Source Rock Kinetics: Goal and Perspectives

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Abstract

Despite international will and policies for reducing the dependency on fossil fuels, Petroleum is still considered as an essential resource to match the demand for petroleum in the coming decades. In order to match the long-term growing demand for petroleum, unconventional resources have taken a significant part of the petroleum offer (5-6 Mbd). The interest for these resources renewed the efforts of research on the mechanisms of petroleum generation, retention and expulsion. Since the source rock also acts as a reservoir in these systems, it also gave access to a large number of source rock samples compared to what was available when the interest was only on conventional petroleum systems, paving the way to interesting new studies.

Though some recent debates on the role of thermodynamics (Uguna et al., 2012) in the conversion of solid organic matter into fluid petroleum, the most accepted way to model this conversion remains the kinetic approach. This latter is mostly used, in combination with basin modeling or not, to predict the state of maturity of source rocks, the amount of generated petroleum and some other mechanisms related to expulsion and retention. Consequently, for exploration perspectives, the main objective when determining kinetics parameters is to get a predictive model of transformation of the organic matter in oil and gas under geological conditions (several millions of years at temperatures ranging between 80 to 200°C).

While first authors proposed kinetic models mostly basing their interpretations on field data (Lopatin et al., 1971; Tissot, 1969; Tissot et Pelet, 1971; Waples, 1980) kinetics parameters are currently mainly determined using artificial maturation procedures in laboratories. All these experimental maturation techniques are performed either using isothermal or non-isothermal temperatures with temperatures ranging between 200 and 700°C associated to heating times span varying from some minutes to few hundreds of hours (e.g. Behar et al., 2008; Lewan and Rubble, 2002). Thus, these laboratory conditions are far from the geological domain. A lot of efforts were put on compositional description of kinetics and there were tremendous progresses in analytical techniques and modeling capacities to better understand chemical processes and characterization of the generated petroleum composition (e.g. Behar et al., 2008; Fusetti et al., 2010). However, previous and recent studies emphasized some inconsistencies or shortcomings in the way kinetic parameters are currently determined (e.g. Prinzhofer, 1994, unpublished). They can lead to strongly erroneous prediction in the maturity of source rocks at regional scale. Indeed authors usually provided only a unique possible solution to the kinetic parameters inversion problem, they dedicated little efforts to perform real validation of this unique proposed solution and did not assess their predictivity at laboratory or geological time scales. Even if the problem is not new (e.g. Ungerer et Pelet, 1987 ; Ungerer, 1989), it was kept at the bottom of the research priority list and remains unsolved. The recent attention to unconventional resources to supply global oil and gas needs has led to a raising interest to both better constrain the determination of kinetic parameters and assessing the uncertainties on their determination appeared.

It seems now clear that in order to better constrain the determination of kinetic parameters for petroleum exploration, laboratory transformation data are not sufficient. Now, with new modeling techniques such as basin modeling we are able to better determine temperature history at basin scale and then it is now possible to quite accurately estimate the temperature history of any sample of rock. Based on the new data and samples derived from the production of unconventional resources, these reservoirs-source rocks can be used to better constrain kinetic parameters of organic matter conversion into petroleum by coupling basin modeling and laboratory experiments.

We applied this new approach combining both usual laboratory immature source rock maturation results with observed characterization data coming from naturally matured samples also completed by laboratory maturations. For this natural series the temperature history was reconstructed based on basin modeling techniques. To get an uncertainty risk on the kinetic parameters we provided not a unique set of kinetic parameters but the sets of parameters that fit equally well the constraining natural and artificial data. Finally the optimization procedure was revisited to keep the transformation description as simple as possible (no more complexity than what is suggested by the data) using some inputs from the theory of information.