Oklahoma Coal: Resources, Production and Uses

By Brian J. Cardott
Oklahoma Geological Survey

INTRODUCTION

Coal is an organic-rich sedimentary rock formed primarily from vascular plants deposited in peat swamps. The bituminous coalfield in eastern Oklahoma covers an area of approximately 14,000 square miles (mi^2; 36,260 square kilometers, km^2) and can be divided into commercial (8,065 mi^2; 20,888 km^2) and noncommercial (6,075 mi^2; 15,734 km^2) areas (**Fig. 1**). The coalfield continues northward into Kansas and eastward into Arkansas and occupies the southern part of the Western Region of the Interior Coal Province of the United States (Campbell, 1917; Friedman, 2010a; East, 2013). Based on physiographic and structural differences, Friedman (1974) divided the Oklahoma coalfield into the northeast Oklahoma shelf ("shelf") and the Arkoma Basin ("basin").

The commercial coal belt contains coal beds ≥ 10 in. (≥ 25 cm) thick that are mineable by surface methods at depths < 100 ft (< 30 m) and coal beds ≥ 14 in. (≥ 36 cm) thick that are mineable by underground methods at depths <1,500 ft (< 457 m; Hemish, 1986).

There are about 40 named and several unnamed coal beds in the Oklahoma coalfield. Coal beds are 0.1 to 6.2 ft (0.03 to 1.9 m) thick in the shelf and 0.1 to 7.0 ft (0.03 to 2.1 m) thick in the basin (Hemish, 1988). The thickest known occurrence of coal in the Oklahoma coalfield is an exposure of the Hartshorne coal (10 ft; 3 m) in Latimer County (sec. 35, T. 6 N., R. 18 E.; Wilson, 1970; Hemish,

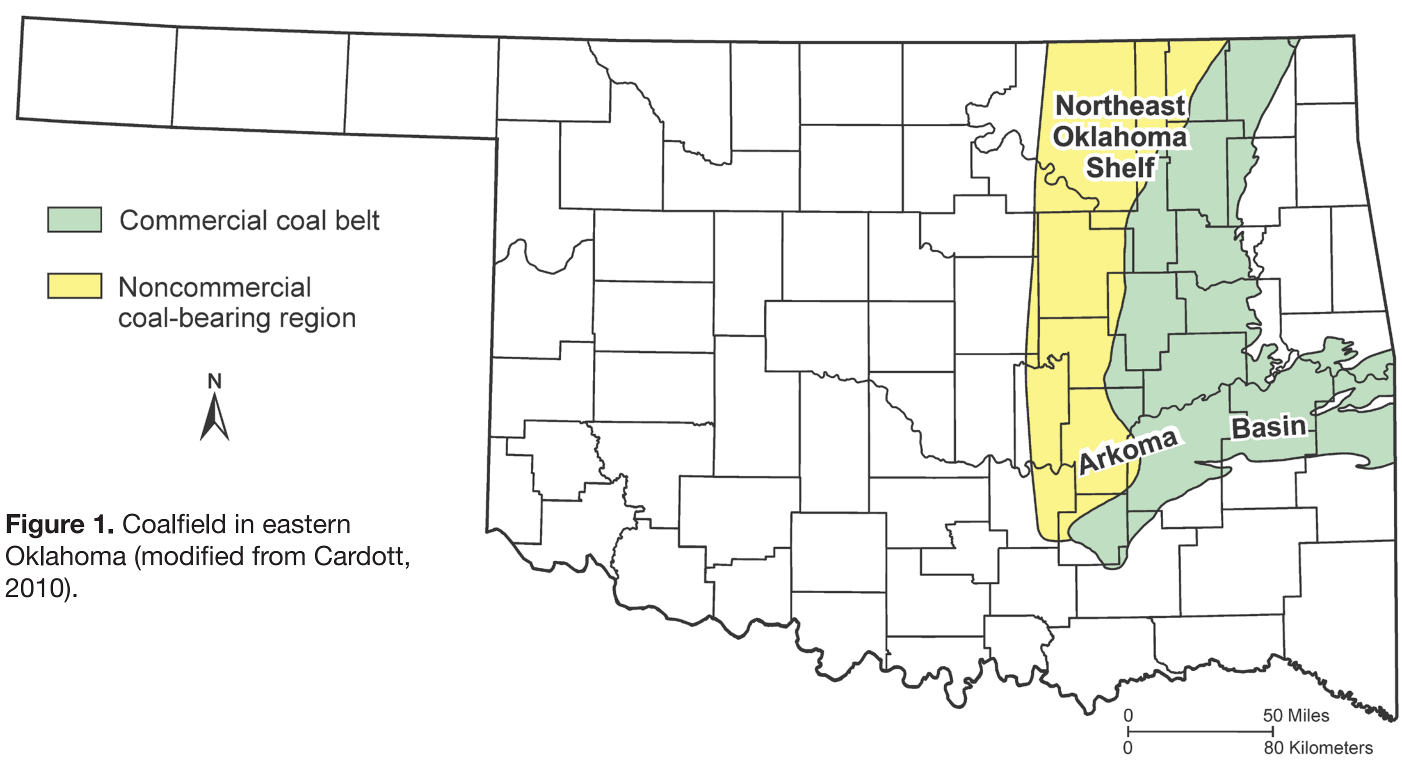

Figure 1. Coalfield in eastern Oklahoma (modified from Cardott, 2010).

