Kinetic Isotope Fractionation Modeling of Natural Gas Geochemistry in the Mamm Creek Field, Piceance Basin, Colorado

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Gas production in Mamm Creek field of the southern Piceance Basin, Colorado is predominately from low porosity/permeability sandstones of the Williams Fork Formation of the Upper Cretaceous Mesaverde Group. The primary source of the gas is generally thought to be the Cameo coal zone within the lower part of the formation, with possible contributions from minor intraformational organic-rich units. The basin-centered gas model is commonly used to explain this gas accumulation, whereby overpressuring results from abundant gas-prone source rocks in close proximity to very low permeability, highly discontinuous sandstone reservoirs. Gas was generated at a faster rate than gas was lost from the system, and the overpressured gas charged the sandstones to irreducible water saturations. This caused vertical natural fractures that allowed gas to migrate upward, forming a significant gas column. However, spatial variability in the molecular and isotopic composition of the produced gases indicates the possibility of a more complex history of gas genesis. Specifically, gases produced from the western portion of Mamm Creek field are isotopically heavier (δ13C) and drier than those in the eastern part of the field.

A source-specific kinetic isotope fractionation model was developed, based on a series of sealed-tube pyrolysis experiments involving immature source rocks from the area. This model was integrated into a three-dimensional geologic model of the southern Piceance basin, allowing for the extrapolation of the kinetics to the natural time-temperature conditions of the region. The model results indicate that the observed trends in the gas geochemistry cannot be explained by a single Cameo coal source for the gases. Moreover, the model predicts that in the western section of the field, Cameo coal-sourced gases may be mixed with a secondary, isotopically lighter source, most likely from the underlying Upper Cretaceous Mancos Shale that contains predominately type II kerogen. Spatial variations in the gas geochemistry throughout the field provide strong evidence for reservoir compartmentalization, the existence of which helps in determining migration pathways and timing of localized gas emplacement. Overall, the integration of a source-specific kinetic isotope fractionation model with local geologic and geochemical data in a three-dimensional framework provides a powerful tool for improved understanding of the generation and accumulation of natural gas.