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Central Appalachian Basin Natural Gas Database: Distribution, Composition, and Origin of Natural Gases

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Open-File Report 2014–1207

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
SALLY JEWELL, Secretary

U.S. Geological Survey
Suzette M. Kimball, Acting Director

U.S. Geological Survey, Reston, Virginia: 2014

Suggested citation:
Colón-Román, Y.A., and Ruppert, L.F., 2014, Central Appalachian basin natural gas database—Distribution, composition, and origin of natural gases: U.S. Geological Survey Open-File Report 2014–1207, 13 p., 1 app., *http://dx.doi.org/10.3133/ofr20141207*.

ISSN 2331-1258 (online)

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Conversion Factors

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
	Volume	
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Pressure	
pound per square inch gauge (lb/in^2)	6.895	kilopascal (kPa)

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Stable isotope ratios are given in per mil (‰).

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Abstract

The U.S. Geological Survey (USGS) has compiled a database consisting of three worksheets of central Appalachian basin natural gas analyses and isotopic compositions from published and unpublished sources of 1,282 gas samples from Kentucky, Maryland, New York, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia. The database includes field and reservoir names, well and State identification number, selected geologic reservoir properties, and the composition of natural gases (methane; ethane; propane; butane, *iso*-butane [*i*-butane]; normal butane [*n*-butane]; *iso*-pentane [*i*-pentane]; normal pentane [*n*-pentane]; cyclohexane, and hexanes). In the first worksheet, location and American Petroleum Institute (API) numbers from public or published sources are provided for 1,231 of the 1,282 gas samples. A second worksheet of 186 gas samples was compiled from published sources and augmented with public location information and contains carbon, hydrogen, and nitrogen isotopic measurements of natural gas. The third worksheet is a key for all abbreviations in the database. The database can be used to better constrain the stratigraphic distribution, composition, and origin of natural gas in the central Appalachian basin.

Natural Gas Database

This report describes and makes available a U.S. Geological Survey (USGS) database, which contains data on molecular and isotopic composition of natural gas in the central Appalachian basin of the United States. Published and unpublished sources were used to compile data for 1,282 gas samples from Kentucky, Maryland, New York, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia. The database can be used to better constrain the stratigraphic distribution, composition, and origin of natural gas in the central Appalachian basin.

Data Fields

The central Appalachian basin natural gas geochemistry database is a spreadsheet consisting of three worksheets in Microsoft® Excel 2010 format (appendix 1). The first worksheet, titled "Molecular Compositions," contains 72 fields describing 1,280 gas samples with their well names, well information, and geologic information including producing strata and stratigraphy. The content and composition of natural gas in mole percent (%) for all of the samples are provided in the worksheet (appendix 1).

A total of 1,231 sample locations and American Petroleum Institute (API) identification numbers are provided for the gas samples. Location and API numbers were obtained from published sources and augmented by public information from a variety of sources, including Charles Threlkeld (data included in U.S. Geological Survey, 2009), Kentucky Geological Survey (2012), Ohio Department of Natural Resources (2012), Tennessee Division of Geology's Electronic oil and gas database (2008), U.S. Environmental Protection Agency (2012), USGS National Geologic Map Database (2012), Virginia Department of Mines, Minerals and Energy (2012), West Virginia Geological and Economic Survey (2012), New York Department of Environmental Conservation (2011), Pennsylvania Department of Natural Resources (2011), and R.T. Ryder (U.S. Geological Survey, written commun., 2011).

The natural gas database contains analytical data on eight hydrocarbons: methane (CH_4, C_1); ethane (C_2H_6, C_2); propane (C_3H_8, C_3); normal butane (or *n*-butane; nC_4H_{10}, nC_4); *iso*-butane (or *i*-butane; iC_4H_{10}, iC_4) or butane (iC_4H_{10}), if the class was not specified in the original report; normal pentane (or *n*-pentane; nC_5H_{12}, nC_5); *iso*-pentane (or *i*-pentane; iC_5H_{12}, iC_5); hexane (C_6H_{14}, C_6); cyclopentane (C_5H_{10}); and one compound class of hexanes ($C_{6+}H_{14}$, C_6, C_{6+}). See table 1 for the number of samples of each hydrocarbon that are included in the database. The natural gas database also contains analytical information on the non-hydrocarbon gases nitrogen (N_2), oxygen (O_2), argon (Ar) carbon dioxide (CO_2), hydrogen (H_2), helium (He), and hydrogen sulfide (H_2S). See table 1 for the number of samples of each non-hydrocarbon gas included in the database.

