

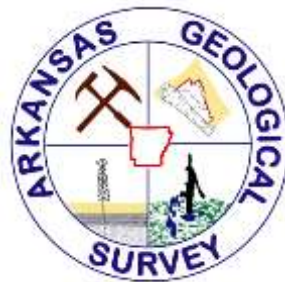
OFR 2017-1000

STATE OF ARKANSAS
ARKANSAS GEOLOGICAL SURVEY
BEKKI WHITE, DIRECTOR AND STATE GEOLOGIST

OPEN-FILE REPORT 2017-1000

ARKANSAS FOSSIL FUELS ACTIVITY UPDATE FOR 2016

Peng Li



Little Rock, Arkansas

2017

STATE OF ARKANSAS
Asa Hutchinson, Governor

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Bekki White, Director and State Geologist

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South Arkansas Oil and Associated Gas

In 2016, south Arkansas oil production fell by 11.4% to 5,470,299 bbls over a year ago, with corresponding associated gas production of 7,831,679 Mcf. Cumulative oil production in south Arkansas as of the end of 2016 is 1,888,428,356 bbls. Only 18 drilling permits were issued and 15 wells were completed in 2016. 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 energy prices have made it more attractive to maintain marginal wells that would otherwise be plugged and abandoned.

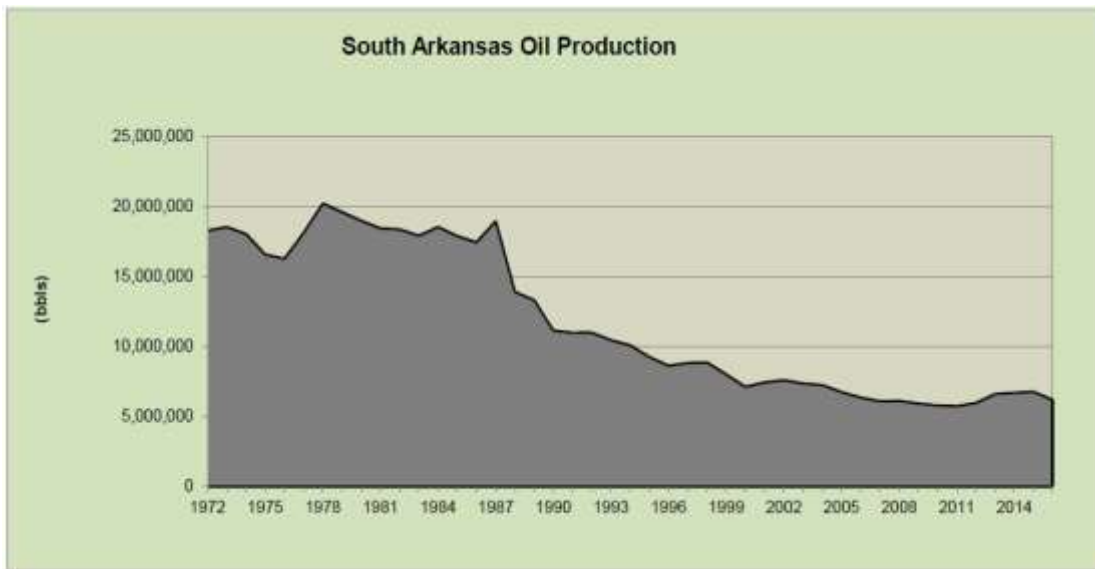


Figure 1. Annual oil production of south Arkansas (from AOGC annual report of production 2016).

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 2016 declined by 9% to 74,073,472 Mcf. Cumulative production in the Arkoma Basin for all conventional gas wells and tight gas sands of the B-44 producing region as of end of 2016 is approximately 7.06 Tcf. 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, that is mostly associated with development of the Fayetteville Shale resource.

