Reservoir organic geochemistry: Processes and applications

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Abstract
This Special Issue of the “Journal of Petroleum Science and Engineering” is devoted to organic geochemistry and published in honor of Dr Alain-Yves Huc. Alain has been involved in promoting and developing reservoir geochemistry as a tool in the field development and exploitation problem solving toolbox. This volume includes general papers on the potential interest of organic geochemistry for production purposes and discusses some physical processes such as hydrocarbon/water interactions and TSR (Thermochemical Sulfate Reduction). It presents new analytical techniques and shows industrial field applications, demonstrating the potential contribution of organic geochemistry in enhancing hydrocarbon production.

1. Introduction
For the past 20 years, organic geochemistry has been widely applied to solve exploration problems such as source-rock recognition, maturity evaluation, oil–oil or oil–source correlations or to predict hydrocarbon fluid composition in a potential target. However, since the late eighties (Kaufman et al., 1990), geochemistry has helped to solve production problems such as reservoir continuity, identification of producing/non-producing intervals or leaking of casing and production allocation. These approaches were based on static approaches where differences in composition are inferred mainly in terms of reservoir continuity. The understanding of physical/chemical laws which control the fluid composition (sourcing, source-rock maturity, source mixing, phase behavior, density segregation, diffusion, water/hydrocarbon interactions, thermal cracking, thermochemical sulfate reduction…) permits the incorporation of dynamic aspects into interpretation and a more reliable prediction of the fluid heterogeneity distribution can be defined at the field scale (Smalley et al., 2004). Special compositional variations can greatly aid the petroleum engineer in defining the production pattern, or in the understanding of unexpected production behavior. This Special Issue focused on organic geochemistry as an aid to classic reservoir engineering techniques. General introductory papers on the subject, recent insights in some physical alteration processes, new detection techniques and field case applications provided both the fundamentals of today’s reservoir geochemistry and potential tools to help production engineering.

2. This Special Issue
This Special Issue consists of eleven papers. The first paper is entitled “Reservoir geochemistry — A reservoir engineering perspective” by W.A. England. This paper is a general paper which reviews the applications of reservoir geochemistry from the reservoir engineering perspective. The principal methods used in reservoir geochemistry are presented and they show how the compositional differences in fluid composition can be applied in a wide range of practical engineering problems. The importance of integrating the geochemical data into all available data is emphasized. Pitfalls are discussed with special attention to the magnitude of the compositional variations and the understanding of these origins, especially for recognition of internal permeability barriers. Finally, subjecting for new developments or improvements are proposed.

The second paper, “Petroleum geochemical proxies for reservoir engineering parameters” by B. Bennet, A. Lager, D.K. Potter, J.O. Buckman and S.R. Larter proposes the use of polar non-hydrocarbon compounds to reveal changes in wettability and/or petrophysical properties.
Core flow experiment was performed in a siltstone core. Results showed that the distribution of the polar non-hydrocarbons is closely related to the change in wettablility of the core leading the authors to consider these compounds as potential proxies for fluid–rock interactions. Additionally a correlation between such molecular markers and petrophysics is exemplified on a North Sea reservoir, indicating that a link can be found between petrophysical properties of the reservoir and the relative distribution of petroleum components at the molecular level. Compilation of geochemical, petrophysical and core data can be used to identify production zones where fluid phase behaviors might be different.

The third paper is called “Polar non-hydrocarbons in crude oils and rock extracts: Recovery and impact of sample storage protocols” by B. Bennett, A. Lager and S. R. Larter. This paper tackles the problem of the compositional change of a rock extract during core storage and then the representative of the samples for interpretation. Even if the storage of samples for geochemical analysis is not too critical for hydrocarbon characterization, alteration of NSO compounds has been clearly detected on core samples on a period of 6 months. Then from the authors view point, it is of paramount importance to sample the core as soon as possible after the core retrieval. The paper also highlights the differences in bulk NSO composition between the produced hydrocarbon fluid and the fluid residing in the reservoir. These differences in the heavy end of the fluid composition can change drastically the fluid phase behavior during production and/or injection.

The paper “Polydispersity of the heavy organics in crude oils and their role in oil well fouling” by G. Ali Mansoori, Dynora Vazquez and Mojtaba Shariaty deals with the problem of heavy organic deposits in wells during production. Based on a case study, the paper first describes, in a synthetic way, how the produced oil samples have been characterized, giving to the non-specialist a good view of the geochemical analysis procedure.

