OFR 2018-3000

STATE OF ARKANSAS

ARKANSAS GEOLOGICAL SURVEY
BEKKI WHITE, DIRECTOR AND STATE GEOLOGIST

OPEN-FILE REPORT 2018-3000

ARKANSAS FOSSIL FUELS ACTIVITY UPDATE FOR 2017

Peng Li

Little Rock, Arkansas

2018

STATE OF ARKANSAS
Asa Hutchinson, Governor

ARKANSAS GEOLOGICAL SURVEY
Bekki White, Director and State Geologist

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South Arkansas Oil and Associated Gas

In 2017, south Arkansas oil production fell by 4.2% to 5,288,375 bbls over a year ago, with corresponding associated gas production of 6,546,451 Mcf. Cumulative oil production in south Arkansas as of the end of 2017 is 1,894,528,093 bbls. Only 27 drilling permits were issued and 22 wells were completed in 2017, while 90 wells were plugged and abandoned in the same year. Figures 1 and 2 illustrate that south Arkansas oil and associated gas production has been steadily declining in recent years, but the level of production may stabilize as higher energy prices have made it more attractive to maintain marginal wells that would otherwise be plugged and abandoned.

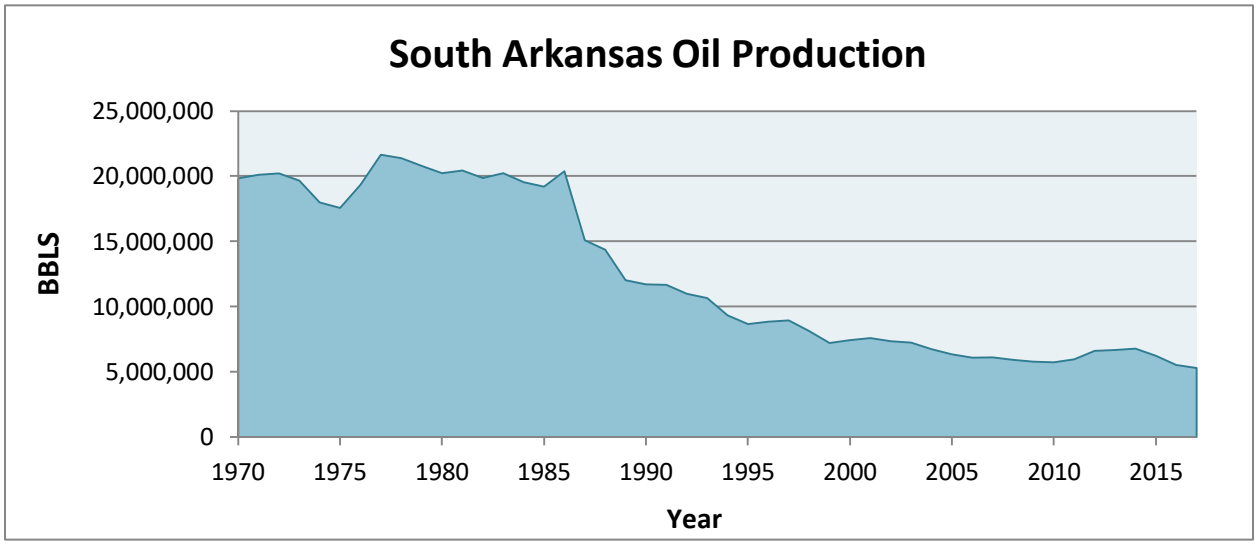

Figure 1. Annual oil production of south Arkansas (1970-2017).

North Arkansas Conventional Gas

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 2017 declined by 4% to 71,313,118 Mcf. Cumulative production in the Arkoma Basin for all conventional gas wells and tight gas sands of the B-44 gas field producing region as of the end of 2017 is approximately 7.13 Tcf. In 2017, approximately 13 drilling permits were issued and 19 gas wells were completed, while 170 gas wells were plugged and abandoned. Figure 3 illustrates that gas production in north Arkansas has had some modest increases since the mid-1980s, with a sharp increase in production in 2005, which is mostly associated with development of the Fayetteville Shale gas play.

