A COMPARATIVE STUDY OF ARCHAEAN AND PROTEROZOIC FELSIC VOLCANIC ASSOCIATIONS IN SOUTHERN AUSTRALIA

by

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This thesis contains no material which has been accepted for the award of any other degree or diploma in any University and, to the best of my knowledge and belief, contains no copy or paraphrase of material previously published or written by another person, except where due reference is made in the text of the thesis.

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THESIS SUMMARY

Integrated field, petrographic and geochemical studies of four Precambrian felsic volcanic terrains in Australia have been undertaken with the object of gaining an insight into the processes of magma generation and crustal development in the Precambrian. The areas examined include two Archaean felsic volcanic centres in the Norseman-Wiluna greenstone belt of the Yilgarn Block and portions of two post-orogenic Middle Proterozoic volcano-plutonic terrains in central-southern Australia.

The Archaean felsic volcanic rocks are confined to discrete centres and show no systematic relationship in space or in time with the tholeiitic and komatiitic volcanic members of the greenstone succession. The two suites examined show typical calc-alkaline major element geochemical characteristics, but appear to have evolved along different lines of liquid descent from common parental magmas. On the one hand, extended fractionation of plagioclase and clinopyroxene at shallow depths (<10km) has yielded acid rocks relatively enriched in REE, Zr, Nb and Y, but depleted in Sr. On the other, prolonged fractionation of amphibole at greater depths (20-30km), perhaps near the base of the crust, has resulted in acid differentiates that are relatively depleted in HREE, Zr, Nb and Y, but enriched in Sr. It is postulated that the primary magmas for the calc-alkaline suites were derived by hydrous melting of a LIL element-enriched mantle source over a significant pressure interval (e.g. 10-20kb). Experimental evidence indicates that melting under these conditions will yield a range of primary magmas that differ chiefly in their MgO and SiO_2 contents, and this can account for the variable levels of MgO, Ni and Cr observed in the andesites. Such an origin is also able to explain why many of the low-silica andesites, which may be little removed by differentiation from their quartz-normative mantle-derived parents, are relatively enriched in MgO, Ni and Cr compared with modern andesites. Available data for calc-alkaline volcanic rocks from four other centres in the Yilgarn Block suggests that these conclusions have general applicability.

The two post-orogenic Middle Proterozoic volcano-plutonic terrains, by contrast, lack calc-alkaline andesites and are characteristically bimodal. Both of the provinces studied are comprised of vast subaerial ignimbrite sheets with subordinate intercalated basic flows and voluminous granitoid rocks, and have undergone minimal deformation and metamorphism. The acid intrusive and extrusive rocks are enriched in all LIL elements compared with modern calc-alkaline suites, and geochemical modelling calculations favour an anatectic origin. The moderately low silica contents of the primary magmas (58-65% SiO_2) indicate a relatively basic crustal source, in order to

avoid the necessity of invoking excessive degrees of melting (>60%). This is supported by trace element modelling calculations which show that at degrees of melting in excess of 40%, the enrichment of LIL elements in the melt is insufficient to account for the levels of these elements observed in the acid volcanics. Of the various possibilities tested for the crustal source, a basic granulitic refractory residue is considered most plausible on geochemical grounds. A literature review demonstrates that late-to post-orogenic bimodal igneous activity is widespread in the Proterozoic of other continents. The acid rocks in particular, show comparable geochemical characteristics to the Australian examples, which the present studies indicate could be explained as follows:

1. Relatively high LIL element contents, as the result of a sialic crustal source.
2. Particularly high Zr, Nb, Y, REE, Fe and Ti contents, due to the relatively high temperatures of melting which contributed to the disintegration of minerals normally refractory under low temperature wet melting conditions (e.g. zircon, apatite, sphene, spinel).
3. Relatively low Al_2O_3, CaO and Sr contents, reflecting a high proportion of residual plagioclase probably as the result of the relatively dry conditions of melting.

Although the felsic volcanics of the Archaean and Proterozoic terrains studied have contrasting origins, it is notable that the relatively minor associated basic volcanics have comparable critical geochemical characteristics (e.g. elemental ratios), indicating derivation from similar LIL element-enriched upper mantle sources. It seems likely that mantle diapirism provided the heat for melting of the upper mantle and crust in both the Archaean and the Proterozoic, although the scale of diapirism probably differed. During the Proterozoic, significant amounts of heat for crustal fusion may have also been contributed by basic magmas that were entrapped beneath the relatively thick, bouyant sialic crust existing at that time (c.f. Archaean). The record of felsic volcanism in the Precambrian can thus be explained in terms of an evolving crust, in which the "sialic" component increased in thickness with time through partial melting of basic igneous precursors and also via direct additions from the mantle of acid, calc-alkaline differentiates. Once formed, the sialic crust was reworked at various stages, culminating with the development of the voluminous acid magmas in the post-orogenic, Middle Proterozoic era.

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