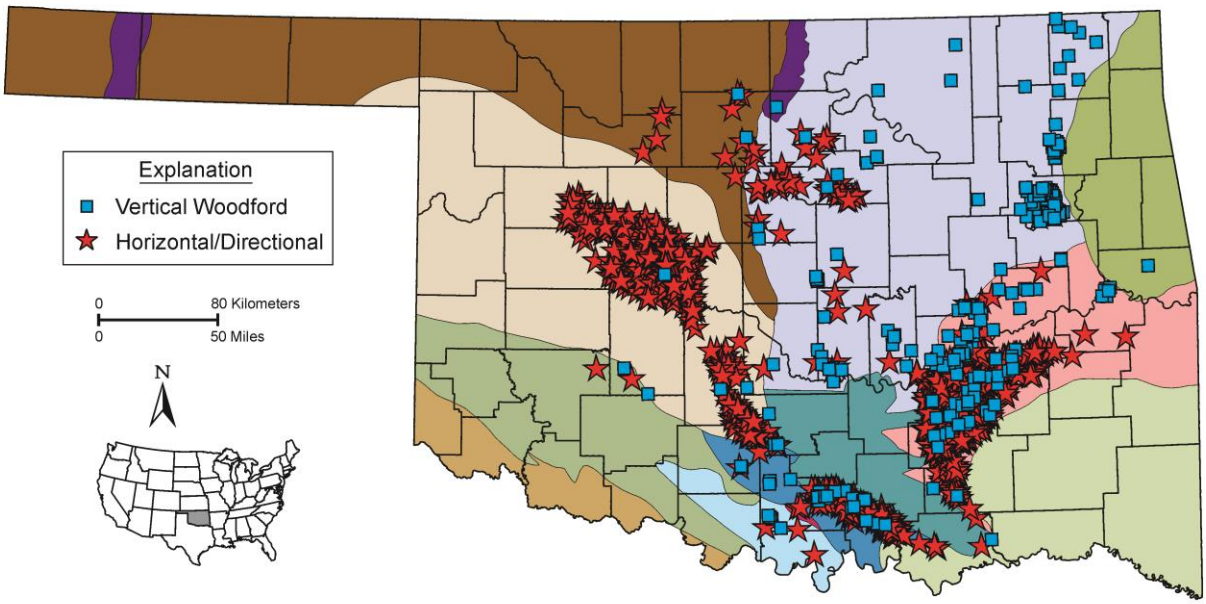
Shale Gas and Oil
The Oklahoma gas shale completions database contains 3,014 wells completed for gas, condensate, and oil in the Woodford Shale (Late Devonian-Early Mississippian), Caney Shale (Mississippian), Barnett Shale (Mississippian), Arkansas Novaculite (Late Devonian-Early Mississippian), Atoka shale (middle Pennsylvanian), Excello Shale/"Pennsylvanian" shale, and Sylvan Shale (Ordovician) in Oklahoma from 1939 to October 2013. From 2004–October 2013, there have been a total of 2,822 Woodford Shale-only well completions (excluding wells commingled with Caney or Sylvan shales). The play has expanded from mainly a thermogenic methane play in the western Arkoma Basin in eastern Oklahoma to include a condensate/oil play in the Anadarko Basin in western Oklahoma and oil plays in the Ardmore Basin in southern Oklahoma and Cherokee Platform in north-central Oklahoma. Of a total of 2,439 horizontal Woodford Shale wells from 2005 to October 2013, initial potential gas rates ranged from a trace to 12,097 thousand cubic feet of gas per day (MCFGPD; average of 2,762 MCFGPD from 2,396 wells) and lateral lengths of 52 to 13,378 ft (average of 3,989 ft from 2,427 wells). A gas shale completions database, lists of references, maps, and several presentations are available on the OGS web site (http://www.ogs.ou.edu/level3-oilgas.php).

The four Woodford shale plays in Oklahoma are as follows:
1) western Arkoma Basin in eastern Oklahoma with thermogenic methane production at thermal maturities from <1% to >3% vitrinite reflectance (VRo) and condensate production up to 1.67% VRo;
2) Anadarko Basin ("Cana" and South Central Oklahoma Oil Province "SCOOP" plays) in western Oklahoma with thermogenic methane production at thermal maturities from 1.1% to >1.6% VRo and oil/condensate production at thermal maturities up to ~1.5% VRo;
3) Ardmore Basin in southern Oklahoma with oil, condensate, and thermogenic methane production at thermal maturities in the oil window (<1.4% VRo);
4) north-central Oklahoma (Cherokee Platform and Anadarko Shelf) with oil and thermogenic methane production at thermal maturities <1.0% VRo.

References
Cardott, B.J., 2012, Thermal maturity of Woodford Shale gas and oil plays, Oklahoma, USA: International Journal of Coal Geology, v. 103, p. 109-119. http://www.sciencedirect.com/science/article/pii/S0166516212001632
Cardott, B.J., 2013, Woodford Shale: From hydrocarbon source rock to reservoir: AAPG Search and Discovery Article 50817, 85 p. http://www.searchanddiscovery.com/documents/2013/50817cardott/ndx_cardott.pdf



Map showing Oklahoma shale gas and shale oil well completions (1939–2013) on a geologic provinces map of Oklahoma.



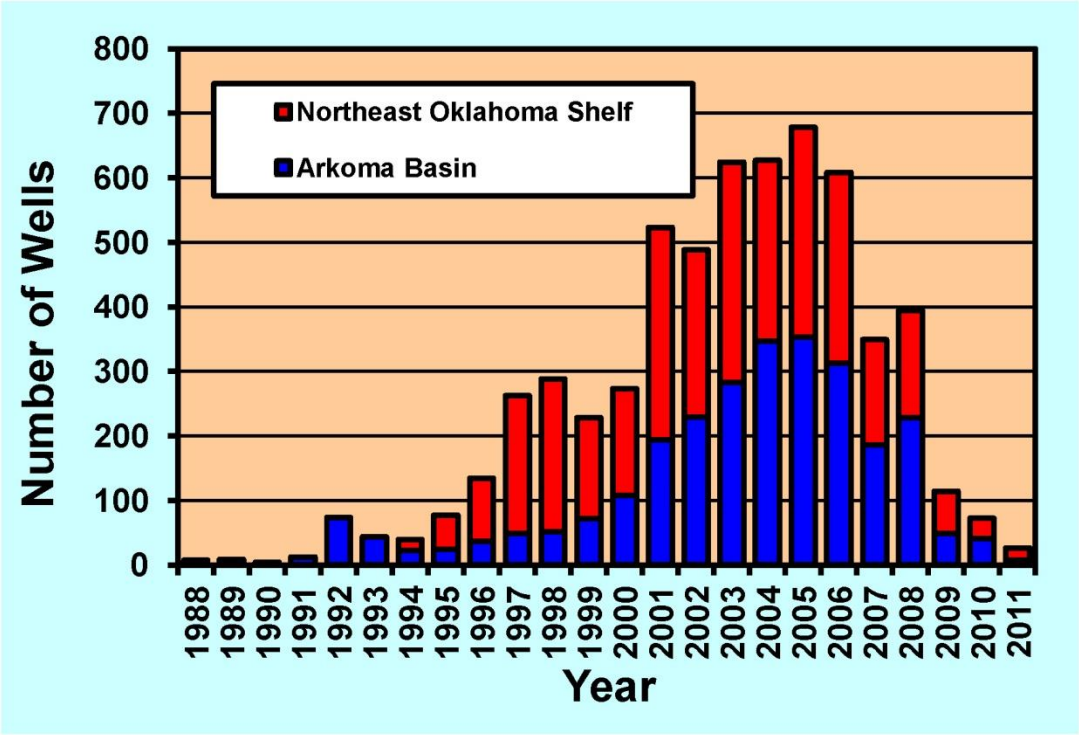
Map showing 2,822 Woodford Shale-only gas and oil well completions (2004–2013) on a geologic provinces map of Oklahoma.