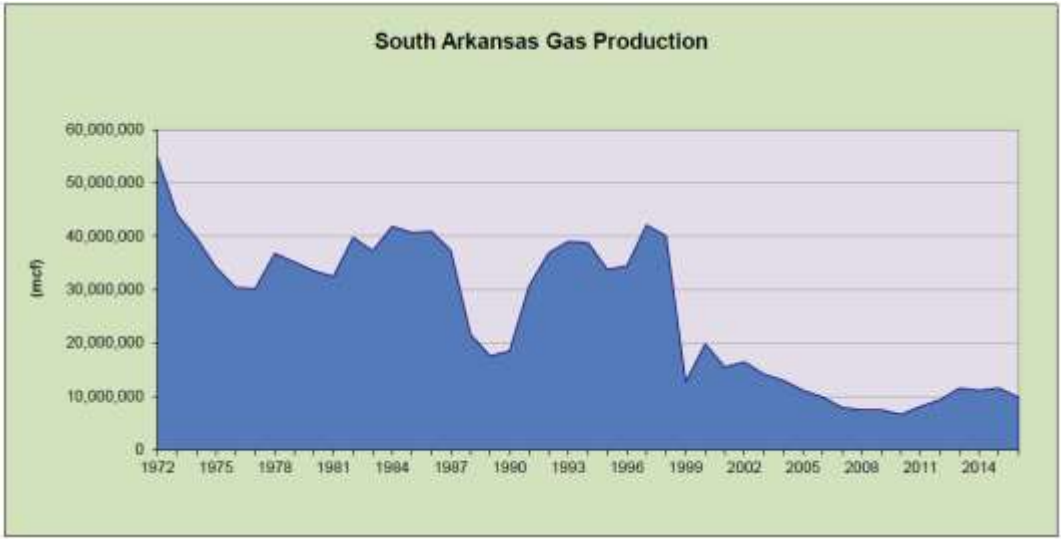


Figure 2. Annual gas production of south Arkansas (from AOGC annual report of production 2016).

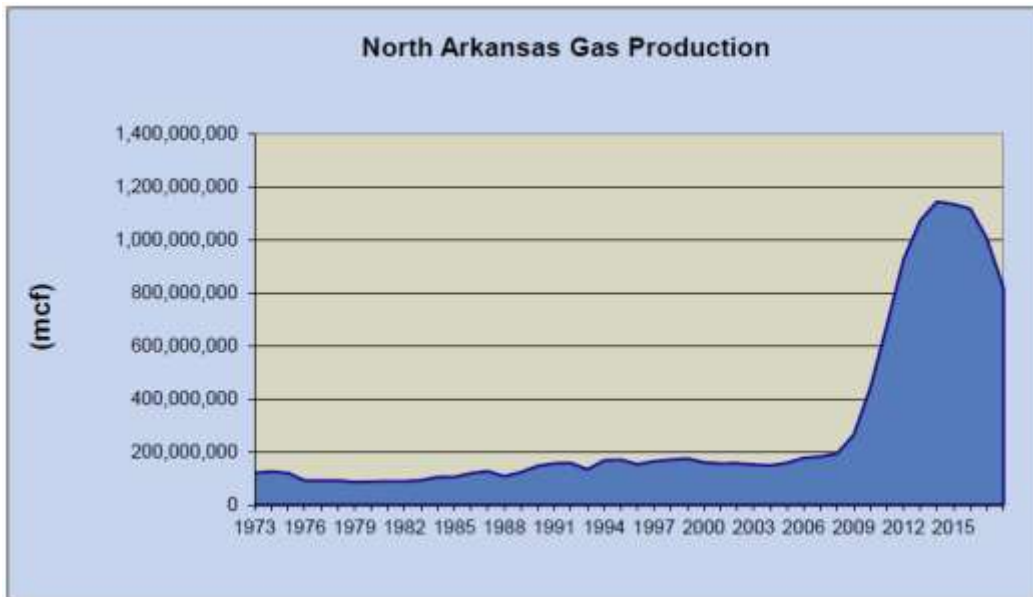


Figure 3. Annual gas production of north Arkansas (from AOGC annual report of production 2016).

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 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 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 cumulative 18.2 Tcf is economically recoverable reserves by 2050. EIA also reports that the proved gas reserves of the Fayetteville Shale in 2013 is 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.

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 2016, there was 743,331,705 Mcf of gas produced in the play, a 19% decline over the last year. Estimated cumulative production of gas as of 2016 has totaled 7.34 Tcf. Initial production rates of horizontal wells in 2016 averaged about 6.0 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>.

After pulling two gas drilling rigs during the last week of 2015, SEECO (a subsidiary of Southwestern Energy) returned a rig to work in Fayetteville Shale in September 2016 as natural gas futures bounced around \$3 per MMBtu. Forty-three (43) wells were completed by SEECO in 2016, an 84% decline compared to 266 completion wells a year ago.

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 2016, Southwestern contributed 558 Bcf in Fayetteville gas sales, good for 75.0% of the play's total sales that year. XTO Energy sold 95 Bcf (12.8%) and BHP traded 89 Bcf (12.0%). The remaining 0.2 % of sales, or 2.0 Bcf, was spread out among eight companies.

