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The architecture of an intrusion in magmatic mush

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Magmatic reservoirs located in the upper crust have been shown to result from the repeated intrusions of new magmas, and spend most of their dwelling time as cristal-rich mush. Despite advances in our understanding of the physical processes that may occur in a magma reservoir, the architecture of the intrusion into a mush remains poorly constrained. The geometry of such intrusions, however, may greatly affect the thermal and compositional evolution of the magmatic reservoir. We performed numerical simulations coupling computational fluid dynamics with the discrete element method to identify the geometry and emplacement dynamics of an intrusion in a mush, and the relevant physical parameters controlling it. Our results show that the intrusion geometry is to first-order controlled by the density contrast between the melt phases of the intruded and resident materials rather than the bulk density contrast as usually considered. When the melt phase of the intruded materials is denser than that of the host, the intrusion ponds at the base of the mush and is emplaced as a horizontal layer. However, when the intruded melt is lighter, the intrusion rises through the mush forming a Rayleigh–Taylor instability. In the absence of density contrast between the two melts, the intrusion fluidizes the host crystal network and slowly ascends through the mush. The presence of a viscosity contrast between the intruded and resident materials as well as the intrusion injection velocity were found to have less of an influence on the final geometry and intrusion dynamics in mush. In addition, we analyzed the eruptive sequence of well documented eruptions involving an intrusion as a trigger, and found good agreement with our modeling results. This study sheds light on the importance of explicitly considering granular mechanisms and the relative motion between the crystals and the melt phase when studying the physical processes of magmas and mush.