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S-type rhyolites from the Tolmie Igneous Complex, Australia: deep crust origins and shallow crustal evolution

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The Late Devonian Tolmie Igneous Complex, in Central Victoria, Australia, is composed mainly of Ba-rich (up to 3000 ppm) S-type rhyolite ignimbrites with SiO_2 varying from 69 to 79 wt% and low Mg#s (1 to 43). Two main ignimbrite flows fill the Wabonga Caldera, the Ryans Creek and the overlying Toombullup Ignimbrites, totalling 750 to 1000 km^3 in volume.

The tectonic environment is late post-tectonic continental extension, with rifting and normal faulting. However, the volcanism was unimodal, without associated mafic lavas or pyroclastic rocks. Devonian red-beds underlie the Complex, Carboniferous, red-bed basins overlie the volcanic rocks, and some mafic lavas are present in the overlying red-bed sequences.

The presence of almandine-rich garnet phenocrysts with rutile, in the Ryans Creek, implies minimum pressures of magma generation of 0.9 – 1.0 GPa. The Toombullup Ignimbrite contains two generations of garnet phenocrysts and three of orthopyroxene. Grt+Opx assemblages in the Toombullup imply early magmatic temperatures near 1000 ˚C. The early phenocryst assemblage of Grt+Opx+Pl+Qtz constrains early magmatic crystallisation to around 0.4 GPa. Later Grt+Opx+Crd+Pl+Bt+Qtz assemblages suggest crystallisation at around 0.3 GPa and 750 to 800 ˚C. The presence of ferroan Opx+Fa as late microphenocrysts suggest continued crystallisation at around 0.15 GPa and 800 ˚C. Thus the magmas may were generated by high-T contact anatectic partial melting of Ba-enriched quartzofeldspathic metasediments near the base of the continental crust, during extension and mantle upwelling. There is then a record of partial crystallisation during ascent to shallow crustal pressures, where the felsic magmas evolved and interacted prior to eruption.

Geochemical variations in the Complex suggest that there are at least 3 separate magma groups. Mafic-felsic magma mixing and restite unmixing can be ruled out as processes responsible for the variation. The chemistry of the magmas is interpreted to be the result of a complex interplay between partial melting of heterogeneous source rocks, variable entrainment of peritectic phases formed during the melting reactions and some crystal fractionation involving garnet, orthopyroxene, plagioclase and accessory minerals (Ap, Mon, Ilm, Zrn).

The implication of these rocks for the local geology is that pre-Palaeozoic supracrustal rocks must have been carried to the base of the crust but escaped high-grade metamorphism and partial melting for 100s of millions of years after the orogenic events that brought them to those depths.