AAPG Energy Minerals Division Mid-Continent Report
December, 2014

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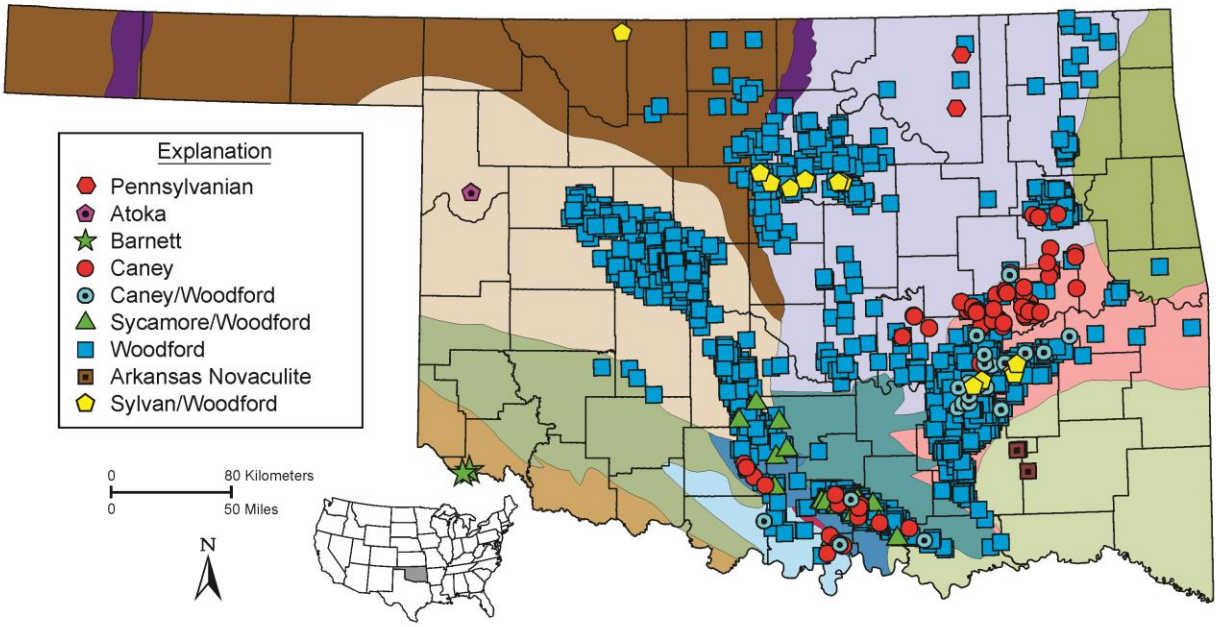
Oklahoma Update for Shale Gas/Oil and Coal-Related Projects
By Brian Cardott (Oklahoma Geological Survey)

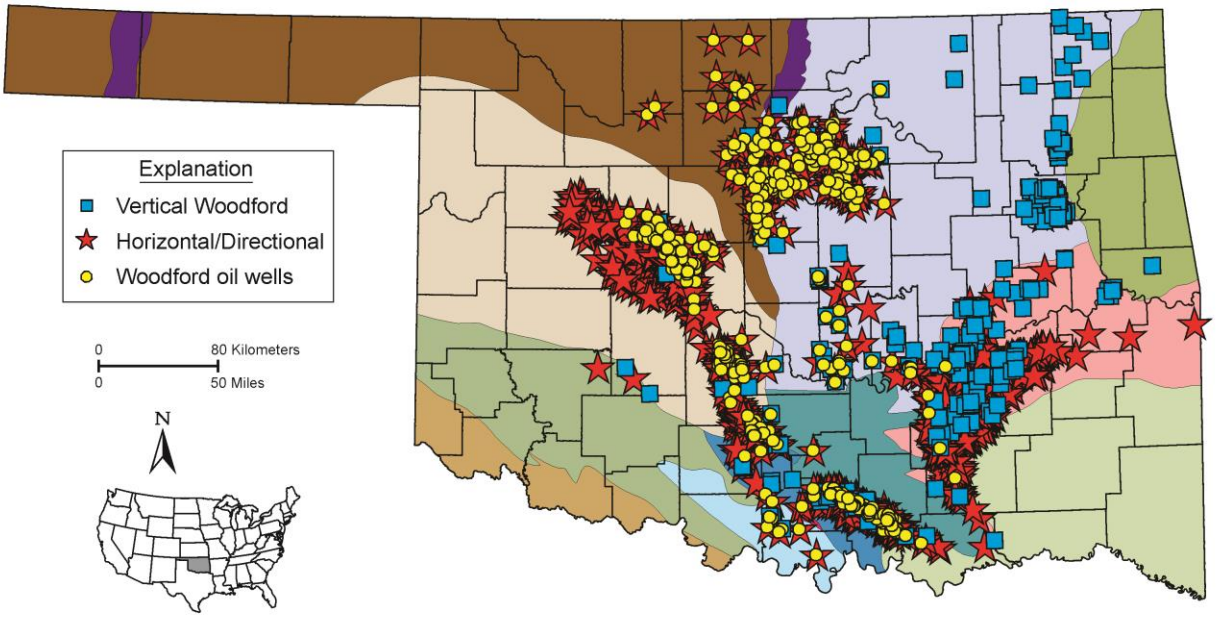
Shale Gas and Oil
The Oklahoma oil and gas shale completions database contains 3,650 wells completed for gas, condensate, and oil in the Woodford Shale (Late Devonian-Early Mississippian), Caney Shale (Mississippian), Barnett Shale (Mississippian), Goddard Shale (Mississippian), Arkansas Novaculite (Late Devonian-Early Mississippian), Atoka shale (middle Pennsylvanian), Excello Shale/"Pennsylvanian" shale, and Sylvan Shale (Ordovician) in Oklahoma from 1939 to November 2014. From 2004–November 2014, there have been a total of 3,443 Woodford Shale-only well completions (excluding wells commingled with Caney, Mississippian Limestone 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 3,037 horizontal Woodford Shale wells from 2005 to September 2014, initial potential gas rates ranged from a trace to 16,680 thousand cubic feet of gas per day (MCFGPD; average of 2,577 MCFGPD from 2,989 wells) and lateral lengths of 3 to 13,378 ft (average of 4,173 ft from 3,025 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).

XTO Energy, BNK Petroleum US, and Continental Resources completed 7 and 5 Caney Shale wells in 2013 and 2014, respectively, in southern Oklahoma. Initial potential oil or condensate (oil gravity of 45 to 54 API degrees) rates ranged from 11 to 523 barrels per day. Initial potential gas rates ranged from 201 to 2,801 thousand cubic feet per day. During 2013-2014, 13 Goddard Shale ("lower Springer shale") wells were completed in Grady and Stephens counties by Continental Resources and Newfield Exploration. Initial potential oil or condensate (oil gravity of 43 to 50 API degrees) rates ranged from 203 to 1,658 barrels per day.

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.
Cardott, B.J., 2013, Woodford Shale: From hydrocarbon source rock to reservoir: AAPG Search and Discovery Article 50817, 85 p.
Cardott, B.J., 2014, Woodford Shale play update: Expanded extent in the oil window: AAPG Search and Discovery Article #80409, 51 p. http://www.searchanddiscovery.com/pdfz/documents/2014/80409cardott/ndx_cardott.pdf.html



Map showing Oklahoma shale gas and shale oil well completions (2004–2014Q2) on a geologic provinces map of Oklahoma.



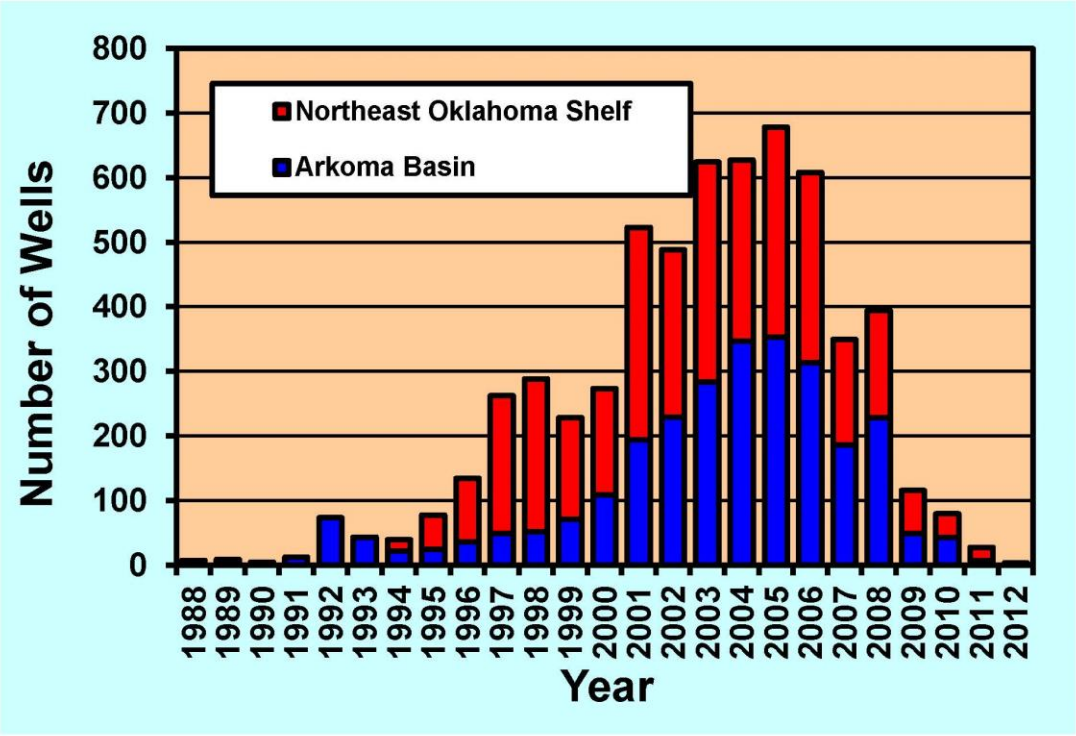
Map showing 3,327 Woodford Shale-only gas and oil well completions (2004–2014Q2) on a geologic provinces map of Oklahoma.

