Basin and petroleum system modeling of gas hydrate deposits in the Walker Ridge area, northern Gulf of Mexico

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Abstract

Gas hydrates hold vast volumes of methane and affect a wide range of scientific interests including drilling hazards, potential future energy resource, global carbon cycling, geohazards, and climate change. The Bureau of Ocean Energy Management estimates 607 trillion cubic meters (21,444 trillion cubic feet) of gas hydrates in place in the Gulf of Mexico (GoM) alone. Total global estimates of gas hydrate volumes vary, but even the most conservative estimates consider methane hydrates to be the world's largest reservoir of fossil fuel with it potentially being up to three times larger than all of the world's available oil, gas, and coal.

There is great opportunity for improving our understanding of gas hydrates through the basin and petroleum system modeling (BPSM) approach. BPSM is a well-established discipline that integrates geology, geophysics, geochemistry, engineering, geostatistics, rock physics and more to predict the sedimentary and tectonic evolution of basins and the generation, migration, and accumulation of petroleum. That prediction is accomplished in a deterministic, iterative, forward modeling approach. Though widely used in academy and industry, BPSM has only recently been used to study gas hydrate systems. BPSM is ideally suited for gas hydrate modeling due to its sophisticated treatment of subsurface pressure and temperature through time, and its ability to handle very short time steps and very fine spatial resolutions. Therefore, BPSM can capture the temporal and spatial variability in gas hydrate deposits as well as changing conditions in the water column that can affect the gas hydrate stability zone (GHSZ).

The research project area of interest is the Terrebonne Basin in the northern GoM continental slope, a ponded salt-withdrawal mini-basin in northwest Walker Ridge (WR) Area. The mini-basin is bound laterally and floored by Louann Salt, deposited in the Late Triassic-Early Jurassic during opening of the GoM basin. Deposition of reservoir-quality sand beds, sealed by shale, occurred most rapidly during the Miocene and continued periodically through present time. Deep-marine sedimentation typical of the GoM comprises the Terrebonne Basin stratigraphy, which features turbidites, hemipelagic clays, sheet deposits, and debris flows, along with levee-bound channel and lobate fan architecture. A combination of the tilted stratigraphy, normal and thrust faults due to extension, uplift, and compression, and syncline geometry influence stratigraphic and structural migration and trapping of hydrocarbons. Notably, the basin has a thermal gradient of 19.5 °C/km, which is lower than typical GoM thermal gradients of 25 to 30 °C/km.

The 2009 GoM Gas Hydrates Joint-Industry-Project Leg II (JIP Leg II) logging-while-drilling (LWD) drilling program confirmed predictions of gas hydrate occurrence in the Terrebonne Basin and provides much necessary background information. WR313 #001 is an industry well in WR block 313 drilled by Ocean Energy in 2001. Two shallower wells, WR313 #G001 and WR313 #H001, were drilled during the JIP Leg II LWD program. Total depths of the WR313 #001, #G001, and #H001 wells are 16,720, 10,200, and 9,770 feet, respectively. Gas hydrate accumulations are found in Lower Pleistocene and younger sediments in all three wells. The base of the GHSZ is encountered at approximately 2,789, 3,114, and 2,953 feet below the seafloor in WR313 #001, #G001, and #H001, respectively.

We are currently constructing an Earth model of the Terrebonne Basin for comprehensive 3D modeling. Well data and a high-quality 3D seismic survey underpin the geologic conditions for the model. Additional model constraints include basal heat flow, seafloor temperature, and paleowater depth through time. Our initial investigation comprises the development of a "pseudo" 2D model centered on the deep WR313 #001 well. We are using this test case to establish the workflow for integrating BPSM with gas hydrate analyses; this will eventually be applied to the entire mini-basin.

A key aspect of investigating the gas hydrate system with BPSM is integrating it with the other active petroleum system(s) in the region, because the methane in hydrate deposits can derive from both biogenic and thermogenic sources. Some of the questions we may consider are: What is the history of these deposits with respect to the gas hydrate stability zone, recognizing that this area is not one characterized by simple continuous sedimentation and subsidence, but instead by periodic uplift, tilting, plate rotation, sea-level change, salt tectonics, and evolution of temperature gradients.

In conclusion, BPSM has been called the ‘great integrator’ in petroleum exploration. Development of a BPSM model of gas hydrates in the Terrebonne Basin of the northern GoM will provide a vehicle within which to integrate other early exploration and assessment research being conducted on gas hydrates, such as in frontier areas like Japan, as a potential resource likely to provide many decades of energy if proven to be commercially producible.