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Buoyancy-Driven Flows in Deformable Porous Media

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Laboratory experiments on buoyancy-driven flows in deformable porous media were conducted to understand the dynamics of magma transport in a partially molten region. As an analogue material of partially molten media, a mixture of transparent hydrogel beads and viscous fluids was used. Since the hydrogel is deformable, the volume fraction of the interstitial fluids is varied, which depends on the pressure distribution in the porous media. A thin transparent tank was filled with the mixture, and a buoyant viscous fluid was injected from a nozzle or from a slit at a constant volume flux into the mixture. The injected viscous fluid was dyed and the flow fields in the deformable porous media were quantitatively visualized by particle image velocimetry (PIV) and laser induced fluorescence (LIF) methods. For the point source experiments, three types of fluid flow were identified: homogeneous permeable flow, pulsating flow, and localized continuous flow. The flow behavior depends on the injection flow rate, the rheological properties of the mixture and the buoyant fluid, the volume fraction of the interstitial fluid, and also the boundary condition of the deformable porous media (wall effect). For the line source experiments, the flow pattern always shows a time-dependent behavior. As the viscous fluid is supplied from the source at a constant volume flux, the fluid infiltrates into the deformable gel beads layer until a gravitational instability (e.g. Rayleigh-Taylor instability) occurs. Then, the flow is localized through channels with a characteristic spacing. The plume-like flow is relatively continuous around the source region; however, the flow along the channels can become unstable and create pulsations. Their characteristic frequency was obtained by image analysis. Our experimental results indicate that the intermittent nature of the volcanic activity is inherent to magma transport in a partially molten zone, which explains the spatio-temporal patterns of volcanic activity.