# Molecular and Isotopic Composition of Associated and Nonassociated Gases and Evolution of Gas in the Berea Sandstone, Eastern Kentucky

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## ABSTRACT

The molecular and isotopic composition of natural gas samples from the Upper Devonian Berea Sandstone and Ohio Shale were analyzed to understand the origin of gas produced from the Berea Sandstone in eastern Kentucky. The gas analysis was part of a broader geochemical investigation into the Berea petroleum system by a public-private consortium in 2015 and 2016. Gas samples were collected along a north-to-south transect extending 85 miles from southern Ohio to southeastern Kentucky, and included six associated gas samples (OAG) from Berea oil wells in the northern updip (-260 to -1,191 feet) part of the play and two nonassociated gas samples (NAG) from the Ohio Shale in southern downdip (-1,831 to -4,964 feet) locations.

In the context of a Schoell plot, all samples are thermogenic oil-associated gas, and are wet gases with methane/(ethane + propane) ratios ranging from 1.9 to 7.9. Compared to the shallower OAG samples, the isotopic composition of $CH_4$ for the deeper NAG samples is more enriched in $^{13}C$ and $^{2}H$, reflecting increased thermal maturity. When plotted versus depth, the isotopic composition for $CH_4$ becomes more positive and gas dryness increases for most samples.

The $\delta^{13}C$ values for methane (C1), ethane (C2), propane (C3), and n-butane (C4), measured on three OAG and two NAG samples, show progressive enrichment in $^{13}C$ with progressively higher molecular weight. When plotted versus the inverse carbon number, the $\delta^{13}C$ values define two populations in which all the OAG and shallowest NAG samples define a trend depleted in $^{13}C$ for C1-C4 compared to the deepest NAG sample. For the isotopically depleted population, the $\delta^{13}C$ composition of n-butane (-33.7 to -34.4‰) is 2 to 3‰ more negative compared to bitumen extracts (-29.1 to -30.9‰) measured in this study, which are interpreted to be possible sources for Berea oil and gas. Though separated by about 50 miles, similarity among the four isotopically depleted samples suggests that gas in these wells was generated from a similar source and under similar thermal-maturity conditions. Located 25 miles south of the shallower NAG sample, the deepest NAG sample is enriched in $^{13}C$ by 4 to 7‰ among the gas components and the $\delta^{13}C$ composition for n-butane is more enriched in $^{13}C$ (-26.7‰) than extract values in this study and other published values for kerogen in the area. The enrichment suggests that this deeper gas was generated from cracking of kerogen, bitumen, or oil under higher thermal-maturity conditions.