

# Impact of Coupled Free Gas Flow and Microbial Methanogenesis on the Formation and Evolution of Concentrated Hydrate Deposits

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## Abstract

To decipher the role of gas hydrate in the carbon cycle, climate change, seafloor geohazards, and as an energy resource, we must understand how it forms and evolves. We build two-dimensional numerical models in PetroMod to investigate how focused free gas flow, microbial methanogenesis kinetics, and hydraulic and petrophysical properties of sediment (e.g. permeability and capillary behavior) couple to concentrate methane in hydrate deposits. PetroMod is a one-, two- and/or three-dimensional basin simulator that couples methane hydrate formation with deposition, basin subsidence, heat generation and heat flow, and the thermal and microbial generation of hydrocarbons and their phase partitions and migrations. We apply this model to the gas hydrate system within a 10 km-wide anticlinal structure above a salt dome at Green Canyon 955 (GC955), in the Northern Gulf of Mexico. We investigate the mechanism by which the highly concentrated-hydrate is formed within a ~100 m-thick sand reservoir that lies at the crest of the anticlinal structure, and explore its evolution over approximately last 3 million years. Gas composition analysis indicates the concentrated-hydrate there is composed of microbial gas. In addition, we observe in seismic data that free gas flows from depth beneath the hydrate stability zone. To simulate this, we need to have significant microbial methane generation beneath the hydrate stability zone. This methane then flows as a separate free gas phase along the stratigraphic layer and accumulates within the reservoir at the crest of the anticline. The concentrated-hydrate reservoir could also form from methane that is microbially generated within the hydrate stability zone and later recycled

back due to hydrate dissociation and free gas flow along the base of the stability zone. We will explore these two mechanisms with numerical simulations. We choose a geothermal heat flux to develop a hydrate stability zone that matches the interpretation from the seismic profile. We set the sediment facies according to the observation from well logging and coring at GC955. In addition, we incorporate the measured sediment permeability, capillary behavior and compressibility from laboratory analysis of cores collected across the hydrate reservoir into the numerical models. We will then test the sensitivity of hydrate distribution and concentration to microbial methanogenesis kinetics, hydraulic and petrophysical properties of the sediment, sediment facies distribution, hydrate formation kinetics, geothermal heat flux and sediment burial history. Our work will provide insights into gas hydrate distribution and concentration along the world's continental margin, and can help us learn the role of gas hydrate in natural environments.