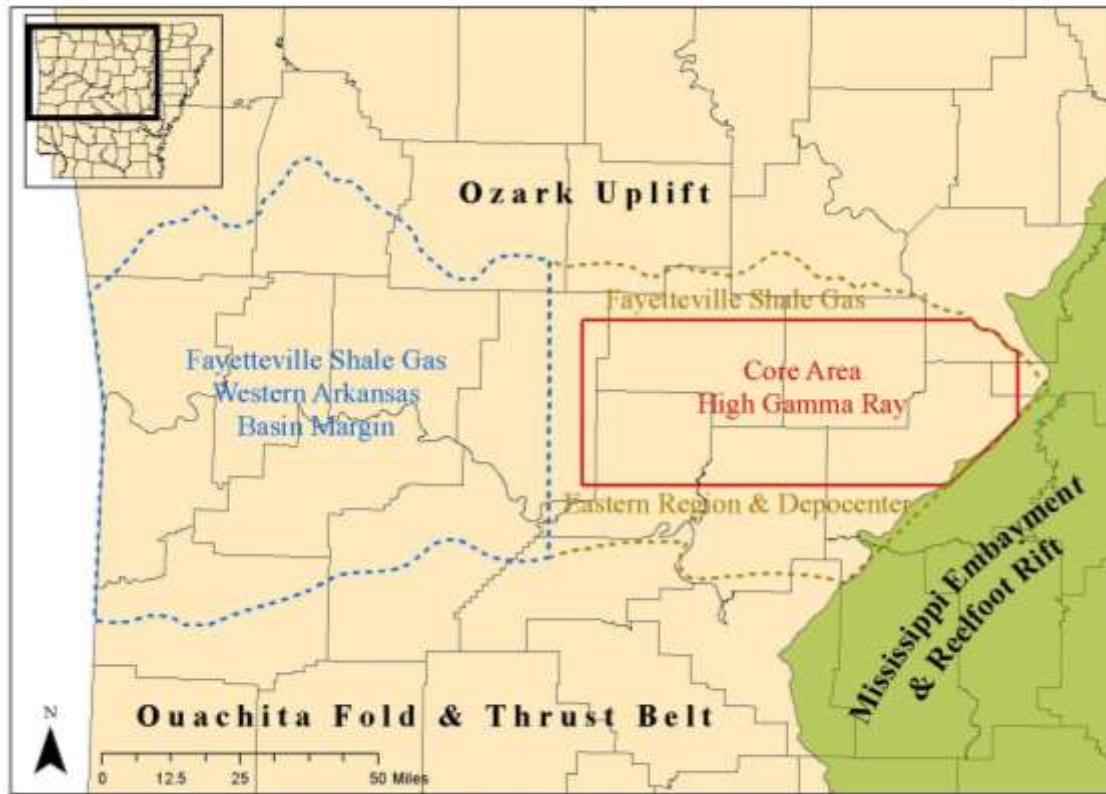


Figure 4. Primary area of the Fayetteville Shale exploration and development in Arkansas.

The top three operators of the Fayetteville gas shale play as of the end of 2016, based on numbers of producing wells, are as follows (Figure 5):

- 1) SEECO Inc. (an exploration subsidiary of Southwestern Energy) (3,934 wells)
- 2) BHP Billiton Petroleum (980 wells)
- 3) XTO Energy, Inc. (a subsidiary of ExxonMobil) (885 wells)