Coalbed Methane

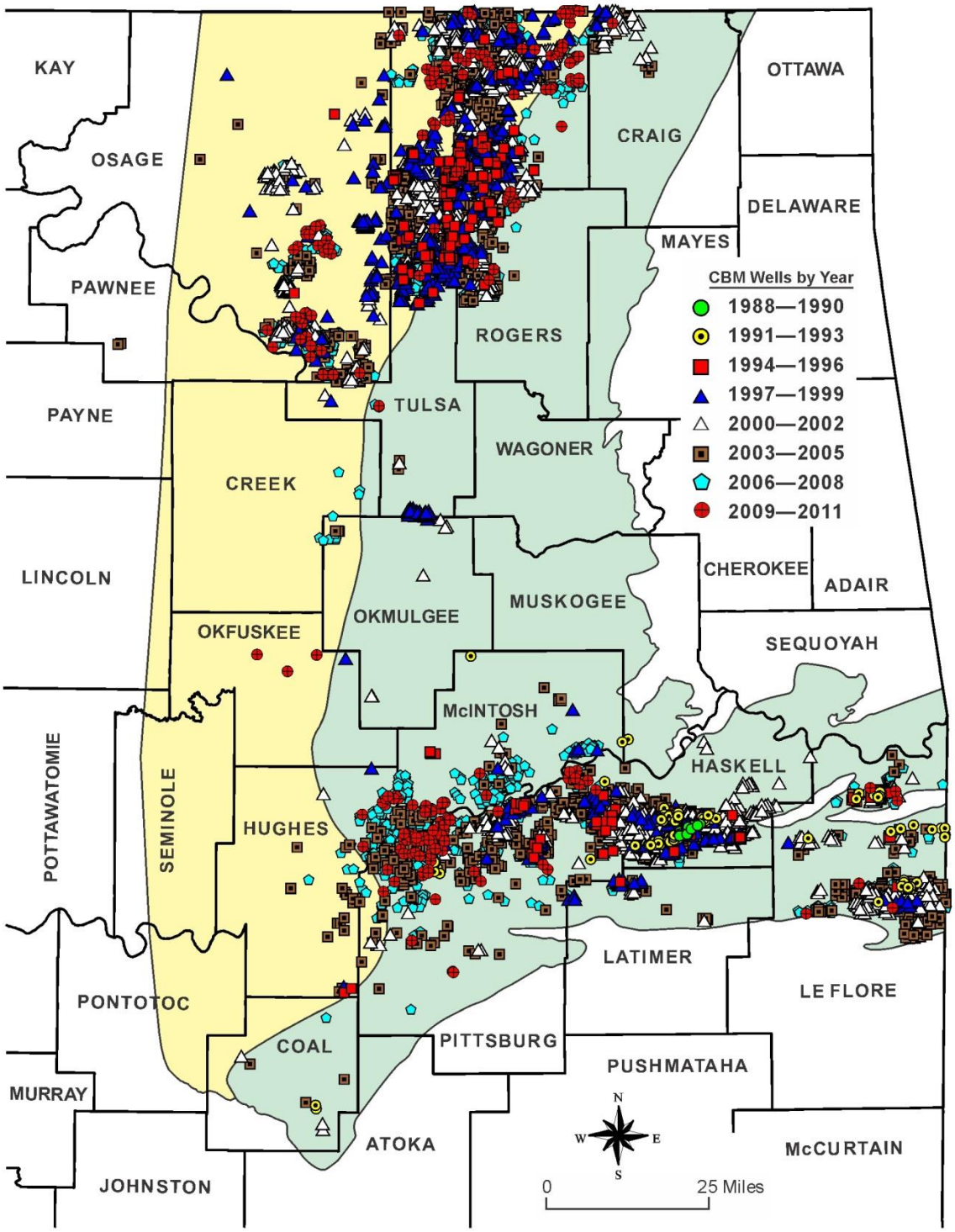
The Oklahoma coalbed-methane completions database contains 6,000 wells from 1988 to November 2014. The completions are from high-volatile bituminous to semianthracite rank coals of Middle Pennsylvanian age in the eastern Oklahoma coalfield from 15 coals in the northeast Oklahoma shelf (3,258 wells) and 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 were no CBM wells completed in Oklahoma during 2013. There were two CBM wells completed in Nowata County in northeastern Oklahoma during 2014. 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.



Histogram showing numbers of Oklahoma coalbed-methane well completions, 1988-2012.

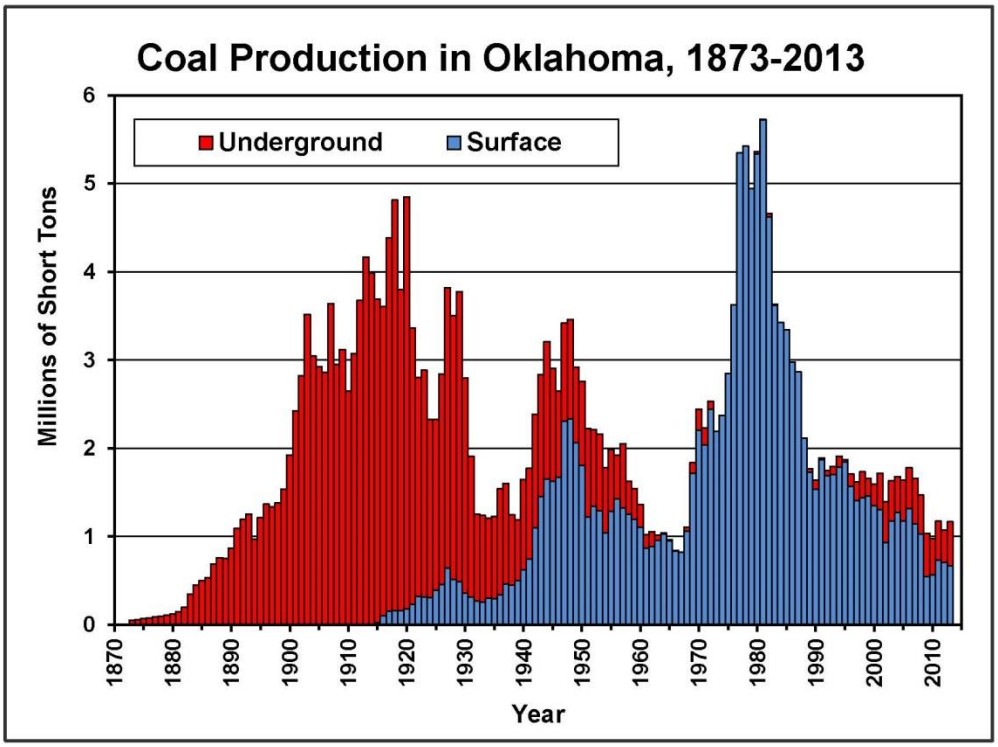


Map showing coalbed-methane well completions in Oklahoma by year (1988-2011).

Coal

From 1873–2013, 296,840,061 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 2013, 1,167,208 short tons of bituminous coal were produced in Oklahoma from 9 mines (1 underground, 8 surface).

According to the Energy Information Administration as of January 2013, the Oklahoma coal Demonstrated Reserve Base is 1.540 billion short tons divided into 315 million short tons surface and 1,225 million short tons underground. About 18.6 million short tons of subbituminous coal were imported from Wyoming in 2012 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.



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

By Peng Li, Arkansas Geological Survey

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 2013 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). A study by the Bureau of Economic Geology at the University of Texas at Austin found the play holds 38 tcf in technically recoverable resources, of which a cumulative18 tcf is economically recoverable reserves by 2050 (OGJ, 2014). EIA also reports that the proved gas reserves of the Fayetteville Shale in 2012 is 9.7 Tcf, 5.1 Tcf of decrease from the 2011 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).

According to the Arkansas Oil and Gas Commission data, estimated cumulative production of gas from the Fayetteville Shale as of August 2014 has totaled 5,338,918,079 Mcf from 5,454 wells. Annual production of Fayetteville Shale for 2013 is 1,029,622,918 Mcf from 4,883 wells, at the same level as 2012. Thirty-day initial production rates of horizontal wells have recently averaged about 4.4 MMcf/day. 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 9 rigs in November 2014. 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. Since 2013, Southwestern Energy has drilled 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 increased by 14% from 4,532 feet in 2010 to 5,165 feet in 2013.

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 three consecutive years, with 829

in 2011, 675 in 2012, and 557 in 2013. As of August 2014, there are a total of 5,454 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. The average cost to drill and complete a Fayetteville well for Southwestern Energy is expected to be $2.6 million in 2014. 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).

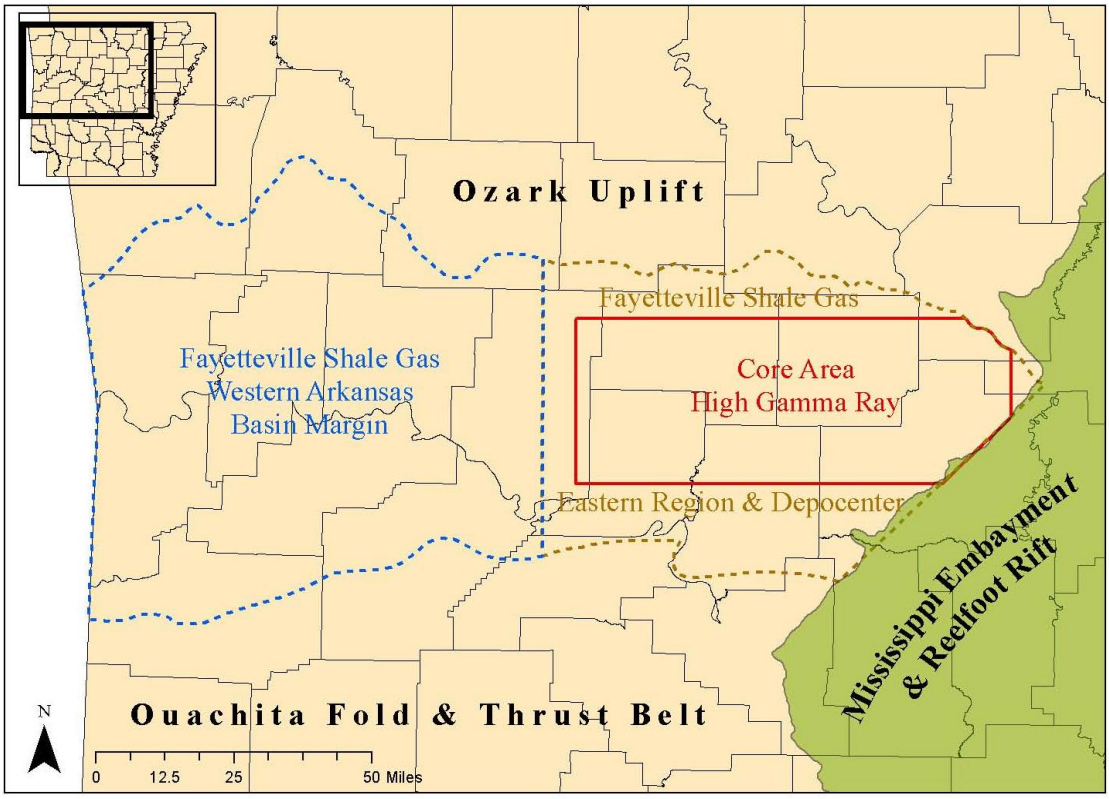


Figure 1. Primary area of the Fayetteville Shale exploration and development in Arkansas.

