

## Source Rock Kerogen Kinetics Using Hydrocarbon Pyrograms from routine Rock-Eval Analysis

Zhuoheng Chen, Xiaojun Liu, Chunqing Jiang and Andy Mort  
Geological Survey of Canada, Calgary, Alberta

### Introduction

Source rock evaluation is a key component in hydrocarbon resource assessment for shale gas/oil plays. Source rock kinetics, along with thermal maturity, controls the onset and rates of oil and gas generation that are critical to both quantitative resource evaluation (Kuhn, et al., 2012) and identifying prolific production zones (Hood, et al., 2012; Chen et al., 2016).

The most common approach for determining oil generation kinetics utilizes laboratory pyrolysis at various heating rates to approximate hydrocarbon generation processes (Aboulkas and Harfi, 2008), allowing the thermal energy required for hydrocarbon generation under differing geological conditions to be inferred. However, the requirements of special laboratory instruments, procedures, and expertise limit the number of source rock samples that can be analyzed for kerogen kinetics due to budgetary and time constraints. Another challenge for the conventional kerogen kinetics approach is that immature source rock samples, required for laboratory pyrolysis to derive the kinetics parameters, are not always available. An example of this is the Utica Shale in Quebec Canada, where the basin has undergone severe thermal alteration (Chen et al., 2014). On the other hand, the requirements for information regarding source rock reactivity and hydrocarbon generation behavior are time sensitive for supporting business decision. Therefore, directly assessing kerogen transformation behavior of a source rock unit based on archived Rock-Eval data would allow rapid and time-sensitive results to be obtained.

We here describe a numerical method that uses archived Rock-Eval hydrocarbon pyrograms to infer the kerogen hydrocarbon generation kinetics of a source rock. The proposed method is validated first through a Rock-Eval sample with kinetic parameters from literature. A case study using regular Rock-Eval data acquired on samples from the Devonian Duvernay Shale system in the Western Canada Sedimentary Basin (WCSB) is utilized to demonstrate the application of the proposed method in source rock evaluation.

### Method and application

The proposed method attempts to reproduce numerically laboratory observations based on regular Rock-Eval hydrocarbon pyrograms so that hydrocarbon generation kinetics of a specific source rock unit can be inferred for data interpretation and hydrocarbon generation modeling.

For the complicated hydrocarbon generation reactions in a source rock, we have the following assumptions: a) kerogen thermal degradation can be approximated by a series of  $n^{\text{th}}$  order, independent and parallel chemical reactions, and the temperature dependency of the reaction rate constants can be described by Arrhenius equation; b) kerogen in a source rock is a mixture of compositional groups. Each group requires distinctive thermal energy for decomposition, and this can be characterized by a specific activation energy  $E_a$  distribution coupled with a frequency factor  $A$ ; and c) each group of kerogen components undergoes independent and parallel reactions and its contribution to the overall production rate depends on its abundance.

An immature sample (C-598636) is used to demonstrate the application of the proposed method. It has a Tmax of 432 °C and a production index of 0.11, indicative of an immature to early mature stage for kerogen thermal decomposition. A numerical solution by fitting the S2 curve of the pyrogram results in a set of kinetic parameters, a distribution of apparent activation energies and a frequency factor A. The kerogen is characterized by a distribution of activation energies with varying relative abundance, while the relative contribution of each kerogen group to the total remaining hydrocarbon generation potential is signified by the height of a bar in the activation energy histogram. A forward modeling utilizing the estimated activation energies generates pairs of Tmax equivalent temperatures and remaining hydrocarbon potentials (or hydrogen index HI) at various maturity levels, and these estimates are then compared with real Rock-Eval data on samples from across the basin.

## Conclusions

We proposed a method that fits Rock-Eval S2 curves to a numerical model of kerogen thermal decomposition, thus deriving the kinetic properties for the source rock unit under examination. The method utilize archived Rock-Eval analytical results directly, and no new samples and pyrolysis are required for calculating kinetics, thus providing a quick response to urgent needs in data interpretation for business decisions or numerical modeling of hydrocarbon generation history. The method can generate as many kinetics parameter pairs as Rock-Eval pyrograms are available to form a population, so we can examine the variation of hydrocarbon generation behaviors in space and time for a source rock system. The variation of the inferred kinetic parameters allows for inference of changes in kerogen composition within the same source rock unit, so that proper subdivision of facies models can be applied in basin modeling and data interpretation.

The cost-effective and time-saving advantages of the new method come with a price. The trade-off for multiple-heating-rate laboratory experiments could be the potential compromise of accuracy in kinetic parameters as suggested by Peters et al. (2015). However, our validation test suggests that the temperature discrepancy is only about 1.5-2 °C in geological time scale for oil window (transformation ratio between 10 and 90%) of the Devonian Duvernay Type II kerogen source rocks from WCSB, far less than the uncertainty range of formation temperature estimates. In addition, the perceived weakness of the method is counterbalanced by its capability of generating a large number of generation kinetics estimates across a basin and computing numerous HI and Tmax pairs for comparing general trends of kerogen thermal decomposition, and this is important for consistency and quality control for numerical modeling and resource estimation for a source rock system.

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