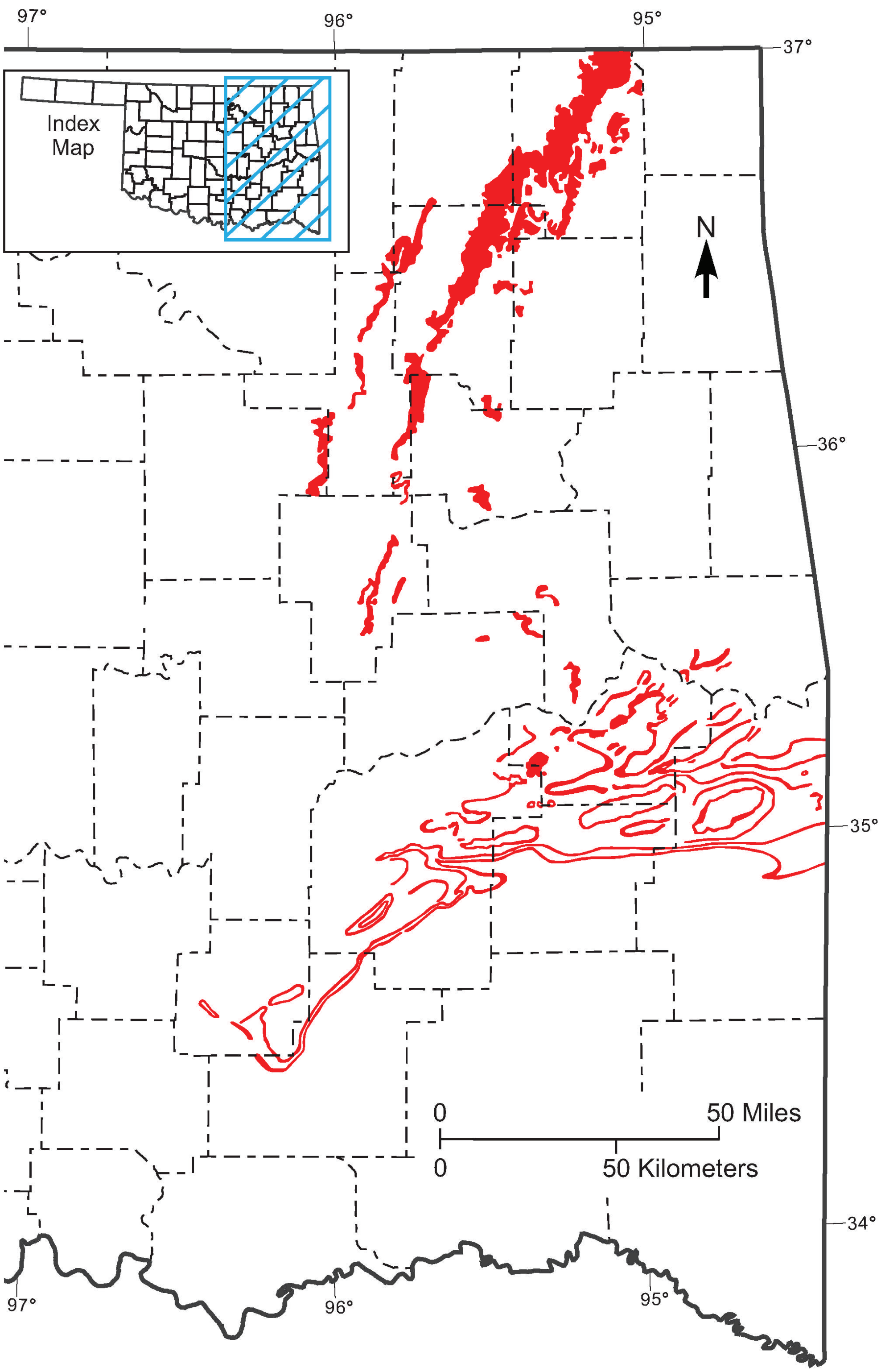

Figure 2. Map showing potentially strippable coal beds (red lines) in eastern Oklahoma (modified from Friedman and Woods, 1982).

1999). The thickest known occurrence of coal in the shelf is the Weir-Pittsburg coal (6.2 ft; 1.9 m) in a coal-company drill hole at a depth of 408 ft (124 m) in Craig County (sec. 28, T. 29 N., R. 18 E.; Hemish, 1986, Plate 4; Hemish, 2002).

The noncommercial coal-bearing region has limited information on coal thickness and quality; the region generally contains coal beds that are too thin, of low quality, or too deep for surface mining. Coalbed methane production has been developed in both the commercial coal belt and the noncommercial coal-bearing region (Cardott, 2010, 2013).

Figure 2 shows coal outcrop and potentially strippable areas in the Oklahoma coalfield (modified from Friedman and Woods, 1982). Coal beds in the shelf strike northeast in outcrop and dip 0.5-2° northwestward from the outcrop to depths ≥ 2,500 ft (≥ 760 m; Johnson, 1974; Friedman, 2010a). Coal beds in the basin are present at the surface and to depths ≥ 5,000 ft (≥ 1,830 m; Iannacchione and Puglio, 1979; Andrews and others, 1998). They are faulted and folded into narrow, northeastward-trending anticlines and broad synclines with dips varying from 3° to nearly vertical (Friedman and Woods, 1982; Friedman, 2010a). Deformation of the Oklahoma coalfield occurred during the Middle Pennsylvanian (Suneson and Stanley, 2017).

