Insights from a model of pressurization and eruption in a system with two linked magma chambers

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A typical volcanic plumbing system contains a deep magma storage reservoir which supplies magma to higher crustal levels and the surface. The parameters which control the rates of magma flow, chamber pressurization, and eruption in such a system are studied using a mathematical model of two chambers linked by a conduit. The lower reservoir is hosted in (hot) viscoelastic rock and contains buoyant magma whereas the shallow chamber is hosted in (cold) elastic low-density country rock. The model describes the time evolution of pressure in both chambers, the rates of magma flow into and, during eruption, out of the shallow chamber, and the volumes of magma transferred. During inflation of the shallow chamber, pressures and flow rates can respond on two timescales controlled by either the elastic properties of the two chambers or the viscosity of the deep country rock. At short (elastic) timescales, the maximum achievable overpressure in the shallow chamber is determined by magma buoyancy in the deep part of the system and the elastic properties and volumes of the two chambers. If this overpressure cannot break open the chamber, then slow viscous relaxation of the deep reservoir's surroundings drives more magma to the shallow chamber, increasing the overpressure to a level now limited only by magma buoyancy. The time required to trigger an eruption is influenced by the elasticity of the system, strength of the shallow country rock, buoyancy, and the ratio of the magma and country rock viscosities in the deep part of the system.

During deflation of the shallow chamber, eruption rate is moderated by decompression of shallow magma and influx of deep magma. For large country rock viscosities and small deep reservoirs, the deep supply system behaves elastically and eruption rate falls to zero over time. Lower country rock viscosities around large deep reservoirs allow the deep reservoir to continuously leak magma, prolonging the eruption. Although many basaltic systems appear to operate in a solely elastic regime (e.g., Hawaii), the model suggests that large volume basaltic systems (flood basalts) and some viscous magmatic systems may operate in a regime controlled by viscous deformation of deep country rock.