Sensitivity Analysis of Thermal Maturation of Alaska North Slope Source Rocks Based on Various Vitrinite Reflectance Models

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ABSTRACT

Basin thermal history is one of the key uncertainties for the evaluation of prospective petroleum systems. Vitrinite reflectance (Ro) is one of the most common measurements used to evaluate thermal maturity. Thermal calibration of basin and petroleum system models (BPSM) should allow replication of dogleg structures in vitrinite reflectance versus depth that are commonly observed at depths corresponding to ~0.7 to 1.0% Ro. In this study, we compared different vitrinite reflectance models (Easy%Ro, its update Easy%RoDL, and Basin%Ro). We assigned the kinetic models to our Alaska North Slope 3D BPSM, a geologically complex petroleum province that evolved through the tectonic stages of passive margin, rift, foreland basin, and foreland fold-and-thrust belt. Rift-related structures and a regional break-up unconformity facilitated trapping and migration of the largest oil and gas accumulations. Thermal maturation was mainly controlled by the Brookian Sequence deposited from WSW to ENE during Late Cretaceous to Cenozoic time in a prograding foreland basin. We calibrated the various model scenarios against well data (>170 wells with Ro and 18 wells with Horner-corrected temperatures) to assess the impact on timing of maturity and hydrocarbon generation. Here, Basin%Ro and Easy%RoDL show significant improvements for calibration against vitrinite reflectance profiles that show the characteristic dogleg structure with different rates of increasing maturity. The calibrated thermal models required different thermal boundary conditions, which influenced timing of source rock maturation, hydrocarbon generation, and migration in relation to trap formation. Based on the results in this study area, we recommend consideration of several vitrinite reflectance models for thermal calibration. It is currently uncertain whether a universal algorithm for vitrinite reflectance exists. In addition, the maturation of vitrinite and oil-prone kerogen are not universally correlated, and may require correction for the individual kerogen types. Basin and petroleum system models that were calibrated only against a selected depth interval above or below a dogleg should be reevaluated.