Coalbed Methane

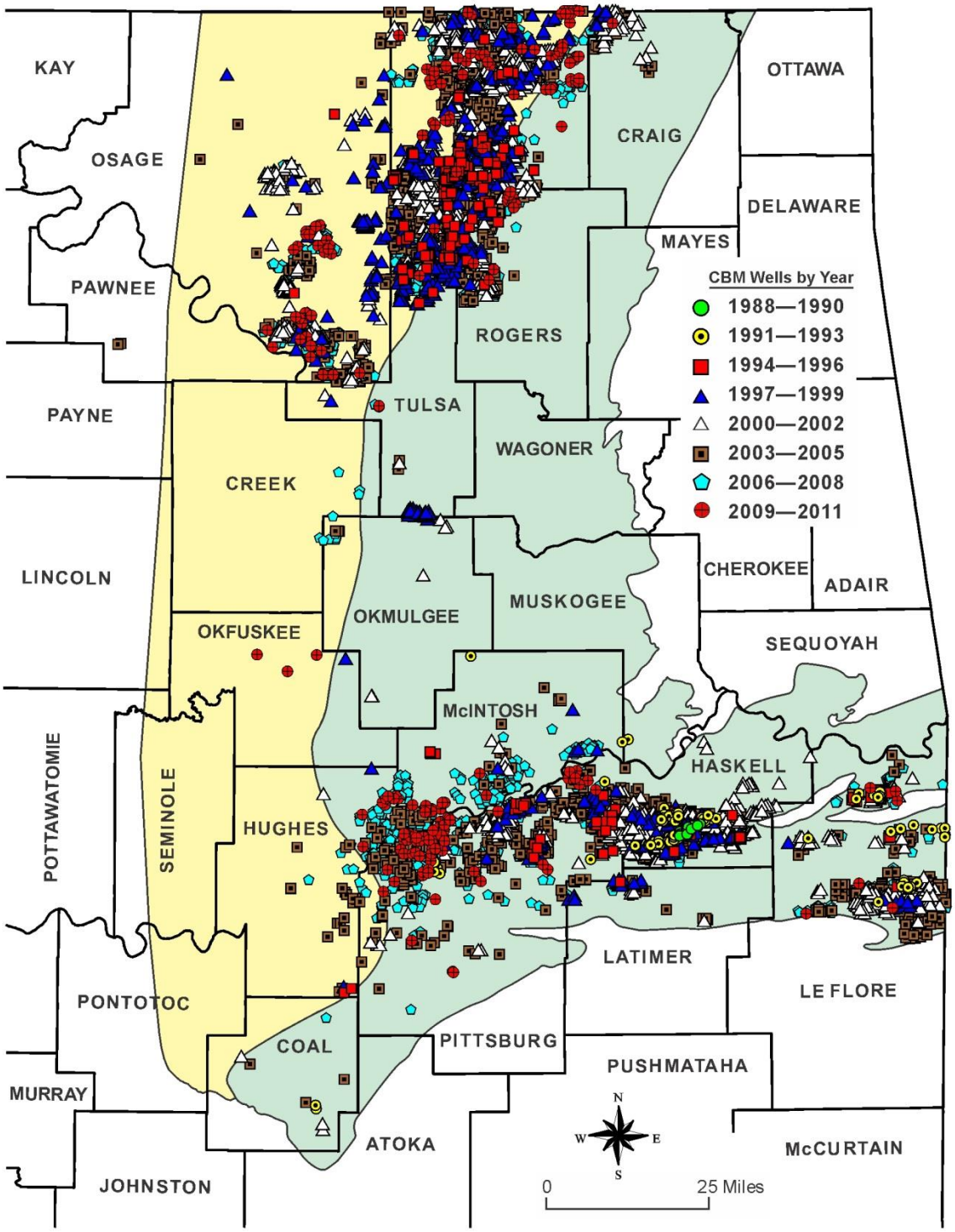
The Oklahoma coalbed-methane completions database contains 5,989 wells from 1988 to October 2013. The completions are from high-volatile bituminous to semianthracite rank coals of Middle Pennsylvanian age in the eastern Oklahoma coalfield from 15 coals in the northeast Oklahoma shelf (3,247 wells) and 5 coals in the Arkoma Basin (2,742 wells; see CBM well completions map below). CBM completions in Oklahoma exceeded 600 wells per year in 2003–2006 with a peak of 678 wells in 2005 (see CBM completions history chart below). Total vertical depths to the top of the uppermost coal ranged from 179–2,962 ft in the shelf and from 42–5,930 ft in the basin. Initial potential gas rates ranged from 0–1,801 MCFD in the shelf and from 0–2,316 MCFD in the basin. In 2012, 3 CBM wells were completed in the northeast Oklahoma shelf and no CBM wells were completed in the Arkoma Basin. There have been no CBM wells completed in Oklahoma during 2013. Presentations, references, illustrations, and the Oklahoma CBM completions database are available at http://www.ogs.ou.edu/coal.php.

Cardott, B.J., 2010, Issues related to Oklahoma coalbed-methane activity, 1988-2008: Oklahoma Geology Notes, v. 70, p. 4-14.

Cardott, B.J., 2013, Hartshorne coal rank applied to Arkoma Basin coalbed methane activity, Oklahoma, USA: International Journal of Coal Geology, v. 108, p. 35-46. http://www.sciencedirect.com/science/article/pii/S0166516211001546



Histogram showing numbers of Oklahoma coalbed-methane well completions, 1988-2011.