All of the coal beds in

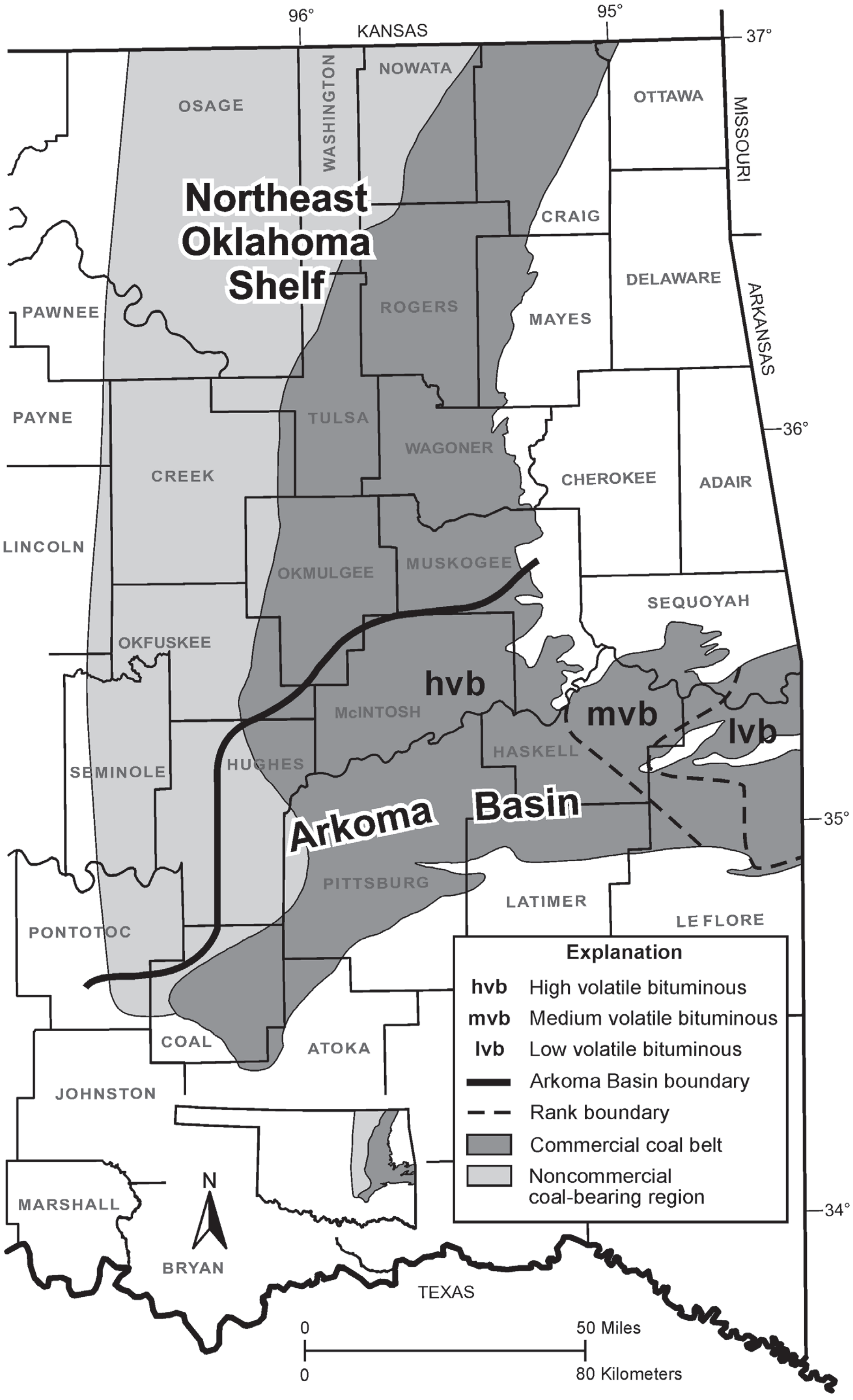

Figure 3. Oklahoma coalfield and surface coal rank from all coal beds (from Cardott, 2013).

the Oklahoma coalfield are humic coals derived from peat swamps. Sapropelic coals (cannel or boghead) are spore- or algae-rich and form in standing bodies of water. There are no known sapropelic coal beds in Oklahoma. The age of commercial coal beds in the Oklahoma coalfield is Middle Pennsylvanian (Desmoinesian). Thin, noncommercial coal beds occur in Morrowan, Atokan, Missourian, Virgilian (Pennsylvanian), and Wolfcampian (Permian) strata as well (Cardott, 1989). Several historical coal rank maps are presented in Cardott and others (1986). Oklahoma coal rank, generalized for all coals at or near the surface, ranges from high-volatile bituminous in the shelf and western basin to medium- and low-volatile bituminous in the eastern basin, attaining semianthracite rank at depth (**Fig. 3**; Cardott, 2013). Oklahoma coal rank and quality data are available on the OGS web site (http://www.ou.edu/content/ogs/data/coal.html).

OKLAHOMA COAL RESOURCES

Resources are an estimate of the presently known deposit while reserves are the economically and technologically recoverable part of resources. Based on estimates by Friedman (1974) and Hemish (1986, 1989, 1990, 1994a, 1998a, 1998b) on 29 coal beds, the remaining identified bituminous coal resources (known or estimated from geologic evidence using measured, indicated and inferred resource categories of reliability; Wood and others, 1983) in beds ≥ 10 in. (≥ 25 cm) thick at <100 ft (< 30 m) deep and ≥ 14 in. (≥ 36 cm) thick at >100 ft (> 30 m)

Table 1. Remaining identified bituminous coal resources in Oklahoma (in thousands of short tons).

County	Original Resources (Friedman, 1974, Tables 21-39)	Remaining Identified Bituminous Coal Resources[1]
Atoka	30,428	29,619
Coal	361,265	292,875
Craig	662,460	640,092[2]
Creek	15,573	15,573[4]
Haskell	1,541,471	1,513,681
Latimer	887,203	841,968
Le Flore	2,040,563	1,973,362
Mayes	31,546	31,094[3]
McIntosh	41,563	36,319[7]
Muskogee	103,197	95,557[6]
Nowata	37,104	29,645[2]
Okfuskee	155,968	155,964[5]
Okmulgee	421,440	340,124[5]
Pittsburg	1,513,445	1,383,833
Rogers	400,060	361,821[3]
Sequoyah	30,370	27,146
Tulsa	179,584	169,974[4]
Wagoner	140,942	128,955[4]
Washington	23,450	23,450[4]
Total	**8,617,632**	**8,091,052**

[1]As of January 1, 1974 (from Friedman, 1974, OGS SP 74-2; Tables 40-58);

[2]Revised as of January 1, 1979 (from Hemish, 1986, OGS Bulletin 140);

[3]Revised as of January 1, 1981 (from Hemish, 1989, OGS Bulletin 144);

[4]Revised as of January 1, 1982 (from Hemish, 1990, OGS GM-33);

[5]Revised as of January 1, 1987 (from Hemish, 1994, OGS SP 94-3);

[6]Revised as of January 1, 1993 (from Hemish, 1998, OGS SP 98-2);

[7]Revised as of January 1, 1994 (from Hemish, 1998, OGS SP 98-6)

