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Late-orogenic, mantle-derived, bimodal magmatism in the southern Adelaide Foldbelt, South Australia

by

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Abstract

Late-orogenic magmas are common to many foldbelts, suggesting a causal link between this thermal pulse and the cessation of deformation. An investigation of such a late-orogenic magmatic suite is made in the southern Adelaide Foldbelt which forms part of the large Late Proterozoic - Early Cambrian Adelaide Geosyncline deformed by the Cambro-Ordovician Delamerian Orogeny. During this orogeny the foldbelt was intruded firstly by a 516-490 Ma syn-orogenic (or deformed) group of magmas and subsequently by a 490-487 Ma late-orogenic (or undeformed) group, these two suites having marked chemical and isotopic differences. The late-orogenic suite is bimodal with mafic dykes and plutons accompanied by high-silica granites and rhyolites. It is argued that these mafic and felsic intrusives are both thermally and compositionally related.

The mafic rocks of the late orogenic suite are exemplified by several layered gabbroic plutons outcropping at Black Hill near the eastern side of the Mt Lofty Ranges. Lithologies include troctolites, peridotites, olivine gabbros and gabbronorites. The mineralogy of these gabbros shows that they crystallized in high level magma chambers from a continental tholeiitic magma. Like layered gabbroic intrusions in other parts of the world they contain a plagioclase plus two pyroxene assemblage with an olivine compositional hiatus. Crystallization occurred under high temperature, low pressure, low fO_2 conditions producing a trend of moderate iron enrichment followed by silica enrichment after the appearance of magnetite. Geochemical and isotopic constraints indicate that the magma underwent fractional crystallization combined with assimilation of the amphibolite grade metasedimentary wall rocks. The greatest contamination occurred near the margins of the plutons resulting, amongst other things, in silica and marked potassium enrichment to produce potassic gabbronorites and pyroxene monzonites. The effect of contamination was to displace the magma from the two pyroxene-plagioclase cotectic resulting in the formation of anorthosites and the stabilization of pigeonite. Geochemical and isotopic evidence is interpretable in terms of 5-20% contamination but such a scenario requires that the initial magma (and therefore probably also the source) be enriched in incompatible elements.

High-silica, potassium-rich rhyolites and rapakivi granites have been examined near Black Hill at Mannum and from the Padthaway Ridge. These form a probable felsic end of the suite and are characterised by low Al_2O_3 and CaO contents and high LREE, Zr, Nb, Y and Ga contents identifying them as A-type magmas. Although various petrogenetic models have been proposed for A-types, their high incompatible/compatible element ratios are most readily obtainable by extended fractionation of mantle derived basaltic magma. Such a model is supported by data from the Padthaway A-types. They

tend towards one feldspar (hypersolvus) varieties and typically contain Fe-rich biotite and ferrohastingsite. Less common are fayalite-hedenbergite assemblages and some samples contain relicts of pigeonite and magnesian-augite. These latter pyroxenes are not in equilibrium with their host rocks and indicate polybaric crystallization from mafic parental magma. The mineral assemblages show that this parental magma was hot (>960 ^oC), relatively anhydrous and consequently able to undergo extensive fractionation when it reached the water-undersaturated granite minimum. Progressive development of low Sr, Al_2O_3, CaO concentrations and negative Eu anomalies support this interpretation. Again plausible crystallization models suggest the need for the mafic parent to be enriched in incompatible elements.

Granophyres from the Black Hill plutons are compositionally similar to the Padthaway Ridge rocks and gravity data suggests both these and Black Hill overlie an extensive tract of mafic plutons. Also located on the gravity high and belonging to the same suite is the A-type Mannum Granite which preserves evidence for contemporaneity of the mafic and felsic magmas. This granite contains numerous dioritic enclaves whose compositions contribute to a tholeiitic fractionation trend similar to the Black Hill gabbros. The droplet-like shapes and microtextures of these enclaves along with geochemical and isotopic data suggest that they and their host granite formed contemporary magmas and that the enclaves may represent draw-up from an underlying layered mafic chamber. The available evidence suggests that despite the high temperatures of both mafic and felsic magma, the viscosity contrast after thermal equilibration was too high for unrestricted mixing and only mingling and diffusion took place.

The range of Nd and Sr isotopic compositions of all of these silicic rocks are virtually indistinguishable from the mafic ones consistent with other data suggesting a common source. Overall εNd varies from +5 to -4 and initial $^{87}Sr/^{86}Sr$ from 0.7035 to 0.7065 so that the entire suite has an isotopic range which is like some parts of the so-called enriched mantle sampled by ocean island basalts. In conjunction with their geochemistry this suggests derivation from an enriched source with relatively little crustal contribution, particularly from the evolved Archaean and Proterozoic material likely to characterize the lower crust in this region. However, a model involving crustal contamination of asthenospheric melts cannot be conclusively rejected although it requires quite high assimilation rates (>30%) to produce the incompatible trace element concentrations. One potential source is subcontinental lithospheric mantle that was previously enriched by infiltration of small partial melts from the asthenosphere. Enriched mantle xenoliths suggest the existence of such a source and T_{DM} Nd model ages for both the late orogenic magmas and many of these mantle xenoliths range from 900 to 1200 Ma which may partially reflect the timing of the enrichment event.

The generation of melts within the subcontinental lithosphere requires a substantial thermal anomaly which is also likely to affect the potential energy of the lithosphere. Following the suggestion of Houseman *et al.* (1981) that mantle lithosphere thickened during convergence may become unstable to convective thinning, theoretical models are outlined which suggest that mantle lithospheric thinning will increase both the potential energy and the thermal budget of the orogen. The increased potential energy accompanying isostatic uplift causes convergent deformation to be terminated or partitioned elsewhere whilst uplift is likely to induce rapid unroofing of the orogen. The increased thermal budget results in the potential for melting in the lower crust and low temperature melting fractions in the mantle lithosphere. Such melts will be relatively anhydrous and able to fractionate extensively to produce silicic differentiates and a bimodal magmatic suite. In the southern Adelaide Foldbelt both the nature of the magmatism and evidence for ca. 10 kms denudation just prior to emplacement of the late-orogenic suite provide some support for such a model. It is suggested that this process may also be responsible for the late-orogenic suites found in other foldbelts. Late-orogenic magmatic episodes may involve considerable new additions to the crust transfering geochemical enrichments from small degree partial melts contained in the mantle lithosphere.