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Modelling of surface tension in magmatic melts using the Gradient Theory: insights on the explosivity of volcanic eruptions

Simone Colucci (1), Raffaello Trigila (2), and Maurizio Battaglia (2)

(1) INGV, sezione di Pisa, Pisa Italy (simone.colucci@pi.ingv.it), (2) Sapienza, Università di Roma, Rome Italy

Magmatic vesiculation is a complex process involving bubble nucleation, growth, and coalescence. The supersaturation pressure triggering the nucleation of gas bubbles in the melt hinges on the melt-vapour surface tension. Despite several experimental studies, the surface tension of magmatic melts has never been studied numerically. The gradient theory method (Cahn and Hilliard, 1959), based on statistical mechanics, allows us to do that. This theory, extended to binary mixtures, can be used for modelling the interfacial properties of a planar interface between a silicate melt and a supercritical water gas phase. This approach has been successfully applied in several studies of industrial liquid mixtures but has never been used before to study systems of volcanological interest.
In the present work we have applied the gradient theory to study the surface tension of hydrous silicate melts at high temperature and pressure. The model has been tested on experimental data of surface tension. The ascribing change in the values of surface tension with increase of pressure, evidenced by the experimental data, is reproduced by our model. The model make us able to understand the effect of pressure on surface tension: increasing the pressure, the partial density of the hydrous melt decreases, for the dominant effect of the increasing solubility, leading to a reduction of the surface tension.
The impact of surface tension on bubble nucleation was discussed applying our model of surface tension to the classical nucleation theory. The key aspect is the dependence of surface tension on pressure that makes nucleation at higher pressure much more easy to initiate thanks to a lower decompression-supersaturation. This may impact the intensity of the eruption enhancing more explosive eruptions from shallower reservoir .