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A new type of microstructure formed in a flowing crystal-rich magma: Formation of melt channels and two sets of preferre

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Microstructures in a magma are important in controlling magma rheology when the crystallinity of the magma is high enough to result in significant interactions between crystals. We have investigated the shear-induced melt localization and the evolution of microstructures within a crystallizing magma based on petrology and 3-D numerical simulations. Within the Miocene Oto-zan lava flow in Shodo-shima Island, SW Japan melts and aqueous vapors have become localized in response to a flow-induced shear strain that developed in the lava flow. This texture is characterized by the groundmass plagioclase exhibiting two preferred orientations and the formation of liquid-rich channels. Reconstruction of the crystallization processes indicates that the observed crystal orientation and channel texture were produced before the magma reached a crystal fraction of ca. 0.6 and a temperature of ca. 900 ?C. A 3-D numerical simulation, developed by coupling a discrete element method with computational fluid dynamics, was performed for a two-phase flow consisting of a viscous liquid and rigid tabular particles. This showed that for liquids made up of between 5 and 40 vol% particles, shear strain enhances the ordering of particles, and thus bulk viscosity decreases to a steady value. The point at which the steady viscosity is reached reflects when the steady-state microstructure forms. For liquids with 40 vol% particles, the steady-state microstructure is characterized by two domains that have distinct preferred particle orientations and different local liquid fractions. Both the crystal-rich and melt-rich domains are oblique to the bulk shear plane at ca. 30 degrees, and they appear alternately. This microstructure is consistent with that observed in the Oto-zan lava. In contrast, this liquid localization is not observed in the simulation of liquids with particle fractions lower than 40 vol%, which instead develop microstructures characterized by the alignment of the long axes of tabular crystals sub-parallel to the bulk shear plane. We propose, unlike many previous models, that the liquid localization does not require a fracturing event. The melt localization occurs as a mirror of the cyclic cluster formation. This self-organized texture is governed by a simple well-known rule that during simple shear flow a stress vector on a plane depends on the plane orientation.

Keywords: shear strain, melt segregation, rheology, texture