Reconstruction of Hydrocarbon Reservoir P-T-X Histories Using Fluid Inclusion Thermodynamics: A Key Information for Basin Modeling

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ABSTRACT

The capability to accurately reconstruct past pressure-temperature histories of petroleum reservoirs and the fluid migration timing is key to reducing uncertainties in basin modeling, as well as, to give insights into processes affecting fluids and rocks in sedimentary basins. Aqueous and petroleum fluid inclusions encountered in the minerals of sedimentary reservoirs provide critical information on reservoir paleo-temperatures, salinity of diagenetic fluids, and evolution of hydrocarbon charge. In the early 2000's, a methodology based on the combination of phase equilibrium for coeval aqueous and petroleum fluid inclusions was developed, which is referred to as the PIT-AIT methodology (Petroleum Inclusion Thermodynamics - Aqueous Inclusion Thermodynamics). This approach constitutes a unique mean to determine the exact Pressure-Temperature-Chemical composition (P-T-X) conditions of the trapping of coeval aqueous and hydrocarbon inclusions using the intersection of their modeled isochores.

The main steps of the PIT-AIT methodology can be summarized as follow:

1. Petrography of coeval aqueous and hydrocarbon inclusions. This step is critical to ensure, based on textural evidence, that pairs of aqueous-petroleum fluid inclusions of interest are cogenetic, i.e. trapped at the same time.
2. Analytical determinations of several critical parameters including: the homogenization temperature (i.e. minimum trapping temperature) of both aqueous and hydrocarbon inclusions (microthermometry), the chlorinity and composition of aqueous inclusions (Raman spectrometry), and the composition and liquid/vapor ratio of hydrocarbon inclusions (Infrared spectrometry, and Confocal scanning laser microscopy).
3. Thermodynamic modeling and P-T-X reconstruction in appropriate phase diagrams. Isochores are modeled for each pair of coeval aqueous and hydrocarbon inclusions following proper characterization. The exact P-T conditions of trapping are given by the intersection between the isochores, accounting for the technique being also known as the "double isochore" technique.

Significant improvements in data acquisition and interpretation processes were carried out in the past 10 years to make the PIT-AIT methodology a more accurate and more routine tool for exploration. Three application cases will be presented to illustrate the added value of using this approach to constrain and/or challenge basin models.