Experimental study of origin of silicic magmas in the primitive, intra-oceanic Tongan arc

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The origin of felsic magmas in intra-oceanic arc settings has been an active topic of debate. Currently, there are two main, but very different, processes suggested: fractional crystallization of basaltic magma and partial melting of lower crustal mafic amphibolites. The physical conditions, such as pressure, melt reactions, rates of melting and fluid dynamics of melt extraction differ markedly between these two mechanisms. A number of sophisticated numerical models of lower crustal amphibolite melting have been developed over the past decade. Such models are becoming widely invoked so there is a need for their applicability to be tested. Fonualei is unusual amongst subaerial volcanoes in the primitive Tongan arc because it has erupted dacitic vesicular lavas, tuffs and phreomagmatic deposits for the last 165 years and makes for an excellent natural laboratory. All of the products are crystal-poor and formed from relatively low viscosity magmas inferred to have crystallized at high temperatures. Major, trace element and isotopic data, along with experimental data from partial melting of amphibolites and phase equilibria experiments on the basaltic andesites from Late have been combined to assess competing models for the origin of the dacites. Positive correlations between Sc and Zr and Sr rule out evolution by closed-system crystal fractionation and an origin by simple direct partial melting of amphibolite cannot reproduce the data either. Instead, we develop a model in which the dacites reflect mixing between two dacitic magmas, both products of fractional crystallization of basaltic-andesite magma. Mixing was efficient because the two magmas had similar temperatures around. Low-pressure equilibration of the magmas has been suggested by the Late phase equilibria experiments.