Since the play's inception, the Fayetteville Shale play has been dominated by a small number of large players. Three operators – Southwestern Energy, BHP Billiton, and XTO Energy (a subsidiary of Exxon Mobil) -- 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 906,000 net acres and more than three thousand producing wells, 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. During 2012, Southwestern contributed 724.8 Bcf in Fayetteville gas sales, good for 70.3% of the play's total sales that year. BHP sold 155.7 Bcf (15.1%) and XTO Energy sold 147.9

Bcf (14.3%). The remaining 0.3% of sales, or 2.4 Bcf, was spread out among nine companies.

The top three operators of the Fayetteville gas shale play as of August 2014 based on numbers of producing wells are as follows (Figure 2):

1) SEECO Inc. (an exploration subsidiary of Southwestern Energy) (3,564 wells)
2) BHP Billiton Petroleum (967 wells)
3) XTO Energy, Inc. (a subsidiary of ExxonMobil) (841 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.

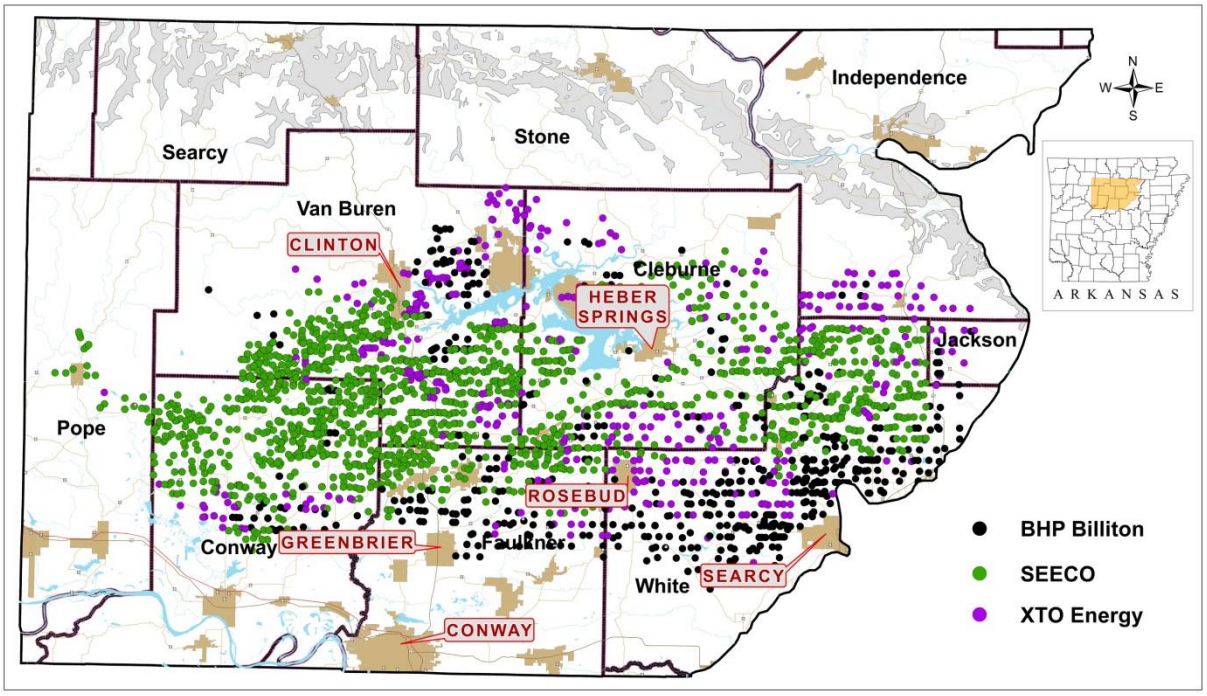


Figure 2. Location map of the Fayetteville Shale producing wells by top 3 operators as of August 2014.

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.

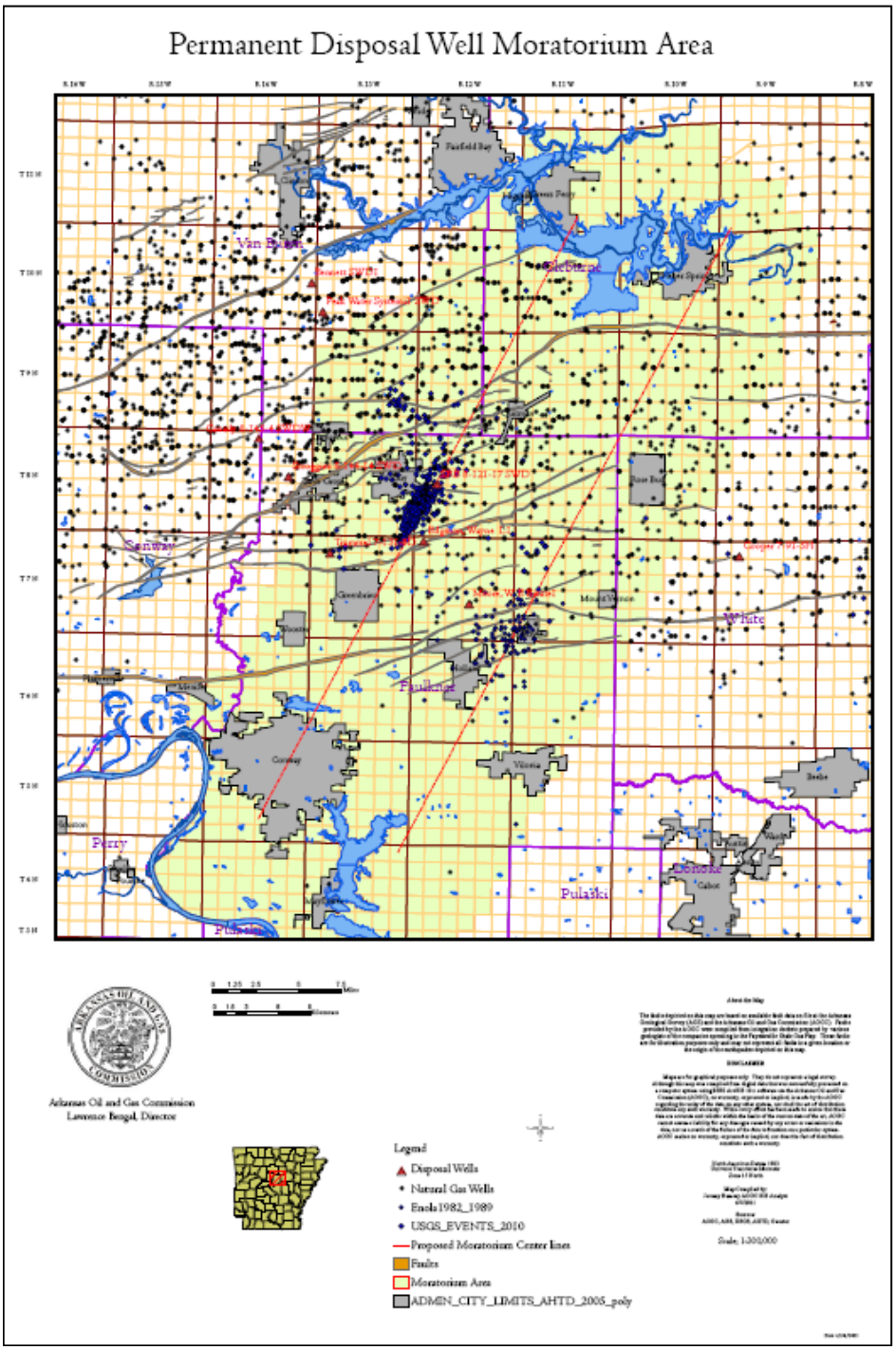


Figure 3. Permanent moratorium area for disposal wells in the Fayetteville Shale Play, Arkansas (from the AOGC website).

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.

Arkansas Coalbed Natural Gas

The development of Arkansas's coalbed natural gas resources began in 2001 and has yielded an approximate cumulative production of 26,663,586 Mcf from 58 wells as of August 2014. Sales of CBM for 2013 are 1,636,828 Mcf from 54 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 2013 is 101,846,663 Mcf from 4,037 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) as of August 2014 is approximately 6.87 Tcf from 5,815 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 2013 is 6,686,243 bbls with corresponding associated gas production of 11,108,536 Mcf. Cumulative oil production in the south Arkansas as of August 2014 is 1,874,010,012 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.

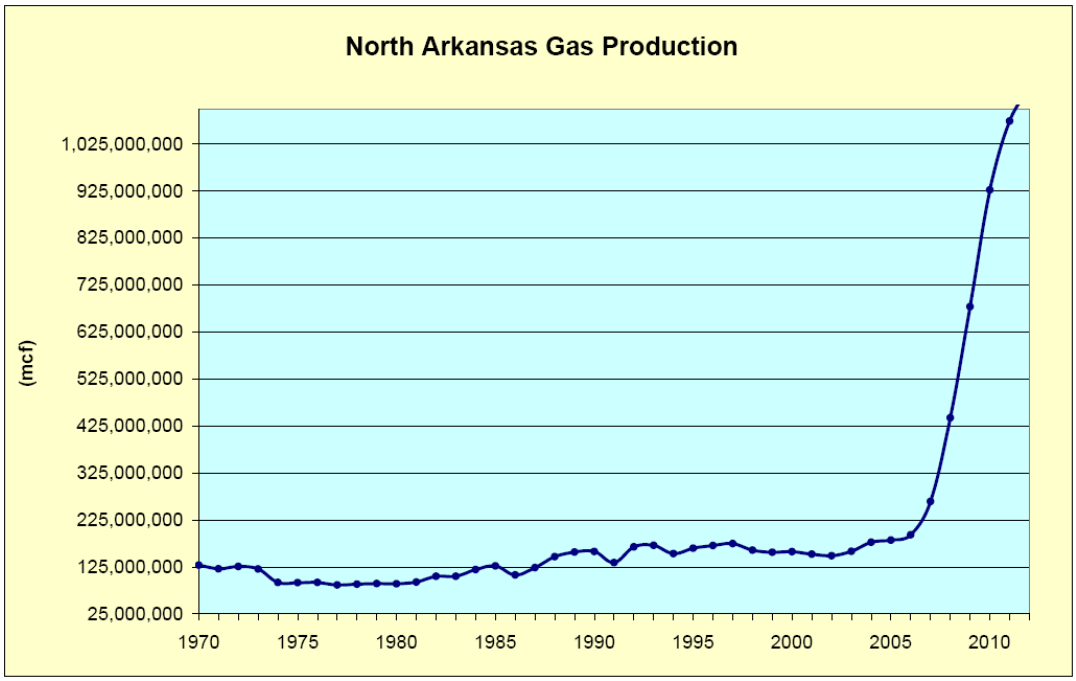


Figure 4. Annual gas production of north Arkansas.

