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Combining Programmed Pyrolysis with Multivariate Curve Resolution to Delineate Hydrocarbon Phases in Bakken Formation Source Rocks

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Abstract

Programmed pyrolysis is one of the most widely used analytical methods for evaluating petroleum source rocks. It can provide information on overall hydrocarbon-generating potential and organic matter (OM) type in immature samples, as well as remaining generation potential, thermal maturity, and oil producibility in source units. A well-known issue with the method is that interpretation of even immature organic matter type can be complicated by the presence of multiple types of organic matter. This issue becomes even more difficult to delineate for samples in the oil window. Evaluation of maceral types and petrographic point counts or biomarker analyses can provide insight into the composition of source rocks with mixed OM types, but are laborious and require specialized expertise to perform. As an alternative interpretation approach, multivariate curve resolution (MCR) has been applied to pyrograms collected on source rock samples from the Devonian-Mississippian Bakken Formation ranging from immature through the late oil window. Results from MCR analysis include both component features (peak shapes, Tmax) and the relative contribution of each component to the original data (component weights). Pyrograms for 198 samples representing lower and upper Bakken source rock intervals from eight cores ranging in depth from 2,300 to 3,400 m were evaluated. Multiple MCR models were developed for comparison, including complete pyrolysis runs (includes S0, S1, and S2 peaks) for the full dataset, complete pyrolysis runs for lower and upper Bakken subsets, S2-only model for all samples, and an extracted subset of samples (32). No systematic difference in model results was apparent for the lower and upper Bakken subsets or between the S2-only and extracted samples. Three components were resolved for the S2 peak in all models with very similar peak shapes and Tmax values of ~410, 430, and 455°C, generally varying by no more than ~2°C. Component weights shifted with increasing burial depth and thermal maturity, with the low Tmax S2 component (410°C) appearing to be converted into the intermediate Tmax (430°C) and retained oil/bitumen (S0+S1) components. The high Tmax component (455°C) contributed roughly the same weight to each sample and did not appear to be reduced through the range of thermal maturities examined (immature to late oil window). The intermediate component is interpreted to represent generation of solid bitumen that is not removed by extraction but has a higher conversion temperature than the original organic matter, possibly due to the loss of reactive heteroatoms. This work shows that MCR can be used to rapidly examine large numbers pyrograms and provides interpretative insights regarding multiple organic phases present in petroleum source rocks of varying maturities.