Highlights and breakthroughs

Stable and metastable silicate liquid immiscibility in ferrobasalts

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Abstract: The onset of immiscibility in ferrobasaltic systems has been the subject of much research recently. The compositional space of the two-liquid field and the maximum temperature of the binodal surface have been investigated experimentally, but results from static and centrifuge experiments are controversial. In the article by Hou and Veksler (2015, May-June issue) entitled "Experimental confirmation of high-temperature silicate liquid immiscibility in multicomponent ferrobasaltic systems," the authors present experimental evidence for immiscibility between silica- and iron-rich melts at 1150–1200 °C, which are significantly higher to previous studies (ca. 1000–1025 °C). These results have important implications for potential large-scale differentiation of magmas by liquid unmixing and for the formation of both Fe-Ti-P-rich melts and rhyolites. **Keywords:** Experimental petrology, binodal, basalt, rhyolite

The formation of immiscible silica-rich and iron-rich melts during cooling of ferrobasalts has been recognized experimentally and in plutonic and volcanic rocks (Philpotts 1982; Charlier and Grove 2012; Veksler and Charlier 2015). However, unmixing of immiscible melts under equilibrium conditions (binodal above the liquidus) or as a metastable process (binodal below the liquidus) has long been discussed. The distinction is essential regarding the ability of liquid immiscibility to produce large-scale differentiation of magmas and contrasting liquid compositions. A metastable process would stay highly localized during eruption of supercooled lavas or late-stage solidification of a crystal mush.

The paper by Hou and Veksler (2015) complements the experimental work of Veksler et al. (2007) that has been highly debated. This last study aimed at supporting potential separation of immiscible melts in ferrobasaltic systems at temperature above 1100 °C using high-temperature centrifugation. In these experiments, sub-micrometer globules were produced but clear pools of equilibrium melts separated by a meniscus were nowhere observed. Based on its own experience from static experiments, Philpotts (2008) commented Veksler's results and interpreted the emulsion of immiscible melts as a metastable process during cooling in the centrifuge of the homogeneous melt that reached a sub-liquidus binodal surface. Static crystallization experiments in 1-atm vertical furnace and rapid quench have usually been used to constrain the binodal surface of ferrobasalt to a maximum temperature of 1025 °C (Dixon and Rutherford 1979; Philpotts 1979; Philpotts and Doyle 1983; Charlier and Grove 2012). In these experimental studies, sharp two-liquid interfaces are usually observed. However, Charlier and Grove (2012) and Longhi (1990) report some static experiments with diffuse contacts between the two liquids, illustrating the difficulty of the equilibrium immiscible melts to separate from each other. This is a consequence of very low interfacial tension between contrasting iron- and silica-rich melts with easy nucleation of immiscible liquid droplets and very slow coarsening (Veksler et al. 2010).

In a detailed reply, Veksler et al. (2008) further explained and reaffirmed the evidence for high-temperature liquid immiscibility. The paper by Hou and Veksler (2015) is a new effort to prove that silicate liquid immiscibility can occur at higher temperature. The approach is based on mixing rather than unmixing experiments. Pairs of potentially immiscible compositions were first fused separately in 1-atmosphere vertical tube furnace at QFM buffer. Fused beads were then suspended in contact with each other and run at 1150 or 1200 °C. Compositional reequilibration of the paired melts is observed but a compositional gap exists between an iron-rich basaltic andesites (53–56 wt% SiO_2 and 14.7–17.7 wt% FeO_{tot}) and rhyolitic melt (69–71 wt% SiO_2 and 4.0–7.9 wt% FeO_{tot}). Interestingly, this compositional range does not include classical ferrobasaltic composition at maximum iron-enrichment [ca. 45–50 wt% SiO_2 and 14–19 wt% FeO_{tot}; Charlier et al. (2013)].

Because the two-liquid field broadens with decreasing equilibration temperature, it is expected that immiscible melts will have less contrasting compositions at high temperature. Thus, it is interesting to observe that Hou and Veksler (2015) obtained iron-rich immiscible melts with 53–56 wt% SiO_2 and 14.7–17.7 wt% FeO_{tot} above 1150 °C, while they range from 30–50 wt% SiO_2 and 18–32 wt% FeO_{tot} below 1020 °C (Charlier and Grove 2012). This means that with increasing temperature, the binodal surface moves from ferrobasalt-rhyolite compositions to basaltic andesite-rhyolite end-members. Consequently, although the experiments of Hou and Veksler (2015) convincingly support the existence of a stable super-liquidus two-liquid field in ferrobasaltic systems above 1150 °C, it will be important to identify whether silicate melts produced along tholeiitic liquid lines of descent can reach SiO_2 content above 52 wt% at such high temperatures. Indeed, silica-enrichment above ca. 50 wt% during tholeiitic evolution is produced by crystallization of Fe-Ti oxides that appear on the liquidus below 1100 °C (Juster et al. 1989; Snyder et al. 1993; Toplis and Carroll 1995). The results of Hou and Veksler (2015) have possible implications for the evolution of tholeiitic andesite in which immiscible globules have also been reported (Philpotts 1982). The Upper Zone of the Bushveld complex is an example of plutonic evolution of magma with andesitic composition (Van Tongeren et al. 2010) for which the development of immiscibility and its role for

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magma differentiation are highly controversial (Van Tongeren and Mathez 2012; Cawthorn 2013).

The study by Hou and Veksler (2015) is an important advance in the understanding of silicate liquid immiscibility. Further experimental studies must test the existence of a stable or metastable two-liquid field by running unmixing and mixing experiments for different magma compositions in a range of magmatic temperature. Further progress should also come from in situ experimental methods and the development of micro-analytical facilities.

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