Table 1. Ranges of natural gas compositions, in percent, for the 1,280 analyses from the "Molecular Compositions" worksheet.

[There was no attempt to remove results that were reported as zero in the original reports. However, the user should consider using the zero values with caution because it is not known whether the gas was analyzed and the component was not detected or whether no attempt was made to analyze the component.]

Gas	No. of analyses	Range (in percent)	No. of analyses with "0" gas	No. of analyses labeled "trace"
Methane	1,267	1.2–99.4	3	0
Ethane	1,262	0.01–64.7	4	0
Propane	1,120	0.001–16.2	19	23
***n*-butane**	993	0.0010–5.6	205	25
***i*-butane**	854	0.0012–3.1	221	57
***n*-pentane**	987	0.0019–2.0000	285	100
***i*-pentane**	602	0.0049–1.4	254	113
Cyclohexane	791	0.1–0.7	213	401
Hexane and Hexane plus	794	0.0011–1.5	245	44
Nitrogen	1,218	0.1–78.1	22	3
Oxygen	435	0.0056–21.35	407	212
Argon	59	0.003–1.9	270	502
Hydrogen	300	0.0021–2.27	451	94
Hydrogen sulfide	2	0.0260–0.51	957	1
Carbon dioxide	830	0.001–83.53	188	209
Helium	1,236	0.0099–1.080	4	0

The second worksheet, titled "Isotopic Compositions," contains 50 fields describing 186 natural gas samples with accompanying carbon and deuterium isotopic data for methane ($\delta^{13}C_1$), deuterium in methane ($\delta^{2}HC_1$), ethane ($\delta^{13}C_2$), deuterium in ethane ($\delta^{2}HC_2$,), propane ($\delta^{13}C_3$), deuterium in propane ($\delta^{2}HC_3$,), *i*-butane ($\delta^{13}C_{i}$-C_4), *n*-butane ($_{\delta}{}^{13}C_{n}$-C_4), *n*-pentane ($\delta^{13}C_{n}$-C_5), butane ($\delta^{13}C_4$), and carbon dioxide ($\delta^{13}CO_2$) reported in mole percent and percent (appendix 1, worksheet 2). Included are five nitrogen ($\delta^{15}N$) isotopic analyses. Isotopic data were obtained from Burruss and Ryder (2003), Burruss and Laughrey (2010), G.E. Claypool and C.N. Threlkeld (USGS, unpublished data, 1977), Dennen and others (in press), Jenden and others (1993), Laughrey and Baldassare (1998), Laughrey and others (2004), U.S. Geological Survey (2009), and Osborn and McIntosh (2010). This worksheet also contains information from published sources augmented with API numbers and location information from the public sources referenced above.

The third worksheet, titled "Abbreviations," is a key for all abbreviations in the database.

Identification Number

Several identification numbers were included in the data to identify each gas well sample. The field "Unique ID" represents the number assigned by the USGS, whereas the identification numbers under the fields "Sample ID," "U.S. Bureau of Mines ID," "U.S. Bureau of Mines Index No. 1," and "U.S. Bureau of Mines Index No. 2" are identification names and numbers given by published sources.

Location of Gas Samples

Two sets of latitude and longitude in decimal degrees are provided in North American Datum of 1983 (NAD 83). Samples in which latitude and longitude were reported in a different coordinate system were converted to NAD 83 for consistency. Because location information was not reported for some of the samples included in the database, two sets of latitude and longitude columns, labeled "Latitude from public source," "Longitude from public source," "Latitude from published source," and "Longitude from published source," are provided. A third set, "LATITUDE" and "LONGITUDE" was created to combine the coordinates from public and published sources for GIS and plotting use. All but 49 of the 1,280 analyses have longitude and latitude information; the 49 analyses lacking coordinates are provided for users because they include well names for future geographic referencing.

