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Multi-scale convective melting in the magma chamber under volcano

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Fresh magma input is necessary attribute of the volcanic activity. Ascending from the depth magma would come into the contact with cooled partially solidified one and may cause its melting (e.g., Izbekov et al., 2004). Viscosity contrast can prevent continuous mixing in the system to keep gravity unstable stratification for some period of time. We consider condition of the convective overturn in the two-layered system composed of the layer of superheated rhyolitic magma overlaid by partially solidified denser counterpart. Temperature at the lower contact of the system is set constant and larger than liquidus one due to contact with more basic and hotter magma. At first problem is treated analytically via analysis of the growth of infinitesimal exponential disturbance of interface in the two layer system with variable viscosity contrast and thicknesses ratio with proper boundary conditions. Time of RTI exponent and melting time for layer half width (at H=200 m, rhyolite material parameters, melting rate 1-4 m/yr) become approximately equal at viscosity ratio 1-5 10^4. Similar estimate of the critical viscosity ratio for the onset of RTI instability at the half melting of 200 m layer have been obtained at numerical modeling. We use Newtonian temperature dependent representation of viscosity for simplicity. Chosen rheology exactly fits data for rhyolitic melt with 4 wt.% of water. At crystal content up to 50% viscosity follows improved Einstein relation (Toda and Furuse, 2006). At higher crystal content it is close to the experimental data by Rutter and Neumann (1995) at slow strain rate. Variants with initial temperatures of the upper layer in the range 650-720^{o}C were considered with lower boundary hold at T=800^{o}C. Viscosity contrast between the cold and hot parts of the system reaches 13 orders of magnitude. It was demonstrated that the initial temperature of the upper layer plays crucial role in the convective dynamics. At the initial viscosity contrast of 3.5 orders of magnitude Raleigh –Taylor instability starts to develop after short transient period. At this regime no large buildup of the internal magma pressure in the chamber is expected since mingling will proceed smoothly. At the viscosity contrast above 4.5 orders of magnitude chaotic thermal convection with melting of the upper layer develops. Chaos is induced by the interaction of the hot plumes of the rhyolitic magma with low viscosity starting from the lower boundary with two-phase more viscous ones generated at the upper boundary. At the melting of the colder upper layer volume of downgoing avalanches reduces that makes convection pattern more regular in space and time. Regime with RTI developing at the melting approximately half of the 200 m thick layer can be achieved at the viscosity contrast around 4-5 orders of magnitude. Both numerical modelling and linear stability analysis of RTI yield similar critical viscosity contrast value. Ascending at convective overturn of sufficiently voluminous magma batches with free fluid phase is able to cause serious eruptions. Considered solutions substantially extend results by Huppert and Sparks (1988) on the melting of the solid granites at underplating

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