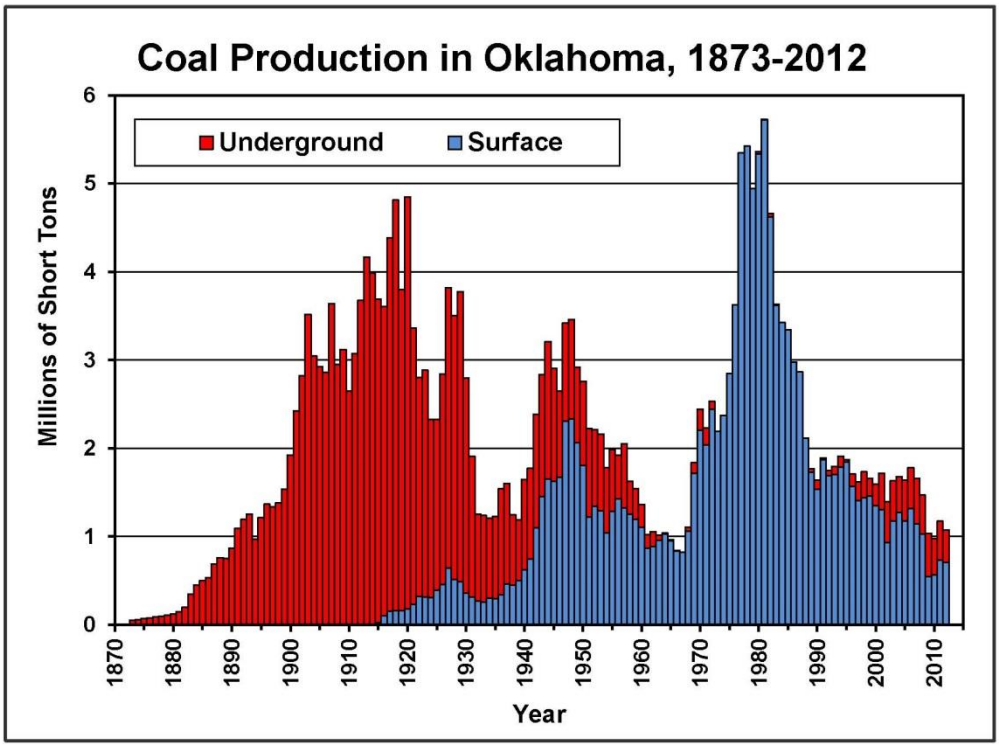


Map showing coalbed-methane well completions in Oklahoma by year (1988-2011).

Coal

From 1873-2012, 296,838,894 short tons of bituminous coal were produced from underground and surface coal mines in the Indian Territory and Oklahoma. Peak annual coal production was 5.73 million short tons in 1981, with smaller production peaks during and immediately following World War I (4,849,288 short tons in 1920) and World War II (3,462,184 short tons in 1948). In 2012, 1,075,070 short tons of bituminous coal were produced in Oklahoma from 8 mines (1 underground, 7 surface).

According to the Energy Information Administration as of January 2012, the Oklahoma coal Demonstrated Reserve Base is 1.542 billion short tons divided into 316 million short tons surface and 1,226 million short tons underground. About 19.4 million short tons of subbituminous coal were imported from Wyoming in 2011 for use in five utility electric power plants. Information on Oklahoma coal (including an updated Hartshorne coal rank map, references, illustrations, and production database) is available at http://www.ogs.ou.edu/coal.php.



Missouri Update for Unconventional Natural Gas and Coal-Related Projects

By:
Christopher Vierrether, RG
Missouri Department of Natural Resources
Missouri Geological Survey
Energy Resources Unit

Missouri Coalbed Natural Gas

Currently, Missouri produces no CBM.

Missouri Coal

Missouri coal production for the period of January through September, 2013 totaled 300,000 tons of coal. The total production is from two pits which comprise the Continental Coal, Inc. Hume No. 1 mine located in southwestern Bates County. A permit for the westward expansion of the original pit was approved in June, 2013. The original pit is expected to cease production in March or April, 2014. At this time, a northward expansion of the west pit is proposed.

The Mulberry Coal is the source of the seam and is mined by stripping methods. All Missouri coal produced to date in 2013 is high volatile A bituminous. The Mulberry Coal is located near the base of the Bandera Shale within the Marmaton Group of Middle Pennsylvanian age.

The majority of the coal produced at the two mines is shipped a short distance to a coal fired power plant in Kansas for electric power generation with a smaller amount shipped to Independence, MO for steam generation. Both sites blend the Missouri coal with sub-bituminous coal from the Powder River Basin in Wyoming.

Arkansas Update for Oil, Natural Gas (Conventional and Unconventional), Coalbed Methane, Coal and Lignite Projects

Peng Li, Arkansas Geological Survey (November 7, 2013)

Arkansas Fayetteville Shale Gas Play

The Upper Mississippian Fayetteville Shale play is the current focus of a regional shale-gas exploration and development program within the central and eastern Arkoma Basin of Arkansas. Approximately 2.5 million acres have been leased in the Fayetteville Shale gas play (Figure 1). Production of thermogenic gas from the Fayetteville began in 2004 and continues to the present.

U.S. Energy Information Administration (EIA) reports in 2011 that the Fayetteville contains 31.96 TCF of technically recoverable gas resource, in which 27.32 TCF is attributable to the core producing area (aka eastern area) and 4.64 TCF for the uncore producing area (aka western area). EIA also reports that the proved gas reserves of the Fayetteville Shale in 2010 is 12.526 TCF, 3.456 TCF of increase from the 2009 estimates. Estimated ultimate recovery (EUR) for a typical horizontal Fayetteville gas well increases from 1.8 BCF in 2008 to 3.2 BCF in 2011 (OGJ, 2012). Estimated cumulative production of gas from the Fayetteville Shale as of August 2013 has totaled 4,309,085,031 MCF from 4,977 wells. For the first eight months of 2013, Fayetteville Shale zone has yielded 682,484,366 MCF dry gas. Annual production of Fayetteville Shale for 2012 is 1,027,711,866 MCF from 4,434 wells. The daily production has amounted to 2.6 BCF in 2012. Initial production rates of horizontal wells have recently averaged about 3,136 MCF/day. Notably, even in the face of the challenging gas price environment in 2011 and 2012, production from the Fayetteville continued to grow at a fast clip, increasing by over 21% since January 2011. For more Fayetteville Shale production information, please refer to the Arkansas Oil and Gas Commission (AOGC) web link at http://www.aogc.state.ar.us/Fayprodinfo.htm.

Like other dry gas plays, the Fayetteville has seen a dramatic decline in its rig count. According to Baker Hughes (BHI), the number of gas-directed rigs active in the play has dropped from 33 rigs in February 2011 to just 13 rigs in December 2012. The continued production growth, in spite of the sharply lower rig count, is explained by the truly remarkable gains in rig productivity and operating efficiencies as the transition towards the full development mode in many areas is beginning to bear fruit. In 2013, Southwestern Energy projects to drill its average well in just 6.5 days, re-entry to re-entry, compared to 11 days in 2010. The comparison is even more impressive given that the average length of the lateral is expected to increase by over 10%.

Fayetteville Shale reports from the AOGC have noted well increases from 24 in 2004, 33 in 2005, 129 in 2006, 428 in 2007, 587 in 2008, 839 in 2009, and 874 in 2010. Since then the numbers of new completed wells declined in two consecutive years, with 829 in 2011 and 675 in 2012. As of August 2013, there are a total of 4,840 producing gas wells in the Fayetteville Shale play. Most Fayetteville Shale wells are drilled horizontally and have been fracture stimulated using slickwater or cross-linked gel fluids. Baker

Hughes' FracPoint Multi-stage fracturing system has provided most of the hydraulic fracturing completions in the Fayetteville Shale. Completed lateral length has increased 82% over the last four years while holding total well costs flat at about $ 2.8 million. Horizontal wells drilled from 2010 to 2012 averaged 5,600 feet in lateral length with some wells up to 8,000 feet. Fayetteville Shale gas production generally ranges over a depth between 1,500 to 6,500 feet. The thickness of Fayetteville Shale varies from 50 feet in the western portion of the Arkoma Basin of Arkansas (fairway area) to 550 feet in the central and eastern regions (primary producing area).

Since the play's inception, the Fayetteville Shale play has been dominated by a small number of large players. As of 2013, three operators -- Southwestern, Exxon Mobil and BHP Billiton -- accounted for over 99% of gross operated production from the field. The three companies hold close to 2 million net acres under lease in the play. Southwestern, with 925,000 net acres and about three thousand operated wells drilled as of August 2013, is by far the largest operator among the three companies, and accounts for about two-thirds of the field's total production volume. Exxon and BHP are approximately equal in terms of their acreage and gross operated production.