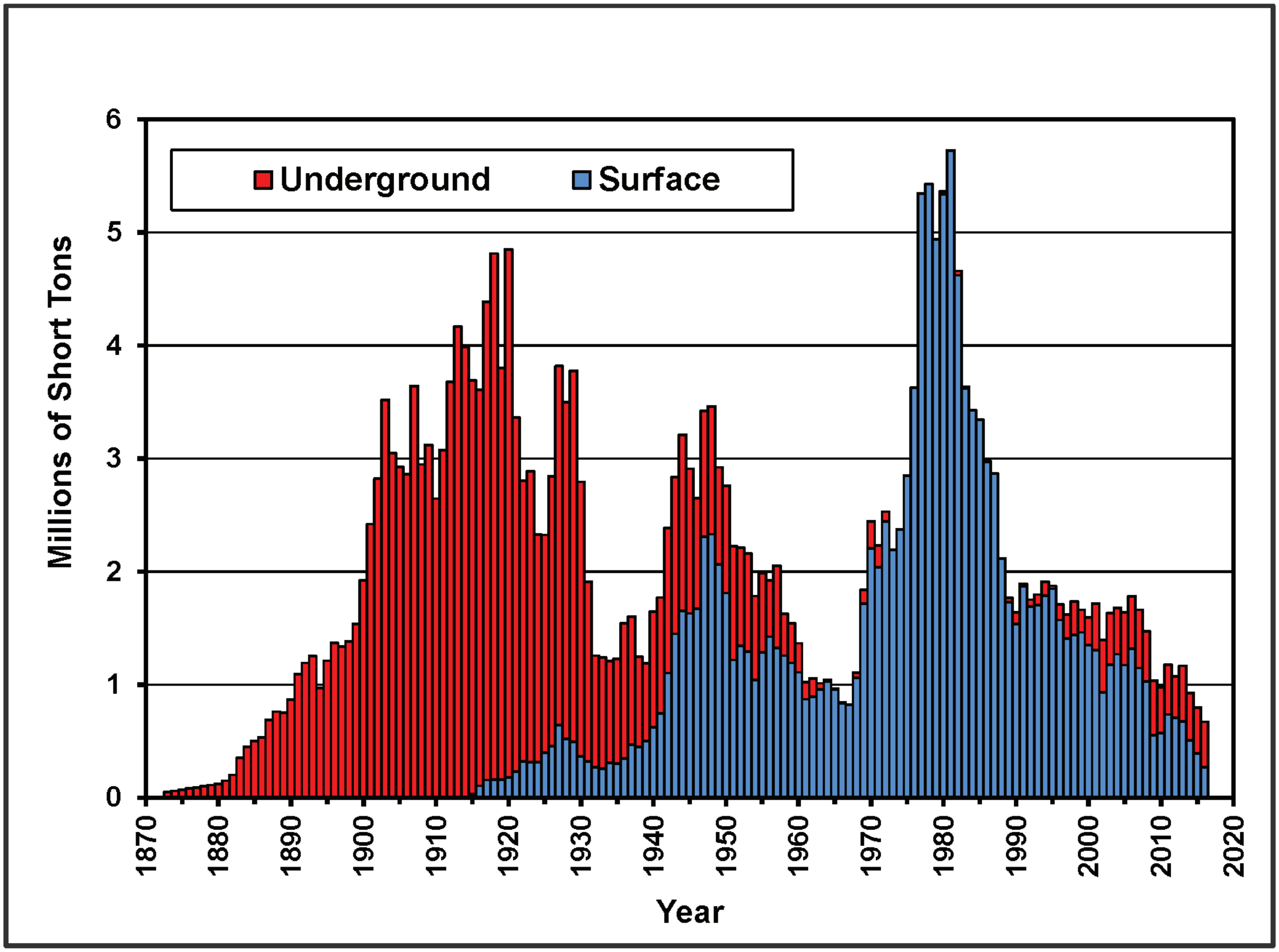

Figure 4. Coal production in Oklahoma ,1873–2016 (from Federal and State data discussed in the text).

deep is 8,091,052,000 short tons in 19 counties in eastern Oklahoma (**Table 1**). The 29 commercial coal beds evaluated for resources are the following (in stratigraphic order, youngest to oldest): Cedar Bluff, Tulsa, Dawson, Jenks, Iron Post, Croweburg, Fleming, Mineral, Tebo, Weir-Pittsburg, Wainwright, Bluejacket, Peters Chapel, Secor Rider, Secor, Lower Witteville, Drywood, Rowe, Cavanal, Tullahassee, Spaniard, Upper McAlester (Stigler Rider), McAlester (Stigler), Keefton, Hartshorne, Upper Hartshorne, Lower Hartshorne.

Available coal reserves are impacted by environmental, land-use, technological and geologic restrictions such as towns, streams, power lines, pipelines, cemeteries, and coal beds too thin or too deep (Eggleston and others, 1990; Carter and others, 1995; Carter and others, 2001; Luppens and others, 2009). The U.S. Geological Survey has assessed U.S. coal resources and reserves (Pierce and Dennen, 2009; Shaffer and others, 2017). Oklahoma's available coal reserves have not been assessed. EIA (2017a, Table 15) provides an estimate of the Demonstrated Reserve Base ("recoverable after excluding coal estimated to be unavailable due to land use restrictions and after applying assumed mining recovery rates") by U.S. state. As of January 1, 2017, the Oklahoma Demonstrated Reserve Base is 1.535 billion short tons (1.393 billion metric tons) of coal divided into 1.222 billion short tons (1.109 billion metric tons) mineable underground and 313 million short tons (284 million metric tons) mineable by surface methods.

OKLAHOMA COAL PRODUCTION

Gunning (1975) reported that the occurrence of coal in Oklahoma has been known since at least 1719. Hemish (1994b) provided a brief history of coal mining in Oklahoma, while Friedman

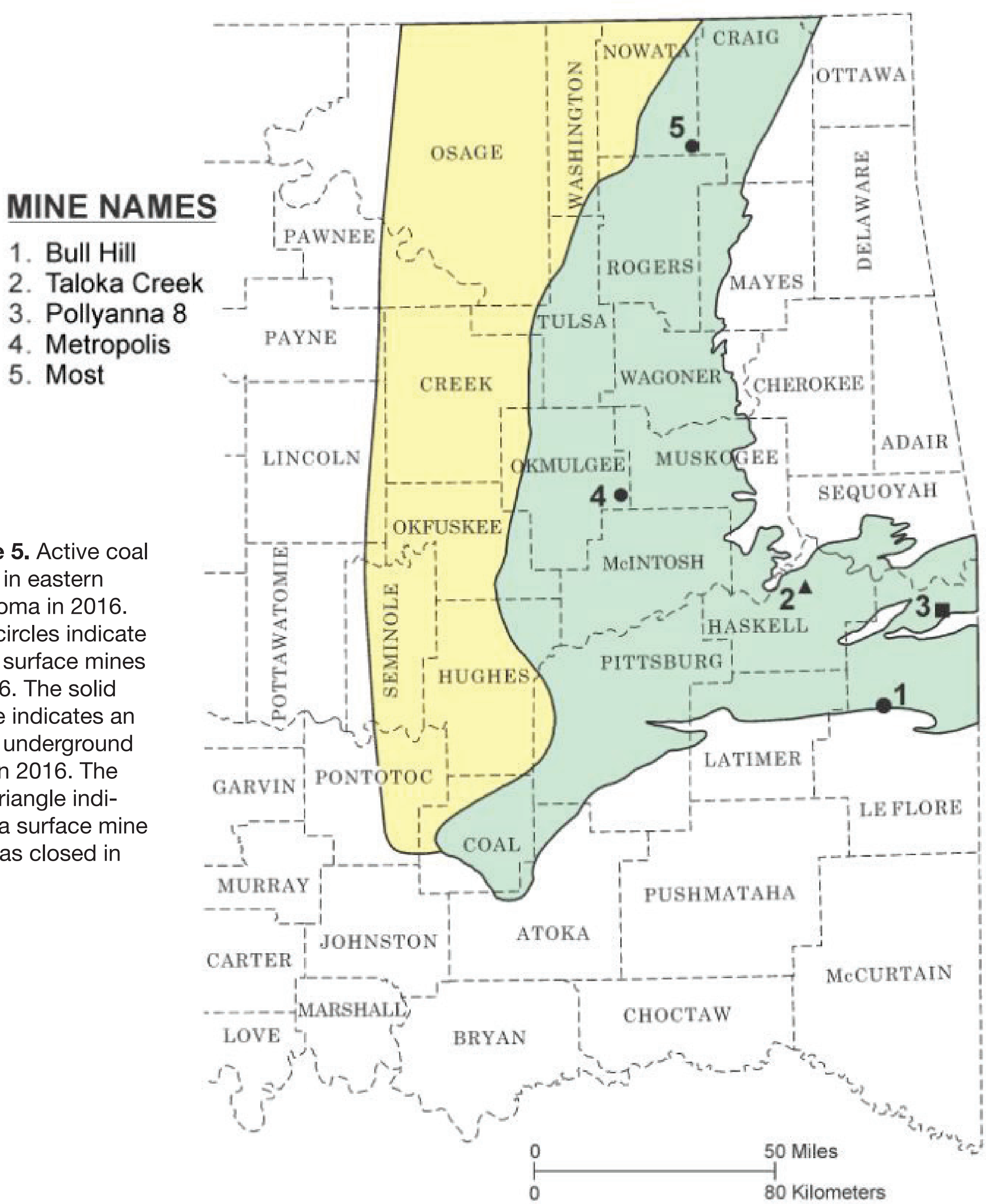

Figure 5. Active coal mines in eastern Oklahoma in 2016. Solid circles indicate active surface mines in 2016. The solid square indicates an active underground mine in 2016. The solid triangle indicates a surface mine that was closed in 2016.