Geologic Information

The database also includes available geologic information such as the producing formation, geologic age, and stratigraphic units. Stratigraphic names were checked against the USGS National Geologic Map GEOLEX (2012) database.

Potential Uses of the Database

As stated previously, the databases can be used to better constrain the areal extent, stratigraphic distribution, composition, and origin of natural gas in the central Appalachian basin. We have used the database to create a series of maps to determine the spatial distribution of the natural gas samples.

Figure 1 shows the methane content of all of the producing formations (Cambrian to Pennsylvanian) and illustrates the areal extent of the distribution of the samples in the central Appalachian basin natural gas database (appendix 1, "Molecular Compositions" worksheet). The map shows an increase in methane content and a general decrease in higher weight hydrocarbons from west to east as the basin thickens (fig. 1). Separate maps of methane content in Devonian and Silurian strata (figs. 2–3) show a similar pattern but with different areal extents. Figure 4 shows the areal extent and content of carbon dioxide in natural gas samples from all strata. Because stratigraphic information and depth are included in the database, users can create maps of the ranges in natural gas content with producing formation or stratigraphic horizon and depth.

The areal extent of the analyses within the isotopic database (appendix 1, "Isotopic Compositions" worksheet) is shown in figure 5. A cursory examination of the isotopic data shows that $\delta^{13}C_1$ and $\delta^{2}D$ measurements on CH_4 for the 186 samples within the database, which vary in age from Cambrian to Carboniferous, range from −55.1 to −26.02‰ and −315.0 to −133.1‰, respectively. Most of the lower $\delta^{13}C_1$ and $\delta^{13}D$ values are from the New Albany Shale. Devonian gases have $\delta^{13}C_1$ and $\delta^{13}D$ CH_4 values ranging from −54.2 to −31.5‰ and −315.0 to −159.0‰, respectively, indicating that most of the Devonian gas is thermogenic in origin.

