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Predicting Original Gas in Place and Optimizing Productivity by Isotope Geochemistry of Shale Gas

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Isotope composition is basic geochemical parameters of natural gas. For shale gas, isotope composition is influenced by both geological factors and production processes. Using advanced kinetics isotopic fractionation integrated with geology and other geochemical parameters, we established a model to predict original gas in place (OGIP) and gas saturation in shale rocks.

The change of gas isotope can also forecast gas production decline curves. Gas is stored in shale source rocks in two important ways: 1) as bound gas, adsorbed on or within the matrices of organic matter and rock; 2) as free gas in pore spaces or in fractures created either by organic matter decomposition, diagenetic, or tectonic processes, or dissolved in fluid in the pore systems. During the gas shale production, the gas recovery is actually impacted by the availability of the free and desorbed gases. At the early production period, the free gas is dominant because it can migrate through the fracture system (either natural or stimulated). With the progress of gas production, the free gas is gradually replaced by desorbed gas, which is released from organic matrixes. The decline production curve results from the dynamic mixing of the fracture gas depletion and the desorbed gas release, which is hard to predict by a priori production data.

Stable isotope ratios of gases would provide a unique way to quantitatively differentiate the contribution of the two kinds of gases. A methane molecule with ^{12}C atom has smaller adsorption energy and a higher diffusivity compared with a methane molecule with ^{13}C atom. Therefore, the production gas enriches of ^{12}C at the early production period (carbon isotope composition more "light"), and the concentration of ^{13}C increases during production (carbon isotope composition becomes more "heavy"). This is similar when hydrogen isotope is considered, and the signal/noise ratio of hydrogen isotope composition is more favored. Therefore, the change of isotope composition provide a composite curve of free and bound gases, which is critical on optimal timing of re-stimulation on the fracture systems, in order to maximize the gas recovery.

To obtain high-density isotope data for differentiating the free gas and bound gas during the gas shale production, we developed a field gas isotope spectrometer to measure gas isotopes in-situ, based on the exiting laser-based isotope measurement technology. Meanwhile, we also investigated the isotope fractionation of the physical and chemical processes during shale gas generation, partition and moving (during production). With the effective isotope data interpretation tool, the sweet spots, overpressure and production can be predicted, and the gas shale and tight sand production and exploitation through field test and deployment can be optimized.