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Three dimensional percolation of magmas

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Volcanic eruptions are assumed to originate from a subsurface magma as a consequence of critical stresses or critical strain rates being exceeded further followed by its catastrophic fragmentation. In a recent paper (Gaonac'h et al., 2003) we proposed an additional mechanism to these classical models based on the properties of complex networks of overlapping bubbles: extensive multibubble coalescence could lead to catastrophic changes in the magma rheology at a critical total vesicularity. Indeed at a critical vesicularity P_c called the percolation threshold, even in the absence of external stresses the magma fragments. By considering 2D percolation with the (observed) extreme power law bubble distributions, we show numerically that P_{2c} has the apparently realistic value $\approx$ 0.7. However, the properties of percolating systems are significantly different in 2D and 3D. We will discuss various new features relevant to 3-D percolation and compare the model predictions with empirical data on explosive volcanism. Among the important results we will demonstrate that a) bubbles and magma have different 3D critical percolation points, b) in 3D percolation the resulting primary fragments have power law distributions with exponent $B_{3f} \approx$ 1.186$\pm$0.002. We will review the relevant percolation literature and point out that the elastic properties may have lower – possibly more realistic - critical vesicularities relevant to magmas. We will then explore the implication of long-range correlations and discuss this in combination with bubble anisotropy.