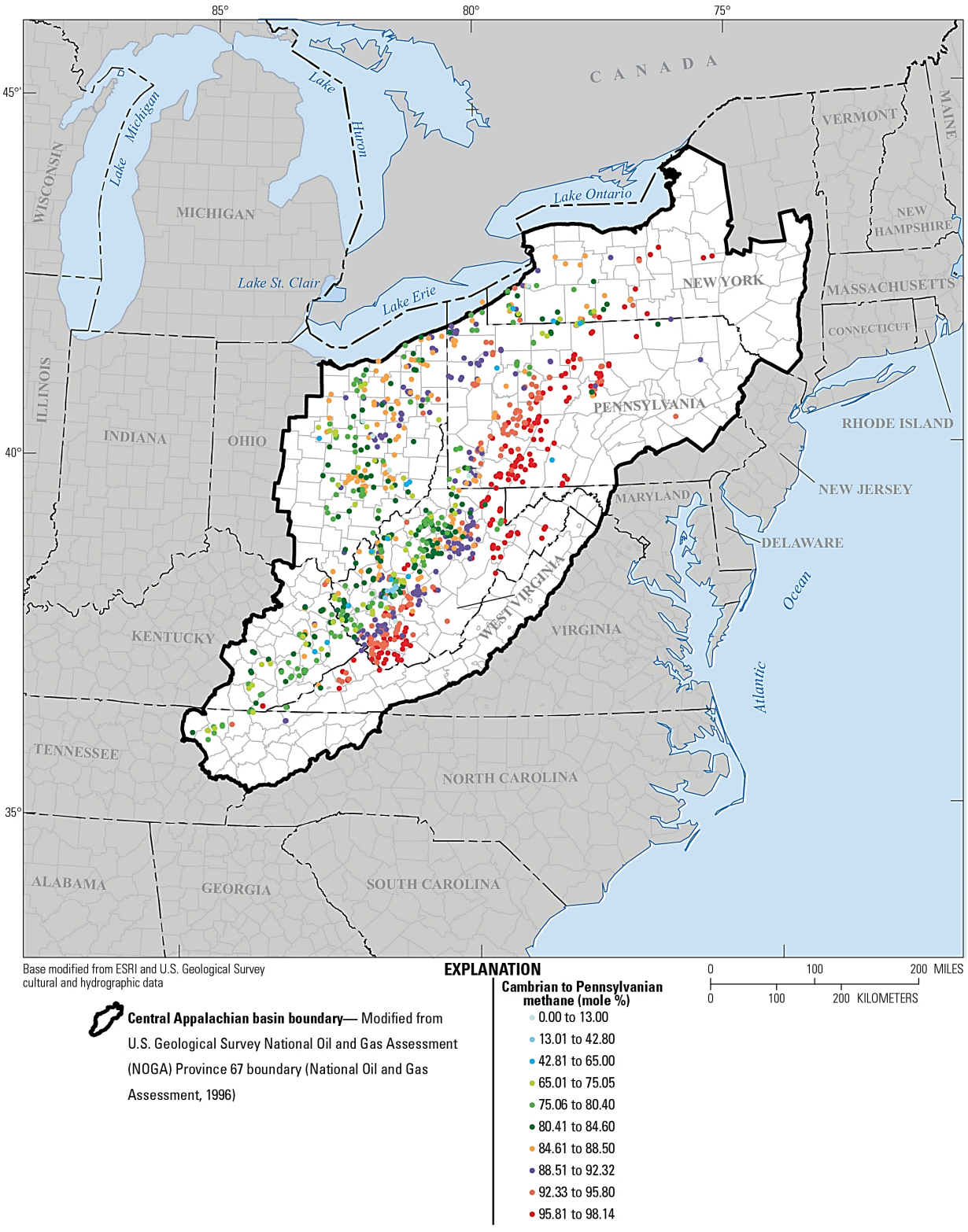

Figure 1. Map of the distribution of methane content in Cambrian to Pennsylvanian natural-gas-producing formations in the central Appalachian basin from the natural gas database. A total of 1,229 methane analyses were used to create the map.

