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Numerical simulations of fragmentation of percolating magmas

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In the last ten years, empirical and theoretical developments have lead to a new picture for the evolution of magma in volcanic eruptions. In this picture, bubbles – in particular the scaling of bubble - bubble interactions (coalescence) plays a central role. The picture starts classically with magma rising in conduits, depressurizing and forming bubbles by the diffusive exsolution of gas and its subsequent expansion. Even with high viscosity, rising magma shears imply that at high vesicularity expansion - coalescence processes can dominate diffusion-expansion processes. This model is supported by analyses of both pumice and lava with vesicle size distribution exponents = 0.85.

As the magma ascends, the vesicularity rises and ternary and then multibubble interactions begin to dominate. In this regime continuum percolation theory should be applicable. This predicts the existence of new multibubble size density regime with a somewhat larger exponent (1.18 in 3-D), and that there will be a geometric phase transition at a critical 3D vesicularity P_{3c} where the largest simply connected void (bubble) diverges to infinity. At a slightly higher vesicularity we reach the two dimensional P_{2c} at which point any magma cross-section will almost surely be cleaved by a sinuous network of bubbles implying a rheological phase transition. Under sufficient stress, such magmas will explode, otherwise the resulting channels will simply facilitate degassing. Computer simulations in show that P_{2c}=0.7 i.e. close to the value in Plinian eruptions. We discuss the percolation model including bubble deformation as well as the vesicularity of fragments.