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Revisions to the original extent of the Devonian Shale-Middle and Upper Paleozoic Total Petroleum System

By Catherine B. Enomoto, William A. Rouse, Michael H. Trippi, and Debra K. Higley

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Abbreviations

AU	assessment unit
NGL	natural gas liquids
TPS	total petroleum system
USGS	U.S. Geological Survey

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Abstract

Technically recoverable undiscovered hydrocarbon resources in continuous accumulations are present in Upper Devonian and Lower Mississippian strata in the Appalachian Basin Petroleum Province. The province includes parts of New York, Pennsylvania, Ohio, Maryland, West Virginia, Virginia, Kentucky, Tennessee, Georgia, and Alabama. The Upper Devonian and Lower Mississippian strata are part of the previously defined Devonian Shale-Middle and Upper Paleozoic Total Petroleum System (TPS) that extends from New York to Tennessee. This publication presents a revision to the extent of the Devonian Shale-Middle and Upper Paleozoic TPS. The most significant modification to the maximum extent of the Devonian Shale-Middle and Upper Paleozoic TPS is to the south and southwest, adding areas in Tennessee, Georgia, Alabama, and Mississippi where Devonian strata, including potential petroleum source rocks, are present in the subsurface up to the outcrop. The Middle to Upper Devonian Chattanooga Shale extends from southeastern Kentucky to Alabama and eastern Mississippi. Production from Devonian shale has been established in the Appalachian fold and thrust belt of northeastern Alabama. Exploratory drilling has encountered Middle to Upper Devonian strata containing organic-rich shale in west-central Alabama. The areas added to the TPS are located in the Valley and Ridge, Interior Low Plateaus, and Appalachian Plateaus physiographic provinces, including the portion of the Appalachian fold and thrust belt buried beneath Cretaceous and younger sediments that were deposited on the U.S. Gulf Coastal Plain.

Introduction

The U.S. Geological Survey (USGS) uses the total petroleum system (TPS) concept of Magoon and Dow (1994) to assess undiscovered oil and gas resources. As defined by Magoon and Dow (1994) and Magoon and Schmoker (2000), a TPS is a naturally occurring petroleum system in the lithosphere that can be mapped, and consists of the geologic elements (hydrocarbon source rock, reservoir rock, seal rock, and overburden rock) and fundamental processes (generation, migration, entrapment, and preservation of hydrocarbons) as well as all genetically related petroleum seeps, shows, and accumulations (both discovered and undiscovered) whose provenance is a pod or closely related pods of active source rock. The maximum geographic extent of the TPS delineates the area beyond which no oil and gas from that source rock will be found. An assessment unit (AU) is a volume of rock within the TPS that encompasses discovered and undiscovered petroleum accumulations that are sufficiently homogeneous in terms of geology, exploration strategy, and risk characteristics to constitute a single population of field characteristics with respect to criteria used for resource assessment. As defined by Levorsen (1967), a field is one or more pools or reservoirs of petroleum that are located on a single geologic feature or that are otherwise closely related.

As part of the 2002 assessment of undiscovered oil and gas resources of the Appalachian Basin Petroleum Province (U.S. Geological Survey, 2002a), the USGS defined six TPSs (U.S. Geological Survey, 2002b; Milici and others, 2003). One of these TPSs was the Devonian Shale-Middle and Upper Paleozoic TPS (fig. 1), which contained four conventional AUs and six continuous AUs. Two of the conventional AUs were assessed for oil, natural gas, and natural gas liquids (NGL), whereas the other two conventional AUs were assessed for natural gas and NGL. The six continuous AUs do not contain oil, and thus were assessed only for natural gas and NGL resources (Milici and others, 2003).

Details of the Devonian Shale-Middle and Upper Paleozoic TPS are described in Milici and Swezey (2006, 2014). According to these studies, the petroleum source rocks in the Devonian Shale-Middle and Upper Paleozoic TPS range in age from Middle Devonian to Early Mississippian. Included were the Middle Devonian Marcellus Shale, the Geneseo Shale Member of the Genesee Formation, several Upper Devonian black shale units, and the Lower Mississippian Sunbury Shale (fig. 2). These