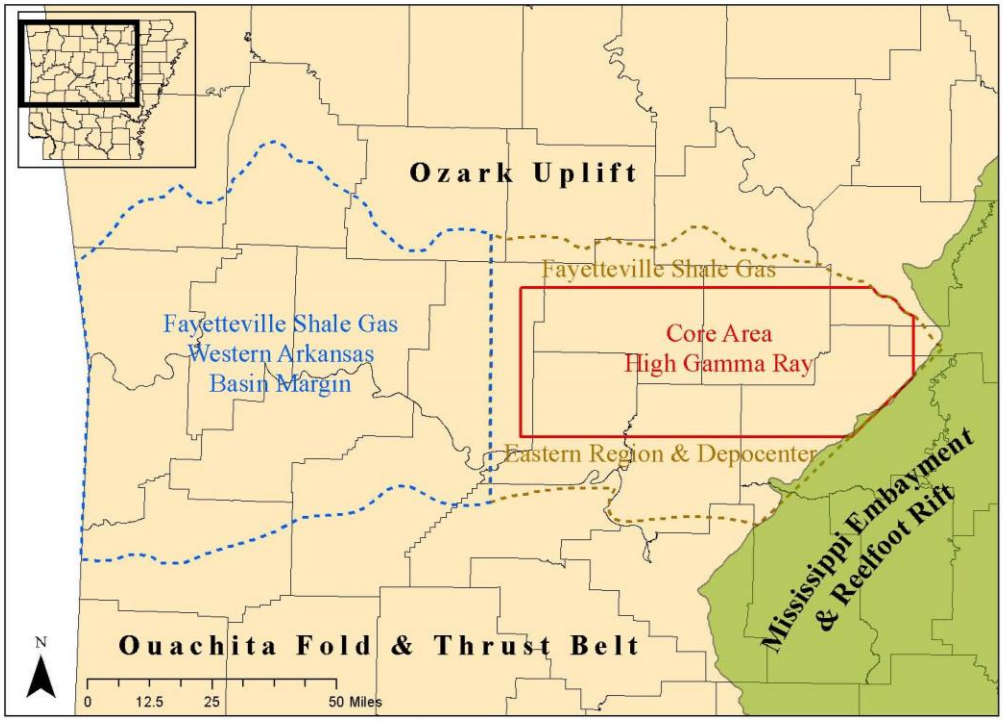


Figure 1. Primary area of the Fayetteville Shale exploration and development in Arkansas.

The top three operators of the Fayetteville gas shale play as of August 2013 based on numbers of producing wells are as follows (Figure 2):

1) SEECO Inc. (an exploration subsidiary of Southwestern Energy) (3,062 wells)
2) BHP Billiton Petroleum (951 wells)

3) XTO Energy, Inc. (a subsidiary of ExxonMobil) (786 wells)

Two different maps are available that illustrate the location and types of wells located in the Fayetteville Shale producing area. Web links for the Fayetteville Shale maps and the associated federal and state agencies are listed below:

(1) The home page of the Arkansas Geological Survey (AGS) website is: http://www.geology.arkansas.gov/home/index.htm and the AGS Fayetteville Shale well location maps can be viewed at http://www.geology.arkansas.gov/home/fayetteville_play.htm. AGS updates these maps and associated well database (in Excel® format) online every two weeks.

(2) The home page of the U.S. Energy Information Administration (EIA) website is: http://www.eia.doe.gov/ and the EIA Fayetteville Shale map is available at http://www.eia.doe.gov/pub/oil_gas/natural_gas/analysis_publications/maps/maps.htm.

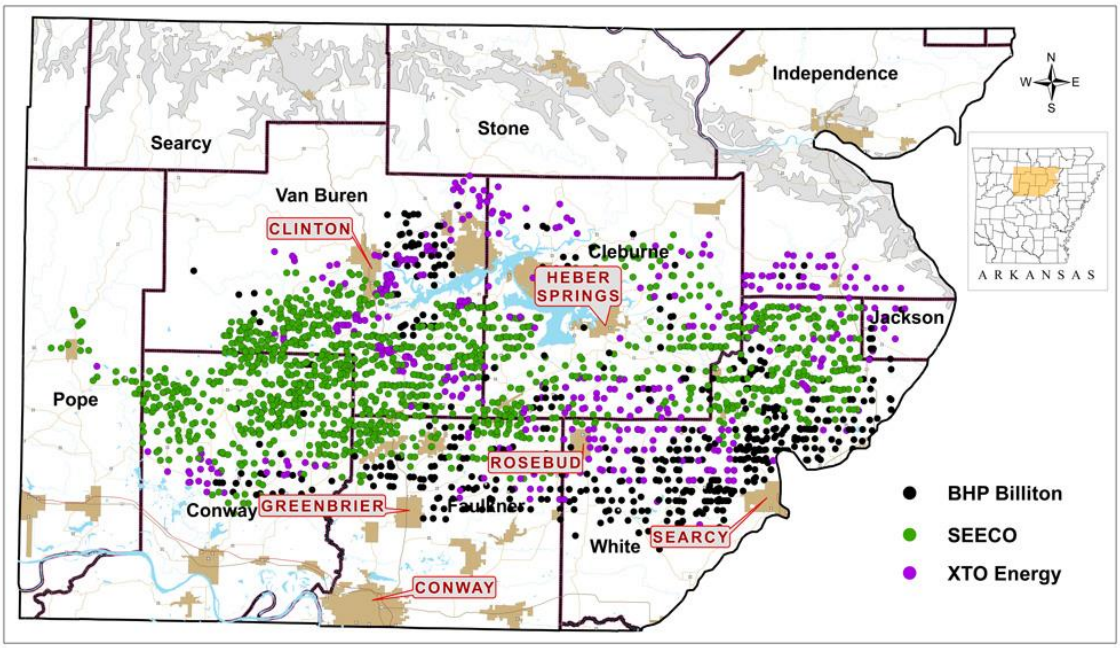


Figure 2. Location map of the Fayetteville Shale producing wells by top 3 operators as of August 2013.

Disposal of production well wastewater through injection wells has gradually mounted a concern in the Fayetteville Shale play area given thousands of recent area earthquakes. Most of the seismic events have been too small to be felt, and a majority of the epicenters form a northeast-southwest trending linear feature near the towns of Guy and Greenbrier in Faulkner County. These earthquakes have become known as the Guy-Greenbrier Swarm. It was recently discovered that the Guy-Greenbrier Swarm earthquakes occurred along and illuminate a previously unknown sub-surface fault, the

Guy-Greenbrier Fault, located near the disposal wells. The fault, nearly 7.5 miles long, could theoretically generate an earthquake of around 6.0 in magnitude. In January 2011, the AOGC imposed a six-month moratorium on new injection wells in a portion of the Fayetteville Shale production area to determine what relationship, if any, there is between the wastewater injection and the earthquakes. The quakes intensified during the last two weeks of February 2011, culminating with a 4.7-magnitude earthquake near Greenbrier on February 27, 2011, the most powerful reported seismic event in Arkansas in 35 years. AOGC held a special meeting on March 4, 2011 to issue an emergency order immediately shutting down all injection operations of two disposal wells through the last day of the regularly scheduled hearing in March 2011. At the March 2011 hearing, AOGC ordered the companies to continue the cessation of all injection operations of these two wells for a period of an additional sixty days. During the July 2011 hearing, the AOGC requested an immediate and permanent moratorium on any new or additional disposal wells or disposal well permits in the moratorium area (Figure 3). At the time of the hearing, there were four disposal wells within the moratorium area, including the two wells that were shut down since March 2011. The frequency of the quakes within the moratorium area saw a significant decrease, about 75%, since the cessation of the injection operation of the disposal wells. This, in turn, gave more evidence to confirm a potential relationship between the injection activities and the earthquakes. Geohazards geologists at the AGS that monitor the earthquakes in the state provide the relevant information to the public and the AOGC.

