The effects of small amounts of water on magmatic differentiation: case studies in the Cascades

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We have performed melting experiments at 1 bar (anhydrous) and 1 and 2 kbar H_2O-saturated conditions to characterize the effect of water content on the differentiation of a basaltic andesite. The starting material was a mafic pumice from the compositionally zoned tuff deposited during the ~75 ka caldera-forming eruption of Newberry Volcano, a rear-arc volcanic center in the central Oregon Cascades. Pumices in the tuff of Newberry caldera (TNC) record a continuous fractionation sequence from basaltic andesite to rhyolite within a single eruptive event, making the TNC an excellent natural laboratory in which to study the conditions of magmatic differentiation. Combining experimental results with the mineralogy and mineral-melt equilibria of the TNC pumices, we have determined the pre-eruptive H_2O contents and temperatures of the TNC liquids.

The most primitive basaltic andesites in the sequence record pre-eruptive H_2O contents of 1.5 wt.% and a liquidus temperature of 1070°C. This low H_2O content produces a distinctive fractionation trend characterized by enrichment in Na, Fe and Ti relative to the calc-alkaline trend more typical of arc volcanic sequences. Low H_2O contents would be expected at Newberry Volcano given its rear-arc position, and the same fractionation trend is also observed in the rim andesites of the rear-arc Medicine Lake Volcano in the southern Cascades. However, the Na-Fe-Ti enrichment characteristic of low-H_2O (1-2 wt.%) is also observed west of Newberry in magmas erupted from the arc axis, such as the Shevlin Park Tuff and several lava flows from the Three Sisters. This indicates that low-H_2O magmas are generated directly beneath the main arc as well as the rear-arc.

Because liquid lines of descent (LLDs) are particularly sensitive to water content in the range of 0-3 wt.% H_2O, they provide a quantitative and reliable tool for precisely determining pre-eruptive magmatic water content using major element data from pumices or lava flows. Coupled enrichment in Na, Fe and Ti is a general feature of fractional crystallization in the presence of small amounts (1-2 wt.%) of H_2O, which may be broadly applied to look for “damp” fractionation sequences elsewhere.