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Characterization and Origin of an Ultrapotassic Aluminous A-type Granitoid from Southwestern India

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Introduction:

Although A-type granitoids are characterized by high contents of K_2O and high K_2O/Na_2O (i.e., molar $K_2O/Na_2O>1$) like potassic igneous rocks, ultrapotassic ($K_2O/Na_2O > 2$, $K_2O >$ 3wt%; Foley et al., 1987) A-type granitoids are rare. Despite the diversity of petrogenetic models proposed for ultrapotassic rocks, most workers agree that the ultimate source of this relatively rare group of magmas lies in the upper mantle and is enriched in incompatible elements, particularly K, Rb, Ba, Sr, REE, P and Zr. The Proterozoic granulite facies terrain of the southwestern part of the Indian Peninsula is intruded by a suite of alkali granite and syenite plutons preserving evidence for a prominent Pan-African felsic magmatic event (Santosh and Drury, 1988; Rajesh et al., 1996). These intrusives are considered to represent anorogenic or post-orogenic A-type magmas generated in rift-related environments of high heat flow and abundant volatile activity, correlative with an extensional tectonic regime and probably including melts generated from both upper mantle and lower crustal sources. The Pan-African (~550 Ma) Peralimala alkali granitoid pluton, northern Kerala, forms the largest pluton in this suite and forms the focus of this study.

Field setting, Petrography, and Conditions of crystallization:

The Peralimala granitoid, exposed as an E-W elongated pluton, is aligned nearly parallel to the NW-SE to E-W Bavali lineament in the basement, consistent with magma ascent along pre-existing deep fault lineament in an extensional tectonic regime. The pluton shows compositional variation from quartz syenite to leucogranite to less dominant marginal syenite, but it is difficult to delineate the different facies within the pluton. The granitic body exhibit sharp contacts (wherever exposures are available) with surrounding gneissic rocks (hornblende gneiss, hornblende-biotite gneiss, and biotite-hornblende gneiss) and opx (cpx±hbl±bt)-bearing quartzo-feldspathic charnockite. The pluton is characterized by the presence of iron-rich hydrous mafic minerals, iron-rich clinopyroxene, primary magnetite, fO_2 above the Ni-NiO buffer and high initial emplacement temperature near 950ºC. Significantly magnetite coexists with titanite, and shows very low mole fraction of the ulvöspinel component and Ti content.

Major, trace, REE, and Sr-isotope chemistry:

The Peralimala granitoid is a high-K (~12 wt%) granitoid belonging to the transitional group IV ultrapotassic rock classification of Foley et al. (1987). The rock composition significantly varies from slightly per-alkaline to mostly meta-aluminous to slightly per-aluminous. Features like higher total alkalis, high total Fe, low CaO and MgO, low Mg-number, and medium to high TiO_2/MgO, are typical of A-type granitoids. Al_2O_3 content ranges from ~14 to 19 wt%, designating the granitoid as aluminous. The REE abundance's generally increase with increasing SiO_2 from syenitic to quartz syenitic to granitic facies within the pluton. In the various tectonic discrimination diagrams, the Peralimala granitoid samples straddle between volcanic-arc granitoid and within-plate granitoid fields, while they belong to the A2 subtype of Eby (1992). The low initial $^{87}Sr/^{86}Sr$ ratio (0.7032) is in the range expected for rocks derived from lower crust or upper mantle protoliths.

A plausible petrogenetic model:

Many of the petrogenetic problems posed by ultrapotassic rocks, like explanation of extreme incompatible element enrichments, etc., are similar to those of other alkaline rock types. Hypotheses previously suggested for the petrogenesis of ultrapotassic rocks (as reviewed by Foley et al. (1987)) seems not to explain the trends of the Peralimala granitoid samples. The major, trace and REE patterns imply that the Peralimala pluton is not related to fractional crystallization process. Major element models that use observed phases are consistent with an origin by partial melting from a charnockitic parent. The overall characteristics of the trace and REE patterns of the Peralimala granitoid are similar to those of igneous charnockites (C-type granitoids) from northern Kerala, southwestern India. Trace element and REE modelling give reliable fits when the igneous charnockite source is used, but fails for other possible source rocks from northern Kerala. A petrogenetic model involving partial melting of a charnockitic mafic-intermediate upper mantle or lower crust is proposed for the Peralimala granitoid. Fluid inclusion studies in the Peralimala granitoid-quartz samples prompt for the notion of infiltrating CO_2-rich fluids enhancing the melting. Thus the melting of the dehydrated and charnockitised upper mantle or lower crust at elevated temperatures (>900ºC) can produce a significant amount of A-type granitoid magmas.

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