

Carbon and Hydrogen Isotope Systematics in Bakken Shale Gases: Prediction of Rock and Fluid Properties from Gas Isotopes as Guide to Mudgas Isotope Data Interpretations

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Interest in Bakken Shale plays has increased the last years and mudgas composition and isotope analyses are acquired to support completion and production decisions. We report here composition and isotope analyses from horizontal Bakken shale wells in North Dakota that penetrated differently mature sections of the Bakken shale. We will show that gas properties are excellent predictors of fluid and rock properties. The 8 wells of this study are in two maturity domains based on the Rock Eval Hydrogen Indices of the penetrated shales: The immature domain has high Hydrogen Indices (HI~450 to 530mg/g) is around Squaw Gap and Bicentennial ("SGB"), whereas the mature domain with lower Hydrogen Indices (HI~170 to 270mg/g) around Pierre Creek, Buckhorn and Elkhorn Ranch ("PCBE"). Properties in the 31-1H well at Pierre Creek are intermediate between these maturity domains. Gases at the immature SGB wells have low Gas/Oil ratios (350 to 390) and high %C₂₊ concentrations (27 to 48%) whereas gases at the PCBE wells have higher GOR (560 to 720) and lower %C₂₊ (around 30%). Carbon isotope signatures of C₁ to n-C₅ gas and n-C₆ to n-C₁₉ oil components clearly demonstrate that the gases are co-genetic products derived from the oils. These relationships suggest a gas-oil maturation-related petroleum system that is contained within the shale, meaning that we report here gas properties from "the kitchen", prior to migration. Whole oil carbon isotope values increase slightly from -29 to -30‰ which is consistent with maturation-related changes in the whole oil caused by the increasing formation of isotopically ¹³C-depleted gaseous compounds. Carbon and hydrogen isotopes of ethane to butane follow the maturity trends of the source rocks very well. In particular δ¹³C-ethane values are an excellent proxy for all maturity-related properties of gases and associated oils as well as rock properties such as HI. For example, at the immature Squaw Gap well (HI~535), the produced gas has ethane carbon and hydrogen values δ¹³C₂ of -38‰ and δD₂ of -206‰, respectively, in contrast to δ¹³C₂ of -34.2‰ and δD-C₂ of -163‰ at the mature Elkhorn Ranch well 44-25H. Similarly, other isotopic properties such as the differences of δ¹³C₂₋₃ and δ¹³C_{iC4-nC4} tend to decrease with maturity. These consistent maturation-related changes of gas isotopes will allow predictions of maturity-related properties in source organic matter and oils from mudgas isotope analyses.