Gas Hydrate in a Fault-Compartmentalized Anticline and the Role of Seal, Green Canyon, Abyssal Northern Gulf of Mexico

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Abstract

We describe the petroleum system associated with a recently drilled gas hydrate accumulation in Gulf of Mexico using 3D seismic analysis and 2D numerical simulations. We provide a model for gas hydrate formation in high saturation from microbial methane that does not exclusively rely on methane recycling at the base of hydrate stability zone (BHSZ). From seismic and well observations, we interpret that the high saturation hydrate accumulation in Green Canyon Block 955 (GC 955) has the following characteristics - a) hydrocarbon occurrence is controlled by an anticline; b) the sandy silt reservoir has a clay-rich top seal; c) the reservoir is compartmentalized by normal faults that are pathways for vertical migration of free gas; d) the faults breach the top seal to create local leak points for gas, as indicated by fault-controlled flat spots within the reservoir and amplitude anomalies associated with fault planes above the reservoir; and e) local leak point for a reservoir compartment can be below or above BHSZ and its position controls the presence or absence of free gas below hydrate; for example, we interpret that the absence of gas column in well GC955-H001 indicates a local leak point that is above the BHSZ.A leak point for free gas above BHSZ implies free gas movement in the reservoir within the hydrate stability zone, suggesting that gas hydrate formation in the reservoir might not preclude either the inflow of free gas from below, or its subsequent upward movement within the reservoir. However, overlying clay-rich seal would prevent gas escape out of the reservoir, except at fault-related leak points. If those two conditions hold, high saturation of gas hydrate could be reached by sustained free gas migration into a segment of reservoir

(and conversion to hydrate) while it is in the hydrate stability zone and is sealed by overlying clay-rich unit preventing gas escape. For such hydrate enrichment to take place, the clay-rich seal has to reach high capillary entry pressure for gas at a shallow burial depth (<400m). Also, given that the gas source is primarily microbial, significant microbial methane generation below the seal layer has to occur after the seal layer has been buried sufficiently. To test our hypotheses, we built 2D numerical models in PetroMod for a 10 km wide anticline of similar scale as the structure at GC955. We simulated burial history, microbial methane generation, and hydrate formation over last 2 million years. We explored a range of petrophysical properties and compaction trends for the sediment layers, and a range of microbial methanogenesis kinetics. Our results show that the observed characters of the hydrate accumulation in GC955 can be achieved if 1) the seal layer experiences rapid compaction, 2) trap configuration allows a gas column shorter than that dictated by seal capacity, and 3) significant microbial methanogenesis continues to occur in deeper parts of the sediment column.