How do magmas differentiate?

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Igneous diversity mostly reflects crustal depth magma differentiation; how differentiation occurs remains nebulous. Clearly, magma evolution follows control of mineral-melt equilibrium. Yet the paradigm that magmas evolve by fractional crystallization or partial melting (e.g. mechanical separation of melt from crystals) does not readily explain the most basic observation of silicic differentiates: these processes imply granites are minimum melts (on the $NaAlSi_3O_8$-SiO_2-$KAlSi_3O_8$ ternary) extracted from a quartz bearing residue. A non-mechanical process that can produce minimum melt-like bulk compositions is wet thermal migration (mineral-melt equilibrium driven diffusion in a temperature gradient). We have shown that andesite + 4wt% H_2O evolves to a granite at the low temperature end (400°C) of a 950-350°C temperature gradient following a typical calc-alkaline differentiation trend. Indeed, compositional trends in the experiment closely follow those of the eruptive sequence of Mt. Mazama.

Could this process apply to all crustal level magma differentiation? I explore this with new experiments on 2 compositions: 1) to understand the zoned 2008 silicate eruption at Ol Doinyo Lengai, I performed a 4 week thermal migration experiment placing nephelinite with 10% Na_2CO_3 and 5% H_2O into a 1000-350°C gradient at 5 kb; 2) an experiment using a tephrite from La Palma +4 wt% H_2O (same gradient and pressure) is currently running. The goal is to assess the degree to which thermal migration reproduces the observed differentiation trends of these zoned eruptions. The nephelinite run product shows clear mineralogical layering and bulk compositional changes with temperature, reproducing the anti-correlation between total alkalis and silica unique to this eruption. Whether the tephrite evolves to phonolite remains to be seen.