geoconvention
Calgary • Canada • May 7-11 2018

Forward and inverse modeling of kerogen generation kinetics based on routine Rock-Eval pyrolysis with application examples from Canadian sedimentary basins and elsewhere

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Summary

Petroleum generation kinetics is important for maturity modeling, hydrocarbon transformation estimation, and source rock heterogeneity study in evaluating oil and gas resource potentials in shale plays (e.g., Chen et al., 2016b; Burnham, 2017; Stainforth, 2009). Traditional approach for generation kinetics faces challenges to meet fast growing needs for robust resource models to support dynamic decision-makings. The challenges include requirements for immature source rock sample, pyrolysis results from multiple heating rates, lack of spatial representativeness, and uncertainties associated with the extrapolation of laboratory results to real geological time scale due to the difference between laboratory settings and natural geological environments (Chen et al. 2017a, b, c, d). By introducing kinetic inversion and forward modeling, the Geological Survey of Canada recently developed novel technics that can overcome some of the difficulties in the traditional approach (Chen et al., 2017a and b).

The kinetic inversion uses HI-Tmax data pairs from routine Rock-Eval results generated on multiple naturally matured samples to directly estimate kinetic parameters without requiring immature sample. The method is applicable to basins where there is no access to immature rock sample or immature source rock does not exist at all due to their high thermal maturity (Chen et al., 2017b). The additional advantages of the method include: (a) spatial representativeness of lithofacies change covered by samples of various maturities across the entire study area; and (b) eliminating uncertainty in data extrapolation associated with differences between laboratory setting and natural environment, such as heating rate, water content, minerals, pressure and others. This is because all samples were thermally altered in their own geological settings, and the thermal degradation is indicated by “kerogen disappearance” (Burnham et al, 2017).

The forward kinetic modeling deconvolutes the hydrocarbon generation into various “kerogen components”, not only capable of revealing kerogen components by the variation in their thermal stability and transformation behaviours, but also providing a geological model for identifying the S1 carry-over and correcting impacts on Rock-Eval parameters from contamination of non-indigenous hydrocarbons or retarded S1 response due to adsorption. The forward modeling constructs thermal decomposition trajectories from FID pyrograms using simulated HI-Tmax pairs for data interpretation and maturity modelling, and is useful for basins lacking high maturity samples (Chen et al., 2017b and d).

Kinetics-based data interpretation can help petroleum geologists to avoid misconceptions in data analysis and interpretation by identifying maturity overprints, kinetic effect on generation potentials and others (Chen et al, 2016b). The paper will present examples from shale resource evaluation case studies in the Canadian sedimentary basins and elsewhere to demonstrate the novel methods and their applications.

Acknowledgements

This represents an output from the Geoscience for New Energy Supply Program of Natural Resources, Canada, and is partly supported by PERD funding.

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