Executive Summary

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Chapter A.1 of
Coal and Petroleum Resources in the Appalachian Basin: Distribution, Geologic Framework, and Geochemical Character
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Introduction

Fossil fuels from the Appalachian basin region have been major contributors to the Nation's energy needs over much of the last three centuries. Early records indicate that Appalachian coal was first mined in the middle 1700s (Virginia and Pennsylvania) and was used sparingly to fuel colonial settlements and, later, a fledgling industrial-based economy along the eastern seaboard of the United States (de Witt and Milici, 1989). In 2011, central Appalachian basin coal production accounted for approximately 77 percent of all U.S. metallurgical (or coking) coal and 29 percent of total U.S. production (U.S. Energy Information Administration, 2013). Following initial discoveries and commercial use in western New York (1821) and Ohio and West Virginia (mid-1830s), the Appalachian petroleum (oil and gas) industry began in earnest in 1859 with the discovery of oil at the Drake well in northwestern Pennsylvania. Between 1860 and 1989, the Appalachian basin produced more than 2.5 billion barrels of oil (BBO) and more than 30 trillion cubic feet of gas (TCFG) from more than 500,000 wells (de Witt and Milici, 1989). Although both oil and gas continue to be produced in the Appalachian basin, most new wells in the region are drilled in shale reservoirs to produce natural gas.

Appalachian coal and petroleum resources are still available in sufficient quantities to contribute significantly to the Nation's energy needs. For example, the U.S. Energy Information Administration (2010) estimated that there are 6,484 million short tons of recoverable coal reserves in the Appalachian basin. Similarly, about 14.7 billion barrels of oil equivalent (BBOE) (1.2 BBO+81 TCFG [or 13.5 BBOE]) of recoverable Appalachian basin oil and gas remain available of an estimated ultimate endowment of approximately 25.5 billion BBOE (cumulative production + reserves + estimated recoverable undiscovered resources) (this volume, chap. C.1).

U.S. Geological Survey (USGS) Professional Paper 1708 is a modern, indepth collection of reports, cross sections, and maps that describe the geology of the Appalachian basin and its fossil fuel resources. Several of the chapters have been published in outside journals or as other USGS publications. Although this volume is not a comprehensive regional treatment of all notable geologic and fossil fuel localities in the Appalachian basin, the selected study areas and topics presented in the chapters cover large segments of the basin and a wide range of stratigraphic intervals. As the title implies, this volume addresses topics that refer to the locations of coal and petroleum accumulations, the stratigraphic and structural framework, and the geochemical characteristics of the coal beds and petroleum in the basin, as well as the results and documentation of recent USGS assessments of coal, oil, and gas resources in the basin.

Many of the maps and accompanying data supporting the reports in this volume are available as downloadable geographic information system (GIS) data files (such as selected coal beds, selected oil and gas fields, locations of oil and gas wells, coal production, coal chemistry, total petroleum system (TPS) boundaries, and bedrock geology). Log ASCII Standard (LAS) files for geophysical (gamma ray) wireline well logs also are included.

This publication supplements and updates older USGS regional studies of Appalachian basin coal and petroleum resources such as those by Arndt and others (1968) and the numerous contributors to USGS Miscellaneous Map Series I–917 (for example, Harris and others, 1978), respectively. USGS Professional Paper 1708 is intended primarily for geoscientists in academia, industry, and government who are interested in Appalachian basin geology and its coal and petroleum resources. Other users, however, may find the wide variety of topics, papers, and digital images of value for land-use and policy planning issues. Among the anticipated benefits of the report are improvements in (1) resource assessment estimates and methodology, (2) exploration strategies, (3) basin models, and (4) energy use policies.

Organization

This collection of reports is organized into eight major sections (excluding the Executive Summary), each of these sections containing between 1 and 13 chapters. The eight sections are briefly described below.

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Introduction to Fossil Fuel Resources

The single chapter in the section on fossil fuel resources discusses the importance to the Nation of the Appalachian basin fossil fuel endowment. Chapter B.1 by Ruppert and others includes numerous maps of the Appalachian basin that show the locations of the major coal fields and petroleum accumulations.

