Buoyancy-driven Volcanism on the Bolivian Altiplano

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Exsolution of magmatic volatiles is often invoked as the driving force behind volcanic eruptions. Yet magmas are generally less dense than the crustal rocks in which they sit. Thus magma buoyancy is an equally plausible driving force for eruptions. Here we assemble geophysical, volcanological, petrological, geodetic and geomorphological observations of Cerro Uturuncu volcano, Bolivia, to show that the exclusively effusive Pleistocene volcanism (1.05 to 0.25 Ma) has been driven entirely by the buoyant upwelling of dacite magmas from the giant Altiplano-Puna magma body (APMB) at a depths of ≥15 km. Dacites are generated within the APMB by a combination of crystallisation of water-rich (~9 wt% H_2O) andesite magmas and dehydration partial melting of Andean metamorphic crust. Experimental petrology and magnetotelluric observations tightly constrain the water content (~4 wt% H_2O) of these water-undersaturated, hybrid dacites magmas, their storage temperatures and their densities. There exist independent constraints on the density of the regional Andean crust.

Buoyancy-driven volcanism can account for the remarkably consistent elevation of volcanoes, including Uturuncu, across the Altiplano and the tendency for erupted volumes to decrease with increasing elevation. Petrologically-constrained thermal models are used to explore the viability of a transcrustal magma column ~20 km in diameter containing ~25% dacite melt linking the APMB to Uturuncu, as imaged from gravity anomalies. The column is constructed through episodic intrusion of dykes from the APMB to the shallow crust. The melts are interconnected through the hot core of the column so maintaining edifice height on timescales of millions of years. The brittle shallow crust serves only to modulate the supply of magma to the surface. In this top-down view of volcanism periods of increased eruptive activity can be ascribed to changes in the edifice height, occasioned by erosion, deglaciation or sector collapse which lead to pressure changes in the transcrustal mush. Similar principles may be applied to arc volcanoes world-wide where there is emerging geophysical evidence for long-lived partial melt reservoirs at depth. Regional variations in volcano height translate to simple functions of the depth to such reservoirs, local crustal density and magma composition.