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Solitary waves: a possible mechanism for rapid fluid transport in low permeability porous media

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Elastic porous media in which the rate of fluid pressure generation is high relative to the rate of fluid pressure diffusion and whose permeabilities are a sensitive function of effective stress may generate solitary waves manifest as discrete pulses of elevated pore pressure and porosity that can travel at velocities that are orders of magnitude greater than the velocities of the pore fluids in the background Darcian flow regime. Solitary waves may thus be important vehicles for fluid transport through porous media whose permeabilities are otherwise too low to allow significant rates of flow. Solitary waves have been hypothesized for diverse geologic settings and processes, including magmatic hydrothermal ore formation, magma transport, fault slip in accretionary wedges and at transform plate boundaries, and primary hydrocarbon migration in sedimentary basins. The present study has focused on solitary waves as agents of oil and methane transport through numerical simulation of their origin and behavior. The results show solitary waves to have limited capacity for transporting oil for several reasons: (1) the rate of fluid pressure generation by typical mechanisms like compaction disequilibrium and hydrocarbon formation is too low to allow solitary waves to form unless permeability is exceptionally low (10^{-24} to 10^{-25} m^2), (2) solitary waves are only able to ascend no more than 1-2 km before dissipating to ambient pressure and porosity values, (3) the waves are too small and the frequency of their formation is too low to account for the amount of oil observed in the reservoirs that they have been hypothesized to feed. Solitary waves have been found to be more effective at transporting methane because of its lower density and viscosity compared to oil, provided that a mechanism for rapid pressure generation exists and permeabilities are very low. If those conditions exist, then solitary waves can ascend over two kilometers at rates on the order of 100's of meters per year compared to millimeters per year for solitary waves transporting oil.