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The thermal impacts of crystal fractionation and volatile degassing from an incipient basaltic magma chamber

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A one-dimensional model of heat flow inside an incipient magma reservoir is derived by considering the thermal effect of repeated basaltic sill intrusions into a column of rock. The critical minimum magma flux rate required in order to maintain melt within the column indefinitely, i.e. to form a molten body or 'magma chamber', is found as a function of intrusion depths between 50 m and 30 km. For shallow intrusions (< 1 km), this critical flux is inversely proportional to depth, whereas for deep intrusions the critical magma flux is only weakly dependent on depth, with a value of 10^{-9} m s^{-1}. This compares with estimated fluxes at Kilauea, Hawaii, of 10^{-6} m s^{-1}, based on magma supply rates from Swanson (1972) and a reservoir area of 0.5 km^2 (Dawson et al., 1999).

By performing simulations using both wet and dry basalt phase relations and a simplified model of fractional crystallisation, we assess the effects of crystal/melt segregation and volcanic degassing on the potential to form a magma chamber. Both fractional crystallisation and degassing enhance crystallisation rates, so greater magma fluxes are required to produce a long-lived magma chamber. For 25 m thick intrusions injected at a depth of 1 km or greater, and a composition based on the 1921 basaltic Kilauea lava studied by Yoder and Tilley (1962), magma fluxes of over 2×10^{-9} m s^{-1} will cause a persistent chamber to form. Fluxes under 6×10^{-10} m s^{-1} are insufficient to sustain melt between intrusions. Intermediate fluxes may or may not sustain a magma reservoir depending on the initial volatile contents of the magma, the extent of degassing of the magma between intrusions and whether effective fractionation can occur.