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An Organic Carbon Mass Balance for the Bakken Formation

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As part of ongoing research into the effects of thermal maturation on sedimentary organic matter, we have created an organic carbon mass balance for the Devonian/Mississippian Bakken Formation. The mass balance is constructed by combining total organic carbon (TOC) and programmed pyrolysis measurements on ~200 drill core samples taken from both the Upper and Lower Bakken Shales and across a depth/thermal maturity gradient. Our study also includes detailed organic petrography on selected samples. Together, the mass balance and organic petrography allow us to describe an organic carbon lifecycle comprising original, transitional, and terminal organic carbon. We observe that original organic carbon in the Bakken Formation (sampled at ~2,300 m) occurs over a wide range of concentrations (~10 to 25 %) and with substantial variability in petrographic characteristics, such as solid bitumen reflectance values. Transitional organic carbon, sampled from between 2,500 and 3,200 m, is actively generating hydrocarbons, and average TOC decreases with depth as hydrocarbons are expelled. However, a similar range in TOC and variability in petrographic characteristics are preserved. Below ~3,200 m in the Bakken Formation, organic matter abruptly reaches the terminal stage where the range in TOC concentrations and the variability in petrographic characteristics are both lost and significant generation and expulsion of petroleum appears to have ceased.

Our mass balance further allows us to discern between mobile and immobile organic carbon pools in the Bakken system, where immobile carbon includes macromolecular organic matter, kerogen, and pyrobitumen. The relative proportions of mobile and immobile pools of original organic carbon are a direct consequence of the depositional environment (i.e., the extent of degradation in the water column and sediments). Because the terminal organic carbon pool consists of only immobile phases, the terminal organic carbon phase is also a direct consequence of the depositional environment. Transitional organic carbon represents both the depositional environment and the particulars of the thermal maturation process. All organic carbon in black shales is susceptible to alteration during thermal maturation. However, the degree to which TOC is susceptible to alteration likely varies between and across basins as a product of paleoenvironmental and depositional conditions.