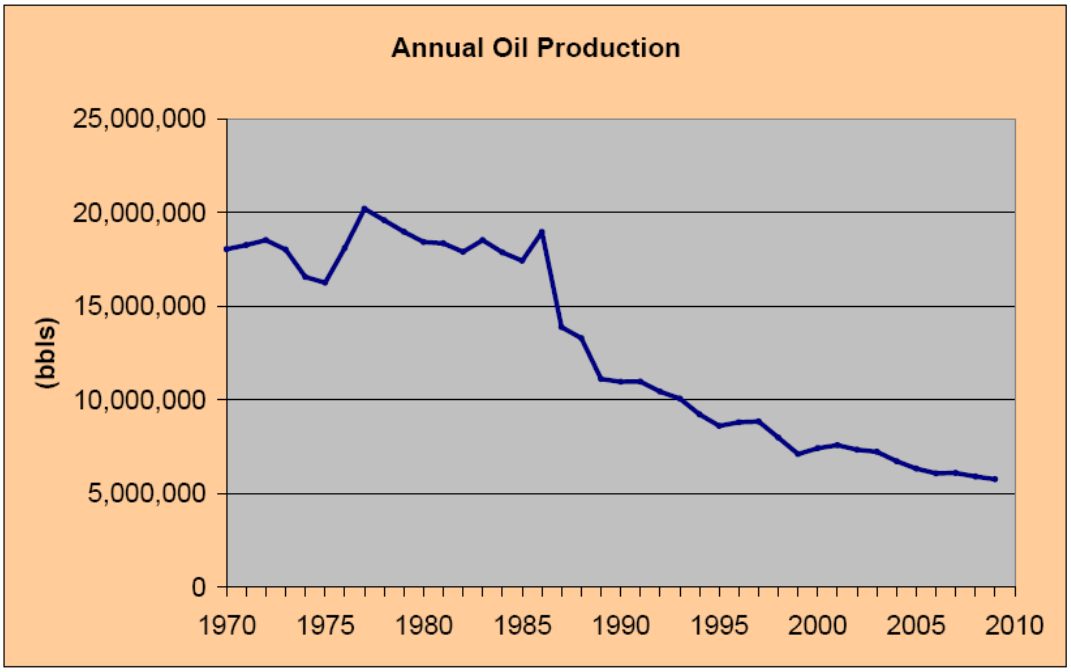


Figure 5. Annual oil production of south Arkansas.

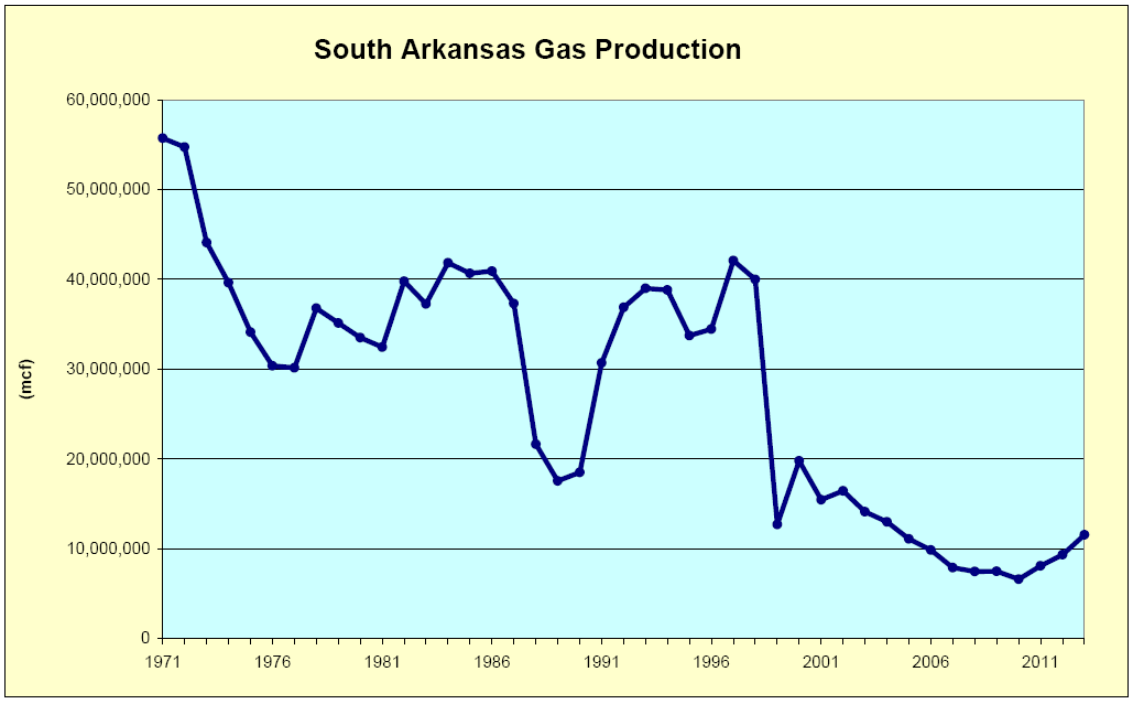
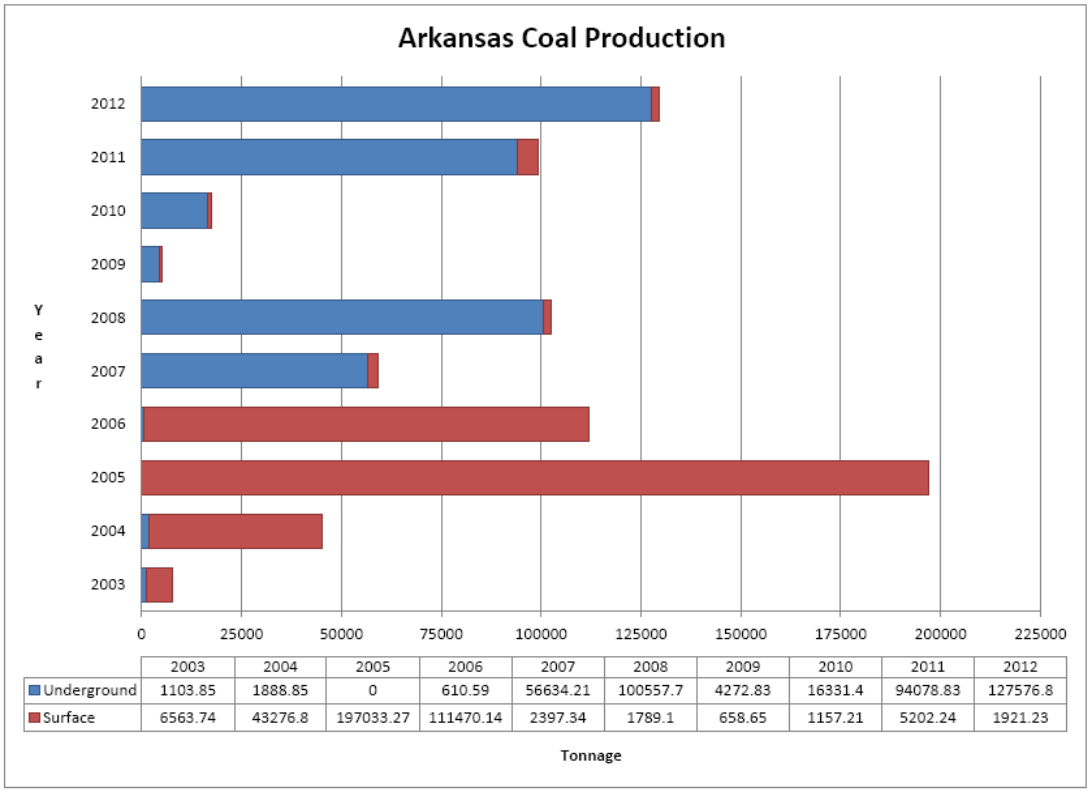


Figure 6. Annual production of associated gas of south Arkansas.

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 2013 is 3,873 tons by the Henry Comer Mining Company. Annual underground coal production in 2013 is 36,963 tons from the Hartford Coal Mine, which is operated by Shriram Sebastian LLC. The Hartford Coal Mine was temporarily shut down in 2013 due to improvements that are necessary to the wash plant, which caused the appreciable decline of production compared with 127,577 tons in 2012. Ouro Mining Inc. has initiated the Heavener coking coal project and acquired six coal leases, totaling approximately 27.72 square kilometers stretching from Heavener, Le Fore County, OK to Bates, Scott County, AR. This lease area is estimated to contain approximately 65 million tons of proven and probable coal reserves and resources in the Lower Hartshorne seam. 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. Ouro has begun the procurement and construction work in 2013 and is expected to commence production in 2015. Figure 7 shows the coal production trend since 2003.



	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.

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. 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.

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.

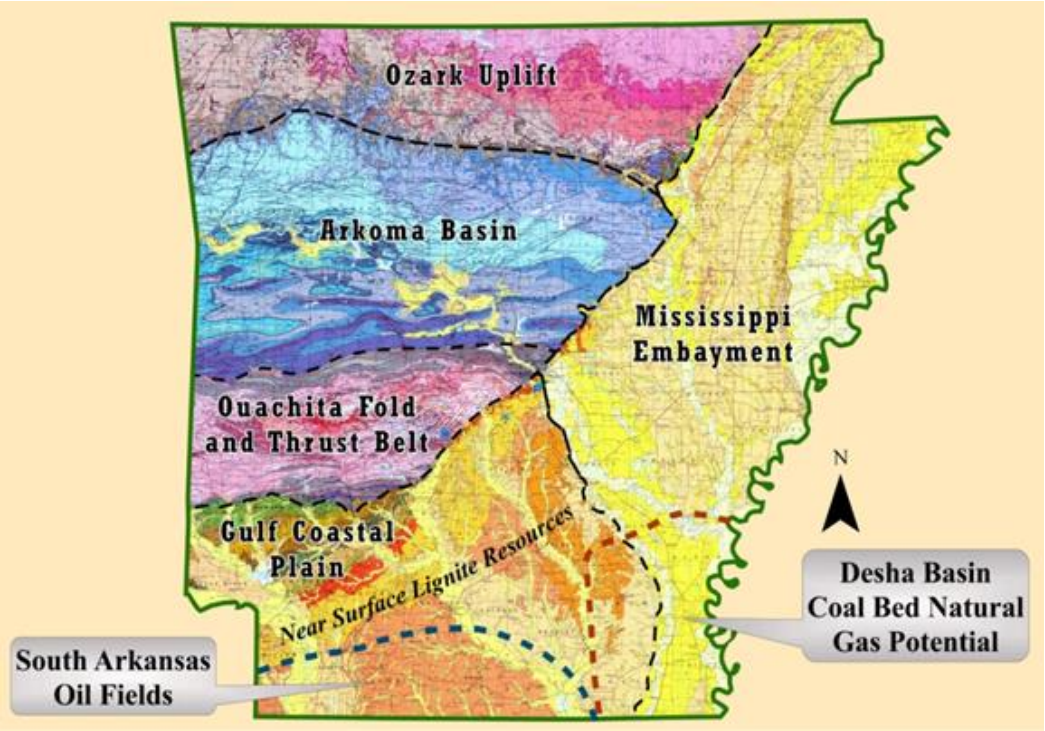


Figure 8. Geologic map and provinces in Arkansas.

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.

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.

