Do high lava-dome extrusion rates foreshadow explosive eruptions?

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Satellite radar, LIDAR, and photogrammetry provide improved measurements of erupting lava domes. Data from these sources combined with petrologic data and historical records raise the question of whether high extrusion rates can be used to forecast explosive eruptions.

Lava dome extrusion takes place both before and after large explosive eruptions (as well as interspersed between explosive eruptions). Examples include Pinatubo (1991), Chaitén (2008-2009), and Merapi (2010). At Pinatubo, mingled magma lava domes were extruded both before and a year after the paroxysmal Plinian eruption on 15 June 1991 (Daag et al., 1996; Pallister et al., 1996). At Chaitén, rapid (>45 m3s-1 extrusion of low viscosity rhyolite followed an initial Plinian eruptive phase (Pallister et al., in press). At Merapi, rapid (25 m3s-1) lava extrusion followed an initial phreatomagmatic eruption on 26 October 2010 and formed a 5 Mm3 lava dome before the main Plinian eruption on 5 November 2010. Rapid (35 m3s-1) extrusion then resumed for a brief period on 6 November, forming a 1.5 Mm3 lava dome that initially inflated and then subsided as the eruption waned (Surono et al., 2012; Pallister et al., 2013).

At both Pinatubo and Merapi intrusion of new gas-rich magma into pre-existing crustal reservoirs triggered the eruptions, and in both cases, ascent was retarded by transit through these viscous crystal-rich reservoirs. However, there are distinct differences in the Pinatubo and Merapi situations. Prior to 1991, Pinatubo was a closed system lacking a conduit to the surface. Gas-rich recharging basalt magma mingled with crystal-rich dacite in Pinatubo's crustal reservoir. It was this mingled magma that augered a new conduit to the surface to form the 7-12 June 1991 lava dome (extrusion rate unknown) and it was dacite that powered the paroxysmal eruption. At Merapi, an unusually large and gas-rich batch of magma invaded and pressurized a dominantly andesitic magmatic system with a pre-existing conduit to the surface. In both cases, the erupted magmas bear petrologic evidence of a difficult passage (e.g., mingled or mixed magmas with varied crystal cargos). Consequently, large or particularly gas-rich replenishing magma batches are most likely to break through these shallow crustal filters (Costa et al, 2013) and trigger eruptions. Such magmas are the vanguards that create and pressurize conduits and thereby generate seismic swarms and near-surface deformation.

Anomalously high rates of dome extrusion, accompanied by increasing and accelerating levels of shallow seismicity and inflation (as seen at Merapi) are a warning sign that a more explosive eruption may ensue. However, when seismicity and inflation are flat or declining, despite a high rate of extrusion (as seen at Chaitén and Merapi following their initial Plinian phases), pressure in the conduit system has declined and the threat of a more explosive eruption has diminished.