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HYDROCARBON MASS BALANCE CALCULATIONS IN PETROLEUM SYSTEMS EXPERIENCING THERMOCHEMICAL SULFATE REDUCTION (TSR)

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Introduction

The quantitative assessment of thermochemical sulfate reduction (TSR) in petroleum systems is to date not entirely understood. Since the term TSR was first established in the 1970's, many equations have been proposed. Each reaction returns very often different numerical results, which reveals the degree of uncertainty. This is highlighted in the present study by evaluating three TSR net equations taken from literature and obtained from experimental studies (Orr, 1974; Goldhaber and Orr, 1995; Worden et al., 1995; Machel, 2001; Mougín et al., 2007; Liu et al., 2013).

The area of study is located in SW France, in the South Aquitaine Basin (Choukroume, 1992; Renard et al., 2019; Elias Bahnan et al., 2020), namely in the Arzacq Basin, where the Lacq petroleum system is located. Apart from the economic importance of the deposit, the area holds great research interest due to the recently revised complex tectonic history. Among major tectonic events, the Lower Cretaceous rift stage is characterized by a hyperextension phase with mantle exhumation (Clerc and Lagabrielle, 2014; Teixell et al., 2018). Such conditions caused very high thermal gradients which rapidly brought source-rocks into the dry gas zone. TSR also occurred in the petroleum kitchen areas leading to the consumption of hydrocarbons.

Results

The organic petrography and Rock-Eval study of the principal source rock in the Arzacq Basin, namely the Kimmeridgian Lons Formation, revealed both type II-S and type-III marine and terrestrial kerogens, respectively.

We aim to evaluate the significance of TSR in hydrocarbon quality/consumption and the development of sour gas in the Deep Lacq petroleum system. The very high level of H₂S in Deep Lacq, often reaching 18% in the total volume of the gas mixture, was used to perform a series of calculations to constrain the mass balance between hydrocarbons generated/destroyed in the source rock kitchen, using the following chemical reaction (Worden et al., 1995; Mougín, 2007; Liu et al., 2013):



We have used well data in this equation, namely 40.68 GM³ of H₂S that correspond to 18% of the bulk gas composition of the Deep Lacq field upon discovery (total volume in place = 226 GM³). Using the stoichiometry of this reaction we have estimated the amount of CH₄ needed to produce that amount of H₂S.

This method was then used in other regional gas fields in South Aquitaine Basin that were suspicious for TSR. As a next step we have calculated the total amount of hydrocarbons produced in the source rock kitchen in two ways:

- 1) By summing together the amount of hydrocarbons stored in Deep Lacq plus those consumed by TSR.
- 2) By calculating the total amount of CH₄ generated in the petroleum kitchen*, using the kinetics of the type II and III kerogens of Lons Formation. The calculations were based on the identification of the drainage area using isobath maps, the thickness of the source rock formation focusing on the prolific intervals using sedimentological logs and the average S₂ value from Rock-Eval pyrolysis.

We have then calculated the number of the total hydrocarbons produced in the source rock by comparing the two approaches presented above..

* Due to flash heating all higher homologs were cracked into dry gas very early in the basin history.

Conclusions

The overall efficiency of the petroleum system including the total amount of hydrocarbons generated, trapped as well as the losses induced by TSR, will be discussed. The reconstructed scenario of fate of hydrocarbons will be confronted to that of the reservoir filling (Elias Bahnan et al., 2020) and the structural evolution of the basin as to contribute to a synthetic model.

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