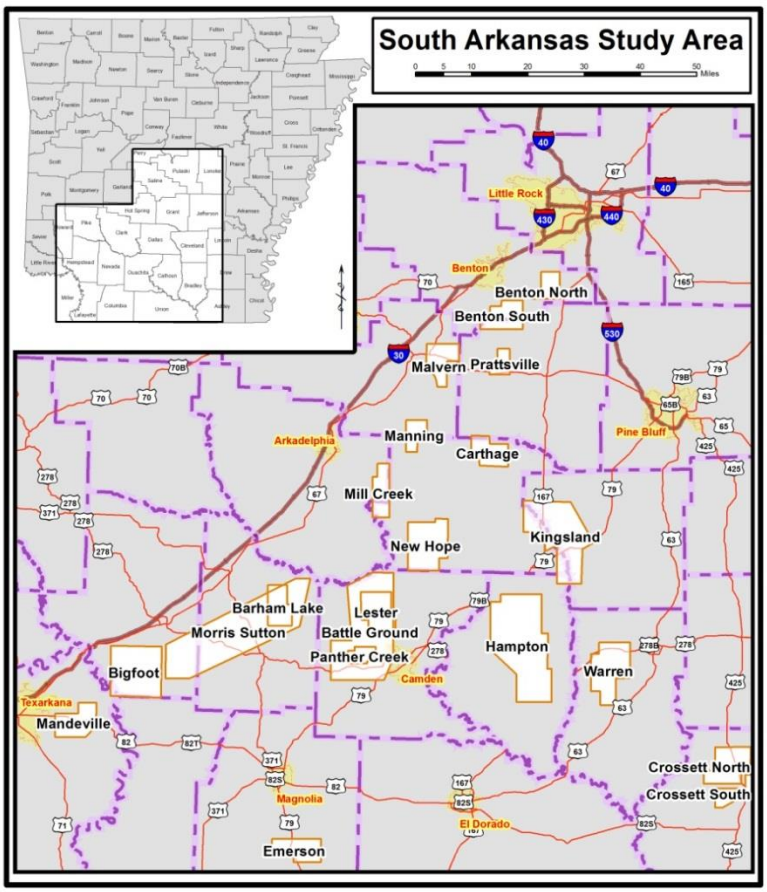


Figure 9. Lignite investigation map in south Arkansas.

AAPG Energy Minerals Division Mid-Continent Report
(Kansas contribution)
December, 2014

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Kansas Coalbed Natural Gas

Coal bed methane (CBM) constituted 10.5% of Kansas annual gas production in 2013 (down from 12% in 2012). 2013 CBM production for Kansas was 30.98 billion cubic feet (BCF) (Figure 1). Prorated production based on the first 8 months of 2014 indicates that 2014 Kansas CBM production will be approximately 28.1 BCF. This represents a 9% drop from 2013.

The peak of Kansas annual CBM production (49.14 BCF) was in 2008 (Figure 1). CBM annual production declined 2.2% from 2008 to 2009, 10.5% from 2009 to 2010, 5.8% from 2010 to 2011, and 11.9% from 2011 to 2012, and 13.3% from 2012 to 2013. The number of wells reporting production during 2014 decreased by 73 wells from 2013 (Figure 1). CBM production in Kansas is principally in four counties in the southeastern part of the state (Figure 2).

Cumulatively, approximately 411 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 due to CBM. CBM production data for Kansas, and associated links, can be found on the Kansas Geological Survey (KGS) website: http://www.kgs.ku.edu/PRS/petroDB.html.

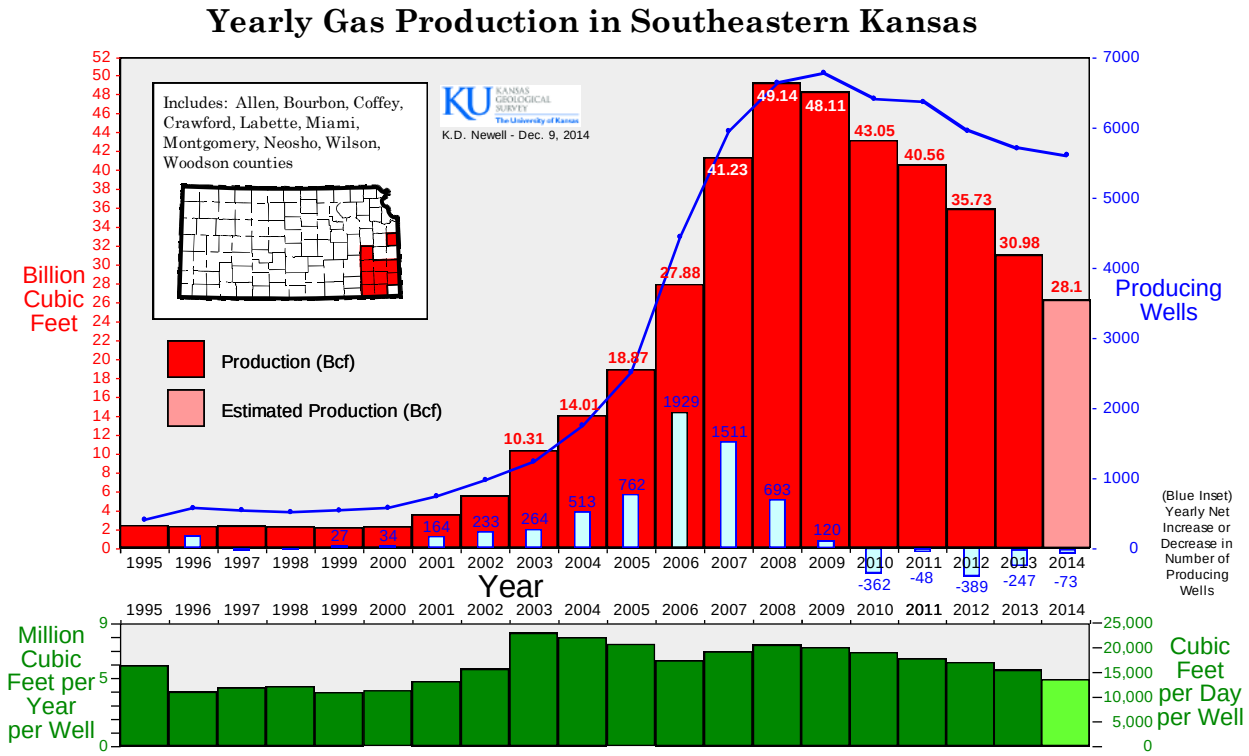

Figure 1 – Eastern Kansas Gas Production (overwhelmingly due to CBM) and the number of producing CBM wells reported annually (in blue), and total annual production divided by the total number of CBM wells (in green).

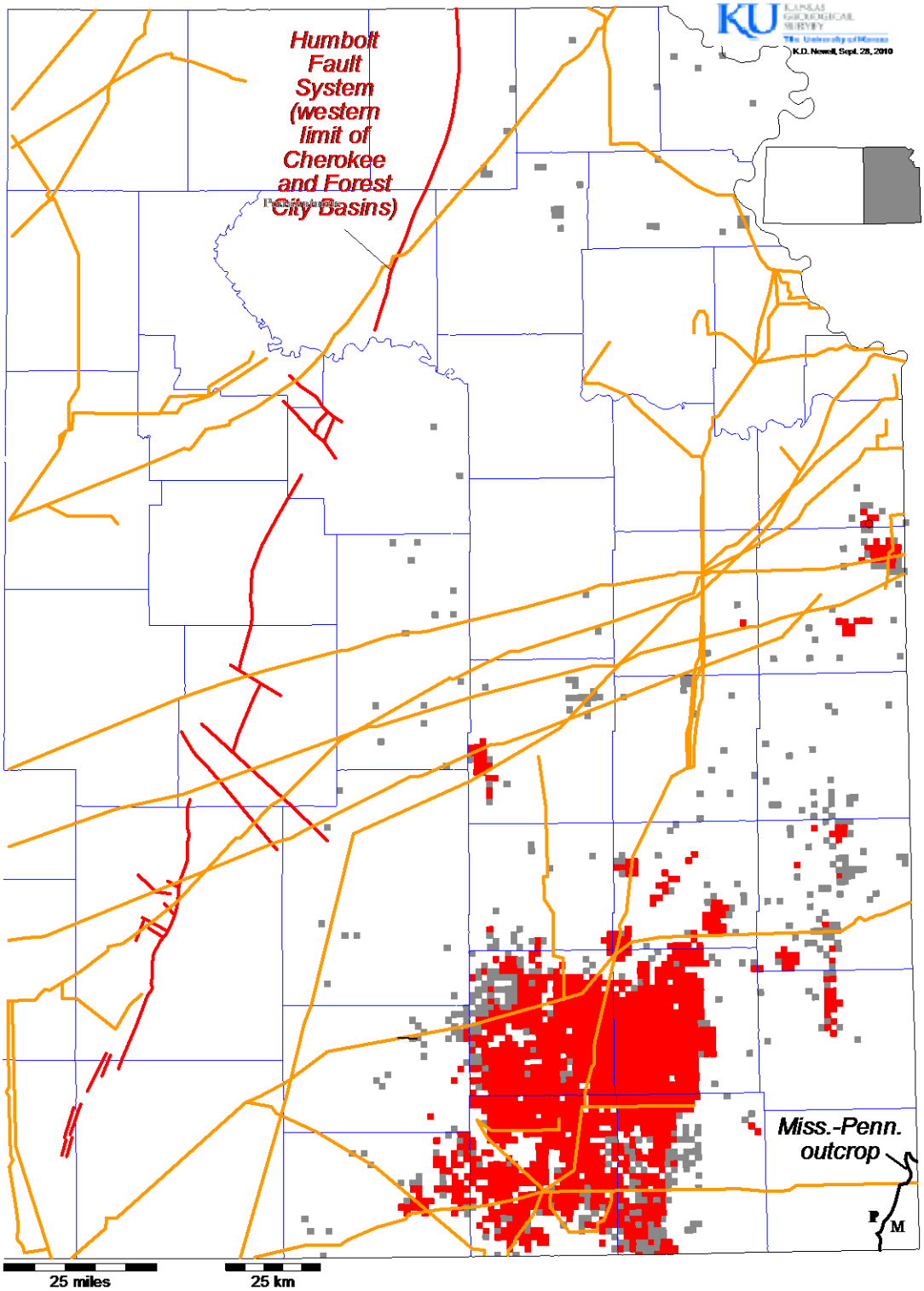

Figure 2 – Locations of sections (nominally 1 square mile) in eastern Kansas with record of CBM production (red) and sections with at least one well drilled for CBM, but with no production recorded (gray). Major gas pipelines are in orange (after Newell and Yoakum, 2010).

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 (August 2014), 7848 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 CBM and drilling at-large for natural gas in Kansas.