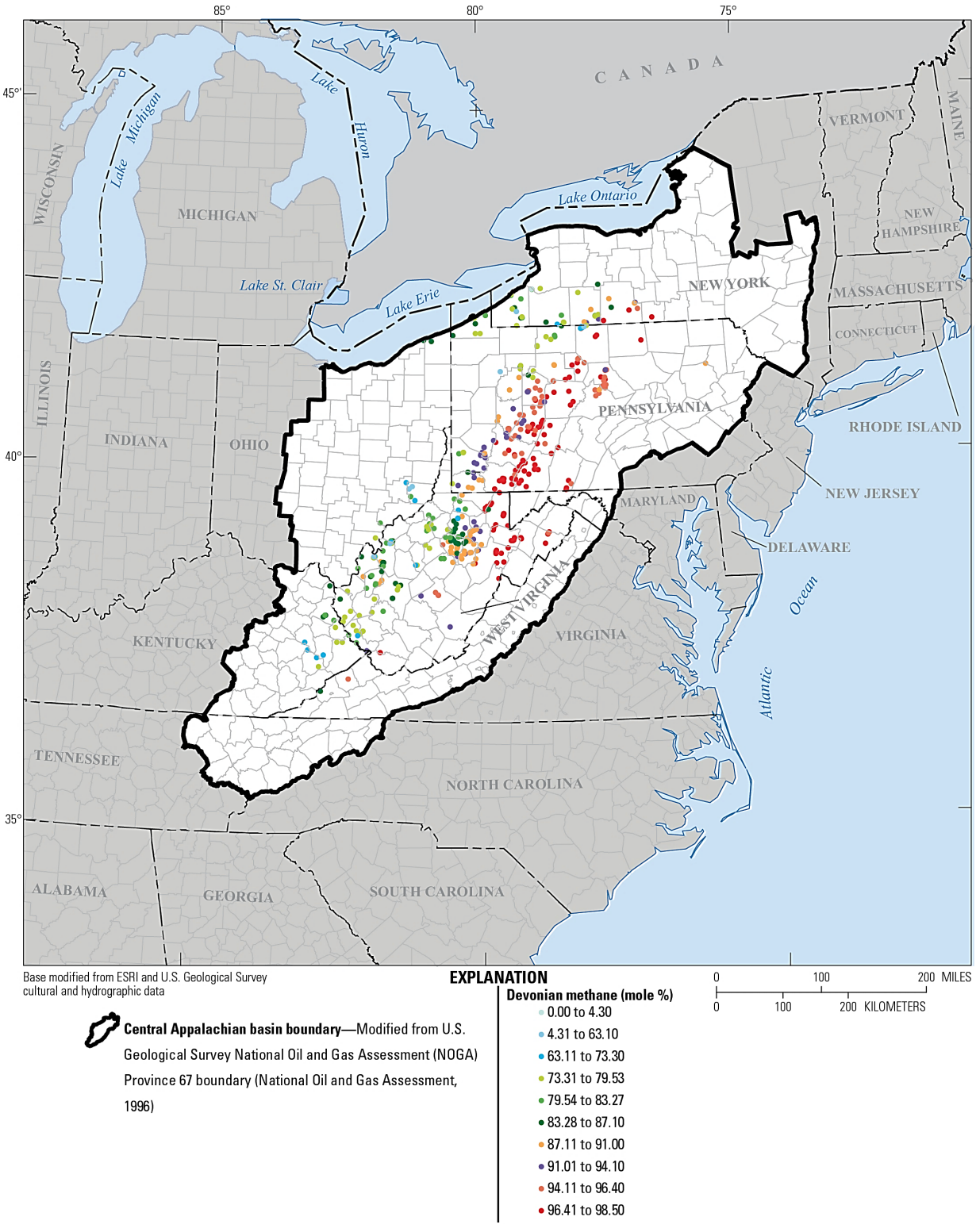

Figure 2. Map of the distribution of methane content in Devonian natural-gas-producing formations in the central Appalachian basin from the natural gas database. A total of 498 methane analyses were used to create the map. In general, methane content increases from west to east where sediments are buried more deeply.