Total Petroleum Systems (TPSs)

In chapter C.1, Ryder and others correlate the four major total petroleum systems (TPSs) in the Appalachian basin with a stratigraphic correlation chart of the Paleozoic stratigraphic section in Ohio and northern West Virginia. In ascending stratigraphic order, the major TPSs as defined by Milici and others (2003) are as follows: (1) Conasauga-Rome/Conasauga TPS, (2) Utica-Lower Paleozoic TPS, (3) Devonian Shale-Middle and Upper Paleozoic TPS, and (4) Carboniferous Coalbed Gas TPS. Also in chapter C.1, Ryder and others estimate the ultimate recoverable oil and gas resources (cumulative production + reserves + estimated recoverable undiscovered resources) of the Appalachian basin to be 25.5 billion BBOE, about 80 percent of which is natural gas.

Chapter C.2, also by Ryder and others, presents a series of maps that show the distribution of oil and gas fields in the Appalachian basin arranged by TPS, assessment unit, and accumulation type (conventional versus continuous).

Coal Systems of the Appalachian Basin

The four chapters in the section on coal systems discuss the most important coal and coalbed-methane resources in the Appalachian basin and their distribution. Chapter D.1 by Trippi and others includes a series of maps that show the important coal fields, coal beds, and coalbed-methane fields in the basin. Chapter D.2 by Ruppert and others presents an overview of the geology of the Pennsylvanian strata and coal fields in the Appalachian basin and includes a detailed chronostratigraphic correlation chart showing the positions of major coal beds and coal zones and key marker beds, by State, across the basin. Chapter D.3 by Milici and Polyak describes the history of coal production in the Appalachian basin and concludes that, without improved technology to facilitate economic mining of thin and deep coal beds and installation of scrubbers to permit the consumption of high-sulfur coal in powerplants, coal production in the Appalachian basin can be expected to decline.

Chapter D.4 by Tewalt and Ruppert presents the methodology and results of past and present coal-resource assessments in the basin by the USGS and State geological surveys. One of the key findings of the USGS coal-resource assessment is that, of the 93 billion short tons of original coal in the Pittsburgh, Upper Freeport, Fire Clay, Pond Creek, and Pocahontas No. 3 coal beds and coal zones in the northern and central Appalachian basin coal regions, about 66 billion short tons of coal remain. Much of the remaining coal, however, is thinner (less than 3.5 feet) and deeper (greater than 1,000 feet) than the coal that has been already mined. In addition, the results of the assessments also indicate that coal-quality issues will continue to drive a change in the location of coal production from the plentiful, high-ash-yielding and high-sulfur-content coal of the northern Appalachian basin region to the low-ash-yielding and low-sulfur-content coal of the central Appalachian basin region and the northern Rocky Mountains in the next decade. Chapter D.4 also includes a discussion of selected research activities by the State geological surveys, which involve the origin and quality of Appalachian basin coal.

Depositional and Structural Framework Geology

Eleven chapters by Ryder and various coauthors show detailed regional cross sections through selected parts of the Appalachian basin. Chapter E.1 shows an index map of the Appalachian basin and the lines of section of 10 regional cross sections. Chapters E.2.1 through E.2.5 are restored regional cross sections of Cambrian and Ordovician strata in parts of Kentucky, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia. These restored cross sections show complex depositional and structural patterns in Cambrian and Ordovician strata from the undeformed craton on the western side of the Appalachian basin, across the basement-faulted Rome trough (a Middle Cambrian rift system), to the thrust-faulted Valley and Ridge province on the eastern side of the basin. Chapters E.3.1 through E.3.3 are restored cross sections of reservoir rocks in the Lower Silurian regional oil and gas accumulation of New York, Ohio, Pennsylvania, and West Virginia. These cross sections show the lithologic and interpreted sequence-stratigraphic relations between the “Clinton” sandstone in Ohio, the Medina Group sandstones in New York and Pennsylvania, and the Tuscarora Sandstone in Pennsylvania and West Virginia. The cross sections indicate that thick, channel-shaped sandstone bodies of estuarine origin may be important tight-gas sandstone reservoirs in the Lower Silurian regional oil and gas accumulation. Chapters E.4.1 and E.4.2 are detailed regional geologic cross sections (each with indepth accompanying text) through the entire Paleozoic section in the Appalachian basin from northwestern Ohio, through the Rome trough in central West Virginia, to the Valley and Ridge province in eastern West Virginia, a distance of about 300 miles. These regional cross sections show examples of basement and thin-skinned styles of deformation in the basin and local examples of basement faults that were reactivated as reverse (contractional) faults to create mildly inverted grabens.