Concerns about the effect of Fayetteville gas exploration and production on public heath, air, water and land are increasing with the spread of hydraulic fracturing technology that is utilized in well completions. Expanded production and potential environmental impacts have increased the need for additional regulations related to all aspects of exploration and production. Arkansas joins Wyoming as the only states that require the full disclosure of all chemical constituents in all frac fluids and additives on a well-by-well basis and the release of these reports to the public. The AOGC's Rule B-19 (available on the AOGC website), which also protects the trade secrets behind proprietary compounds, went into effect January 15, 2011. AOGC also issued a revised surface casing and production casing cementing requirements for all Fayetteville Shale wells. All operators of such wells since June 1, 2011 are required to set surface casing to a depth equal to 500 feet below the lowest ground surface elevation occurring within 1 mile of the proposed well, with a minimum of 1000 feet of surface casing to be set and cemented to surface. In addition, cement shall be circulated to the surface on all production casings, so as to isolate from all strata encountered in the wellbore above the Fayetteville Shale horizon.

AGS has completed two extensive geochemical research projects on the Fayetteville Shale and has provided this information to the oil and gas industry and the public to assist with exploration and development projects. These studies are available at the Arkansas Geological Survey as Information Circular 37 (Ratchford et. al., 2006) and Information Circular 40 (Li et al., 2010) and integrate surface and subsurface geologic information with organic geochemistry and thermal maturity data.

The AGS continues to partner with the petroleum industry to pursue additional Fayetteville Shale related research. Ongoing AGS research is focused on the chemistry and isotopic character of produced gases, mineralogy of the reservoir, and outcrop to basin modeling.

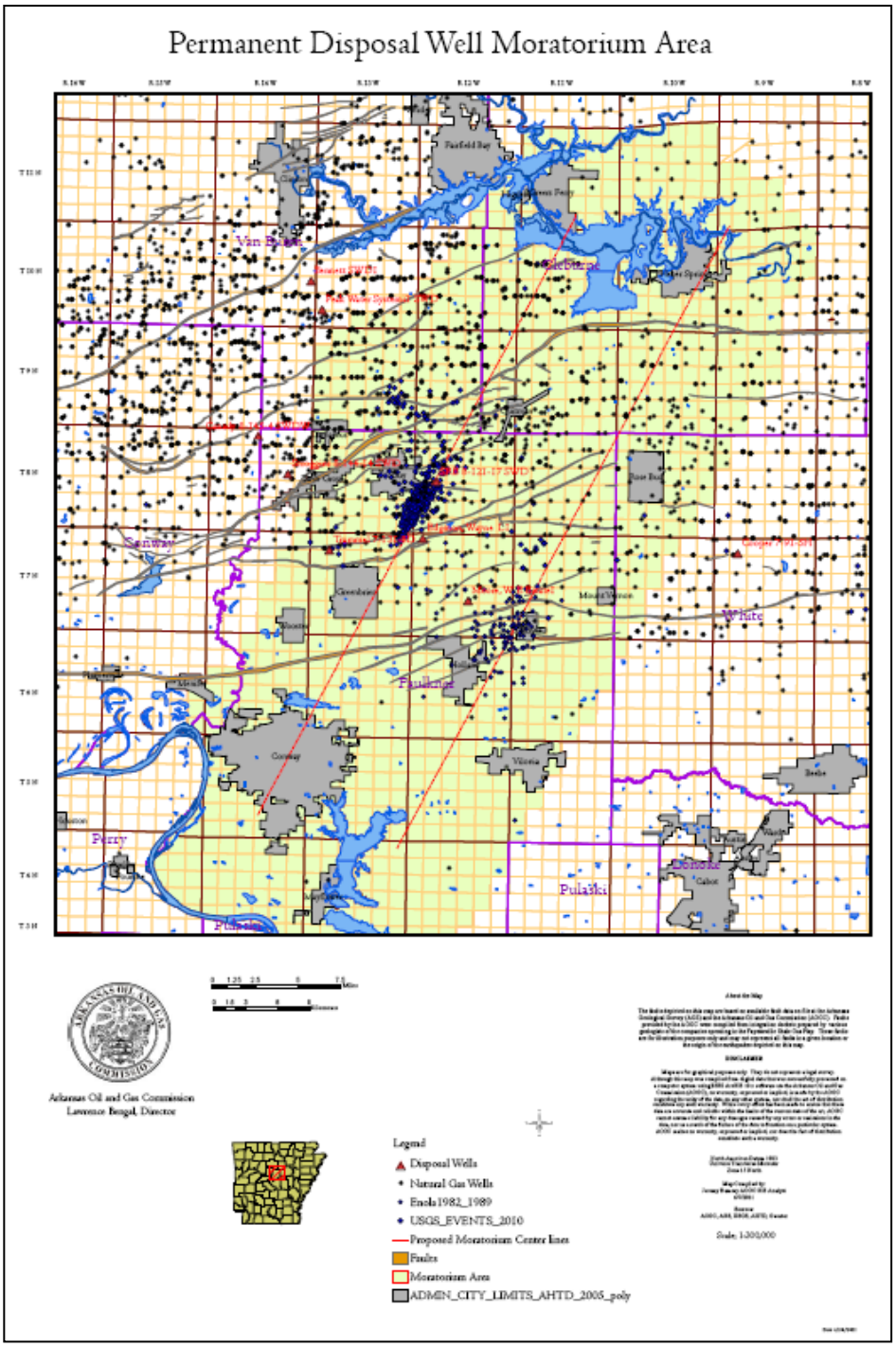


Figure 3. Permanent moratorium area for disposal wells in the Fayetteville Shale Play, Arkansas (from the AOGC website).

Arkansas Coalbed Natural Gas

The development of Arkansas's coalbed natural gas resources began in 2001 and has yielded an approximate cumulative production of 25,051,043 mcf from 58 wells as of July 2013. Sales of CBM for the first seven months of 2013 are 970,340 mcf from 55 wells. EnerVest Operating LLC acquired all CMB wells in 2009 from CDX Gas LLC, who was previously the only producer of this resource in Arkansas until it filed bankruptcy in late 2008. Another active operator, Ross Exploration Inc., has commenced CBM production in Arkansas since 2009 and possesses 3 producing wells to date. Most of producing wells are Z-pinnate horizontal wells. The wells are completed in the Pennsylvanian Lower Hartshorne Coal and over 560,000 feet of horizontal lateral has been drilled in Arkansas. On average, approximately 15,000 feet of horizontal lateral is drilled for each of CDX's Z-pinnate wells in the Lower Hartshorne Coal. The Arkansas Geological Survey routinely updates a map which reflects producing and permitted horizontal and vertical coalbed natural gas wells and can be downloaded from the AGS website at:
http://www.geology.ar.gov/maps_pdf/fossilfuels/CSNG%20Lower%20Hartshorne%20Coal.pdf

North Arkansas Conventional Gas Resources

The western Arkoma Basin of Arkansas has long been a gas producing province with the bulk of the production coming from a stacked succession of Pennsylvanian sandstone reservoirs. Production of conventional gas for the first seven months of 2013 is 60,348,900 mcf from 4,004 wells. Cumulative production in the Arkoma basin for all conventional gas wells and tight gas sands of the B-44 producing region (not including the Fayetteville Shale gas) is approximately 6.79 tcf from 5,833 wells. Figure 4 illustrates that gas production has had some modest increases since the mid 1980s with a sharp increase in production in 2005 that is mostly associated with development of the Fayetteville Shale resource.

