Determining unconventional shale gas maturity: A carbonate vein tale
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One big challenge for unconventional shale gas exploration is to determine the maturity level because the traditional methodologies are either not applicable or erroneous. For instance, the traditional technique of measuring vitrinite reflectance may not be applicable due to lack of woody debris, particularly in the early Palaeozoic shales. Other methods including Rock-Eval Tmax and Rock-Eval H Index also have various challenges to obtain accurate numbers, particularly for the mature gas fields. Thermo information preserved in carbonate veins offers an alternative to determine shale gas maturity.

Carbonate veins, which commonly formed during late diagenesis and catagenesis, are abundant in unconventional source/reservoir shales. The vein minerals formed at different periods of time at different temperatures. Particularly some veins were precipitated from hydrothermal fluids which were associated with either volcanic activity or intrusion of igneous rocks, and permeated through open fractures into petroleum basins. Elevated temperature in deep burial basins plus additional heat from hydrothermal fluids, resulted in petroleum cracking and CO2 generation. The CO2 reacted with cations (Ca2+, Mg2+) in formation water, and precipitated calcium and/or calcium-magnesium carbonate minerals – calcite (CaCO3) and/or dolomite (CaMg(CO3)2) in fractured pores. Oxygen isotopes (i.e., 18O, 16O) in the carbonate minerals then recorded the conditions of the mineral formation. Temperature and fluid are two main factors to control oxygen isotopes and their fractionation during carbonate mineral precipitation. Thus obtaining O-isotopes of carbonate minerals and fluid can determine the formation temperature, which in turn determined maturity of source rocks. O-isotopes of fluid may be estimated or measured from formation water or/and fluid inclusion in carbonate minerals.

Maturity in source rocks determines the degrees of petroleum cracking to form either oil, wet gas, or dry gas. This study presents such an innovative example, in which O-isotopes of carbonate veins and formation water in the unconventional gas shale were utilized to help determine the paleo temperature and maturity level. Mapping out maturity through an unconventional gas field/play after determining the maturity of cored samples from selected wells can help understand the spatial distribution of shale gas, and identify the sweet spots (i.e., dry gas intervals).