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Gas hydrate dynamics in heterogeneous media – challenges for numerical modeling

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Gas hydrates are ice-like crystalline cage structures containing various greenhouse gases, such as methane or CO_2, which are locked within their spatial structure. Gas hydrate distribution in oceanic settings is mainly controlled by three factors: 1) low temperature regimes, 2) high pressure regimes, and 3) presence of biodegradable organic matter. Due to their composition, hydrates are vulnerable to temperature, pressure, and, to a smaller degree, salinity changes. The occurrence of gas hydrates in marine sediments was discovered mainly along continental margins (slope and rise) where water depths exceed 400 m and the bottom water temperatures are small enough to sustain their presence.

The amount of gas hydrates present in marine sediments on a global scale is still under debate. Several numerical models of a different complexity have been developed to estimate the potential amount of clathrates locked world-wide within marine sediments. The range of estimates starts from 500 Gt up to 57,000 Gt of methane carbon which implies a variation of several orders of magnitude.

It has been already established that current climate changes are triggering some of the methane releases around the world. Prominent gas hydrate occurrence zones, such as Blake Ridge, can provide important information of the scale of potential hazards and help to predict a future impact of such events. Blake Ridge is a well investigated gas hydrate province containing a large amount of a locked methane gas.

With the new numerical multiphase model we have been investigating 1) the potential risk of gas hydrate destabilization caused by several environmental factors (e.g. bottom water temperature rise, sea-level variations), 2) the effect of changing sedimentation regimes to the total amount of gas hydrate, 3) dynamics of hydrate formation in heterogeneous sediment layers, and 4) the impact of dynamic compaction on fluid and gas flow regimes. The model contains four phases (solid porous matrix, pore fluids, gas hydrate, and gaseous methane) and several chemical species (particular organic carbon (POC), dissolved inorganic carbon (DIC), dissolved methane, dissolved sulfates, free methane gas). Chemical reactions are resolving for the bio- chemical processes in anoxic marine sediments (POC degradation via sulfate reduction, methanogenesis, and anaerobic oxidation of methane (AOM)). The model has been calibrated to the data derived from well drilling, seismic analyzes, and climate models.