Oil & Associated Gas Production

South Arkansas oil production for January through August 2013 is 4,781,185 bbls with corresponding associated gas production of 7,634,059 mcf. Cumulative oil production in the south Arkansas as of August 2013 is 1,868,124,579 bbls. Figure 5 and Figure 6 illustrate that oil and associated gas production has been steadily declining in recent years but the level of production may stabilize as energy prices have made it more attractive to maintain marginal wells that would otherwise be plugged and abandoned.

Arkansas Coal

The Pennsylvanian coal fields of west-central Arkansas are located in the Arkoma basin and encompass approximately 1,700 square miles of low volatile bituminous to semi-anthracite coal. Arkansas annual surface coal (low volatile bituminous) production for 2012 is 1,921 tons by the Henry Comer Mining Company. Annual underground coal production is 127,577 tons from the Hartford Coal Mine, which is operated by Shriram Sebastian LLC. The Hartford Coal Mine has been temporarily shut down since January 2013 due to improvements that are necessary to the wash plant, and is scheduled to

resume operation in early May 2013. Ouro Mining Inc. acquired eight coal leases totaling approximately 7,734 acres across the border of Oklahoma and Arkansas, from

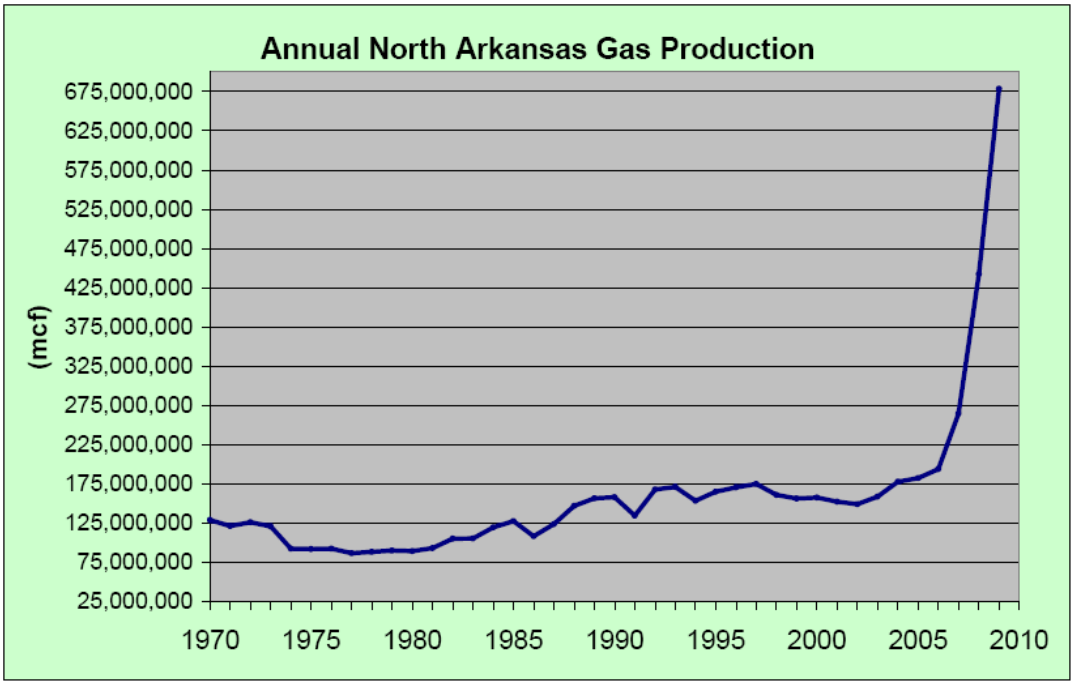


Figure 4. Annual gas production of north Arkansas.

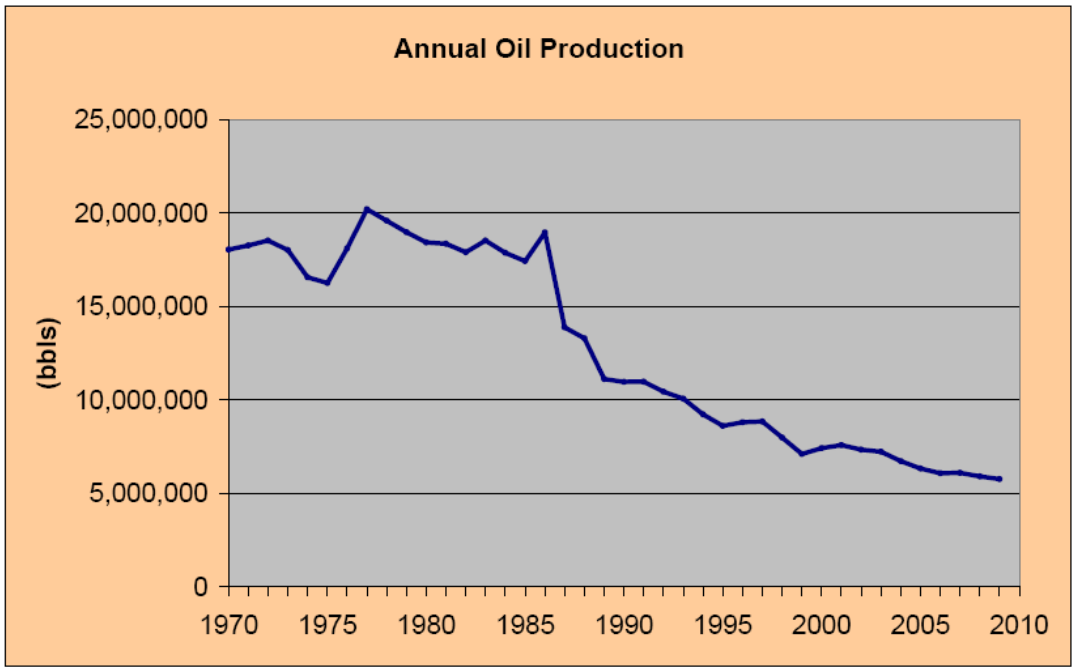


Figure 5. Annual oil production of south Arkansas.

