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Across-arc patterns in mafic-magma chemistry controlled by thermal and chemical gradients at the slab interface

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A range of recent studies demonstrate systematic across-arc variations in the volatile and trace element contents of primary arc magmas. Most of these studies used olivine-hosted melt inclusions to bypass upper crustal modifications, and thereby estimate the chemical composition of parental magmas in equilibrium with the mantle. The patterns preserved in these melts can be used to investigate variation in the volatile-rich flux that enters the core of the mantle wedge, and which is sourced from the subducting plate. Similarly, the implied variability in the composition of this flux provides information about fluid and melt transport through the mantle wedge, and of the mineral breakdown processes occurring within the downgoing slab.

Here, we report on results from a detailed study of olivine-hosted melt inclusions sampled from a set of scoria cones in southern Chile. These samples include some highly primitive rocks from Apagado, with picritic composition and containing unzoned highly-forsteritic olivine (Fo_{88}). Such rocks are extremely rare in continental arcs. The Chilean rocks display a variation in their water, CO_2, and trace element content that suggests that the primary-melt chemistry reflects the pattern of element release at the subducting slab interface. This down-slab chemical gradient is consistent with predictions from modelling, geothermometry and experiments. The flux feeding the arc magmas becomes progressively less water-rich and increasingly dominated by hydrous melts over a distance of a few kilometres. We suggest that this change marks the onset of significant water-fluxed melting of sediment at the downgoing slab-surface.

The short length scale of the across-arc chemical patterns in southern Chile is perhaps surprising. The fact that such changes are preserved within our sampled rocks suggests that there is limited across-arc mixing and focussing of fluids or melts as they ascend through the mantle wedge. Our results suggest that slab-surface inputs exert a first-order control on arc-magma chemistry. The chemical patterns that we observe are replicated in other arcs, such as the Kamchatka and Izu-Bonin arcs, in spite of the plate-scale thermal differences between these subduction zones (i.e. downgoing plate age and descent rate). The common patterns between these arcs implies that sub-arc slab-surface temperature ranges may be similar in all three settings. This unexpected result hints at a thermal control on the precise position of volcanic arcs within subduction zones.