66 wells were drilled in 2012 in Kansas for CBM, but only 4 new CBM wells were reported for 2013:

- Cherokee Wells, LLC (2 wells)
- PostRock Energy, LLC (*once Quest*) (1 well)
- Jones Gas Corp. (1 well)

Eleven CBM wells have been so far reported for 2014, with the most recent being spudded in June:

- Dart Cherokee Basin Operating Co., LLC (4 wells)
- LR Energy, Inc. (4 wells)
- Cherokee Wells, LLC (1 well)
- Magnum Exploration Kansas LLC (1 well)
- Running Foxes Petroleum, Inc. (1 well)

2013 CBM production data has PostRock Energy, LLC recording the greatest CBM production for any operator in Kansas in 2013 (15.6 BCF). Dart Cherokee Basin Operating Co. (5.3 BCF) and Layne Energy Operating (3.4 BCF) follow. Production by these companies in 2014 (prorated from the first 8 months of production) is projected to be 14.3, 4.6, and 3.0 BCF, respectively. In light of this decrease in gas production, and considering the better price commanded by oil in recent years, several operators are changing their business model and are reviewing data from their CBM wells with effort directed to find previously overlooked or ignored oil accumulations.

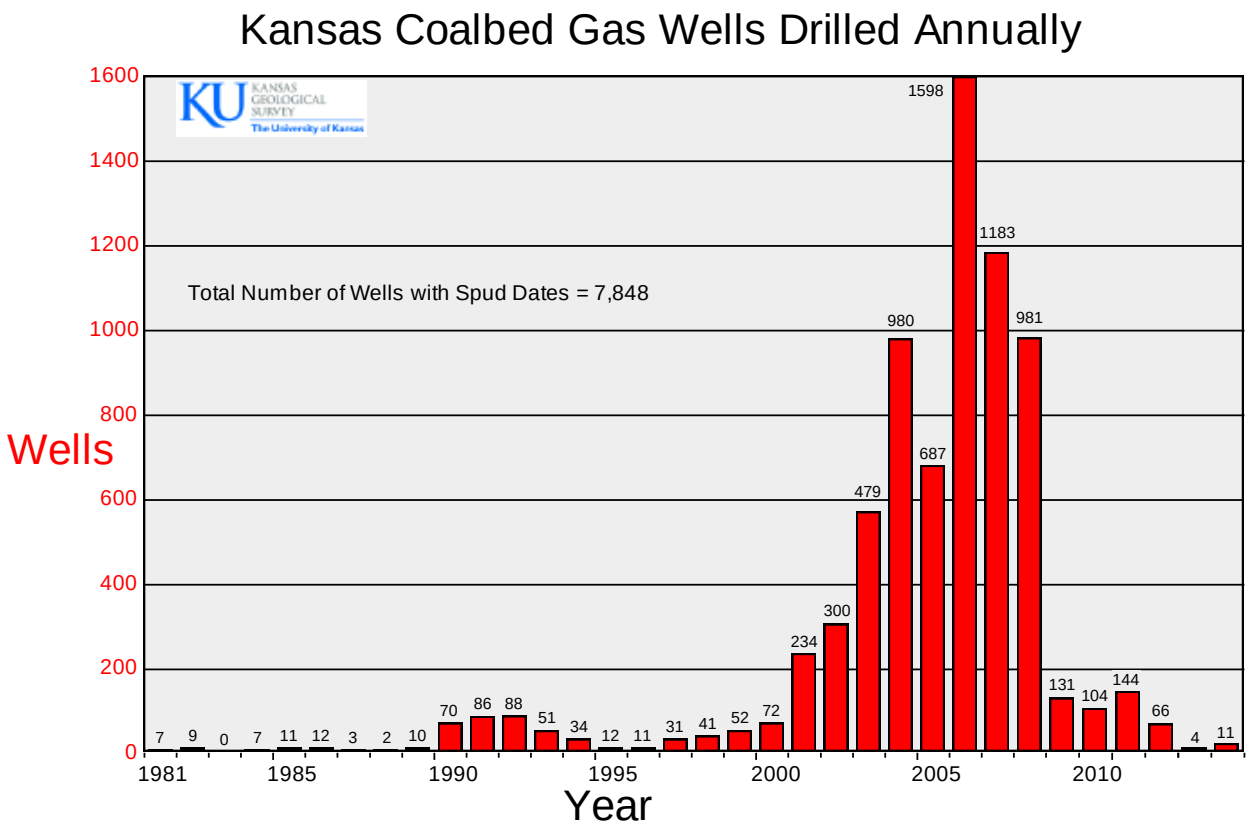

Figure 3 – CBM wells (dry and producing) drilled in Kansas.

The KGS 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 KGS 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 2013 totaled 24,994 short tons. Of this total, 22,149 tons were produced from one permit area at the Phoenix Coal Company Garland Mine in southeastern Bourbon County (Figure 4). The coal produced was primarily Mineral coal, with Croweburg being a secondary target. The remaining 2,845 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. The last year Kansas produced at least one million tons of coal was 1987, and the last year the state produced at least 100 thousand tons of coal was 2010.

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.

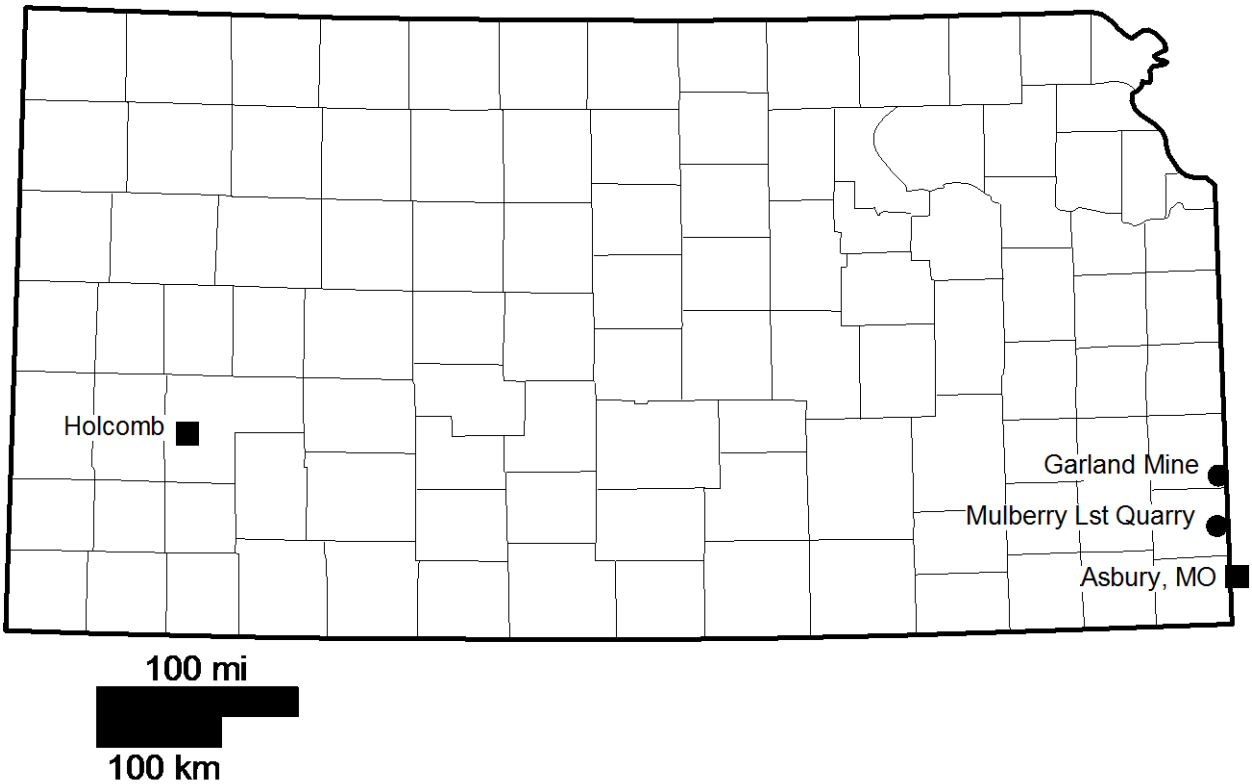

Figure 4 – Coal mines in Kansas, and Asbury power plant, and location for the proposed Sunflower power plant in Holcomb, KS.

Proposed Coal-Fired Power Plant in Kansas

The proposed power plant has been the center of legal disputes for over 6 years. The $2.8 billion project involves construction of an 895-megawatt coal-fired plant to be operated by Hays, KS-based Sunflower Electric Power Corp. in southwestern Kansas, next to an existing coal-fired plant near the town of Holcomb (Figure 4). The plant will have the capacity to power approximately 500,000 homes, and Tri-State Transmission and Generation Association Inc. of Westminster, CO (an electricity wholesaler) would get 75% of the power for customers in Colorado.

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 2010 permit issued by the Kansas Department of Health and Environment (KDHE) for the proposed power plant. The Sierra Club attempted 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 the 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.

Sunflower Electric maintained that the company would "continue to take the steps necessary to preserve and advance the project", and as a result of their efforts to amend the 2010 permit, the KDHE in May 2014 approved the permit only days before the federal government was expected to announce new rules for utilities designed to curb greenhouse gas emissions. The Sierra Club, through Earthjustice, followed-on in June 2014 with a lawsuit filed with the state Court of Appeals alleging that the KDHE did not adequately impose limits on various pollutants that will be produced by the plant, including mercury, nitrogen dioxide, and sulfur dioxide. In addition, the lawsuit alleges that carbon dioxide emissions by the plant would not meet federal air-quality standards that the state is required to enforce. Litigation thus continues.

Horizontal Wells and the Mississippian Limestone Play

Although about 1000 horizontal wells have been drilled in Kansas over several decades, 2010 marked the beginning of a new era in drilling where staged massive hydraulic fracturing 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.

Some companies, including Chesapeake Energy, Shell Oil Gulf of Mexico, EnCana Oil and Gas (USA), 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. In February 2014, Tapstone Energy LLC (Oklahoma City, OK), a company founded by erstwhile SandRidge-Energy CEO Tom Ward, agreed to buy Shell's Kansas assets and leases (~600,000 acres). SandRidge Energy (Oklahoma City, OK), Unit Petroleum (Tulsa, OK), and Woolsey Petroleum (Wichita, KS) continue to be active in the play, as are several other independents from Oklahoma, Texas, Kansas, and Colorado.

The number of intents-to-drill, which are posted on the website of the Kansas Corporation Commission (KCC), can aid in monitoring of the types of wells that are soon to be drilled in Kansas. As indicated by the intents-to-drill, the number of horizontal wells in the southern part of the state rapidly increased in 2011 and early 2012, and has remained relatively constant since then (Figure 5). Drilling of horizontal

wells in western Kansas has decreased since mid-2012, with most of the remaining activity being concentrated in western Reno County and Trego County. Horizontal wells in Trego County have mostly targeted Pawnee Limestone and Marmaton pay zones instead of Mississippian strata.

