Survival during ascent in the crust: the presence of early, deep crystallizing primitive phenocrysts

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How fast magmas travel throught the crust particularly in focus zones that feed long-lived volcanoes and sustain crustal magma storage regions remains largely unknown. The conventional view suggests that arc magmatism is dominated by middle to upper crustal storage regions below the large volcanic edifices with records of deeper processes being often elusive or completely lacking [1-4]. While various radiogenic isotope systems are consistent with prolonged storage (kyrs – Myrs; [5]), elemental diffusion suggests that some crystals of the magmatic system spend very little time in the middle to upper crust prior to eruption (months to years [6,7]). In fact, in some cases magmas carry early-formed primitive crystal cargo from uppermost mantle depths to the surface [7]. Given the relative cold conditions (even in the lower crust) compared to temperatures of mantle-derived melts, ascending primitive melts experience heat loss to the surroundings early on, leading to crystallization of high Mg# silicates. Slow ascent and prolonged storage in the crust inevitably causes the fractionation of those high Mg# phases or diffusive re-equilibration to more evolved compositions. Thus, the presence of high Mg# silicates (e.g. olivines with $Fo_{>88}$) require transiting the entire crust rapidly.

I present a thermal dike model that explores how fast magmas have to rise to preserve deep crystallized high Mg olivines. There exists only a narrow window of survival for such crystals (depending on the exact thermal structure of the crust). Whereas slow ascent ($\ll$ 1 km/day) leads to fractionation and potentially solidification of the melts during dike transport, very fast transport rates of $\gg$ 10 km/day (adiabatic ascent; [8]) cause back melting of early forming crystals due to shallow fluid-undersaturated liquidi in P-T space compared to the P-T path of the ascending magma. Thus, the presence of early and deep crystallizing olivines in arc magmas provides strong evidence that batches of primitive magmas only take weeks to months to transit the arc crust and any existing shallow magma storage region.

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