The Opal-CT to Quartz Phase Transition and Unconventional Oil in Siliceous Shale Source Rock, San Joaquin Basin, California

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Porcelanite and chert are diagenetic products of marine diatoms that form during burial of diatomite and subsequent conversion of unstable amorphous opal (opal-A) to cristobalite and tridymite (opal-CT), and finally quartz. Porosity decreases during this process, but remains significant even in the quartz phase. However, permeability increases during the transformation of opal-CT to quartz (Reid and McIntyre, 2001), which can result in diagenetic seals and stratigraphic traps for petroleum where no structural traps exist (Figure 1; Grau et al., 2003; Kidney et al. 2003). The depth of the opal-CT to quartz phase transition is partly controlled by temperature, clay content, and water chemistry and occurs at ~4,500 ft (~1,375 m) subsea in the Monterey Formation within the Elk Hills Field (Zumberge et al., 2005). Changes in silica phase can be identified visually in hand specimens, but are sometimes difficult to identify in the subsurface using seismic data. The ability to accurately predict the locations of these traps would be invaluable for oil and gas exploration.

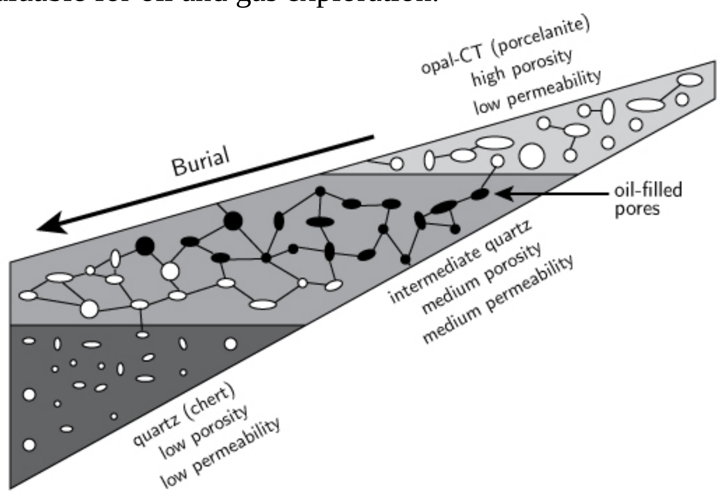

Figure 1. Schematic depiction of a diagenetic trap formed at the opal-CT to quartz phase transition.

We built a prototype module in our petroleum system modeling software to determine the depth of the opal-CT to quartz phase transition along a cross-section from the SJ-6 seismic line (Bloch, 1991) in the east-central portion of the San Joaquin Basin (Figure 2). Ernst and Calvert (1969) determined zero-order kinetics for this transition based on hydrothermal experiments using distilled water. However, the opal-CT to quartz phase transition is a dissolution and re-precipitation process (Stein and Kirkpatrick, 1976), where both the silica dissolution rate and solubility contribute to the rate of the reaction. It is now known that the chemistry of migrating fluids affects the depth and temperature of silica transformations (Ireland et al., 2009). By using kinetics for the opal-CT to quartz phase transition that are currently being determined by hydrous pyrolysis experiments on porcelanite collected from Lompoc California and Hokkaido Japan, we hope to predict the locations of stratigraphic petroleum accumulations in siliceous source rocks like those recently discovered in the Rose and North Shafter fields in the San Joaquin Basin (Grau et al., 2003). The kinetics and software module may be useful to identify silica-phase-transition stratigraphic traps throughout the Pacific Rim where siliceous source rocks are common (e.g., Miocene-Oligocene near Sakhalin Island).

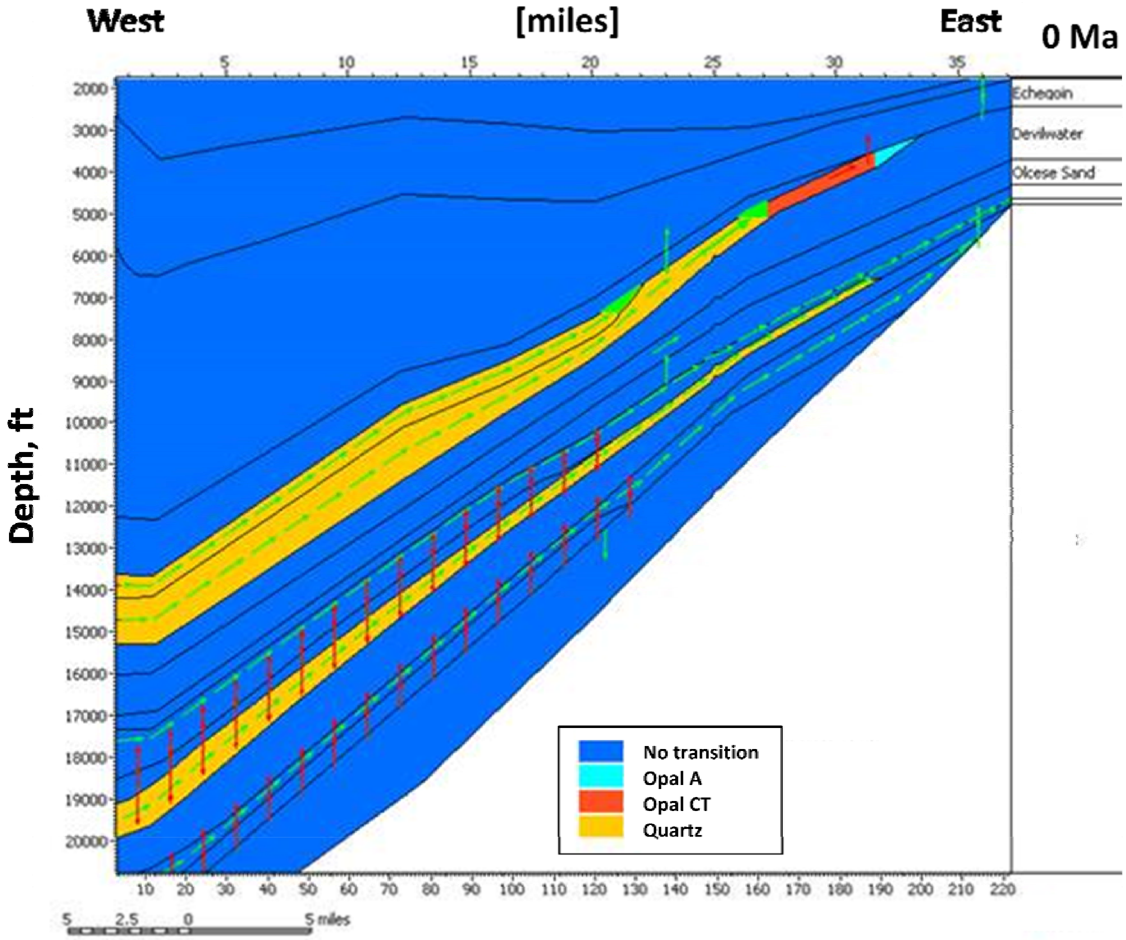

Figure 2. The figure shows preliminary results from a test of the prototype opal-CT to quartz module along the SJ-6 seismic line in the San Joaquin Basin, California. This hybrid simulation (Darcy flow and flowpath migration) is based on stratigraphy and geohistory for multiple wells along the line, appropriate kinetics for oil generation from the siliceous source rocks, and kinetics for the opal-CT to quartz phase transition from an early paper (Ernst and Calvert, 1969). Note the present-day petroleum accumulation (green) in the siliceous McLure Shale at the depth of the calculated transition from opal-CT to quartz.

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