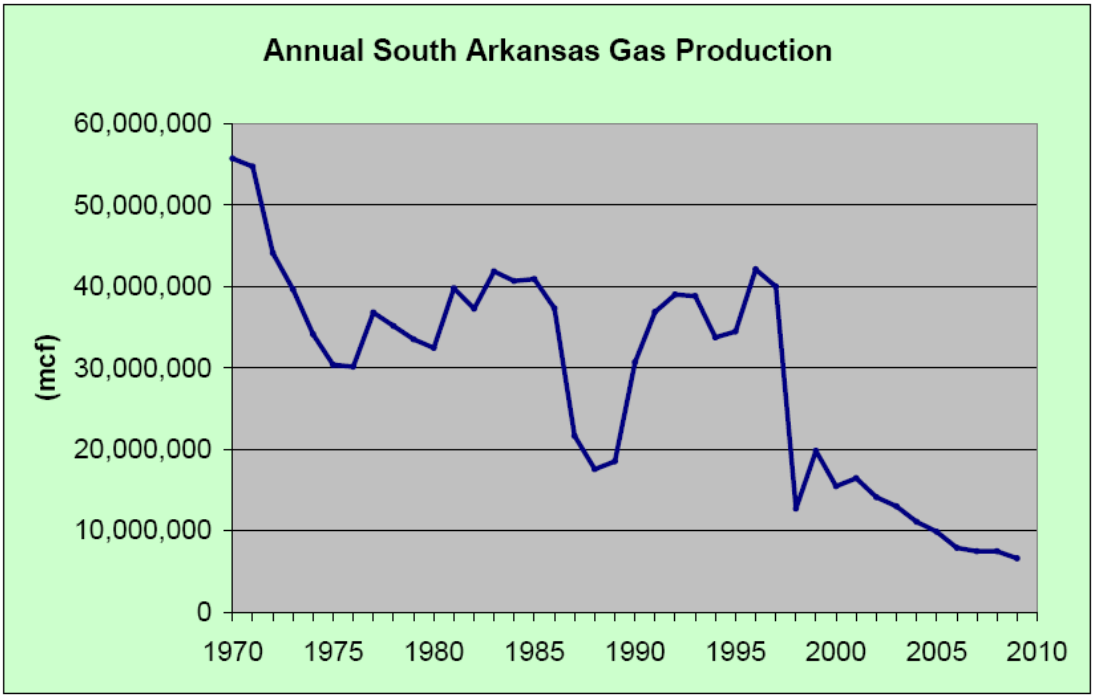
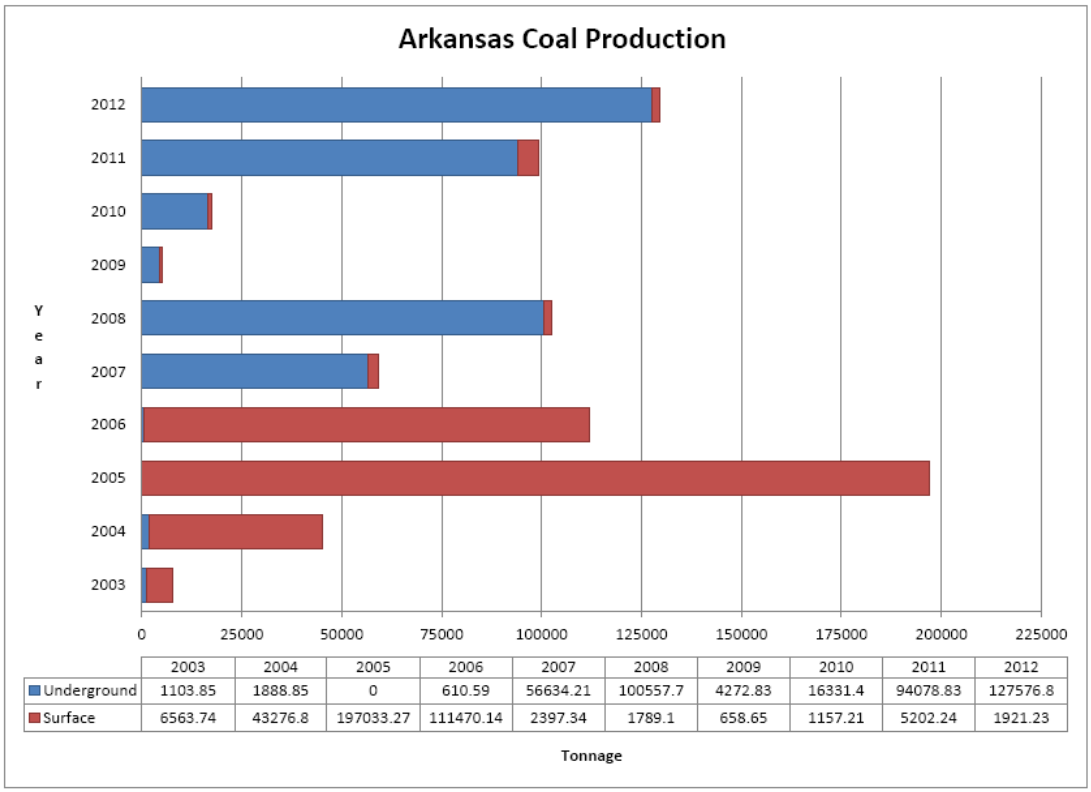


Figure 6. Annual production of associated gas of south Arkansas.



	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Underground	1103.85	1888.85	0	610.59	56634.21	100557.7	4272.83	16331.4	94078.83	127576.8
Surface	6563.74	43276.8	197033.27	111470.14	2397.34	1789.1	658.65	1157.21	5202.24	1921.23

Figure 7. Annual coal production of Arkansas.

the west in the Heavener region of Le Fore County, OK to the east in the Bates region of Scott County, AR. The surface mining title has been permitted due to recent open cut mining by the previous owner, Farrell Cooper Mining Company. The underground mining permit application is underway. According to the company's investor presentation in March 2013, Ouro has begun the procurement and construction work in 2013 and is expected to commence production in the second quarter of 2014. Figure 7 shows the coal production trend since 2003.

Lignite Research and Proposed Commercial Testing for Liquid Fuels Production

The Arkansas Geological Survey (AGS) has provided multiple presentations to the Joint Energy Committee of the Arkansas Legislature and recommended an accelerated synfuels research program on the State's lignite resources. During the last 10 years, legislation was introduced in two separate bills by the Arkansas House of Representatives to support the commercial testing of Arkansas lignite, but funding for both pieces of legislation failed.

Lignite is distributed throughout the Gulf Coastal Plain of southern Arkansas (Figures 8 and 9)**.** Lignite resources in the United States have primarily been used for electrical power generation. However, the unique physical properties of lignite permit this resource to be converted easily to petroleum by-products such as liquid transportation fuels.

Consequently, lignite could be considered as a low-cost alternative to conventional development of crude oil and thus facilitate the increasing demand for liquid transportation fuels. The three Tertiary formations in Arkansas containing lignite are, listed from oldest to youngest as: the Wilcox Group, the Claiborne Group and the Jackson Group. Lignite within the Wilcox and Claiborne Groups are considered the primary economic targets owing to their inherent physical and chemical characteristics for fuel production.

The AGS has conducted research on Arkansas' lignite resources since the mid-1970s and has estimated that approximately nine (9) billion tons of lignite resources (suspected but unproven) are present within 150 feet of the surface throughout the Gulf Coastal Plain of Arkansas.[i] A series of industry reports published by The Ozarks Regional Commission (1980) indicates that over four (4) billion tons of lignite reserves (technically recoverable) are presently delineated in Arkansas[ii].

Lignite is virtually untapped within the state and represents an enormous energy asset that could be developed and utilized for the economic benefit of all Arkansans. Our neighboring states of Mississippi, Louisiana and Texas continue to develop their lignite resources which, in turn, are creating high paying jobs and additional revenue sources for their states.

