Relating the Composition of Rock Volatiles Extracted from Lower and Upper Bakken Source Rocks to a Suite of Thermal Maturity Parameters

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Abstract

Previous work on source rocks from a variety of basins has demonstrated that volatile organic and inorganic compounds can be sampled from immature mudstones and that the distribution of those volatile compounds can provide useful information relevant to petroleum systems. The Rock Volatiles Stratigraphy (RVS) technique is used in this study to obtain detailed geochemical information of saturated, cyclic and aromatic hydrocarbons, organic and inorganic acids, noble gases, air components, and water for samples from the lower and upper source rock units of the Devonian-Mississippian Bakken Formation of the Williston Basin (Montana and North Dakota). RVS involves vacuum extraction (20 and 2 mbar) of volatiles from freshly crushed cuttings or core samples, separation of extracted volatiles by sublimation from a liquid nitrogen temperature cold trap, and analysis by mass spectrometry to identify and quantify extracted volatiles (non-condensable gases like methane and helium are analyzed immediately upon extraction). The Bakken samples evaluated are from five cores representing a thermal maturity gradient from immature (~2,300 m) to late oil window (~3,400 m) and have been thoroughly evaluated using a suite of standard geochemical and petrographic methods. These include measurements of solid bitumen reflectance (%BRo), programmed pyrolysis parameters (hydrogen index, Tmax), and isoprenoid to n-alkane ratios (pristane/n-C_{17}, phytane/n-C_{18}) in chloroform-soluble extracted organic matter. The purpose of this work is to determine if the distribution of volatiles from RVS varies systematically with thermal maturity, and, if so, can RVS-derived parameters like total oil content, gas-to-oil ratio (GOR), and gas dryness (C_1/sum[C_1-C_5]) provide thermal maturity proxies that can be used in reservoir evaluation studies. In general, the results were consistent with expectations based on previous studies of petroleum product compositional changes with thermal maturity, such as increased liquid hydrocarbon content through the oil window along with increased GOR and gas dryness at higher maturities, suggesting that RVS can be used to evaluate thermal maturity in source-rock reservoirs. Additionally, the results provide some insights into the composition of the programmed pyrolysis “S0” peak. The S0 peak is distinct from the more widely utilized S1 peak (300°C), which represents “free hydrocarbons”, and may be the result of adsorption and strong binding of hydrocarbon gases to organic matter in Bakken source rocks.