AAPG HEDBERG CONFERENCE
"***Hydrocarbon Habitat of Volcanic Rifted Passive Margins***"
September 8-11, 2002, Stavanger, Norway

Thermal Controls on Clay Diagenesis in Mudstones: Can They Help Predict Hydrocarbon Charge and Biodegradation Risks in Passive Margins?

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Geologic models for the effects of clay diagenesis on shale/mudstone properties are under evaluation for their use in predicting the distribution of hydrocarbon occurrences and risk of biodegradation. Traditional clay petrology studies show that the onset of these reactions, often described as smectite to illite diagenesis, begins at 60° to 80° C in sedimentary sequences (´Srodo´n and Eberl, 1984). Petrophysical models based on the precipitation of diagenetic clay within shale pore systems indicate rapid and severe permeability reduction at the onset of these reactions (Bjørkum and Nadeau, 1998; Nadeau et al., in press).

Evaluation of hydrocarbon systems in rifted margins, including the Norwegian Continental Shelf and the Gulf of Mexico (Seni et al., 1997), indicate an exponential increase in formation fluid over-pressure and hydrocarbon occurences at and above these temperatures, along with concurrent reductions in the risk of biodegradation of reservoired petroleum. The mechanism by which these risks are controlled in both cases can be related to clay diagenetic induced permeabilty reduction, which increases the probability of vertical hydrocarbon migration via hydrofracturing of low-permeability shale units. Hydrocarbons which migrate to shallower depths and lower temperatures show an increased risk of biodegradation.

Initial studies indicate that this increased risk can result from formation water flow through reservoired hydrocarbon columns and their relatively permeable shale top seals, which may be required to facilitate the biodegradation process. The vertical flow model can be supported by formation water residual salt Strontium isotopic compositional data, as well as the lack of plagioclase feldspar in Gullfaks Field reservoirs with biodegraded oil (Ehrenberg and Jakobsen, 2001). The combined geologic model also predicts that, for the most part, petroleum is charged to stratigraphic levels within these passive margin settings having an overall low risk of biodegradation, which is consistent with data from their hydrocarbon systems.

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