Given the current national focus on utilization of clean coal technologies (CCT) and carbon capture with sequestration (CCS), it is imperative that the lignite resources of Arkansas are properly evaluated and tested so that the best development options can

be identified and selected. For example, coal gasification is the chemical conversion of coal to a gaseous state which permits the easy removal of natural pollutants contained in the lignite. The end product, called syngas, is a mixture of carbon dioxide, hydrogen and carbon monoxide. Syngas is burned in conventional natural gas turbines to generate electrical energy. Coal gasification units also offer unique flexibility in that the syngas can be chemically converted to liquid fuels for use in transportation vehicles (indirect coal liquefaction). Alternatively, direct liquefaction is yet another proven technique whereby lignite is converted directly to a syncrude liquid product by chemical methods without gasification. The direct liquefaction approach is attractive because it is less expensive, has higher yields and fewer emissions.

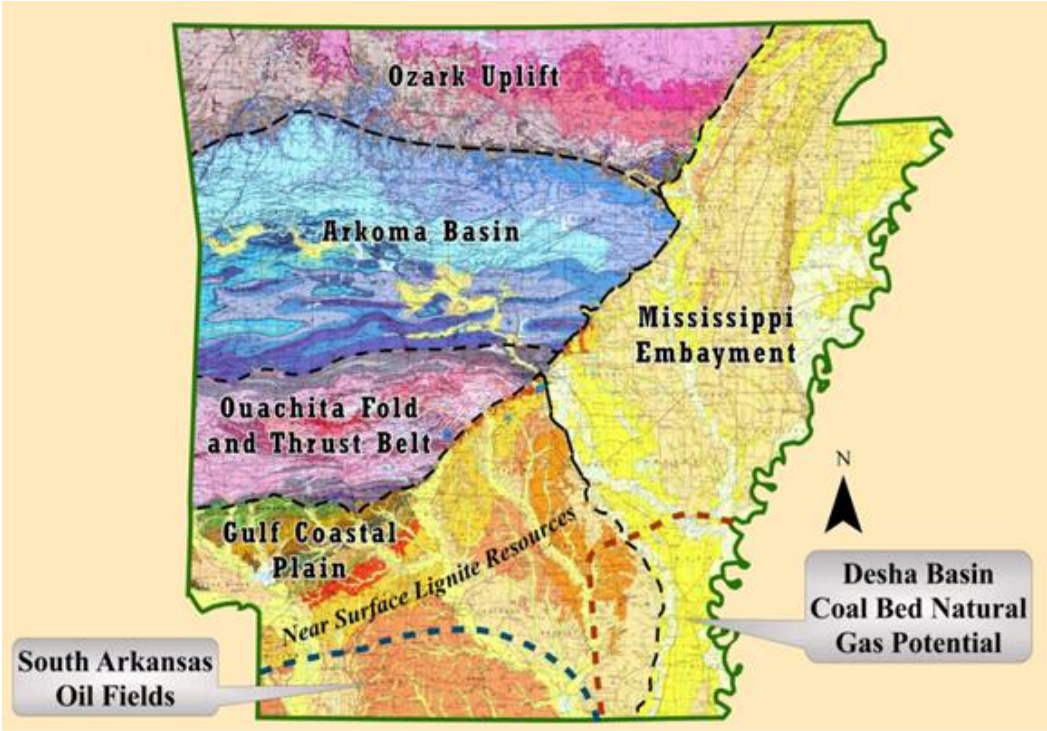


Figure 8. Geologic map and provinces in Arkansas.

The AGS staff indicates that gasification or direct liquefaction processes are likely the best economic and environmental alternative for developing the lignite resources of south Arkansas and will result in a permanent industry that supports hundreds of high-paying jobs.

Technological advances today permit the extraction of Arkansas' lignite resources in a manner which is consistent with environmentally sound goals. Lignite mining and reclamation practices are proven techniques in Texas, Louisiana, Mississippi and North Dakota, and these practices have demonstrated that areas mined for lignite can be restored to productive forest and/or pasture lands. In Arkansas, the lignite reserves represent an important, viable energy resource and feedstock for liquid fuels production,

and could boost the state's economy while simultaneously reducing our national dependency on foreign oil imports.

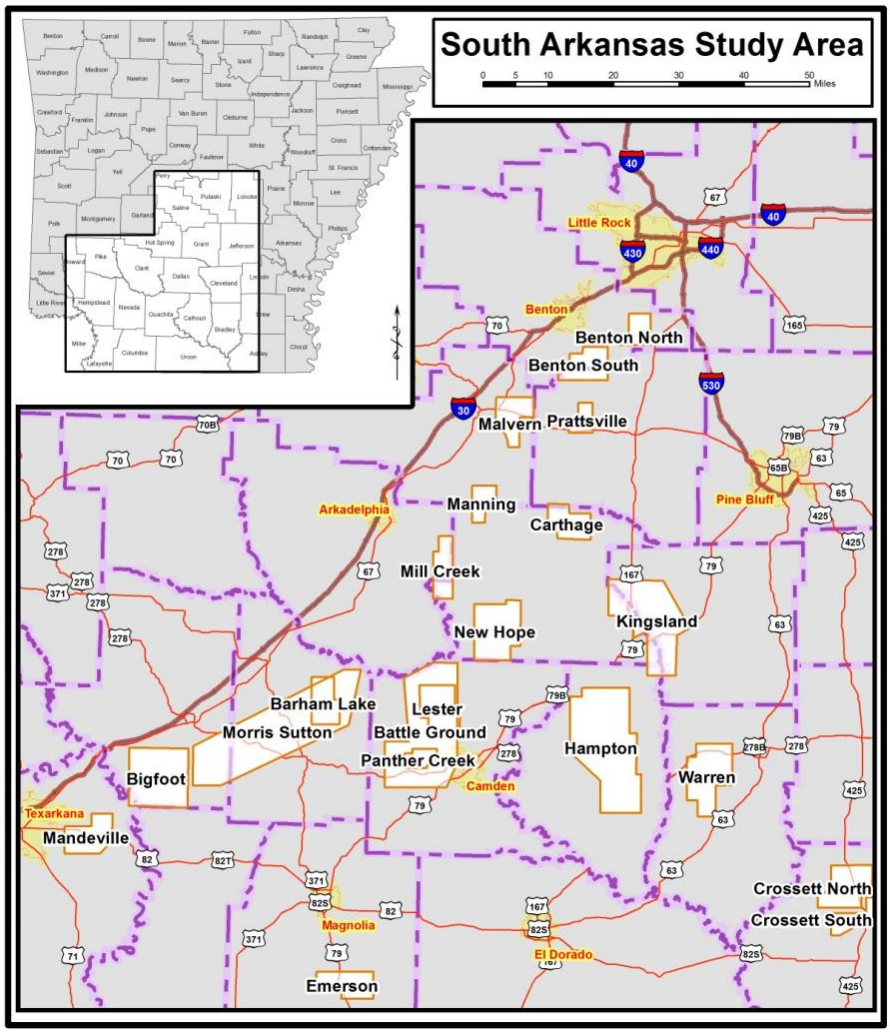


Figure 8. Lignite investigation map in south Arkansas.

[i] Prior, W.L, Clardy, B.F., Baber, Q.M., 1985, Arkansas Lignite Investigations, Information Circular 28-C, Arkansas Geological Commission

ii The Ozarks Regional Commission, (1980) Lignite Research Agenda – Final Report, prepared by Synergic Resources Corporation, Arkansas State Library, Little Rock, YC. 099\8-3:5)