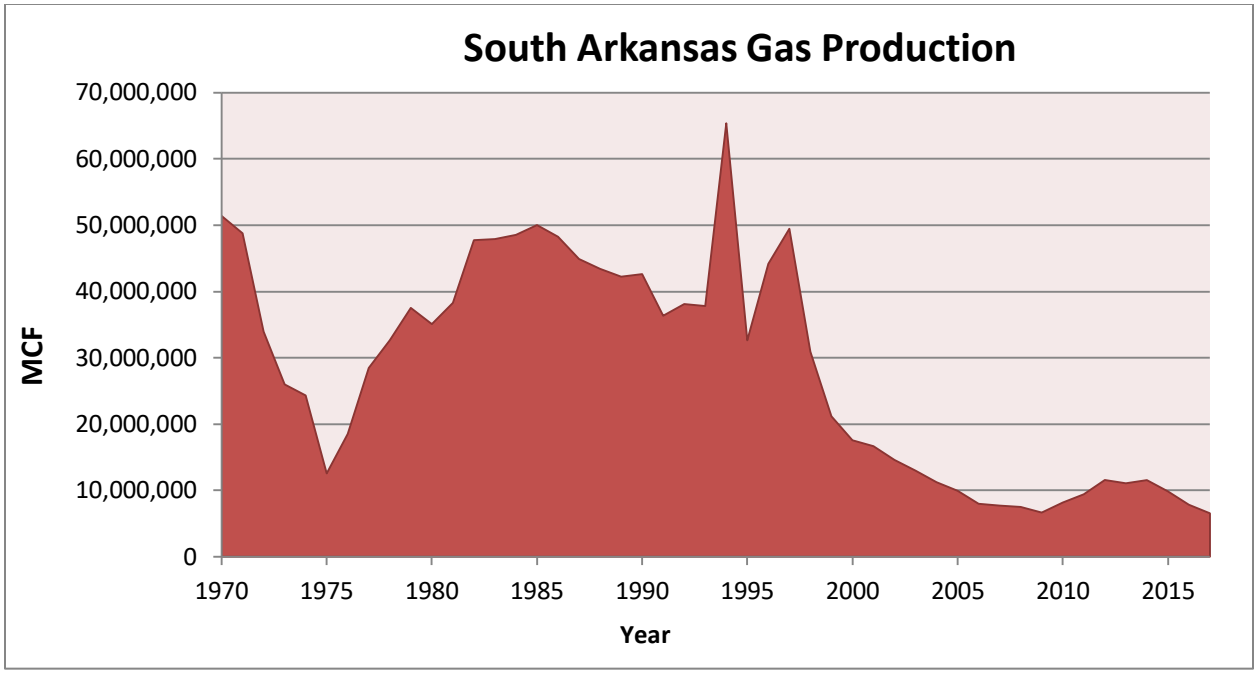

Figure 2. Annual gas production of south Arkansas (1970-2017).

