Modeling biogenic gas processes at the basin scale: A case study from the Bay of Biscay

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Biogenic gas has received increasing attention in the last few decades as a major and cleaner fossil energy source (Rice 1992; Katz 2011). Despite the growing interest for biogenic methane gas, its generation mechanisms are still not well understood. The efficiency of the production process is largely determined by biogeochemical mechanisms at the sea bottom that depend on the quality and quantity of the Sedimentary Organic Matter (SOM). In this study we present a new numerical approach to simulate biogenic methane processes at the basin scale applied to the Bay of Biscay (southwestern coast of France) where a few thousand methane gas seeps have been recorded in the water column at 140-220 m water depths (Dupré et al. 2020). The carbon isotope signature of methane indicates that the system is charged by primary biogenic gas generated from CO2 reduction (Ruffine et al. 2017).
The new numerical approach accounts for three different SOM fractions: a labile-SOM which is degraded into methane following the model of Middelburg (1989), a thermo-labile-SOM which is transformed into labile-SOM at higher temperatures as function of first order kinetics and a bio-refractory-SOM which is non-reactive and constant during biogenic gas simulations. Finally, the generated gas is distributed in the basin as either adsorbed to the organic matter, dissolved in water, or as free gas in a vapor phase (in decreasing order of importance).
In order to better describe the organic matter deposited in the study area, Rock-Eval analyses were performed on cuttings collected from two different offshore wells (Baudin et al. 2015). The sedimentary column shows very poor Total Organic Carbon content (~0.35% TOC) for the Plio-Pleistocene series whereas the Miocene occasionally shows high values (~10% TOC). The system is charged by gas from a type III continental-derived SOM (HI<100 mg/gTOC) which is immature (Tmax < 425°C). The model includes the deposition of Methane Derived-Authigenic Carbonate (MDAC) pavements in the uppermost layers which result from the oxidation of methane during upward migration through Anaerobic Oxidation of Methane (AOM) (Pierre et al. 2017).
A sensitivity analysis was performed on the model input critical parameters to quantify their impacts on the biogenic gas production and expulsion/migration processes and identify the more influential ones. Our results show that the generated methane is mainly transported as dissolved phase in formation water and released as free gas at the water-sediment interface. Migration pathways are mainly vertical, from the Plio-Pleistocene source rocks directly to the seafloor controlled by sediment permeability and geometry. The model reproduces observations such as emission points and distribution of seeps both located at the Aquitaine Shelf edge along a narrow line oriented N-S parallel to the shelf break. The origin of the biogenic methane, which is sourced by an active system from Miocene to Plio-Pleistocene sediments, is discussed and a first quantification of the total amount of emitted gas into the water column over time is performed.

Mots-Clés : Biogenic gas modeling, Methane migration, Sedimentary Organic Matter degradation, Bay of Biscay, Methane Derived-Authigenic Carbonates