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Scaling of Thermodynamic and Transport Processes for Predicting Gas Hydrate Distribution and Saturation in Submarine Settings

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Modeling the accumulation of marine gas hydrate systems has previously been attempted for specific hydrate sites with separate sources of methane, i.e. biogenic (in-situ generation) or upward flux from a deeper source. We have developed a numerical model in one spatial dimension that simulates the formation and accumulation of hydrates due to either or a combination of the two sources. The model consists of component balance equations that are solved with a coupled sedimentation-compaction model for fluid flow in sedimentary basins. The effect of seawater salinity on the hydrate distribution is also studied in the simulations. Using these simulation results, we first delineate the basic modes of hydrate distribution on the parameter space (e.g. no hydrate formation and hydrate formation with or without free gas below the hydrate stability zone) for each type of methane source. The results are then scaled using combinations of the dimensionless variables, such that the dependence of average hydrate saturation on the numerous parameters can be summarized using two contour maps, one each for in-situ and deeper methane sources. It is also shown that large changes in the sediment parameters like seafloor depth, seafloor temperature and geothermal gradient, cause a very small change in the average hydrate saturation when shown in these maps with the scaled variables. This causes existing models of hydrate accumulation to be special cases of our model. We have also shown where points corresponding to well studied hydrate locations, such as Blake Ridge (offshore southeastern USA), Hydrate Ridge (offshore northwestern USA), Peru Margin and Costa Rica Margin, would lie on these saturation maps. As compared to the earlier site-specific parameter studies, our model presents a unifying picture of hydrate accumulations, that can be used to predict hydrate saturations and distribution at sites for which seismic or core data is not available.