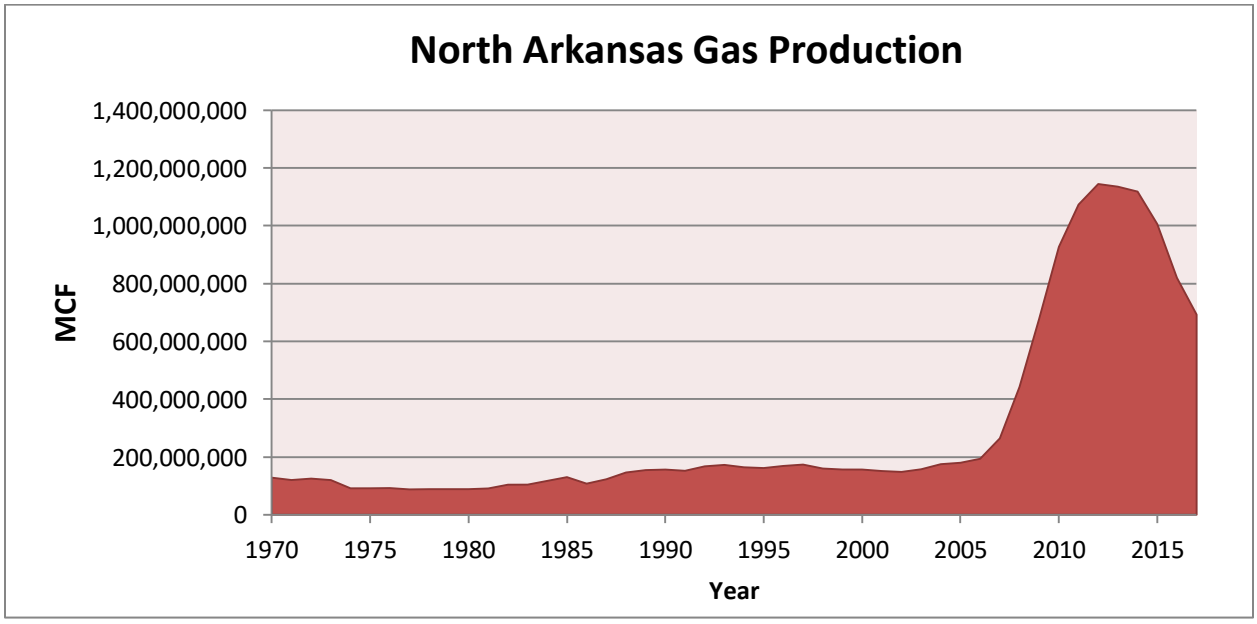

Figure 3. Annual gas production of north Arkansas (1970-2017).

Fayetteville Shale Gas Play

The Upper Mississippian Fayetteville Shale play is 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 4). 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 Shale contains 31.96 Tcf of technically recoverable gas resource, of which 27.32 Tcf is attributable to the core producing area (eastern area) and 4.64 Tcf for the remainder of the producing area (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 cumulative 18.2 Tcf are economically recoverable reserves by 2050. EIA also reports that the proved gas reserves of the Fayetteville Shale in 2013 are 12.2 Tcf, an increase over the 2012 estimate of 9.7 Tcf. Estimated ultimate recovery (EUR) for a typical horizontal Fayetteville gas well decreased from 3.2 Bcf in 2011 to 3 Bcf in 2013.