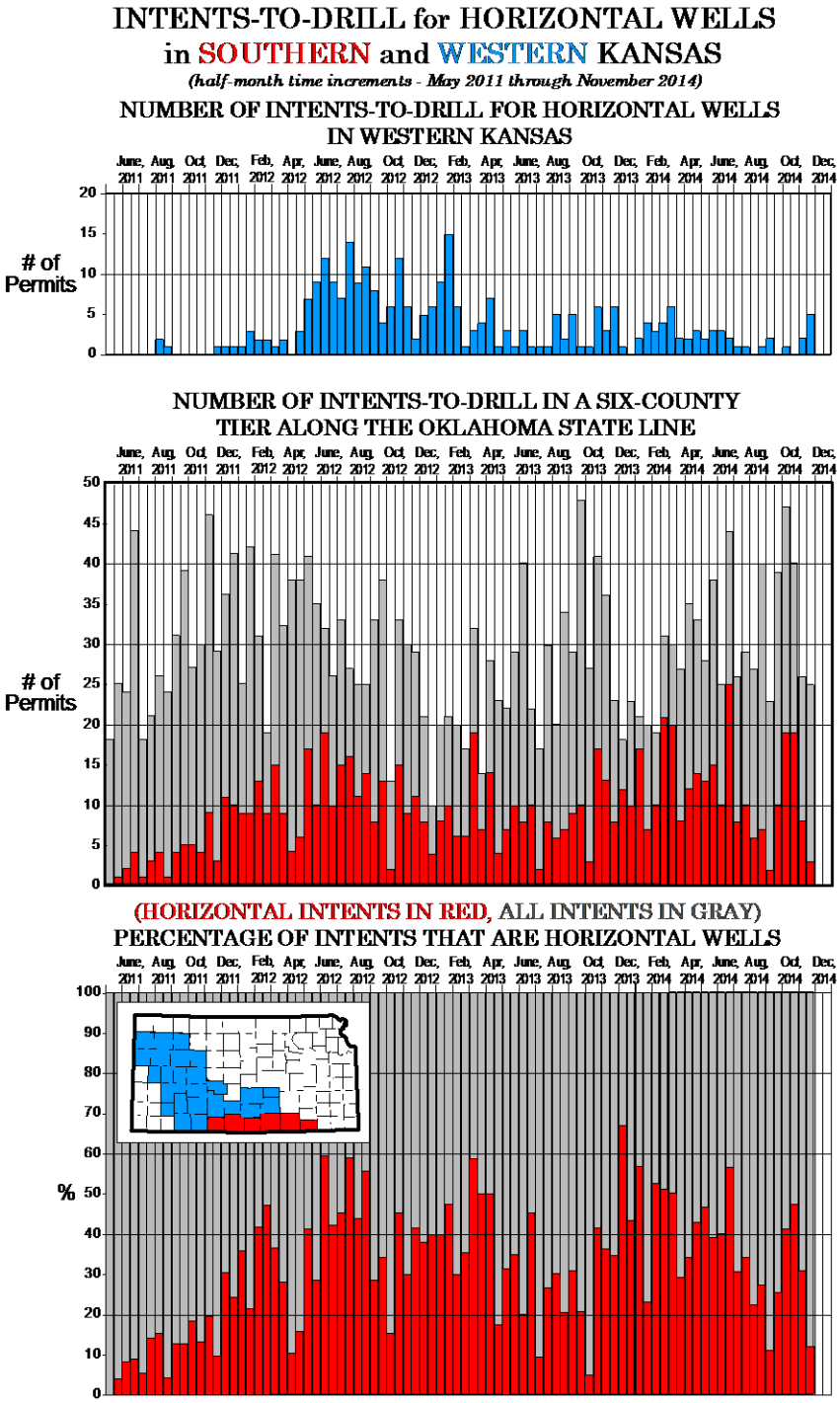

Figure 5 – Intents-to-drill for Kansas counties immediately north of the Oklahoma state line (in red), and western Kansas (in blue).

As of December 2014 (and since September 2010), 665 horizontal wells have been drilled in Kansas, not counting a few miscellaneous gas-storage, salt-water-disposal, CBM, Niobrara, and Hugoton-Field horizontal wells. 469 of these wells have had some recorded oil or natural gas production (Figure 6). Ten of these producing wells have been officially plugged and abandoned. 53 wells, the majority of which are recently drilled, have yet to report any production, but are still active. 28 wells with some production have been reassigned to inactive status, or approved for temporary abandonment. 119 wells have had no production reported and have been plugged or approved for plugging, or approved for temporary abandonment.

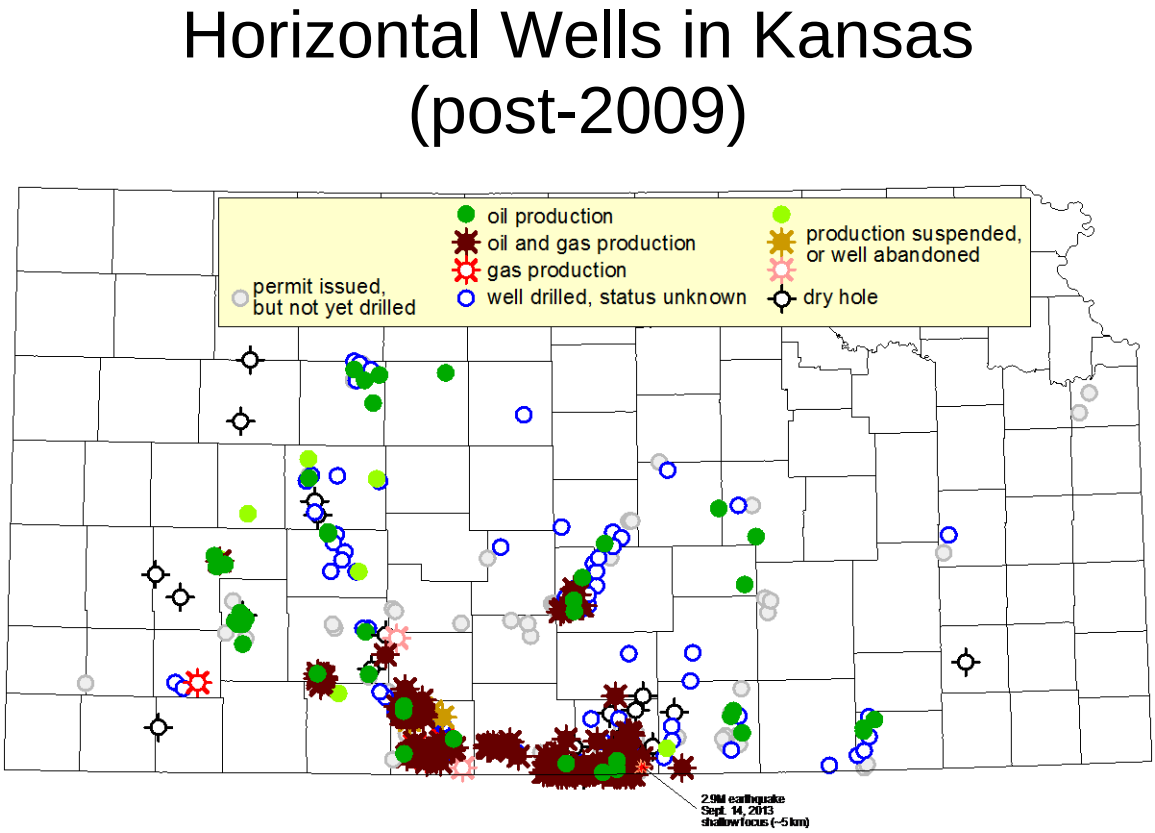

Figure 6 – Modern horizontal wells in Kansas. Most horizontal wells in the southern tier of counties in the state are targeting the Mississippian.

Examination of production in the first 113 MLP horizontal producing wells in Kansas by Newell and others (2014) indicates average monthly production one year after the peak month will be on the order of 25% of the peak month. Production declines continually decrease the longer a well is produced. The initial rapid declines are collective expressed as a drastic decrease in production wells drilled annually (Figure 7). If MLP wells cost about $3,000,000 to drill and complete, only one-fourth of the MLP horizontal wells are projected to recoup these costs with 2 years production.

The most prolific Kansas MLP horizontal well with respect to cumulative production is the SandRidge Bernice #1-17H well in sec. 17-T.35S.-R.07W. in Harper County just

north of the Oklahoma state line. In 27 months (production reported through November 2013), this well has produced 200,326 bbls of oil and 932,037 thousand cubic feet (mcf) of natural gas (gross income ~$20.1 million). No production has been reported for this well since September 2013, and in October 2014 the KCC approved an application filed for its temporary abandonment. The second-most prolific MLP well (gross income ~$17.5 million in 33 months) is the SandRidge Lake #1-21H well in sec. 21-T.34S.-R.06W. in Harper County. Third is the SandRidge Lori #1-21H well in sec. 02-T.35S.-R.10W. in Barber County (gross income ~$15.2 million in 30 months). The respective gross incomes are inferred from a simple multiplication of the monthly product price (published by the federal Energy Information Agency) times the respective monthly volumes of oil and gas (reported by the operator to the KCC).

