Prediction of Low-Maturity / Biogenic Gas Accumulations:
Application to the Offshore Lebanon

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ABSTRACT

Biogenic gas is becoming increasingly important as an exploration target in the petroleum industry because it occurs in geologically predictable circumstances and in large quantities at shallow depths as free gas or gas hydrates. As accumulations of biogenic gas result in a subtle synchronization between early generation and early trapping, we integrated a macroscopic model of microbial gas generation within a 3D basin and petroleum system forward simulator.

The current view is that most of the large dry gas accumulations in shallow reservoirs are microbial in origin. For example, the generated gas of the Carupano Basin located offshore Venezuela is characterized by low maturity and it has been attributed to biogenic processes because of its carbon isotopic signature. Nevertheless, gas compositions show that a thermogenic signature predominates with an increase of gas maturity where condensates were found associated with gas. In this area, the main part of the fields' drainage area is in a low-maturity domain where the vitrinite reflectance (Ro) is less than 0.6%.

Based on microscopical considerations we developed a macroscopical model of low maturity / biogenic gas generation in which hydrocarbons are generated through first order kinetic reactions at low maturity. The kinetic parameters used for basin modeling are not able to reproduce the nature of the fluids generated at low maturity. Indeed, the kinetic parameters used are mainly calibrated with kerogen samples for which Ro is taken to be approximately 0.6%. Considering type III kerogen as a starting point and using observed natural data such as gas compositions, a new set of kinetic parameters were derived to account for low gas maturity. This modified type III kerogen differs from the previous one by a 13% increase of the hydrogen index. The simulations conducted with this modified type III scheme allowed us to reproduce quite well the filling of the fields, as well as the composition of the hydrocarbons.

In our simulations, most of the gas is generated at a very low maturity: Ro less than 0.6 %. In this domain, it has been stated that the thermal C-C–bound breakage is unlikely to be significant without catalysis. Because microbial enzymes are the most efficient low temperature catalysts known, we could describe our kinetic model as a microbially enhanced thermal model.

The previous model has been applied successfully on different basins such as the Carupano Basin (offshore Venezuela) Magdalena Delta (offshore Colombia) and the offshore Vietnam where direct observations of low-maturity gas were available. Furthermore, it has been applied in the offshore Lebanon in order to check the viability of a biogenic gas system. An integrated interpretation of regional 2D seismic surveys offshore Lebanon provided structural maps and an improvement of the geological knowledge. These data allowed the building of a geological

model in 3 dimensions at the scale of the whole offshore Lebanon. The thermogenic source rocks observed in surrounding basins were implemented and tested in the model. An advanced methodology has been developed for identifying which layers could develop a biogenic gas generation potential.

The computed HC composition indicated: (1) the gas, mostly biogenic, completely dominates the shallow plays from the Pliocene to the Oligocene; (2) the oil/condensate content would increase in the Eocene, and overall in the Cretaceous-Jurassic; (3) then the gas (mostly thermogenic) content increases, up to 100% in the Triassic play.

Recent works seem to demonstrate that the same deep biosphere is responsible for early gas generation and biodegradation of thermogenic hydrocarbons. Furthermore, the exploration for unconventional gas demonstrated that late biogenic gas can be generated from old source rocks. Further efforts will be done toward a better modeling of the effects of the deep biosphere on the petroleum systems.