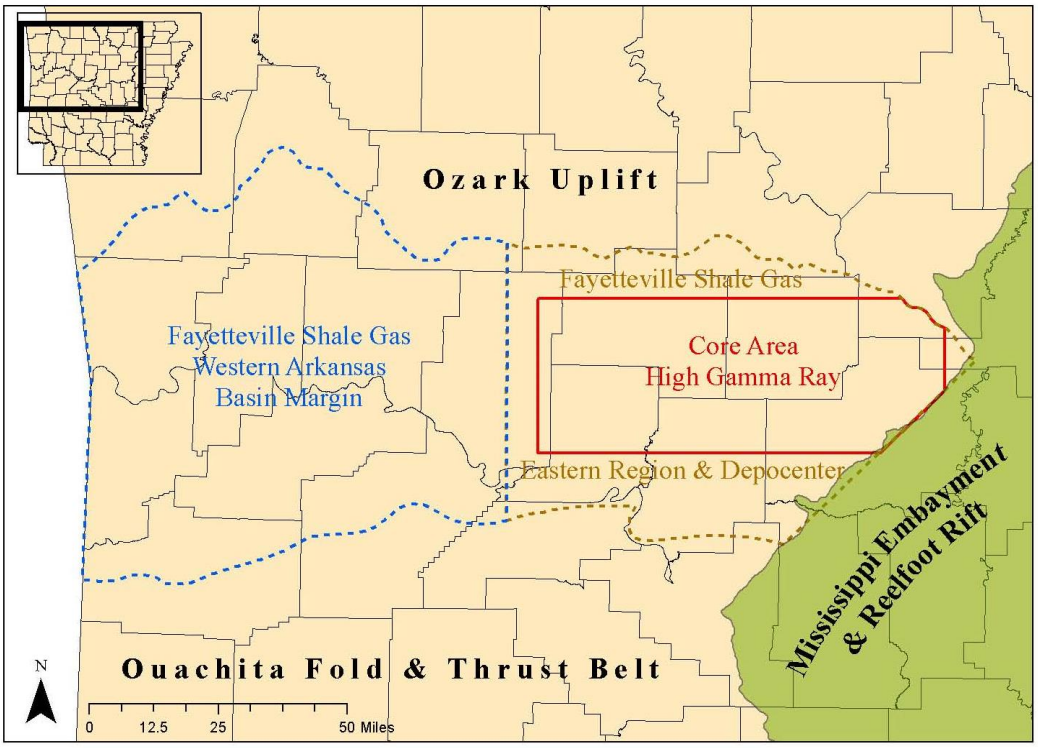

Figure 4. Primary area of the Fayetteville Shale exploration and development in Arkansas.

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. 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).

Due to a decline in drilling activity driven by lower natural gas prices, Fayetteville Shale gas production has decreased since peaking in 2013. In 2017, there was approximately 621,300,071 Mcf of gas produced in the play, a 17% decline over the last year. Estimated cumulative production of gas as of 2017 has totaled 7.96 Tcf. Initial production rates of horizontal wells in 2017 averaged about 5.3 MMcf/day. For more Fayetteville Shale production information, please refer to the Arkansas Oil and Gas Commission's web link at http://www.aogc.state.ar.us/Fayprodinfo.htm.

In 2017, only one rig operated by SEECO (a subsidiary of Southwestern Energy) worked in the Fayetteville Shale gas play (Figure 5). Eleven (11) wells were drilled in 2017, which demonstrated a rapid decline in well completion since 2015 (Figure 6).

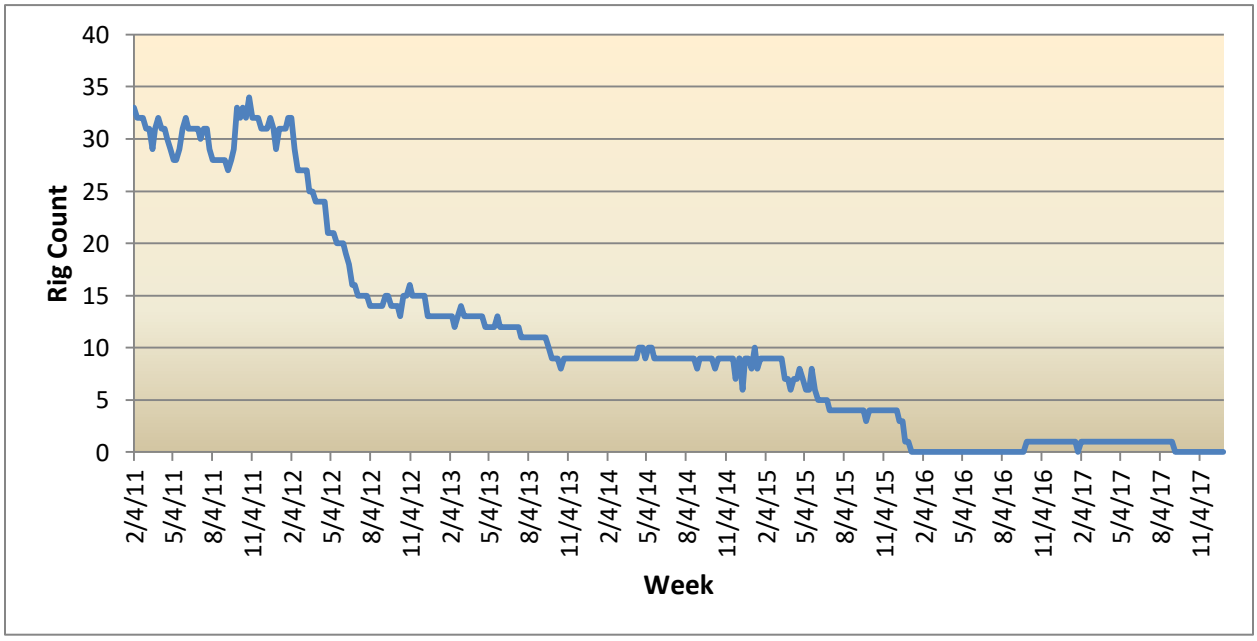

Figure 5. Weekly drill rig numbers in the Fayetteville Shale gas play (2011-2017).

