Andesites and the continental crust

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The relationship between andesites and the continental crust occupies a special place in petrology. Compositionally andesites resemble continental crust both in intermediate silica contents, and in their LREE enrichment. The relationship between andesites and subduction is also compelling given that continental crust seems to have formed predominantly at subduction zones. The association suggests that if we can establish how andesites form we can, as a consequence, determine the origin of the continental crust.

One possibility is that andesites are the natural result of density filtering by the crust. Such a suggestion gains support from consideration of tectonic environments such as the Andes. Here subduction related magmas rise through continental crust at composite volcanoes, while to the east on the Altiplano, extension permits shoshonitic and more mafic magmas to pass through the crust. The composite volcanoes of the Andes therefore seem to be filtered or stewed in the crust. But there is perhaps a circular argument here if we are suggesting that the manufacture of andesites actually requires a crustal filter. It may well be that andesites are self filtering.

The hydrous character of andesites at subduction zones means that they will be subject to prolific crystallisation. For mafic primary or primitive magmas, olivine crystallisation will be promoted. This will lead to rapid decreases in MgO and NiO and increases in silica, generating major element compositions similar to the crust. Nevertheless, olivine crystallisation alone cannot rotate REE patterns to match those of the crust. For this, and to satisfy Dy Yb relationships, the involvement of amphibole appears to be required (either as a fractionate or a residue). Amphibole crystallisation will similarly leverage silica contents to intermediate values. Note that some models advocating an adakitic origin for the crust (high pressure wet melting of basalt) are more consistent with garnet fractionation, which, in turn, does not fully satisfy the Dy Yb systematics of continental crust. So wet andesites may fractionate olivine at first, but the most significant differentiation will likely involve plagioclase and amphibole fractionation, producing continental crust like compositions via multiple mixing and cannibalisation of magma batches. Magmas will contain significant crystal cargoes, and will be capable of filtering via both density and rheology.

A witness to this processs is provided by the crystal cargo itself, especially plagioclase, for which examination of crystal core rim stratigraphy, in particular Sr isotopes and dissolution surfaces, invariably provides evidence of multiple open system cycling and mixing.