(1990) provided a brief history of coal production in Oklahoma. With the introduction of the Missouri-Kansas-Texas Railroad in 1872, the earliest record of commercial coal production in Indian Territory was 50,000 short tons (45,359 metric tons) produced in 1873 by subsurface methods (Eavenson, 1942). Annual Oklahoma coal production amounts are reported in the following publications: 1873-1879 (Eavenson, 1942); 1880-1923 (USGS Mineral Resources of the United States); 1924-1931 (USBM Mineral Resources of the United States); 1932-1948 (USBM Minerals Yearbook); 1949-present (Oklahoma Department of Mines annual report). Annual Oklahoma coal production by county is available in a spreadsheet on the OGS web site (http://www.ou.edu/content/ogs/data/coal.html).

From 1873 to 2016, 299,234,593 short tons (271,461,056 metric tons) of bituminous coal were produced from underground and surface mines in the Indian Territory and Oklahoma (Federal and State data; **Fig. 4**). From 1873 to 1914 the coal production in Indian Territory and Oklahoma was strictly by underground methods. Coal production from

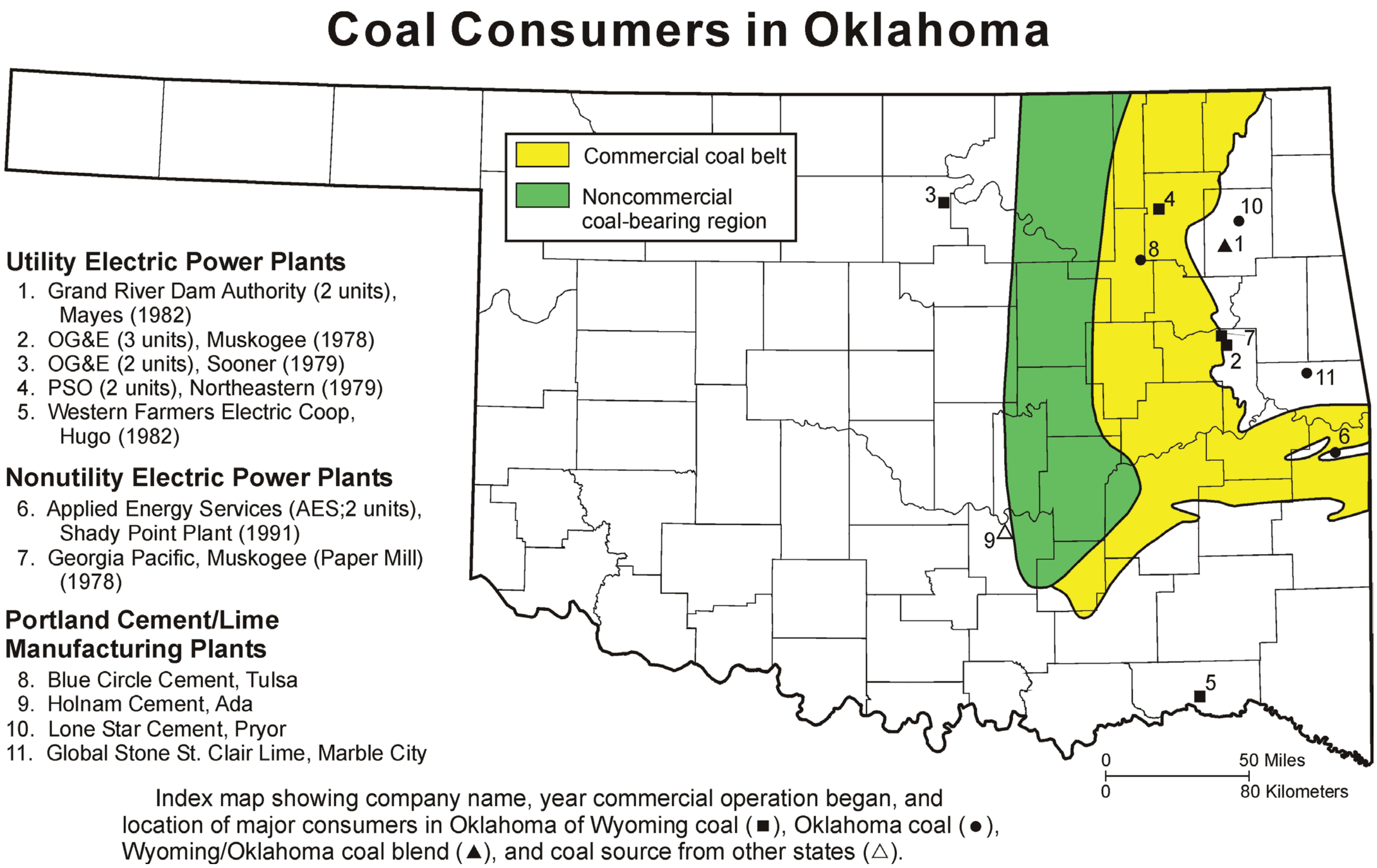

Figure 6. Coal consumers in Oklahoma (from Boyd and Cardott, 2001).

surface mines surpassed underground mines in 1943. Maps showing the locations of abandoned underground coal mines in Oklahoma prior to 1979 are in Hendricks (1937, 1939), Knechtel (1937, 1949), Dane and others (1938), Oakes and Knechtel (1948), Dunham and Trumbull (1955), Hemish (1990), and Friedman (1994a, 1996, 2006, 2008, 2010b).

Peak annual coal production in Oklahoma was 5.73 million short tons (5.20 million metric tons) in 1981, with smaller production peaks during and immediately following World War I and World War II. In 2016, 670,610 short tons (608,367 metric tons) of bituminous coal were produced in Oklahoma from five mines (four surface, one underground; **Fig. 5**), which is the lowest annual coal production since 1886 when 534,580 short tons (484,962 metric tons) of bituminous coal were produced (USGS, 1912). Oklahoma coal production ranked 22nd out of 25 coal-producing states in 2015 (EIA, 2017b). Coal production by origin state and by destination state is in EIA (2017c).

