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Numerical Modeling of the Generation and Flow of Petroleum in Viscously Deformable Sediments

The generation and flow of hydrocarbons in sedimentary basins commonly occurs in viscously deformable sediments. A one-dimensional numerical model was constructed to investigate the behavior of hydrocarbons in this rheologic environment. Specifically, the model describes the formation of petroleum from kerogen and the expulsion of the petroleum from a saturated and viscously-deformable compacting porous medium for a prescribed burial rate and thermal gradient using published kinetic rate equations for petroleum formation, and mass and momentum balance equations for the flow of the pore fluid and matrix. The motion of the petroleum pore fluid is driven by the density contrast between the pore fluid and matrix. Predicted pore fluid velocities for conditions representative of the typical oil window in sedimentary basins were on the order of 10^{-4} m/yr, allowing kilometer-scale vertical transport on the order of about 10^{7} years. However, petroleum transport rates could be increased locally by factors as high as 2-3 in regions of elevated porosity created as the kerogen-rich source layer passed through the oil window. That is, as ongoing burial of the kerogen-rich source layer led to the kerogen's thermal maturation and conversion to petroleum, the extra volume of pore fluid generated was entrained in a series of 'porosity waves', defined as regions of elevated porosity compared to the background porosity of the porous medium. The porosity wave phenomenon has implications for primary hydrocarbon migration in that it suggests a mechanism of increased transport efficiency in environments where sediments are viscously deformable.