Burial and Thermal History

The two chapters in the section on burial and thermal history describe thermal maturity patterns in the Ordovician, Devonian, and Pennsylvanian strata of the Appalachian basin.

These patterns are based on conodont color alteration index (CAI) and (or) vitrinite reflectance values and were identified by modeling the burial and thermal history of the basin using thermal maturity data and the regional cross sections presented in chapter E. Chapter F.1 by Repetski and others provides maps and a discussion of Ordovician thermal maturity isograds that are based on CAI data and Devonian thermal maturity isograds that are based on both CAI and vitrinite reflectance data. Because these maps are largely based on subsurface data, they greatly improve our understanding of regional thermal maturity patterns beyond previous maturity studies that were based largely on outcrop data.

Chapter F.2 by Ruppert and others provides maps and a discussion of thermal maturity isograds based on vitrinite reflectance data from Pennsylvanian coal beds. The detailed dataset presented in this chapter provides well-constrained isograds that show previously unrecognized salients and re-entrants. These salients are suggestive of westward- to northwestward-flowing hot fluids derived from deeper in the basin during the Alleghanian orogeny, which was a period of structural change in the basin.

Energy Resources

The topics in the section on energy resources include (1) an assessment of undiscovered oil and gas resources of four major TPSs and one possible TPS, (2) coalbed methane, (3) oil and gas source rocks, (4) the chemical characteristics of several oils and gases, and (5) sulfur content and sulfur-dioxide emissions of coal mined for electrical power. Of the 13 chapters in this section, 5 focus on the geology, production history, and assessment of TPSs (and their respective assessment units) in the basin. The four identified total petroleum systems are as follows in ascending stratigraphic order: Conasauga-Rome/Conasauga TPS (chapter G.8 by Ryder and others), Utica-Lower Paleozoic TPS (chapter G.10 by Ryder), Devonian Shale-Middle and Upper Paleozoic TPS (chapter G.9 by Milici and Swezey), and Pottsville Coal-bed Gas TPS and Carboniferous Coal-bed Gas TPS (chapter G.1 by Milici). Chapter G.11 by Ryder and others describes the search for a Silurian TPS, which yielded inconclusive evidence for its existence.

Chapter G.13 by Coleman and others describes Appalachian basin petroleum source rocks and includes a series of maps that identify shale units having total organic carbon values (in weight percent) that might be high enough to qualify them as source rocks.

Chapters G.6 and G.7 by Burruss and Ryder describe the geochemistry of thermogenic gases from the Lower Silurian "Clinton" sandstone and Medina Group sandstone reservoirs in Ohio and Pennsylvania and conclude that the gases become isotopically heavier with increasing depth in the basin. In chapter G.12, Dennen and others discuss the geochemistry of oils in Ordovician reservoirs in southwestern Virginia and suggest that the oils possibly were derived from source rocks of Ordovician age. Chapters on coalbed-methane production in the Appalachian basin (chapter G.2 by Milici) and degassing experiments involving coals from selected coal beds in northern West Virginia (chapters G.3 and G.4 by Ruppert and various coauthors) identify areas of existing and potential production. Chapter G.5 by Trippi and others describes the sulfur content of Appalachian basin coal used at coal-fired powerplants and documents the type and quantity of gaseous emissions that are released to the atmosphere from such plants.

Selected References

Chapters H.1 through H.6 (variously authored) present selected references for coal and petroleum deposits in the Appalachian basin. These references are provided to the reader for additional background information.

Digital Data

Chapter I.1 contains a variety of downloadable digital data related to coal and petroleum resources in the Appalachian basin. The available data layers for use in a GIS include extents, thicknesses, and elevations of selected coal beds; coal production and chemistry; locations of oil and gas fields and wells; TPS and assessment unit boundaries; and bedrock geology. The GIS project can be downloaded and viewed in ArcGIS and Google Earth.

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