Estimation of Oil and Gas Volumes in Unconventional Systems: Mass Balances and Kinetic Modeling

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Introduction

The aim of the study is to propose a compositional kinetic model predicting the different thermal cracking reactions occurring in source rocks for oil and gas generation at increasing thermal maturities ranging from Ro = 0.5 to 3.0%.

Theory and/or Method

It is demonstrated that kerogen is decomposed into asphaltenic compounds which rapidly undergo secondary cracking and contribute to a first source of hydrocarbons. The thermal cracking of these heavy compounds produce a solid residue and resin compounds, the cracking of which generates a second source of hydrocarbons constituting the major part of the oil window.

After the oil window, the residual kerogen and prechar undergo a secondary reaction generating a dry gas with minor contribution of ethane. At the same time, retained compounds which were not expelled undergo secondary cracking reactions to generate gas in maturity higher than 1.5% for Ro.

A full compositional kinetic model was elaborated from artificial maturation of both kerogens and oil in closed system pyrolysis. Typically, oil generation was simulated in the temperature range 275 – 375°C and time between 3h and 1 week. Subsequently, the mature kerogens were artificially heated at 375°C/24h in order to mature the kerogens to the beginning of the gas window and remove all generated products by solvent extraction. The goal is to create post-oil generative kerogen in order to measure generated products from mature kerogen only. These oil-free mature kerogens were heated to higher temperatures between 450 and 550°C for evaluation of late gas generation.

This full compositional kinetic approach was applied to two case studies: shale oil and shale gas petroleum systems. Results show that retained fluid in source rock after the main phase of expulsion undergoes significant thermal cracking for the aromatic hydrocarbons leading to a fluid largely dominated by saturated hydrocarbons. Then, i.e. for Ro higher than 1.2-1.4 the saturates are cracked to generate light hydrocarbons and wet gas. The complete transformation of light saturates into gas occurs at maturity corresponding to a Ro range between 2.0 and 2.5%.

During secondary cracking of oil inside source rock, late gas generation from the mature kerogen starts at Ro higher than 1.4% up to Ro equal to 3.0. Consequently, due to these successive reactions the molecular gas composition varies continuously with increasing maturity. At Ro = 1.0% the dryness being 60% sharply increases to 90% at maturities between 2 and 3% Ro.

From compositional modeling of oil generation and degradation within source rock, it is now possible to anticipate the best maturity range to optimise fluid quality : below Ro at 1.5, the fluid retained in source rock is mainly dominated by liquid compounds in stantard conditions whereas at higher maturity late gas genration from the mature kerogen dramatically increases the GOR.