Sedimentological Control on Hydrate Saturation Distribution in Arctic Gas-Hydrate-Bearing Deposits

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Grain size and other physical properties of host sediments have a strong influence on gas-hydrate distribution and morphologic characteristics. In the arctic, strata several meters thick, containing large saturations of gas hydrate are often separated by layers of varying thickness that contain little or no hydrate. A sample of such hydrate saturation distribution is in the Mt. Elbert well in Alaska's North Slope.

We argue that the distribution of hydrate in isolated layers, such as that observed in Alaska's North Slope, is consistent with the establishment of a gas phase saturation within the sediment when the base of gas hydrate stability zone (BGHSZ) was located above the sediment package. The accumulated gas was subsequently converted continuously to hydrate as the BGHSZ moves downward below the lowermost gas accumulation. We develop a simple, quantitative model of this idea and compute the saturation of gas hydrate as a function of depth. The key input to the model is the variation of capillary entry pressure with depth, which in turn depends on the variation in grain-size distribution.

We validate this model with data from the Mount Elbert well on the Alaskan North Slope. In this well, thick (> 10 m) gas-hydrate-bearing sandy deposits are overlain by finer-grained sediments. The variation with depth of the capillary entry pressure of the sediments was estimated from grain-size and absolute-permeability measurements obtained from core samples. The supportable gas column heights inferred from the capillary entry pressures match the modern observations of gas-hydrate saturation. The location of low hydrate saturations (10-15%) is consistent with the location of the residual gas phase which could have been established during cyclic movement of the BGHS or as a consequence of volume changes during hydrate formation. We anticipate that this model will also provide insight into the presence of thick, sandy hydrate-bearing deposits in the marine environment, including the Gulf of Mexico.