OKLAHOMA COAL USES

Bituminous coal produced in Oklahoma was used initially as steam coal for locomotives. The primary use of Oklahoma coal both in-state and out-of-state has been as fuel for steam used in electric power plants and for coke used in steel production. The quality and rank made the coal beneficial as a coking coal for use in the steel industry (Friedman, 1990). Trumbull (1957) reported that 45% of the coal produced in Oklahoma in 1952 was used to produce coke. Oklahoma coal has also been used as process heat in cement and lime kilns, paper mills, and an automobile plant, as well as for chemical feedstock or the production of briquettes (Friedman, 1990). Friedman (1990, p.162) reported that “Since 1981 the coal industry in Oklahoma has lost its premium, coking-coal markets, and it has not been able to compete in the rapidly expanding international steam coal markets.” Boyd and Cardott (2001) summarized the in-state coal-fired power plants (**Fig. 6**). In 1998, Oklahoma utility electricity generation by

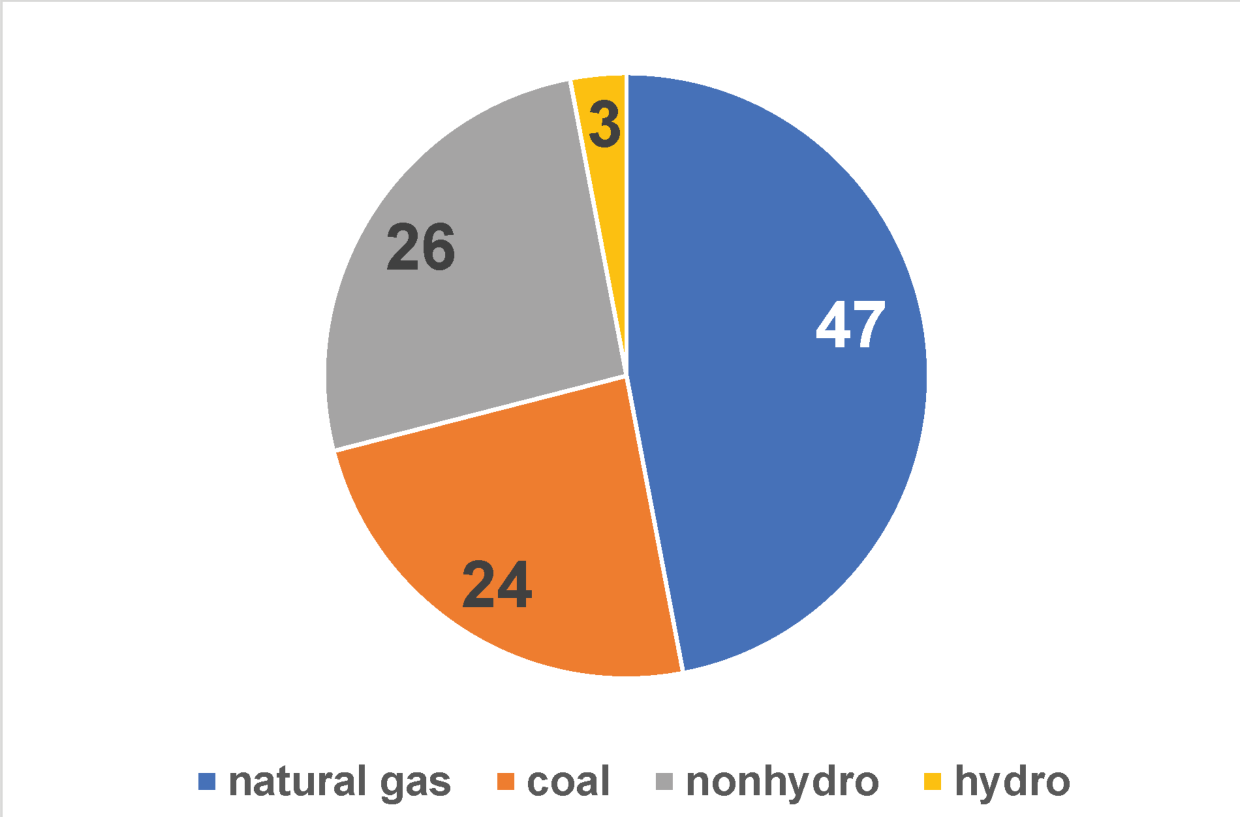

Figure 7. 2016 Oklahoma net electricity generation by source (natural gas, coal [subbituminous and bituminous], nonhydroelectric renewables [wind, other biomass, solar thermal and photovoltaic], hydro-electric)(EIA, 2017e).

Table 2. Oklahoma coal-fired power plant 2016 fuel consumption (EIA, 2017d, f).

Power Plant	Plant ID	Bituminous coal (short tons)	Subbituminous coal (short tons)
Grand River Dam Authority	165		1,722,631
OG&E Muskogee	2952		4,018,677
OG&E Sooner	6095		2,497,320
PSO Northeastern	2963		1,389,467
Western Farmers Hugo	6772		1,348,447
AES Shady Point	10671	614,204	578,925
Total		614,204	11,555,467

primary energy source was distributed as follows: 60% coal, 33% natural gas, 7% hydroelectric (Boyd and Cardott, 2001). **Figure 7** shows Oklahoma net electricity generation by source (includes electric utilities electric generator and combined heat and power [industrial power, electric power, and commercial power]) in 2016.

In 2016, the Applied Energy Services (AES) Shady Point fluidized-bed combustion non-utility, co-generation plant near Spiro, Oklahoma (Friedman, 1994b), used 578,925 short tons (525,192 metric tons) of subbituminous coal from Wyoming and 614,204 short tons (557,196 metric tons) of bituminous coal from Oklahoma and other states to generate electricity and provide food-grade carbon dioxide (**Table 2**). The AES plant is the primary user of Oklahoma coal. In 2016, Oklahoma imported 10.6 million short tons (9.6 million metric tons) of subbituminous coal by railroad from Wyoming (EIA, 2017c), while 11.6 million short tons (10.5 million metric tons) of subbituminous coal (including stockpiles leftover from purchases in 2015) were used by coal-fired power plants in 2016 (**Table 2**; EIA, 2017d, f).

In addition to well-known uses of coal such as electric power generation (combustion), process heat, coke manufacture in the steel industry (carbonization), and gasification and liquefaction (conversion; EIA, 2017g), there are lesser-known uses of coal such as for plastics, dyes, synthetic rubber, medicine, perfumes, paint thinner, insecticides, and many others described in the coal byproducts tree illustration (Schweinfurth, 2003, 2009). Future potential uses of Oklahoma bituminous coal may include these applications.

