NUMERICAL MODELING OF POROSITY WAVES AS A MECHANISM FOR RAPID FLUID TRANSPORT IN ELASTIC POROUS MEDIA

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ABSTRACT

Rapid transport of fluids in low permeability rocks has been well documented in various geological settings, including the Eugene Island hydrocarbon field in the Gulf of Mexico basin and the Nankai subduction zone, offshore Japan. Pore fluids that are close to lithostatic pressure can reduce effective stress and increase porosity and permeability to form porosity waves, which can travel faster than fluids in the background Darcian flow regime, enabling them to serve as an efficient means for fluid transport in low permeability geologic media. The present study evaluated the formation and fluid transport capabilities of porosity waves in elastic porous media using a pore fluid mass balance equation and Darcy’s law.

Results show that sediment diagenesis in a hydrocarbon source rock (~4.5 km depth) would generally increase fluid pressures at rates sufficient enough to form porosity waves in oil-saturated sediments but not methane-saturated sediments, which require geologically instantaneous pressure generation rates, possibly caused by earthquakes. Once formed methane-saturated porosity waves can ascend 1-2 km at velocities of at least 10’s of m year\(^{-1}\). However, because Eugene Island’s geologic history has been seismically quiet and because most of the reservoirs at Eugene Island are separated by more than 2 km from the hydrocarbon source rocks, it is unlikely that porosity waves have played a major role in charging the Eugene Island reservoirs. Results from the Nankai accretionary wedge show that porosity waves can propagate along the décollement at the 1’s of km day\(^{-1}\) velocities needed to cause aseismic slip, provided
that fluid pressures at the porosity wave source exceed lithstatic pressure, or are near slightly below lithostatic pressure but other hydrogeologic parameters have values near the limits of their geologically reasonable ranges.