Public Abstract

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Title:Numerical Modeling of Porosity Waves as a Mechanism for Rapid Fluid Transport in Elastic Porous Media

The rapid ascent of fluids through kilometer-scale thicknesses of low permeability sediments at rates much faster than predicted Darcy fluxes has been observed in numerous locations around the world. A consistently observed condition associated with this anomalously rapid fluid flow is high fluid pressure approaching lithostatic pressure. This high fluid pressure can be produced by a number of geologic processes, including the production of hydrocarbon fluids by maturation of organic matter, the production of water through dehydration reactions of hydrous minerals, compaction disequilibrium during the deposition and burial of sediments, and earthquakes. As fluid pressure increases in a deformable porous medium, the pore spaces in the medium expand, increasing porosity and permeability. This zone of increased fluid pressure, porosity, and permeability, termed a porosity wave, may travel much faster than fluids flowing at Darcy fluxes in the surroundings, provided that permeability is a sensitive function of fluid pressure or effective stress. In addition, because porosity waves have higher porosity than their surroundings, they can serve as a mechanism for enhance fluid transport. The main goal of the present study was to evaluate the formation and fluid transport capabilities of porosity waves in elastic rocks. The study was performed using a numerical solution to a mass conservation equation for fluids in porous media and Darcy's law.

Results of the study show that rates of fluid pressure generation by sediment compaction disequilibrium and hydrocarbon formation in porous media saturated with dense and viscous fluids like oil or water can generally only form porosity waves at depths below ~4 km, and are unable to form porosity waves in porous media saturated with low density and viscosity fluids like methane. In order to form porosity waves in methane-saturated porous media, geologically instantaneous rates of fluid pressure generation are needed, which may be possible from earthquakes. Once formed, methane-saturated porosity waves may travel at speeds of ~10's of m per year for distances of 1-2 km under geological conditions similar to those of the Eugene Island hydrocarbon field in the Gulf of Mexico basin, one of the focus areas of the present study. However, porosity waves are unlikely to have played a major role in transporting methane to shallow reservoirs at Eugene Island. This is in part because Eugene Island appears to have been seismically quiescent throughout its geological history and because most of the reservoirs are separated by more than two kilometers from the hydrocarbon source rocks. In the Nankai accretionary wedge, another focus area of the present study, results show that porosity waves formed at a depth of ~2 km can ascend along the décollement at the minimum 1's of km per day velocities needed to cause aseismic slip, provided that fluid pressures in porosity source region either exceed lithostatic pressure or are slightly below lithostatic pressure but other hydrogeologic parameters are near the limits of their geologically reasonable ranges. Though the present study was focused on two specific field sites, the results have implications for rapid fluid transport in other geologically similar environments in other locations around the world.