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Formation of Magmatic Brine Lenses via Focussed Fluid-flow beneath Volcanoes

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Many active or dormant volcanoes show regions of high electrical conductivity at depths of a few kilometres beneath the edifice. We explore the possibility that these regions represent lenses of high-salinity brine separated from a single-phase magmatic fluid containing H_2O and NaCl. Since the chloride-bearing fluids have an exceptional capacity to transport metals and are highly conductive, the regions can be an indicator of a hydrothermal ore deposits located or forming beneath volcanoes. To investigate this possibility we have performed hydrodynamic simulations of magma degassing into permeable rock. In our models the magma source is located at 7 km depth and the fluid salinity approximates that expected for fluids released from typical arc magmas. Our model differs from previous models of a similar process because it is (a) axisymmetric and (b) includes a static high-permeability pathway that links the magma source to the surface. This pathway simulates the presence of a volcanic conduit and/or plexus of feeder dykes that are typical of most volcanic systems. The presence of the conduit leads to a number of important hydrodynamic consequences, not observed in previous models. Importantly, we show that an annular brine lens capped by crystallised halite is likely to form above an actively degassing sub-volcanic magma body and can persist for more than 250 kyr after degassing ceases. Parametric analysis shows that brine lenses are more prevalent when the fluid is released at temperatures above the wet granite solidus, when magmatic fluid salinity is high, and when the high-permeability pathway is narrow. The calculated depth, form and electrical conductivity of our modelled system shares many features with published magnetotelluric images of volcano subsurfaces. The formation and persistence of sub-volcanic brine lenses has implications for geothermal systems and hydrothermal ore formation, although these features are not explored in the presented model.

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