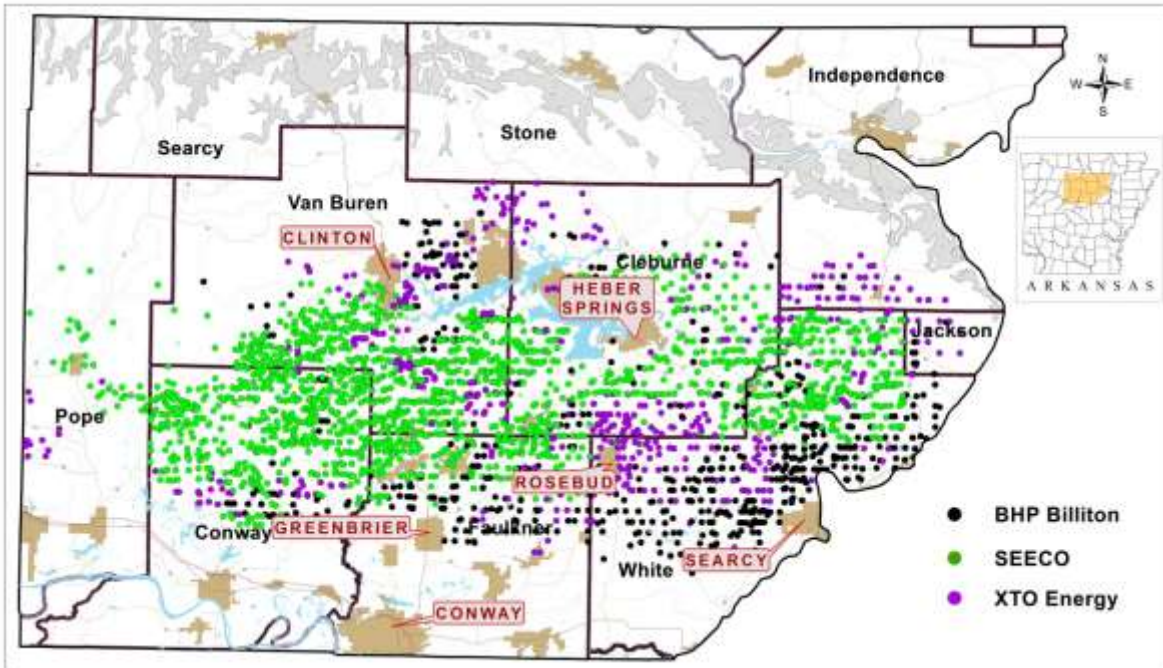


Figure 5. Location map of the Fayetteville Shale producing wells by top three operators.

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.

Coalbed Methane

The development of Arkansas coalbed methane (CBM) resources began in 2001 and has yielded an approximate cumulative production of 29,529,592 Mcf from 58 wells as of year-end 2016. In 2016, sales of CBM declined by 8% over the last year to 1,150,102 Mcf from 48 wells. Figure 6 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

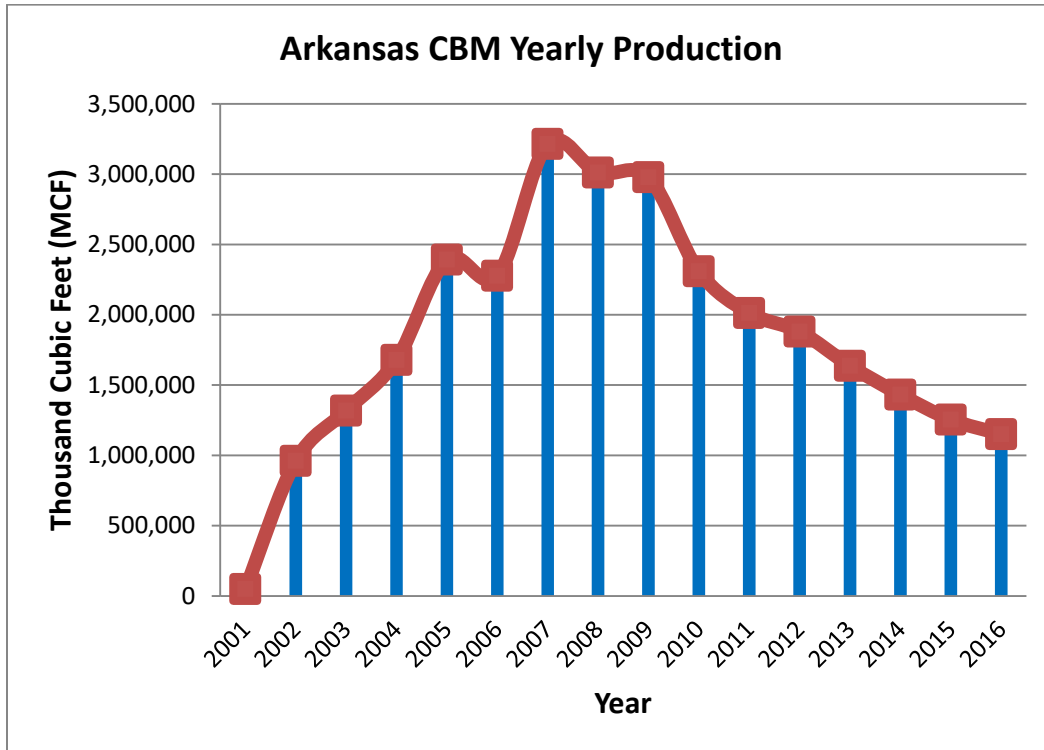


Figure 6. Annual production of coalbed methane in Arkansas.