Since the play's inception, the Fayetteville Shale play has been dominated by a small number of large players. Three operators – Southwestern Energy (SWN), BHP Billiton, and XTO Energy (a subsidiary of ExxonMobil) – 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 Energy, with 918,535 net acres lease and nearly four 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. XTO and BHP are approximately equal in terms of their acreage and gross operated production. In 2017, Southwestern contributed 463 Bcf in Fayetteville gas sales, good for 74.6% of the play's total sales that year. XTO Energy sold 78 Bcf (12.6%) and BHP traded 79 Bcf (12.7%). The remaining 0.1 % of sales, or 1.8 Bcf, was spread out among eight companies.

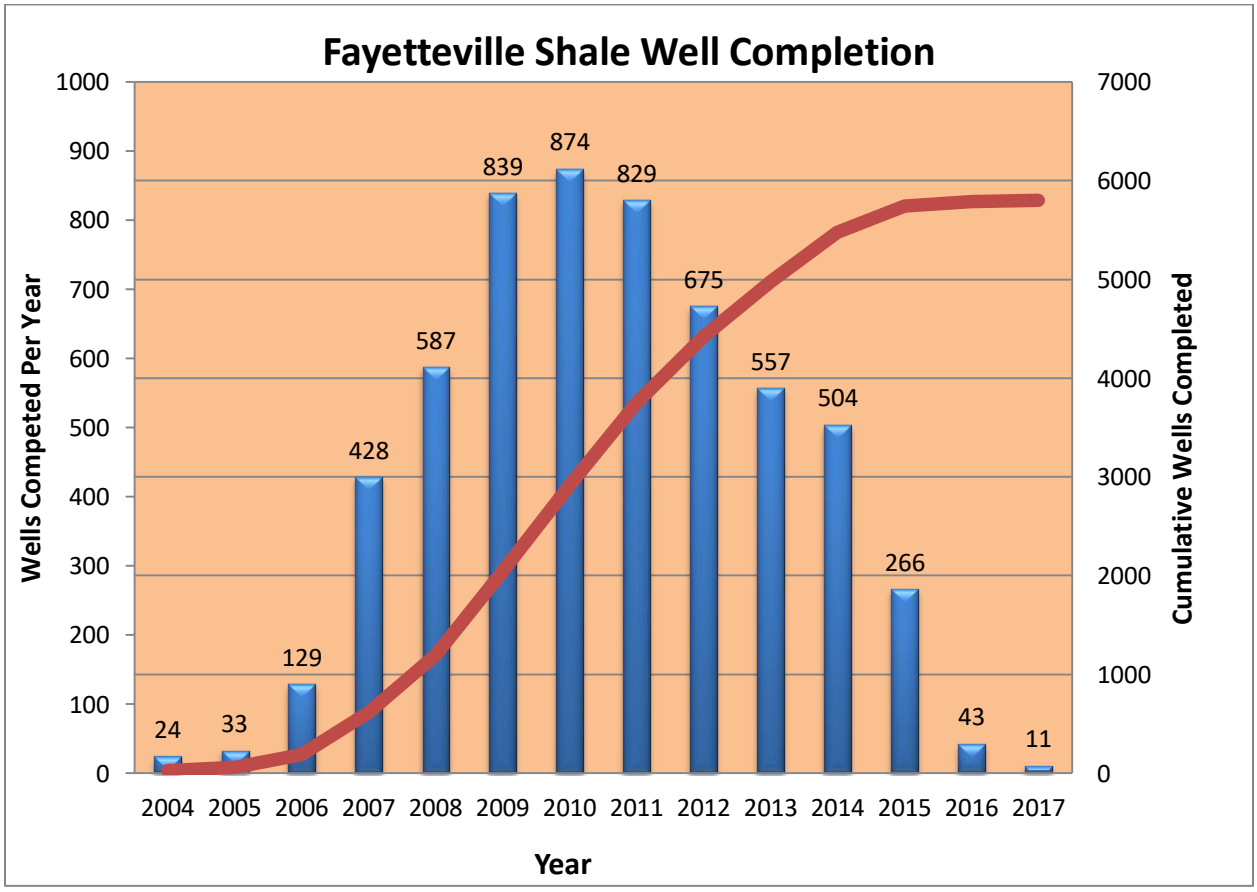

Figure 6. Fayetteville Shale well completion numbers.

