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A 3D Model for Gas Transfer, Storage and Resulting Displacement in a Permeable Volcanic Edifice

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The total volume of gas in a magma, dissolved and subsequently exsolved, greatly influences the degree of explosiveness of a volcanic system. There is a marked contrast between the behaviour of a volcano in an open system compared to one which is closed. Whilst gas release is evident from surface gas emission measurements, gas storage is also thought to play an important role, as evidenced by large gas emissions after some large dome collapse events, suggesting gas may be stored in large volumes at shallow depths within the dome and edifice. Consequently, it is essential to understand degassing, to appreciate how much gas may be stored and where, and under what conditions it may be transferred or emitted to the atmosphere.

We use previous experimental data on permeabilities to create 3D numerical models to investigate gas transport and storage in a permeable volcanic edifice. We combine the continuity equation, Darcy's law and the ideal gas law to derive a partial differential equation which is solved using a finite element method to obtain the gas pressure. The associated pressure gradient is then used within Darcy's law to calculate the gas velocity. In addition, we use the momentum equation to investigate how the presence of gas and variations in permeability influence the rate and degree of deformation in the volcanic edifice. Hence this provides two important surface constraints: gas emissions and surface displacement.

Geometries are created to simulate the topography of actual volcanoes and the pressure and permeabilities incorporated into the model as boundary and domain conditions, respectively. This method is applied to investigate a variety of volcanological phenomena affecting gas, for example regions of high permeability due to fractures, or low permeability due to sealing.