The three following papers are related to the use of numerical modeling to calculate the variations in fluid composition in a reservoir in order to better predict the vertical and lateral distribution of the fluid heterogeneity. Modeling of physical and/or chemical phenomena which control the composition and distribution of fluids in an oil field permits to put the measured geochemical data into a more dynamic field scale context. The numerical models proposed are based on thermodynamic approaches. The first paper entitled “Initial state of petroleum reservoirs: A comprehensive approach” by F. Montel, J. Bickert, A. Lagisquet and G. Galliéro, is related to the modeling of phase equilibrium and transport phenomena. It proposes a new numerical approach which is able to calculate the fluid composition and pressure distribution in a field. The authors underline the importance of external fluxes at the boundary of the reservoir. A comparison of the modeling results and the actual fluid distribution can be used to assess the connectivity of the different compartments of a field, exemplified by a case study. The second paper, “The effect of diffusion on the modeling of the water-washing phenomenon” by S. Shakir and J-C de Hemptinne, is related to water-washing. The authors used a water/hydrocarbon equilibrium model in order to reconstruct the compositional evolution during a laboratory experiment where the interactions between recombined production oil and water have been simulated. Two models have been tested, a first one taking into account the solubility of the light compounds and a second one which takes additionally the diffusion coefficients of the hydrocarbon species. Effects of water-washing on the fluid composition are documented and the additional non-negligible effect of diffusion on the change of composition of the hydrocarbon fluid are highlighted. The third paper is named “Thermodynamic of thermochemical sulfate reduction” by P. Mougin, V. Lamoureux-Var, A. Bariteau and A.Y. Huc. The paper addresses the presence of hydrogen sulfide (H₂S) in the reservoir. The authors present the Thermochemical Sulfate Reduction (TSR), one of the most common origin for sour gazes, through a review of literature field cases where TSR has been recognized. Chemical interactions between hydrocarbons and evaporate minerals (anhydrite) are investigated and two different thermodynamic calculations have been used to predict the chemical compositions at the equilibrium state. Both approaches converge to similar results, in agreement with field observations.

The next four papers are field case studies. The first two papers promote the use of isotope measurements performed during drilling to detect reservoir compartmentalization.

One paper is by E. Rein and L. Kristin Schulz and is entitled “Applications of natural gas tracers in the detection of reservoir compartmentalization and production monitoring”. The authors measured mud gas carbon isotopes in horizontal wells. They present the potential interest of such measurement on barrier detection and production allocation in fields where isotopic variations are detected. Three field cases studies are reported from the North Sea. Variations in carbon isotopes of the gas samples are considered due to bacterial activity and/or variations in maturity. The study permits the recognition of hydrocarbon heterogeneities indicating compartmentalization and production allocation. Moreover, in one example, the authors are able to discriminate between sealing and non-sealing fault within the reservoir.
The second paper is entitled “Integration of mud gas isotope logging (MGIL) with field appraisal at Horn Mountain field, deepwater Gulf of Mexico” by L. Ellis, T. Berkman, S. Uchytíl and L. Dzou. The paper presents the mud gas isotope logging (MGIL) technique and its application in a complete field scale reservoir context. The paper first introduces the MGIL technique and its potential for reservoir engineering; then the application of the technique to the Horn Mountain Field in the Gulf of Mexico is developed. Information on compartments, seals and gas origin is provided.

The following paper is on the use of Fourier Transform Infra Red (FTIR) spectroscopy to characterize the geochemical composition of oil samples. The paper named “Reservoir compartmentalization assessment by using FTIR spectroscopy” by A. Permanyer, C. Rebufa and J. Kister presents the technique and its application at basin and field scale. The authors propose the method as an alternative technique to the traditionally used gas chromatographic fingerprints. Comparison of results is presented.

The last paper, “Tar mats and residual oil distribution in a giant oil field offshore Abu Dhabi” by B. Carpentier, H. Arab, E. Pluchery and J.-M. Chautru, presents an integrated study of field data. It describes how geochemical data combined with wireline log interpretation allows for the recognition of the distribution and continuity of bitumens in a main reservoir of an offshore giant field in Abu Dhabi. Two types of bitumen rich levels were recognized with different origins and distributions. Relations with structural location and field geological tilting have been found. Numerical modeling of a geological scenario led to the prediction of a distribution of fluids (water, movable oil and residual oil) very close to the one observed at present-day time in the field. This modeling has been used to better define an optimal production scheme.

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