Insights into subduction-zone melting processes from across-arc and down-slab variation in thermal and chemical parameters

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Arc magmatism is sustained by fluids released into the overlying mantle at subduction zones. Simulations of melting processes suggest significant variability both within and between arcs in the depth and rate of fluid release, dependent on the thermal structure of the downgoing slab. These models are not well tested against eruption products. By examining primitive volcanic rocks in across-arc profiles, a better understanding can be obtained of the processes of fluid release at the slab interface, and of melt generation and transport processes in the intervening mantle wedge.

Here, we investigate the melt-inclusion chemistry of a suite of primitive volcanic rocks from across the southern Chilean arc, ranging from picrites to high-magnesium basalts. These rocks preserve the chemical signature of a systematic down-slab gradient in fluid chemistry. The chemical gradient is consistent with predictions from modelling, geothermometry and experiments, and suggests that the fluid escaping from the slab changes from a water-rich fluid to one dominated by hydrous sediment melt, over an across-arc distance of a few kilometres. This change is due to the thermal regime of the slab in this particular arc, where the wet-sediment solidus is crossed in the zone of fluid release feeding the sub-arc melting region. Thus, the material driven off the slab is a mix of aqueous fluid and sediment melt, whose proportions follow opposite trends as slab temperature increases. This same gradient appears to influence major element compositions (K2O-SiO2 trends) of volcanic rocks throughout the arc, and therefore exerts a first-order control on magma chemistry. Our observations also imply that discrete melt paths are maintained through the mantle wedge, without focussing or mixing of separate melts in an across-arc direction.