ACKNOWLEDGEMENTS

I thank Bill Ambrose (Bureau of Economic Geology) and Julie Chang (OGS) for constructive reviews of the manuscript. I thank Jim Anderson and Russell Standridge (OGS) for preparation of Figures 1, 2, 3, 5, and 6.

REFERENCES

Note: Bibliographies on several topics on Oklahoma coal are available at http://www.ou.edu/content/ogs/research/energy/coal/bibliography.html.

Andrews, R.D., B.J. Cardott, and T. Storm, 1998, The Hartshorne play in southeastern Oklahoma: regional and detailed sandstone reservoir analysis and coalbed-methane resources: OGS Special Publication 98-7, 90 p.

Boyd, D., and B. Cardott, 2001, Oklahoma's energy landscape: OGS Information Series 9, 15 p.

Campbell, M.R., 1917 (1929), The coal fields of the United States; general introduction: U.S. Geological Survey, Professional Paper 100-A, 33 p.

Cardott, B.J., 1989, A petrographic survey of high-volatile bituminous Oklahoma coal beds: OGS Oklahoma Geology Notes, v. 49, p. 112-124.

Cardott, B.J., 2010, Issues related to Oklahoma coalbed-methane activity, 1988-2008: OGS 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.

Cardott, B.J., L.A. Hemish, C.R. Johnson, and K.V. Luza, 1986, The relationship between coal rank and present geothermal gradient in the Arkoma Basin, Oklahoma: OGS Special Publication 86-4, 65 p.

Carter, M.D., T.J. Rohrbacher, G.A. Weisenfluh, N. Fedorko, A.G. Axon, C.G. Treworgy, H. Cetin, D.D. Teeters, R.I. Geroyan, R.S. Sites, and N.K. Gardner, 1995, Federal and state coal availability/recoverability studies in eastern United States—A new approach to coal resource assessment, in L.M.H. Carter, ed., Energy and the environment—Application of geosciences to decision-making: U.S. Geological Survey Circular 1108, p. 48-50.

Carter, M.D., T.J. Rohrbacher, D.D. Teeters, D.C. Scott, L.M. Osmonson, G.A. Weisenfluh, E.I. Loud, R.S. Sites, A.G. Axon, M.E. Wolfe, and L.J. Lentz, 2001, Chapter J—Coal availability, recoverability, and economic evaluations of coal resources in the northern and central Appalachian Basin coal regions: U.S. Geological Survey Professional Paper 1625-C, DVD.

Dane, C.H., H.E. Rothrock, and J.S. Williams, 1938, Geology and fuel resources of the southern part of the Oklahoma coal field; part 3, the Quinton-Scipio district, Pittsburg, Haskell, and Latimer Counties: U.S. Geological Survey, Bulletin 874-C, p. 151-253.

Dunham, R.J., and J.V.A. Trumbull, 1955, Geology and coal resources of the Henryetta mining district, Okmulgee County, Oklahoma: U.S. Geological Survey, Bulletin 1015-F, p. 183-225.

East, J.A., 2013, Coal fields of the conterminous United States—National Coal Resource Assessment updated version: U.S. Geological Survey Open-File Report 2012-1205, one sheet, scale 1:5,000,000. https://pubs.usgs.gov/of/2012/1205/

Eavenson, H.N., 1942, The first century and a quarter of American coal industry: Pittsburgh, PA, privately printed, p. 568.

Eggleston, J.R., M.D. Carter, and J.C. Cobb, 1990, Coal resources available for development—a methodology and pilot study: U.S. Geological Survey Circular 1055, 15 p.

EIA, 2017a, Annual coal report 2016: Washington, D.C., U.S. Energy Information Administration, 59 p. https://www.eia.gov/coal/annual/

EIA, 2017b, Rankings: Coal production, 2015: EIA Web Site. https://www.eia.gov/state/rankings/?sid=OK#series/48

EIA, 2017c, Annual coal distribution report 2016: Washington, D.C., U.S. Energy Information Administration, 101 p. https://www.eia.gov/coal/distribution/annual/

EIA, 2017d, Form EIA-923: EIA Web Site. https://www.eia.gov/electricity/data/eia923/

EIA, 2017e, Electricity detailed state data: Washington, D.C., U.S. Energy Information Administration, Net generation by state by type of producer by energy source table, 1990-2016. https://www.eia.gov/electricity/data/state/

EIA, 2017f, State profile and energy estimates: Washington, D.C., U.S. Energy Information Administration. https://www.eia.gov/state/?sid=OK#tabs-4

EIA, 2017g, Coal explained: Use of coal: Washington, D.C., U.S. Energy Information Administration. https://www.eia.gov/energyexplained/index.cfm?page=coal_use

Friedman, S.A., 1974, Investigation of the coal reserves in the Ozarks section of Oklahoma and their potential uses: OGS Special Publication 74-2, 117 p.

Friedman, S.A., 1990, A brief history of coal production in Oklahoma, 1873-1989, in R.B. Finkelman, S.A. Friedman, and J.R. Hatch, eds., Coal geology of the Interior Coal Province, western region: Environmental and Coal Associates, Reston, Virginia, p. 161-165.

Friedman, S.A., 1994a, Map showing location of abandoned underground coal mines in Okmulgee and Okfuskee Counties, Oklahoma, in Hemish, L.A., Coal geology of Okmulgee County and eastern Okfuskee County, Oklahoma: OGS Special Publication 94-3, Plate 7.

Friedman, S.A., 1994b, Oklahoma's newest large electric power plant: OGS Oklahoma Geology Notes, v. 54, p. 177-178, 220.

Friedman, S.A., 1996, Map showing the distribution of underground mines in the Hartshorne and McAlester coals in the Hartshorne 7.5' quadrangle, Pittsburg and Latimer Counties, Oklahoma: OGS Open-File Report 7-96, scale 1:24,000.

Friedman, S.A., 2006, Map showing locations of underground coal mines in eastern Oklahoma: OGS Open File Report 52-2004, scale 1:250,000.

Friedman, S.A., 2008, Map showing the distribution of underground mines in the Lower Hartshorne and McAlester coals in the Adamson 7.5' quadrangle, Pittsburg and Latimer Counties, Oklahoma: OGS Open-File Report 1-2008, scale 1:24,000.

Friedman, S.A., 2010a, Coal geology of Oklahoma: Jacksonville, FL, Keystone Coal Industry Manual, Mining Media International, p. 537-543.

Friedman, S.A., 2010b, Desmoinesian coal deposits in part of the Arkoma Basin, eastern Oklahoma: OGS Guidebook 37, 61 p.

