Studying Methane Migration Mechanisms at Walker Ridge, Gulf of Mexico, via 3D Methane Hydrate Reservoir Modeling

We have developed a 3D methane hydrate reservoir simulator to model marine methane hydrate systems. Our simulator couples highly nonlinear heat and mass transport equations and includes heterogeneous sedimentation, *in-situ* microbial methanogenesis, the influence of pore size contrast on solubility gradients, and the impact of salt exclusion from the hydrate phase on dissolved methane equilibrium in pore water. Using environmental parameters from Walker Ridge in the Gulf of Mexico, we first simulate hydrate formation in and around a thin, dipping, planar sand stratum surrounded by clay lithology as it is buried to 295mbsf. We find that with sufficient methane being supplied by organic methanogenesis in the clays, a 200x pore size contrast between clays and sands allows for a strong enough concentration gradient to significantly drop the concentration of methane hydrate in clays immediately surrounding a thin sand layer, a phenomenon that is observed in well log data. Building upon previous work, our simulations account for the increase in sand-clay solubility contrast with depth from about 1.6% near the top of the sediment column to 8.6% at depth, which leads to a progressive strengthening of the diffusive flux of methane with time. By including an exponentially decaying organic methanogenesis input to the clay lithology with depth, we see a decrease in the aqueous methane supplied to the clays surrounding the sand layer with time, which works to further enhance the contrast in hydrate saturation between the sand and surrounding clays. Significant diffusive methane transport is observed in a clay interval of about 11m above the sand layer and about 4m below it, which matches well log observations. The clay-sand pore size contrast alone is not enough to completely eliminate hydrate (as observed in logs), because the diffusive flux of aqueous methane due to a contrast in pore size occurs slower than the rate at which methane is supplied via organic methanogenesis. Therefore, it is likely that additional mechanisms are at play, notably bound water activity reduction in clays. Three-dimensionality allows for inclusion of lithologic heterogeneities, which focus fluid flow and subsequently allow for heterogeneity in the methane migration mechanisms that dominate in marine sediments at a local scale. Incorporating recently acquired 3D seismic data from Walker Ridge to inform the lithologic structure of our modeled reservoir, we show that even with deep adjective sourcing of methane along highly permeable pathways, local hydrate accumulations can be sourced either by diffusive or advective methane flux; advectively-sourced hydrates accumulate evenly in highly permeable strata, while diffusively-sourced hydrates are characterized by thin strata-bound intervals with high clay-sand pore size contrasts.