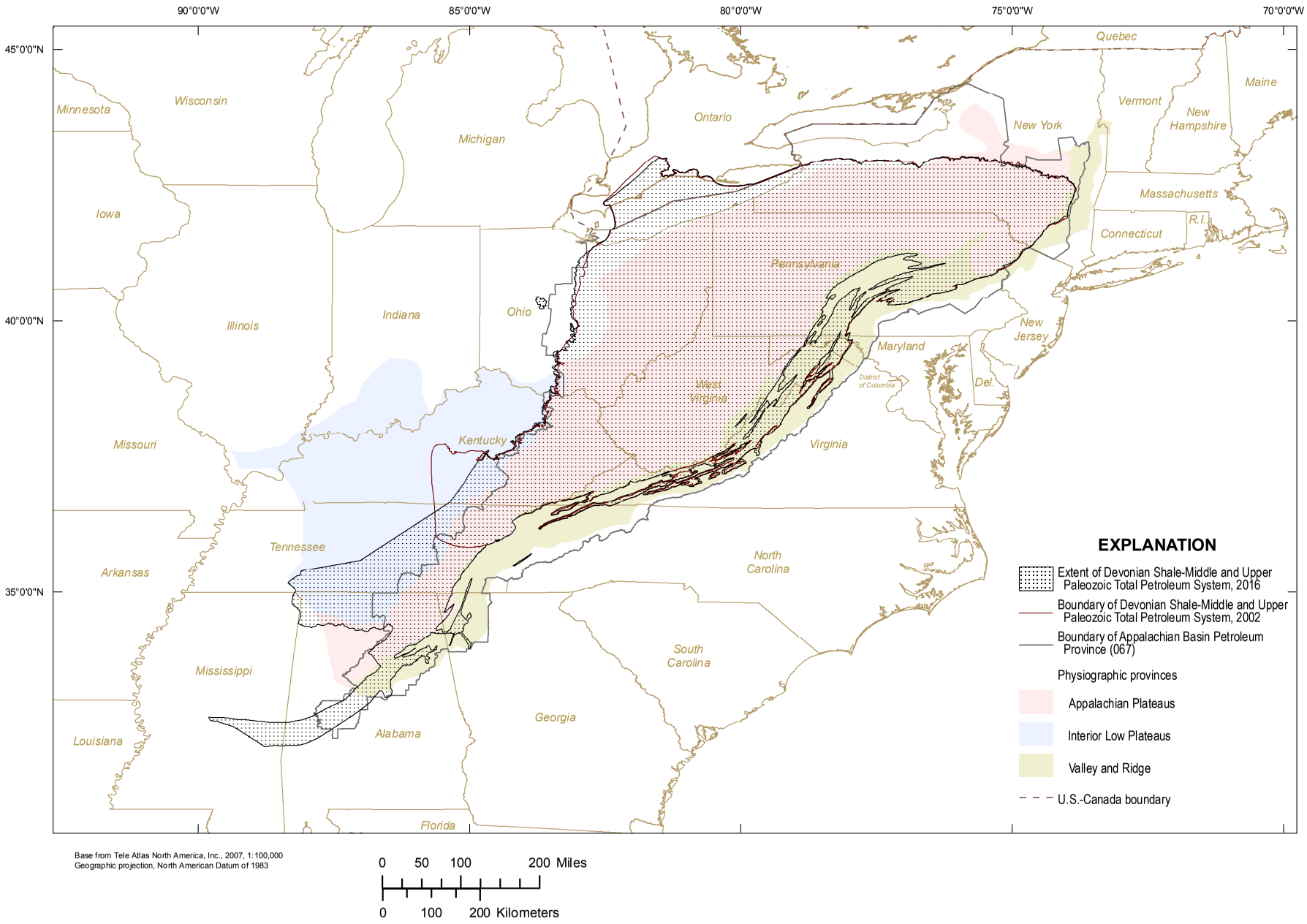

Figure 1. Map showing the original boundary of the Devonian Shale-Middle and Upper Paleozoic Total Petroleum System (from U.S. Geological Survey, 2002b), and the revised extent as described in this report. Locations of the Valley and Ridge, Interior Low Plateaus, and Appalachian Plateaus physiographic provinces are taken from Fenneman and Johnson (1946), and the boundary of the Appalachian Basin Petroleum Province is from U.S. Geological Survey (2002a).