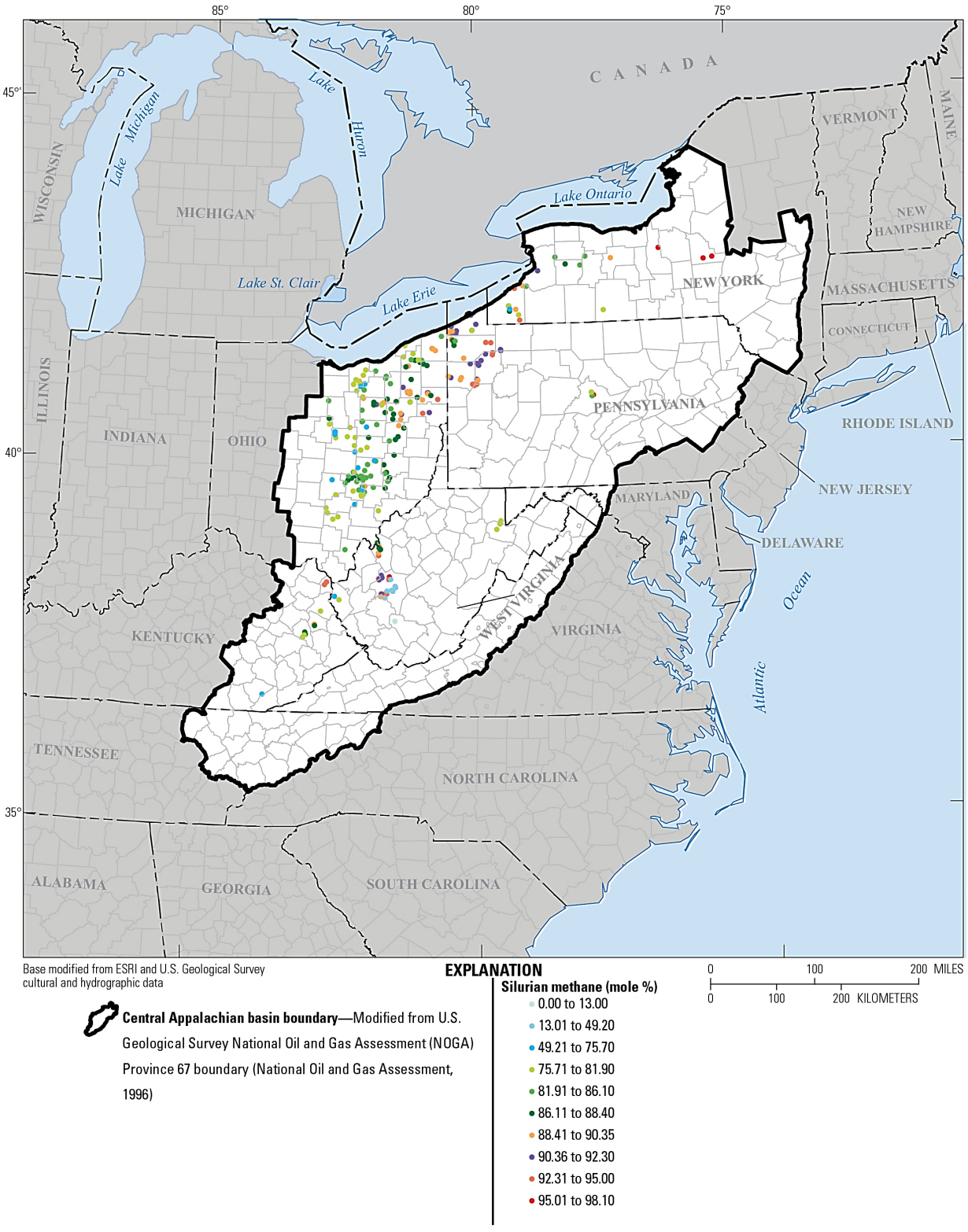

Figure 3. Map of the distribution of methane content in Silurian natual-gas-producing formations in the central Appalachian basin from the natural gas database. A total of 299 methane analyses were used to create the map.

