



## **Pore-scale controls on gas hydrate distribution and gas migration due to production and climate change**

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Recent work has highlighted the great importance of capillary phenomena in controlling phase equilibrium and spatial distribution of marine gas hydrates. These phenomena, including preferential growth of hydrate in coarser-grained sediments and the possible coexistence of hydrate and free gas in different portions of the pore size distribution, are particularly prevalent at pressures and temperatures close to the hydrate phase stability boundary. This may have significant implications for the response of gas hydrates to climate change and methane production. Arctic gas hydrates, for example those in the Barents Sea, are recognized as the marine hydrate deposits that are most susceptible to climate change because cold subsurface temperatures and relative shallow occurrences place them closer to the phase stability boundary than those at lower latitudes. Production, particularly by pressure drawdown, similarly occurs close to the phase stability boundary. Capillary phenomena are predicted to affect production scenarios in channel levee and overbank deposits at Green Canyon in the Gulf of Mexico, and similar scenarios should occur for example in exploration targets in the Danube and Dnepr deltas in the Black Sea.

Numerical simulation results have shown that, when hydrate approaches the phase equilibrium boundary either through temperature increase or pressure reduction, hydrate in the largest pores tends to dissociate first, resulting in gas filling the larger pores first. This is due to the combined capillary effects on both the hydrate and the gas phase. Hydrate preferentially exists in the larger pores to start, but the higher interfacial energy of the gas-water interface makes the localization of these interfaces in the larger pores the lowest-energy configuration, so gas, once formed, will prefer to exist in the larger pores. We show that, particularly for arctic hydrates in relatively shallow water, dissociation in the larger pores first may alleviate what would otherwise be an increased susceptibility to gas-driven fracturing since the gas phase is at a relatively lower capillary pressure. At the same time, the relative permeability to the gas phase is large, while the relative permeability to the water phase is low, thus promoting porous flow of gas while somewhat inhibiting that of water. This is more amenable to gas production, but potentially problematic for climate change-induced dissociation.