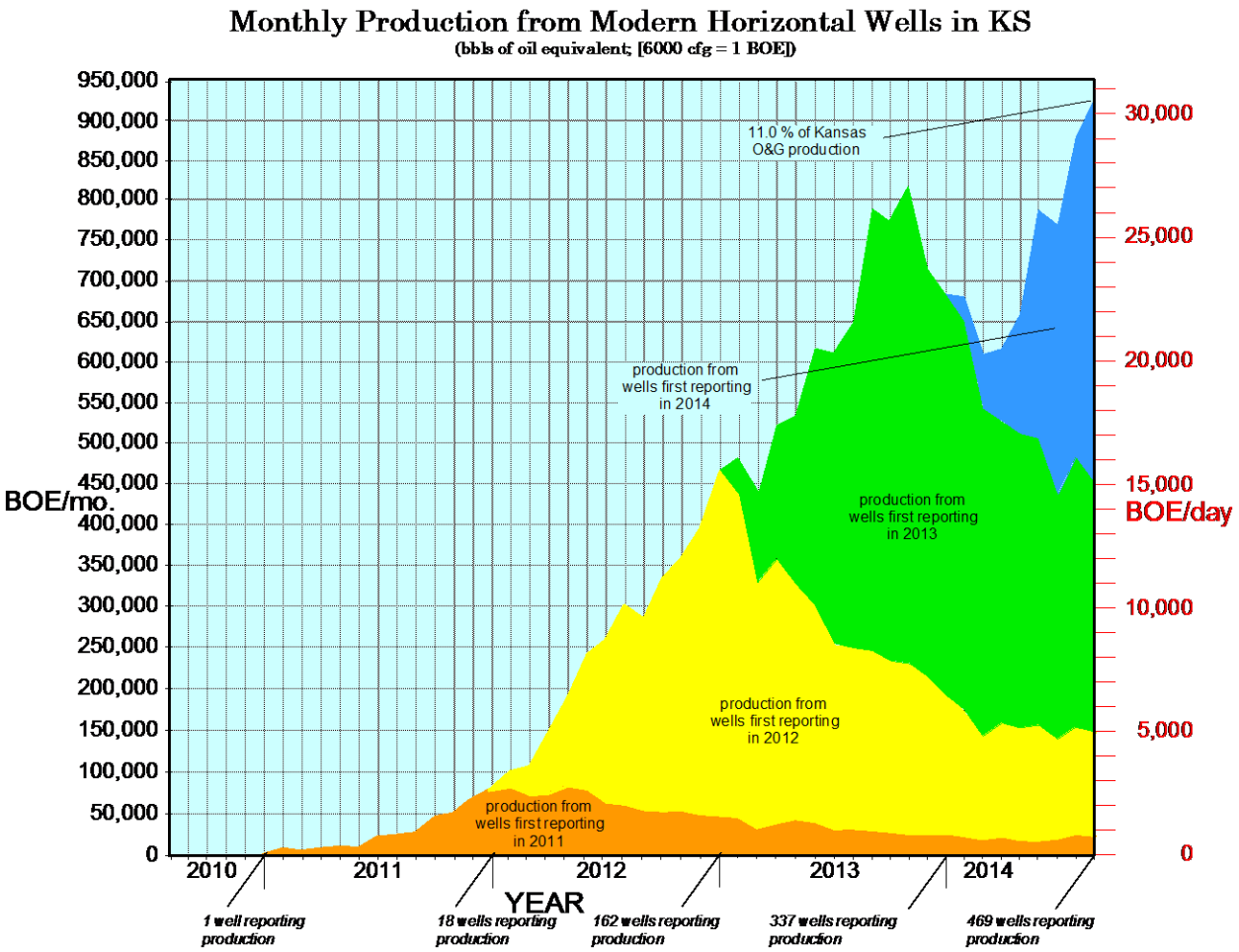

Figure 7 – Production from modern horizontal wells in Kansas. 469 wells, 453 of which target the MLP, reported production as of August 2014.

In terms of monthly production in BOE (barrels of oil equivalence), in which natural gas is mathematically converted to barrels of oil with an approximate energy-equivalence of 6000 cubic feet equal to 1 barrel of oil, five wells stand apart with production greater than 1000 BOE/day (see Table 1). The nearest well after these five wells comes in at 883 BOE/day. The price discrepancy between natural gas and oil (where 6000 cubic

feet of natural gas costs approximately 1/5 of its energy-equivalent one barrel of oil) affects the relative economic importance of these wells. Wells with greater liquids production fortuitously produced in months when oil prices are high (for example, the SandRidge Dean 3408 #1-27H well (Table 1) thus score high in a ranking based on monthly gross income.

TABLE 1 – Most prolific monthly production for Mississippian horizontal wells

WELL and location	**Mo. of prod.**	**Date**	**Monthly OIL *(bbls/day)***	**Monthly GAS *(mcf/day)***	**Monthly BOE *(bbls/day)* *[6000 cf = 1 BOE]***	**Projected Income *(monthly price X monthly volume)***
SandRidge Lori #2-2H 02-T35S-R10W, Barber Co.	2nd	June 2012	237	7061	1414	$1,081,328
SandRidge Dean 3408 #1-27H 27-T34S-R08W, Harper Co.	3rd (see note below)	Aug 2014	982	1756	1274	$2,837,385
SandRidge Lori #1-2H 02-T35S-R10W, Barber Co.	2nd	April 2012	598	3576	1194	$1,943,432
SandRidge 3404 Peter #1-20H 20-T34S-R04W, Sumner Co.	3rd	Sept 2013	846	1753	1138	$2,720,638
SandRidge Bernice #1-17H 17-T35S-R07W, Harper Co.	5th	Dec 2011	849	1603	1116	$2,500,850

NOTE: SandRidge Dean 3408 #1-27H has recorded only 3 months production as of August 2014

In August 2014 (the most recent publication of production data) 453 MLP horizontal wells (and 16 additional horizontal wells targeting other geological formations), constituted 11.0% of Kansas oil and gas production (Figure 7, 8). This percentage has increased from 8.6% recorded in December 2013. The remaining 89% of oil and gas production in the state is from approximately 51,000 oil wells and 24,000 gas wells.

According to KCC and KGS data, in 2013 SandRidge was the #1 oil producer in Kansas, with production of 2,222,905 barrels (bbls), which translates to 5.6% of the total production in the state. In 2012, they were in 6th place with 995,091 bbls annual production, which was 2.5% of the total oil production in the state. With respect to natural gas in 2013, SandRidge was in 4th place with 20.16 BCF production (5.3% of total production in Kansas). The first three producers -- Linn Operating, Inc., ExxonMobil, and OXY USA -- are all major producers in the giant Hugoton-Panhandle Field. In 2012 SandRidge was in 8th place, with 9.40 BCF production (2.5% of total production in Kansas)

New horizontal wells in Kansas in the month of August 2014 produced 405,099 bbls of oil and 3,048,989 mcf of natural gas. Overall gas-oil ratio (GOR) for that month is 7.52 mcf/bbl. Cumulative production for these wells is 7,365,501 bbls and 58,569,286 mcf of natural gas. The cumulative GOR (7.95 mcf/bbl) indicates that 64% of the energy production from the new Kansas horizontal wells is attributed to natural gas. Most of

this natural gas is associated with oil production. The cumulative production of the new horizontal wells since September 2010 represents ~$880 million gross income.

Production reports acquired by the KCC and subsequently published on the KGS website are subject to a four-month time lag. As posted in early December 2014, the 469 producing horizontal wells in Kansas drilled since September 2010 reflects the latest production reports up to and including August 2014. Operators for these 469 wells are:

PRODUCING WELLS	COMPANY
307	SandRidge Energy
32	Shell Gulf of Mexico/Tapstone Energy
29	Unit Petroleum
14	Source Energy Midcon
13	Woolsey Operating
11	Osage Resources
9	Tug Hill Operating
6	Chesapeake Operating
6	Samuel Gary Jr. & Assoc.
5	Dorado E&P Partners
5	McElvain Energy
56	(20 other companies, none with more than 4 wells)

Kansas oil production has generally increased since 2010 despite the additional production supplied by the new horizontal wells. Conversely, natural gas production in Kansas has generally decreased despite the additional production supplied by the new horizontal wells (Figure 8). This drop in natural gas production in Kansas is largely due to the relatively low price commanded by natural gas in recent years (ergo, fewer natural-gas wells and completions) and the depletion of the giant Hugoton-Panhandle Field. Natural gas and oil production in Kansas are virtually equivalent with regard to the energy content of each of these commodities (Figure 8), but the income produced by the natural gas is presently only a fraction (~1/5) of that of the oil.

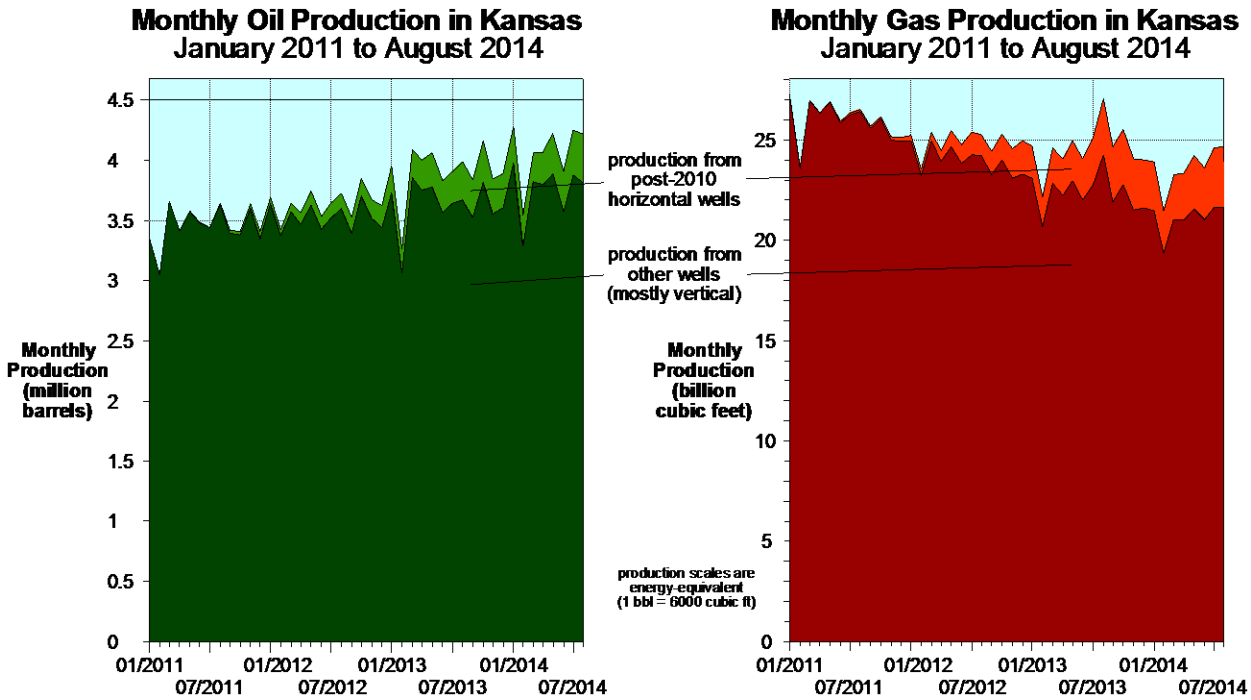

Figure 8 – Kansas oil and gas production, with contribution from the 469 new horizontal wells. Scales are energy equivalent.

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Missouri Update for Unconventional Natural Gas and Coal-Related Projects

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Energy Resources Unit

Missouri Coalbed Natural Gas

Currently, Missouri produces no CBM.

Missouri Coal

Missouri coal production for the 2013 calendar year totaled 413,703 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 permitted pit ceased production in November, 2013. The approval of a westward expansion of the original pit granted in July, 2013 and mining began in August, 2013. A northward expansion of the west pit area has been proposed for permitting.

Missouri coal production for the period of January through September, 2014 totaled 295,970 tons of coal. As in 2013, the total production is from two pits which comprise the Continental Coal, Inc. Hume No. 1 mine located in southwestern Bates County. Early on, coal production was from the westward expansion pit area. A permit for the northwest expansion from the westward expansion pit was approved in April, 2014 and mining in the new area began the same month.

The Mulberry Coal is the source of the seam and is mined by stripping methods. From January, 2013 through September, 2014, the Mulberry Coal displayed a thickness range of thirty-two (32) and thirty-five (35) inches. Its characteristics included a sulfur content of about 3.8%, 15.9% ash, and a btu rating of approximately 10,700. All Missouri coal produced from January, 2013 through September, 2014, 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 Hume No. 1 mine is shipped a short distance to coal fired power plants in Missouri and 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.