The top three operators of the Fayetteville Shale gas play as of the end of 2017, based on numbers of producing wells, are as follows (Figure 7):

1) SEECO Inc. (an exploration subsidiary of Southwestern Energy) (3,663 wells)
2) BHP Billiton Petroleum (909 wells)
3) XTO Energy, Inc. (a subsidiary of ExxonMobil) (844 wells)

The Arkansas Geological Survey (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. The results of these studies were published by the AGS as Information Circular 37 (Ratchford et al., 2006) and Information Circular 40 (Li et al., 2010), which integrated surface and subsurface geologic information with organic geochemistry and thermal maturity data.

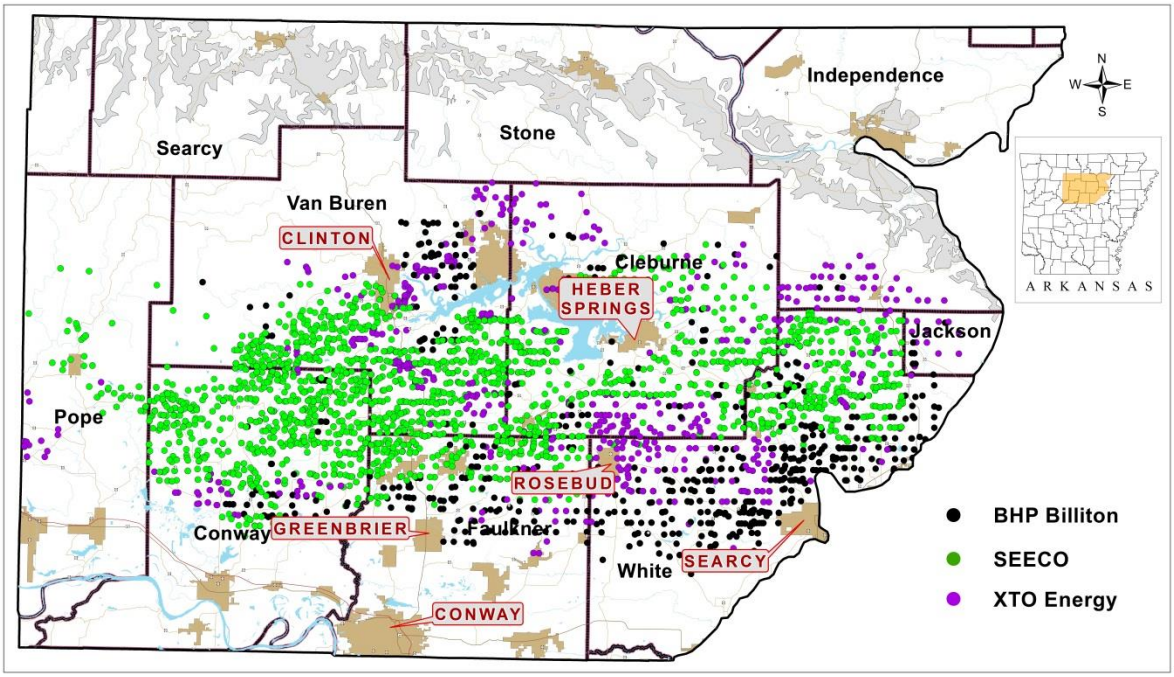

Figure 7. Location map of the Fayetteville Shale producing wells of top three operators.