Coal

In 2016, Arkansas coal production decreased by 25% to 136,463 gross tons compared to 2015. Underground mined coal production (128,255.97 gross tons) again far surpassed that from surface mining (8,237.03 gross tons).

Comer Mining sold 5,978.47 tons of surface coal to the AES power plant in Oklahoma. The underground mine operated by Sebastian Mining in southern Sebastian County produced 128,255.97 gross tons in 2016. Most of its production also went to the AES power plant. The new surface Stryton Mine No. 1 started production in 2016 but had quality control problems and only produced 2,258.56 tons. The production from this mine was also going to the AES power plant. Figure 7 shows the coal production trend since 2000.

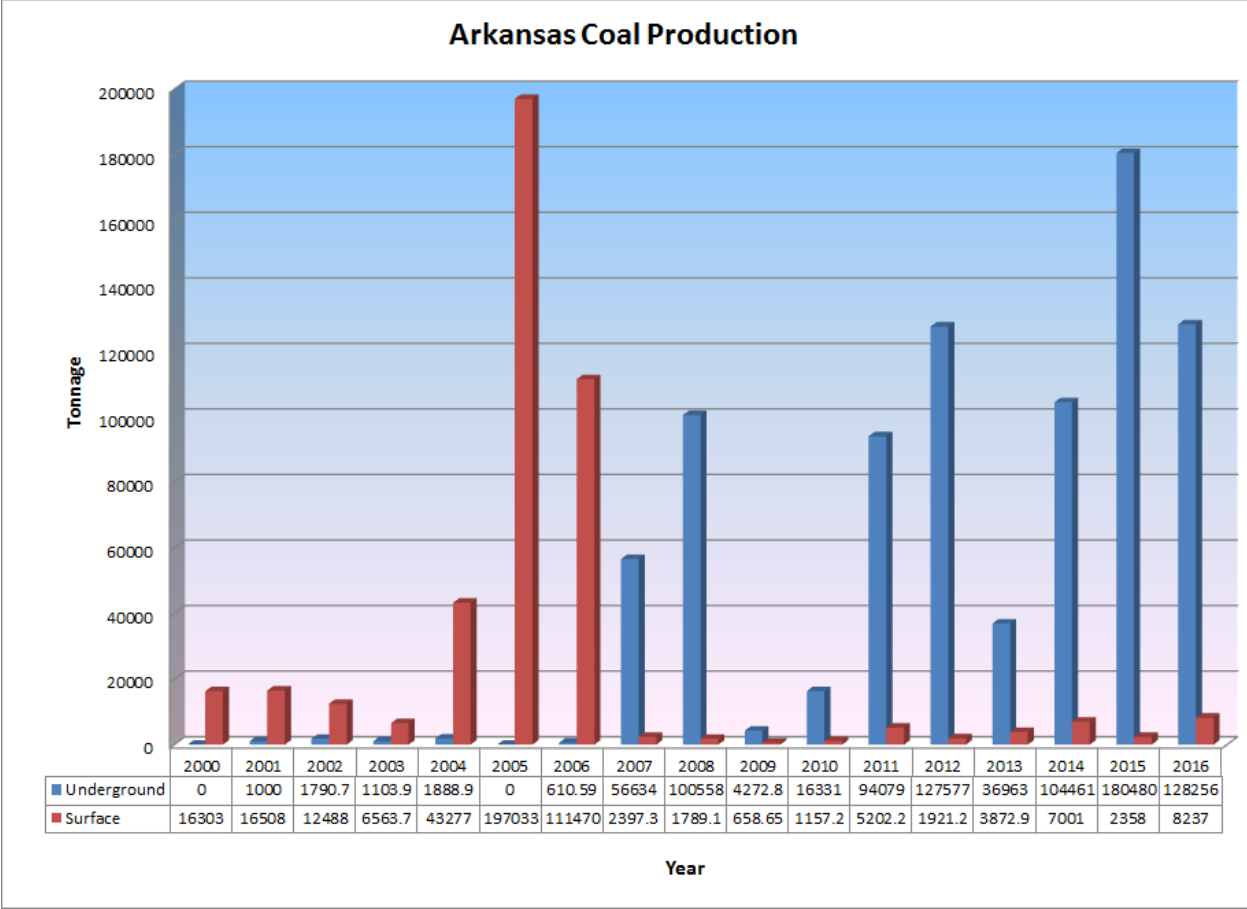


Figure 7. Annual coal production of Arkansas.

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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.