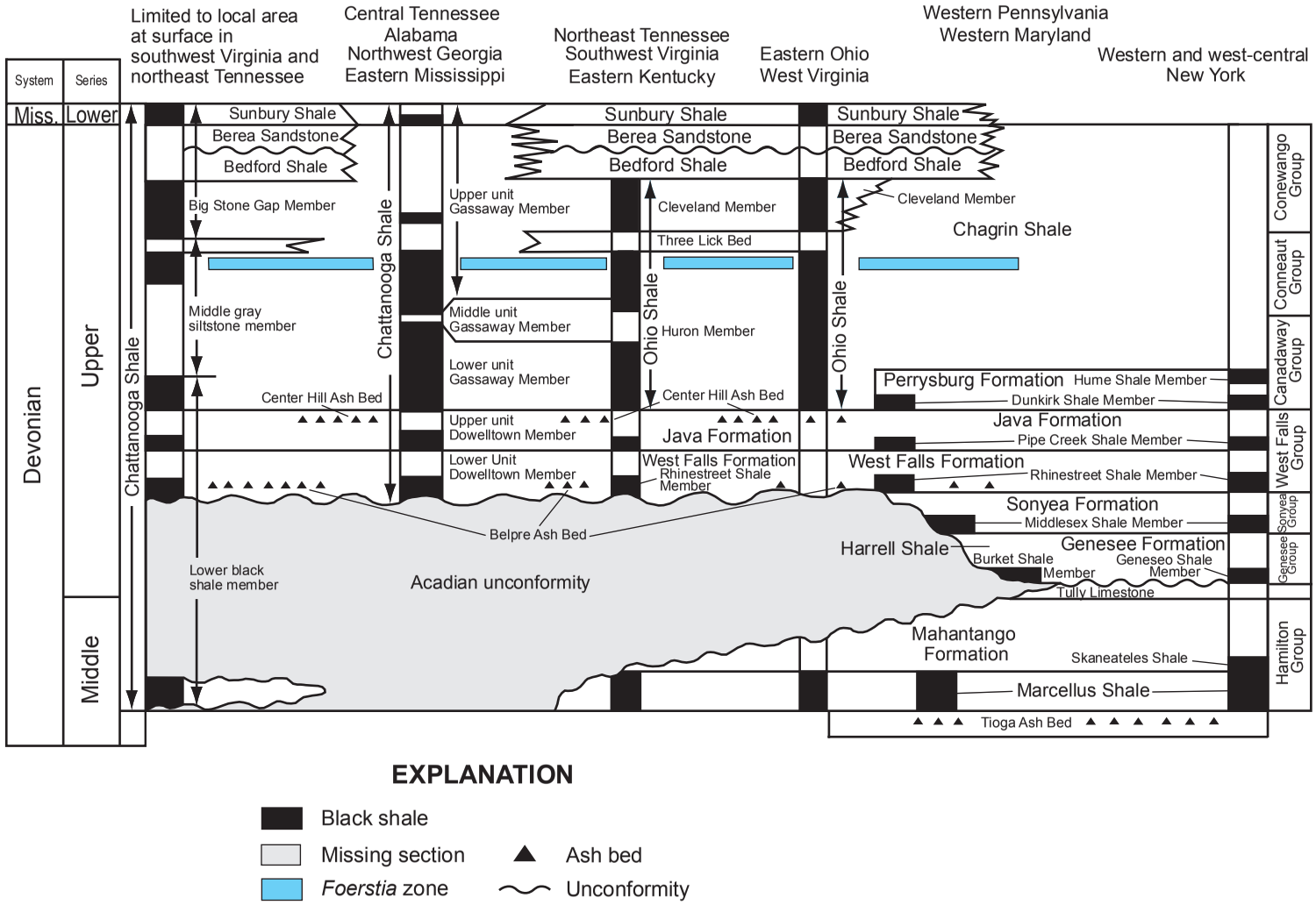

Figure 2. Chart showing the correlation of Devonian and Mississippian black shale units and some related strata in the Appalachian basin. Modified from de Witt and others (1993); modifications are based on information from Dockery (1996), Harper (1993), Milici and Swezey (2014), Over (2007), Ryder and others (2012), and Van Tyne (1983). Miss., Mississippian.

source rocks charged hydrocarbon reservoirs that range in age from Silurian to Late Mississippian. Hydrocarbon seals in the Devonian Shale-Middle and Upper Paleozoic TPS included the Silurian Salina Group, Middle Devonian Marcellus Shale and Onondaga Limestone, Lower Mississippian Sunbury Shale, Middle Mississippian Greenbrier Limestone, and shale and limestone beds intercalated locally with reservoirs. In a subsequent USGS assessment of only the Middle Devonian Marcellus Shale, this formation was divided into three continuous AUs, which were assessed for natural gas and NGL resources (Coleman and others, 2011).