Moorefield Shale

Southwestern Energy has increasingly made exploration efforts in the Mississippian Moorefield Shale, which lies underneath the Fayetteville Shale in north-central Arkansas. Moorefield wells showed initial production (IP) rates that were comparable, and in some cases, superior to Fayetteville Shale well IP rates. The most impressive Moorefield well in 2017 came in at an IP of over 8,000 Mcf/d. In 2017, fourteen (14) Moorefield wells were reported to be completed. Nine (9) of them have been producing gas and the others were plugged. The majority of the Moorefield wells are located in White County with a few wells in Cleburne County. Based on the isopach maps in docket documents of the Arkansas Oil and Gas Commission, the thickness of the Moorefield Shale in the exploration area is averaged at 500 feet.

Coalbed Methane

The development of Arkansas coalbed methane (CBM) resources began in 2001 and has yielded an approximate cumulative production of 30,581,398 Mcf as of year-end 2017. In 2017, sales of CBM declined by 8.5% over the last year to 1,051,806 Mcf from 50 wells. Figure 8 shows the CBM production trend since 2001. EnerVest Operating LLC acquired all CBM 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 the 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

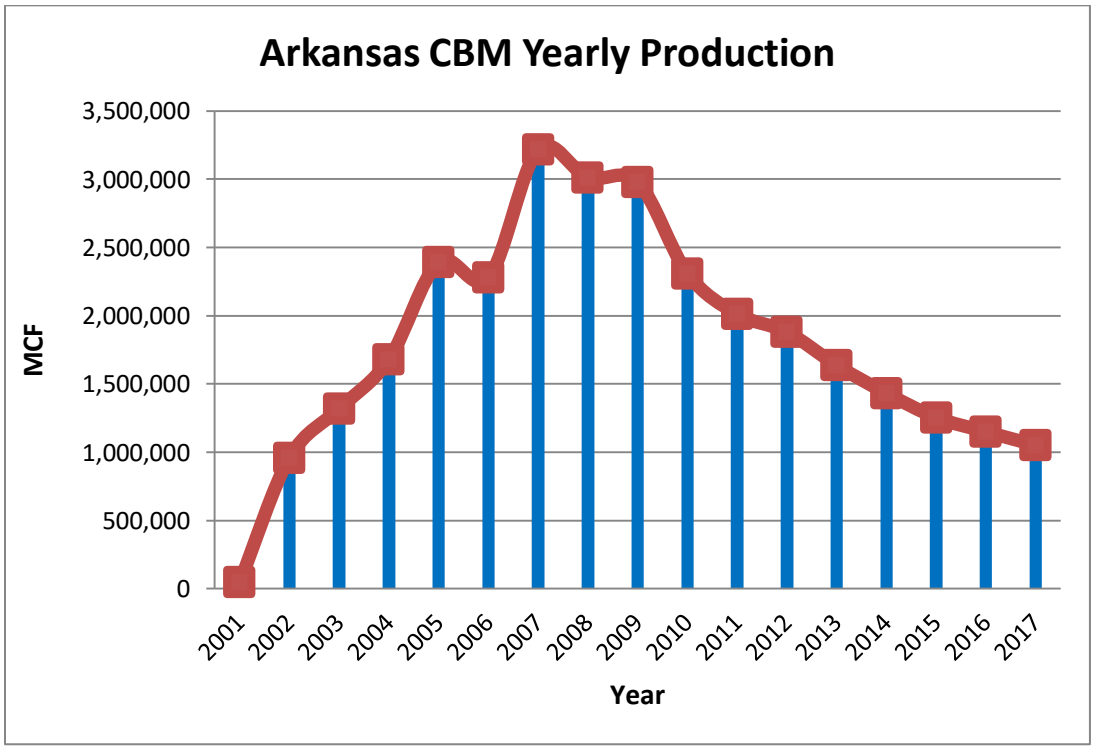

Figure 8. Annual production of coalbed methane in Arkansas.

Coal

Arkansas coal production decreased in 2017 by 18.6% to 111,126 gross tons compared to 136,463 gross tons in 2016. Underground mined coal production (85,519 gross tons) far surpassed that from surface mining (25,608 gross tons). Figure 9 shows the coal production trend since 2000.