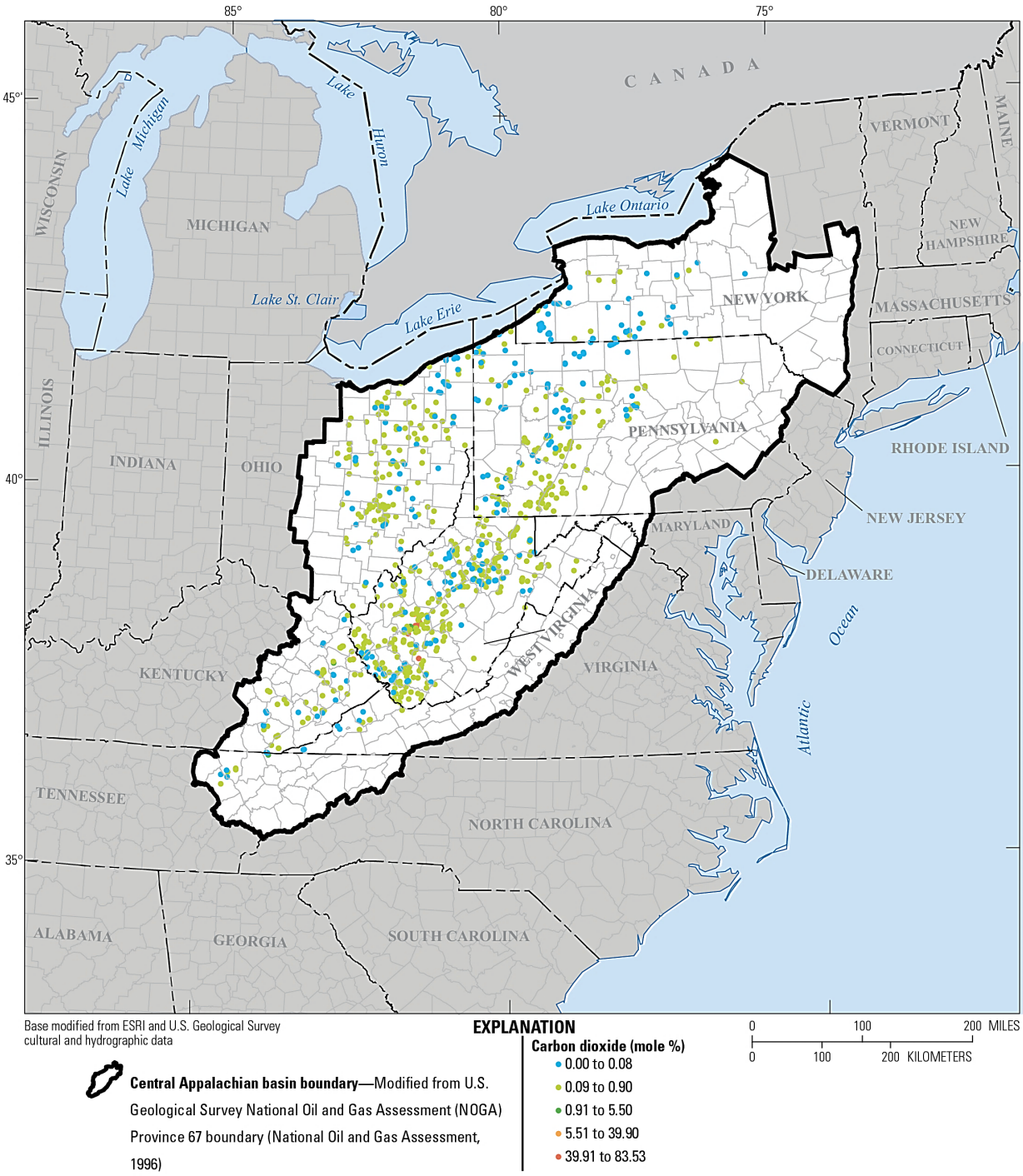

Figure 4. Map of the distribution of carbon dioxide in Cambrian to Pennsylvanian natural-gas-producing formations in the central Appalachian basin from the natural gas database. A total of 991 carbon dioxide analyses were used to create the map. Carbon dioxide contents ranged from 0 to 83.53 mole percent.