Revision

This publication describes a revision to the maximum extent of the Devonian Shale-Middle and Upper Paleozoic TPS as used by Milici and others (2003) and defined in U.S. Geological Survey (2002b). The revised boundary of the TPS, along with the previously published boundary as used by Milici and others (2003), are illustrated in figure 1. In this revised version, the northern and northeastern limits of the Devonian Shale-Middle and Upper Paleozoic TPS are generally maintained as defined in Milici and others (2003). New modification to the eastern extent of the TPS involved removing areas in central Pennsylvania, western Maryland, eastern West Virginia, and western Virginia where Devonian strata are absent due to erosion in parts of the Valley and Ridge physiographic province (fig. 1), based on Dicken and others (2005b) and Nicholson and others (2005). The northwestern extent of the TPS was changed to eliminate overlap with the Devonian Antrim TPS in the Michigan Basin Petroleum Province (USGS Michigan Basin Assessment Team, 2005; Swezey and others, 2015). The western extent of the TPS was modified slightly to include all of the areas where the Middle and Upper Devonian strata that contain black shale units are present in the subsurface up to the outcrop in Ohio (Nicholson and others, 2005) and central Kentucky (Nicholson and others, 2005).

The most significant revision was to the southwestern and southern extent of the TPS in Kentucky, Tennessee, Georgia, Alabama, and Mississippi. In south-central Kentucky and north-central Tennessee, the southwestern extent of the revised TPS has a common border with the Devonian to Mississippian New Albany Continuous Gas AU within the Devonian to Mississippian New Albany TPS of the Illinois Basin Petroleum Province (USGS Illinois Basin Assessment Team, 2007a,b). The boundary of the revised TPS also follows the boundaries of the Appalachian basin and the Illinois basin as mapped in Swezey (2009). The revised TPS boundary in southern Tennessee, northeastern Mississippi, and Alabama (fig. 1) outlines the mapped extent of the Middle to Upper Devonian Chattanooga Shale in the subsurface up to the outcrop on the Highland Rim section of the Interior Low Plateaus physiographic province (Fenneman and Johnson, 1946; Nicholson and others, 2005), and in the Appalachian Plateaus and Valley and Ridge physiographic provinces (Fenneman and Johnson, 1946; Dicken and others, 2005a; Nicholson and others, 2005). In northwestern Georgia and northern Alabama (fig. 1), the revised TPS boundary encloses the mapped extent of the Chattanooga Shale in the subsurface up to the outcrop in the Valley and Ridge physiographic province (Fenneman and Johnson, 1946; Dicken and others, 2005a; Pashin and others, 2010). Exploratory natural gas drilling has confirmed the presence of the Middle to Upper Devonian Chattanooga Shale in the subsurface from southeastern Kentucky to Alabama (Pashin and others, 2010; Rouse, 2015). Natural gas production has been established in the Chattanooga Shale in the Appalachian fold and thrust belt of the Appalachian Plateaus physiographic province of northeastern Alabama (Pashin and others, 2010; IHS Energy Group, 2014).

Finally, the southernmost limit of the revised Devonian Shale-Middle and Upper Paleozoic TPS in central Alabama and eastern Mississippi (fig. 1) represents the subsurface extent of Devonian strata within the Appalachian fold and thrust belt as mapped by Thomas and others (1989). In this area, the Appalachian fold and thrust belt is buried beneath Cretaceous and younger sediments that were deposited on the U.S. Gulf Coastal Plain (Dicken and others, 2005a). Exploratory drilling has encountered Middle to Upper Devonian strata containing organic-rich shale in the Greene-Hale synclinorium in west-central Alabama (Pashin and others, 2010).

Conclusion

The Devonian Shale-Middle and Upper Paleozoic Total Petroleum System (TPS), originally extending from New York to Tennessee, has been revised. The most significant modification to the maximum extent of the TPS is to the south and southwest, adding areas in Tennessee, Georgia, Alabama, and Mississippi where Devonian strata, including potential petroleum source rocks, are present in the subsurface up to the outcrop. Recently published research reports and recent drilling activity have facilitated the compilation of the maximum extent of Middle and Upper Devonian and Lower Mississippian potential hydrocarbon source rocks in the Appalachian Basin Petroleum Province. The areas added to the TPS are located in the Interior Low Plateaus, Appalachian Plateaus, and Valley and Ridge physiographic provinces, and include Devonian strata in the portion of the Appalachian fold and thrust belt buried beneath Cretaceous and younger sediments that were deposited on the U.S. Gulf Coastal Plain.

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