Eruption of Extremely Fractionated Magmas: Implications for Magmatic Versus Volatile Processes

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The resurgence of fluid fractionation as an enrichment mechanism of highly evolved magmas, based on evidence from incompatible element abundances and key element ratios, like Zr/Hf, Y/Ho, and Nb/Ta, has provoked a renewed interest in these fundamental processes and their role in formation of some magmatic-hydrothermal deposits through to pegmatites. Although the Australian Brockman tuff (Niobium tuff) is well known, few would argue about the crystal fractionation mechanism for its enrichment, similarly to other highly evolved peralkalic magma systems, even though significant volatile volumes can also be involved. However, for low-P to high-P, F-, and B-bearing peraluminous systems that are responsible for hydrous high-level (subvolcanic, hypabyssal) Sn-, Ta-, and Li-enriched granites, there are ongoing debates about the rheology of these magmas, their mechanism to facilitate crystal-melt separation to fractionate; most have abundant evidence and some cryptic vectors of high-T alkali alteration, which makes analysis of enrichment processes challenging. In fact, the role of the volatile phases has long been argued in the enhanced evolution of pegmatites. However, extremely evolved aplite and felsite dikes are quenched subvolcanic systems, Argemela (Portugal) can be interpreted as erupted pegmatite melt, and the Macusani tuff (southern Peru) is an ash fall. With the surge in interest in Li, new extremely fractionated volcanic rocks are identified—both explosive and effusive varieties. In the eruptive conduits to subvolcanic and extrusive systems (rhyolites and tuffs), volatile reaction with the quenching melt-glass (gas-melt-glass) cannot be significant, and in fact these melts may not be rheologically challenged, although pyroclastic mechanisms of eruption may enhance their ascent regardless. Depression of liquidi and solidi due to various fluxes (Li, P, F, B) in addition to water, together with enhanced crystal-melt fractionation within an anomalous source and thermal regime, causes extreme fractionation without reaching for fluid fractionation as an additional enrichment mechanism.