Modeling Natural Hydrogen Systems: Extending the Basin Modeler's Comfort Zone

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Abstract

Exploration activity for natural hydrogen (H2) has grown significantly in recent years. Our understanding of the geologic concepts and processes required to identify and produce economic accumulations of natural hydrogen are increasingly being refined to support exploration efforts around this new low-carbon geo-energy resource. The hydrogen system concept, somewhat similar to the petroleum system approach, is now being applied in many exploration projects around the world, but the tools at hand are mainly based on geophysics and surface sampling of H2. Effective tools to quantitatively model the hydrogen system are only now being developed to de- risk exploration projects and better assess prospectivity. By combining the workflows from hydrocarbon and mineral exploration, we use two- and three-dimensional reactive transport modeling to test our concepts and hypotheses for efficiency and consistency. Based on two case studies, one assuming hydrogen generation due to serpentinization and a second one relying on radiolysis, we will present how hydrogen systems can be modeled from input to output.

Model inputs are very similar to those of a classic petroleum systems model, except that the chemistry is inorganic. Seismic data interpretation is commonly used to define 2D or 3D geometries in the subsurface. In contrast to classic hydrocarbon systems, single geometry modeling techniques (e.g., present day geometries) may be sufficient for some hydrogen systems. Coupled multi-phase fluid-flow with chemical reaction modeling (thermodynamic equilibrium or kinetic) allows for quantification of hydrogen generation and migration. To accurately predict pathways and potential hydrogen accumulations, we model both the hydrogen generation rate and the rate of hydrogen transport in the subsurface. All geological factors such as porosities and permeabilities, as well as temperatures and pressures, are simulated to define the basis for the reactive flow simulations. Additionally, hydrogen generation rates, solubilities, and densities also play a significant role in determining where free-phase hydrogen may be found in the subsurface and where hydrogen is dissolved in the water phase only. Hydrogen systems modeling allows for calculation of hydrogen solubilities as a function of pressure and temperature, facilitating evaluation of migration.

Combined with uncertainties and probabilistic calculations, hydrogen systems modeling allows for assessing and quantifying key geological constraints affecting the prospectivity of a hydrogen system from source to trap. We will demonstrate the utility of this approach for de-risking geologic hydrogen exploration by evaluating geologic and geochemical concepts and validation with field data.