Correlations Between Petroleum Systems and Serpentinization

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Abstract

In 2001, during the AAPG Annual Convention in Denver, a major oil & gas company's research group asked the question: "When we do the accounting for supergiant giant oil & gas accumulations the books don't balance (not enough HC's in source rocks, Mg required for dolomitization and foreign metals in oil). Do you have any idea what we are missing?" A promising answer is the ultra-deep hydrothermal (UDH) process of serpentinization, which is the hydration of peridotite under supercritical conditions. It is an exothermic reaction causing 40% expansion of its protolith peridotite, accompanied by large volumes of hydrothermal heavy brines charged with kerogen and Mg released into basement fractures/faults. The correlation of low-grav/strong-mag is a unique characteristic of serpentinites and observed globally, indicating serpentinite diapirs at depth. Basement faults are associated with the diapirs and often with oil fields. The timing of oil generation can be predicted using this model in light of oil, kerogen and black shale Re/Os data and rock-eval pyrolysis data. Serpentinization is the deepest known penetration of water into the Earth, forming the the Serpentosphere, a 3-12 km thick near Earth- wide layer/shell of rock dominated by serpentine group minerals. It is initiated at oceanic spreading centers as lizardite and when subducted transitions to antigorite releasing hydrothermal brines. During rifting the antigorite of the continental Serpentosphere can be dehydrated to steatite (talc) also releasing hydrothermal brines. The Serpentosphere coincides with the seismic and gravity transition from crustal to mantle material, known as the Moho. Beneath the North Sea the top of the Moho lies as little as 2 km below the bottom of the North Sea Basin. Spider plots of 45 trace-elements in oils from numerous basins correlate closely with the same 45 trace-elements in serpentinites. Hydrothermal minerals such as talc, serpentine, and clinochlore are interlayered with Permian Basin evaporites. During the hydration of the peridotite, simultaneously serpentinite and brine products are being made. The brine product then migrates to the upper crust crossing the sub-critical/super-critical boundary at about 11 km where the kerogen ionizes and is electrostatically attracted to hydrogen to ultimately alkylate into liquid oil. Diamondoids form in serpentinite brines and chemical muds at this transition. A spectacular example near King City, California is the New Idria 15-mile diameter mud volcano carrying 1% TOC and lying close to a major oil field. It erupted 5 cubic miles of chemical serpentinite mud (the Big Blue Formation) on the same timeline as the Monterey Shale. The UDH process of serpentinization suggests petroleum systems may be part of a much larger process than biogenesis in basins– serpentinization answers the question asked by a major oil company's research group during the 2001 AAPG Annual Convention in Denver and 'balances the books'.

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