Comer Mining's 2017 production of 602 tons is the last for coal production from Henry Comer as he has retired now and only leases to a sandstone quarrying operation. The underground mine operated by Sebastian Mining in southern Sebastian County produced 85,519 gross tons in 2017. The company stopped mining in October 2017 and has filed for bankruptcy. The new surface coal mine, Stryton Mine No. 1, started production in 2016 but has had quality control problems and production was only 25,006 tons. The production from this mine discontinued in October of 2017. All of the mines in Arkansas sold their coal to the AES Shady Point coal-fired power plant in eastern Oklahoma.

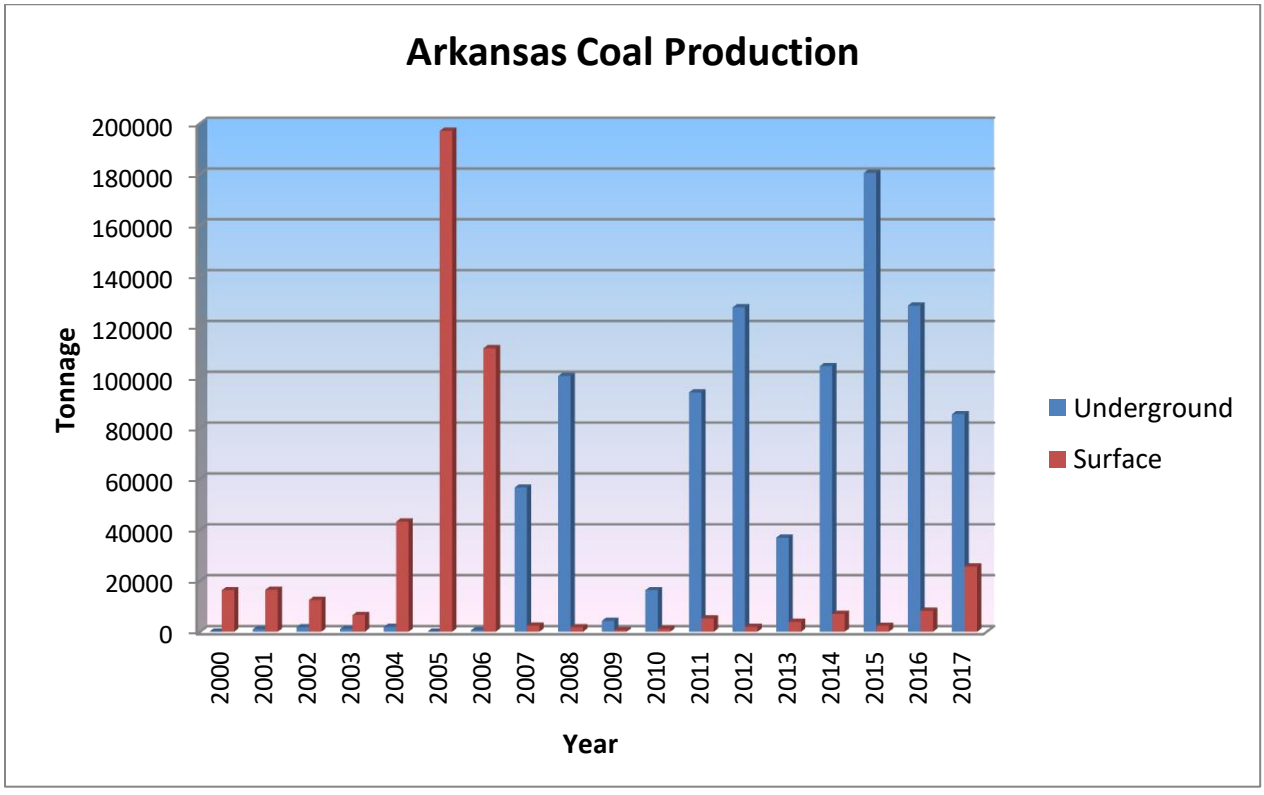

Figure 9. Annual coal production of Arkansas.

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Ratchford, M.E., L.C. Bridges, W.G. Dow, A. Colbert, and D.M. Jarvie, 2006, Organic geochemistry and thermal maturation analysis within the Fayetteville Shale study area – Eastern Arkoma Basin and Mississippi Embayment regions Arkansas: Arkansas Geological Survey Information Circular 37, 200p, 23 Map Plates.