Friedman, S.A., and R.J. Woods, 1982, Map showing potentially strippable coal beds in eastern Oklahoma: OGS Map GM-23, scale 1:125,000, 4 sheets.

Gunning, I.C., 1975, When coal was king: coal mining industry in the Choctaw Nation: Eastern Oklahoma Historical Society, 105 p.

Hemish, L.A., 1986, Coal geology of Craig County and eastern Nowata County, Oklahoma: OGS Bulletin 140, 131 p.

Hemish, L.A., 1988, Report of core-drilling by the Oklahoma Geological Survey in Pennsylvanian rocks of the northeastern Oklahoma coal belt, 1983-1986: OGS Special Publication 88-2, 174 p.

Hemish, L.A., 1989, Coal geology of Rogers County and western Mayes County, Oklahoma: OGS Bulletin 144, 118 p.

Hemish, L.A., 1990, Coal geology of Tulsa, Wagoner, Creek, and Washington Counties, Oklahoma: OGS GM-33.

Hemish, L.A., 1994a, Coal geology of Okmulgee County and eastern Okfuskee County, Oklahoma: OGS Special Publication 94-3, 86 p.

Hemish, L.A., 1994b, A brief history of coal mining in Oklahoma, in N.H. Suneson and L.A. Hemish, eds., Geology and resources of the eastern Ouachita Mountains frontal belt and southeastern Arkoma Basin, Oklahoma: OGS Guidebook 29, p. 42-43.

Hemish, L.A., 1998a, Coal geology of Muskogee County, Oklahoma: OGS Special Publication

98-2, 111 p.

Hemish, L.A., 1998b, Coal geology of McIntosh County, Oklahoma: OGS Special Publication 98-6, 74 p.

Hemish, L.A., 1999, Hartshorne coal bed, Latimer County – thickest known coal in Oklahoma: OGS Oklahoma Geology Notes, v. 59, p. 34, 78.

Hemish, L.A., 2002, Surface to subsurface correlation of methane-producing coal beds, northeast Oklahoma shelf: OGS Special Publication 2002-2, 22 p.

Hendricks, T.A., 1937, Geology and fuel resources of the southern part of the Oklahoma coal field; part 1, the McAlester district, Pittsburg, Atoka, and Latimer Counties: U.S. Geological Survey, Bulletin 874-A, 90 p.

Hendricks, T.A., 1939, Geology and fuel resources of the southern part of the Oklahoma coal field; part 4, the Howe-Wilburton district, Latimer and Le Flore Counties: U.S. Geological Survey, Bulletin 874-D, p. 255-300.

Iannacchione, A.T., and D.G. Puglio, 1979, Methane content and geology of the Hartshorne coalbed in Haskell and Le Flore Counties, Oklahoma: U.S. Bureau of Mines Report of Investigations 8407, 14 p.

Johnson, K.S., 1974, Maps and description of disturbed and reclaimed surface-mined coal lands in eastern Oklahoma: OGS Map GM-17, 12 p., 3 sheets, scale 1:125,000.

Knechtel, M.M., 1937, Geology and fuel resources of the southern part of the Oklahoma coal field; part 2, the Lehigh district, Coal, Atoka, and Pittsburg Counties: U.S. Geological Survey, Bulletin 874-B, p. 91-149.

Knechtel, M.M., 1949, Geology and coal and natural gas resources of Northern Le Flore County, Oklahoma: OGS Bulletin 68, 76 p.

Luppens, J.A., T.J. Rohrbacher, L.M. Osmonson, and M.D. Carter, 2009, Coal resource availability, recoverability, and economic evaluations in the United States—A summary, *in* B.S. Pierce and K.O. Dennen, eds., The National Coal Resource Assessment overview: U.S. Geological Survey Professional Paper 1625, chapter D, 21 p. https://pubs.usgs.gov/pp/1625f/

Oakes, M.C., and M.M. Knechtel, 1948, Geology and mineral resources of Haskell County, Oklahoma: OGS Bulletin 67, 136 p.

Pierce, B.S., and K.O. Dennen, eds., 2009, The National Coal Resource Assessment overview: U.S. Geological Survey Professional Paper 1625-F, 402 p. https://pubs.usgs.gov/pp/1625f/

Schweinfurth, S.P., 2003, Coal—A complex natural resource: an overview of factors affecting coal quality and use in the United States: U.S. Geological Survey Circular 1143, 39 p. https://pubs.er.usgs.gov/publication/cir1143

Schweinfurth, S.P., 2009, An introduction to coal quality, *in* B.S. Pierce and K.O. Dennen, eds., The National Coal Resource Assessment overview: U.S. Geological Survey Professional Paper 1625, chapter C, 20 p. https://pubs.usgs.gov/pp/1625f/

Shaffer, B.N., J.E. Haacke, D.C. Scott, P.E. Pierce, S.A. Kinney, R.A. Olea, and J.A. Luppens, 2017, Assessing U.S. coal resources and reserves: U.S. Geological Survey Fact Sheet 2017-3067, 4 p. https://pubs.er.usgs.gov/publication/fs20173067

Suneson, N.H., and T.M. Stanley, 2017, The age of Oklahoma's mountain ranges: OGS Oklahoma Geology Notes, v. 76, No. 4, p. 4-19.

Trumbull, J.V.A., 1957, Coal resources of Oklahoma: U.S. Geological Survey, Bulletin 1042-J, p. 307-382.

USGS, 1912, Mineral resources of the United States, calendar year 1911: U.S. Geological Survey, Oklahoma coal, p. 163-166.

Wilson, L.R., 1970, Palynology of Oklahoma's ten-foot coal seam: OGS Oklahoma Geology Notes, v. 30, p. 62-63.

Wood, G.H., Jr., T.M. Kehn, M.D. Carter, and W.C. Culbertson, 1983, Coal resource classification system of the U.S. Geological Survey: U.S. Geological Survey Circular 891, 65 p.

About the Author

Brian established the Organic Petrography Laboratory (OPL) at the Oklahoma Geological Survey in 1981. His primary research involves gas shales and tight oil (primarily the Late Devonian–Early Mississippian Woodford Shale), coalbed methane, and the petrologic characterization of coals, hydrocarbon source rocks, and solid hydrocarbons (e.g., asphaltites and asphaltic pyrobitumens) of Oklahoma.

Brian has written more than 60 articles and books on coal, coalbed methane, gas shales, unconventional energy resources, hydrocarbon source rocks, solid hydrocarbons, organic weathering, vitrinite reflectance, and graptolite reflectance.

Brian is a member of The Society for Organic Petrology (serving as President, 1995-1996), International Committee for Coal and Organic Petrology, American Association of Petroleum Geologists (serving as President of the Energy Minerals Division, 2004-2005), Geological Society of America, Oklahoma City Geological Society, and Tulsa Geological Society.