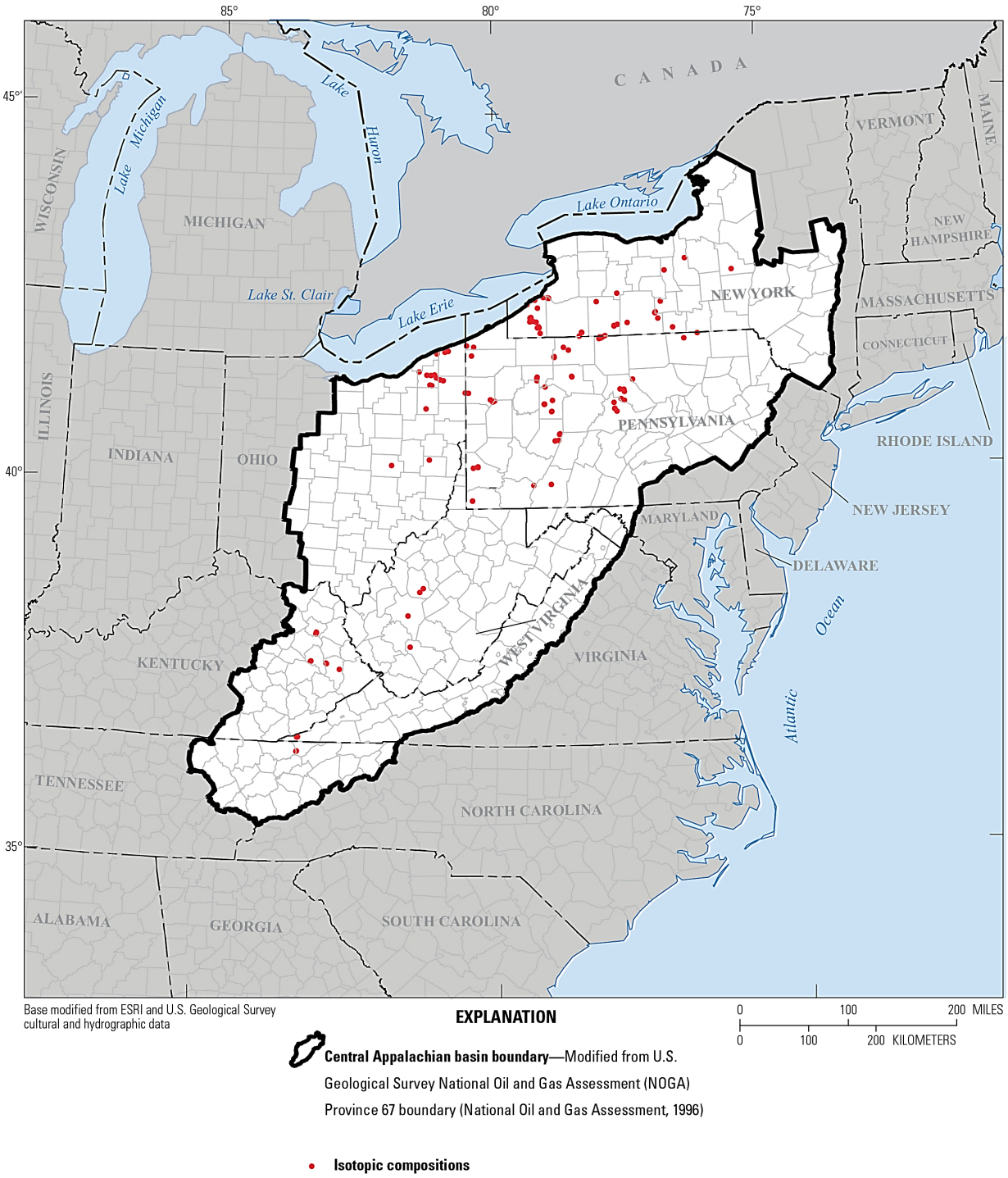

Figure 5. Map of the distribution of isotopic measurements contained in the database. A total of 151 analyses from the database were used to create the map

Acknowledgments

The authors would like to give special thanks to Linda Bragg and Robert Ryder (USGS, Emeritus), and Michael Trippi and Christopher Garrity (USGS), for their help and constructive feedback.

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Appendix 1. Natural_Gas_Geochemical_Database_2013

[Available at *http://pubs.usgs.gov/of/2014/1207/*.]

The database, in .xls format, consists of three worksheets titled "Molecular Composition," "Isotopic Composition," and "Abbreviations." The Molecular Composition worksheet contains molecular analyses of 1,280 samples of natural gas, characterized in 70 fields. The Isotopic Composition worksheet contains stable isotopic data for 186 samples, described in 48 fields.

The Abbreviations worksheet includes the following, in order, for the Molecular Compositions database: ID = identification number; No. = number; API = American Petroleum Institute number; USGS = U.S. Geological Survey; ft = feet; psig = pounds per square inch guage; mcfd = thousands of cubic feet per day; % = percent; *n*-butane = normal butane; *i*-butane = iso-butane; *n*-pentane = normal pentane; *i*-pentane = iso-pentane; C_1 = methane; C_{2+} = ethane plus higher molecular weight hydrocarbons; C_{4+} = *iso*-butane plus higher molecular weight hydrocarbons; C_{6+} = hexane plus higher molecular weight hydrocarbons; N_2 = nitrogen; O_2 = oxygen; Ar = argon; H_2S = hydrogen sulfide; CO_2 = carbon dioxide; BTU = British thermal units.

Abbreviations, in order, for the Isotopic Compositions database are the following: ID = identification number; No. = number; API = American Petroleum Institute number; USGS = U.S. Geological Survey; ft = feet; m = meters; BTU = British thermal units; ft^3 = cubic feet; $\delta^{13}C_1 = \delta^{13}C$ of methane; ‰ = permil; $\delta^2HC_1 = \delta^2H$ of methane; $\delta^{13}C_2 = \delta^{13}C$ of ethane; $\delta^2HC_2 = \delta^2H$ of ethane; $\delta^{13}C_3 = \delta^{13}C$ of propane; $\delta^2HC_3 = \delta^2H$ of propane; $\delta^{13}C$ *i*-$C_4 = \delta^{13}C$ of *i*-butane; $\delta^{13}C$ *n*-$C_4 = \delta^{13}C$ of *n*-butane; $\delta^{13}C$ *n*-$C_5 = \delta^{13}C$ of *n*-pentane; $\delta^{13}C_4 = \delta^{13}C$ of butane; $\delta^{13}CO_2 = \delta^{13}C$ of carbon dioxide; $\delta^{15}N = \delta^{15}N$ of N_2; $\delta^2H_{\ i}$-$C_4 = \delta^2H$ of *i*-butane; $\delta^2H_{\ n}$-$C_4 = \delta^2H$ of *n*-butane; $\delta^2H_{\ n}$-$C_5 = \delta^2H$ of *n*-pentane.

ISSN 2331-1258 (online)
http://dx.doi.org/10.3133/ofr2014-1207