BASIN MODELING AND UNCONVENTIONAL RESOURCES: INNOVATIVE GEOCHEMICAL APPROACHES

I. Kowalewski, R. Traby, M. Ducros, , X. Guichet, S. Wolf

IFP Energies nouvelles, France

The fast development of unconventional resources exploration is a global opportunity to meet the world's growing demand for energy. Unconventional gas, either in shale plays or from biogenic origin, represents a large and increasing part of the overall gas production. Biodegraded oils (consumption of light compounds by microbial activity leading to heavy oil/bitumen in reservoirs) and sour oils (formation of H_2S and sulfurization of oil by Thermal Sulfur Reduction: TSR) are known to be a sink of huge volumes of hydrocarbon.

Current intensive R&D works aim at better understanding geochemical processes and better characterizing the generation of these unconventional oil and gas reserves. All these developments contribute to the continuous improvement of oil and gas in place evaluation accuracy. Recent concepts proposed for explaining the formation of these unconventional resources lead to solutions, which have been developed and integrated into petroleum systems modeling software (TemisFlow®). These innovative approaches will be investigated and illustrated through several cases studies.

The model developed for biogenic methane (C1) generation depends on the distribution of initial sedimentary organic matter (SOM) and its intrinsic susceptibility to microbial activity, which is controlled, among others, by temperature (T< 90°C). The produced biogenic methane can then be adsorbed onto organic matter (Langmuir equation), solubilized in formation water (Duan and Mao, 2007) or migrate as a free phase (Darcy law). The application of post-processing techniques makes it possible to detect the formation of methane hydrates based upon its thermodynamics properties, water salinity, pressure and temperature conditions. A first case study focusing on the prediction of biogenic gas accumulations in offshore Lebanon will illustrate the potential of recent modeling tools for these newly explored petroleum systems (Barabash et *al.*, 2016).

In shale plays, thermal cracking of shale kerogen generates a second source of methane. The amount of thermal methane depends on total organic carbon (TOC) content, total porosity, organic matter type and chemical composition, as well as maturity level. The produced thermal methane, like biogenic methane, can then be adsorbed onto organic matter, migrated with the formation water or as a free phase. This will be illustrated by a second case study predicting the adsorption of C1 onto residual organic matter in the Montney shale Formation of the Western Canadian Sedimentary Basin (WCSB) (Pauthier et *al.*, 2016).

At reservoir scale, during reservoir infilling history, oxidative alterations of oils (Biodegradation and TSR) can occur depending on temperature, which leads to a strong decrease in quantity and quality of hydrocarbons in place. For low reservoir temperature (T<90°C), an oil biodegradation model is accounted for, which entails significant changes in oil composition and volume, and in biogenic methane production. The 3D biodegradation model describing the microbial activity that occurs in the low temperature tertiary reservoirs of the Llanos Basin will be detailed (Martin et al., 2017).

Last, in anhydrite-rich carbonate reservoirs at high temperature (T>110°C), a risk of TSR can be computed based on temperature, hydrocarbon saturation and sulfate content. The corresponding maximum amount of H_2S that can be produced is calculated based on a stoichiometric equation proposed by Uteyev (2011). This produced H_2S can then be dissolved in the water formation or released as a free phase. This model was successfully applied to the Devonian Nisku Formation in Western Canada (Guichet et *al*., 2017).

References

Duan, Z., Rui, S., Rong, L., Chen, Z., 2007. Accurate Thermodynamic Model for the Calculation of H_2S Solubility in Pure Water and Brines. Energy and Fuels 21, 2056-2065.

Guichet, X., Kowalewski, I., Euzen, T., Gasparrini, M., Bachaud, P., Maurand, N., 2017. H_2S Risk Assessment at the Basin Scales. Abstract. American Association of Petroleum Geologists Annual Meeting, Houston..

Martin, L., Kowalewski, I., Traby, R., Ducros, M., 2017. 3D Modeling of Petroleum System of Llanos Basin (Colombia): Prediction of petroleum composition. Abstract28th International Meeting on Organic Geochemistry, Florence.

Barabasch, J., Ducros, M., Nader, F.H., Carpentier, B., Pujol, A., Bou Daher, S., Littke, R., 2016. Towards an Integrated 4D Stratigraphic and Petroleum System Basin Model in a Frontier Province The Case of the Levant Basin (Eastern Mediterranean). Abstract. Hedberg Conference The Future of Basin and Petroleum Systems Modeling, Santa Barbara.

Pauthier, S., Ducros, M., Chauveau, B., Euzen, T., Sassi, W., 2016 Modeling source rock distribution, thermal maturation, petroleum retention and expulsion: The Case of the Western Canadian Sedimentary Basin (WCSB). Abstract. Hedberg Conference The Future of Basin and Petroleum Systems Modeling, Santa Barbara.

Uteyev, R., 2011.Etude thermodynamique et expérimentale du cycle géochimique du soufre dans les bassins sédimentaires. Ph.D. thesis, France , Nancy Université, 244 p.