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# Geochemical diversity of late-Archaean Mg-K-rich mafic magmas (sanukitoids) and its implication for metasomatic processes between silicate melts and mantle peridotite

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The oldest high-Mg and high-K mafic magmas identified on Earth are the so-called sanukitoids that emplaced during the late-Archaean (3.0–2.5 Ga) in almost all cratonic domains worldwide. A compilation of >200 mafic to intermediate sanukitoid samples (mostly monzodiorites, quartz-diorites and quartz-monzonites with $SiO_2$ = 45–62 wt.%), reveals that they clearly define two groups on the basis of their geochemistry: (1) low-Ti sanukitoids display moderate Ti, Fe as well as HFSE and REE contents, but high Mg# (0.55–0.70) and elevated concentrations in transition elements (Ni, Cr); (2) high-Ti sanukitoids, by contrast, are much richer in Ti, Fe, HFSE and LREE, but show significantly lower Mg# (0.45–0.55) as well as Ni and Cr contents. We investigated the origin of both series using geochemical modeling based on Monte-Carlo numerical simulations.

As pointed out by previous work on experimental and natural systems [e.g. 1–2], our modeling indicates that both low- and high-Ti sanukitoids derive from the interactions, at mantle levels, between peridotite and a silicate melt. On the other hand, we demonstrated that (1) critical differences between low- and high-Ti sanukitoids (e.g. Ni, Cr, HFSE, REE contents) primarily results from two distinct mechanisms of melt-peridotite interactions; while (2) the nature of the metasomatic agent (either derived from metabasalts or metasediments in the models) only accounts for second-order variations within each group (e.g. K contents, Ba/Sr, La/Yb ratios and Eu anomaly).

Specifically, the composition of low-Ti sanukitoids is best explained by a “one-step” hybridation of silicate melt with mantle peridotite, and is in equilibrium with a residual solid made up of garnet, clino- and orthopyroxene. By contrast, high-Ti sanukitoids likely derive from a “two-step” process: firstly, the silicate melt is fully consumed by interactions with peridotite, giving rise to a metasomatic, orthopyroxene-, amphibole- and phlogopite-rich assemblage. In turn, non-equilibrium melting of the latter, with hydrated K-rich minerals as the main melt-producing phases, generates liquids which composition matches that of high-Ti sanukitoids.

These results, coupled to previous experimental data [e.g. 3–5], indicate that low-Ti sanukitoids derive from high-pressure (> 2.5 GPa) interactions between high volumes of silicate melt and mantle peridotite (melt/rock ratio >1), while high-Ti sanukitoids result from the melting of a metasomatic assemblage equilibrated at lower pressures (1.0–2.5 GPa) owing to the interactions between peridotite and smaller volumes of melt (melt/rock ratio <1). These particular petrogenetic conditions would be adequately accounted for by a model which considers the migration of subduction-related silicate melts in the mantle, which are progressively consumed by melt-rock interactions during their upward percolation. Such a model would explain the sequential emplacement of low- and high-Ti sanukitoids within some Archaean cratons (Superior province, Dharwar craton, Baltic shield). Moreover, this interpretation and the worldwide occurrence of sanukitoids in the late-Archaean advocates that modern-style subduction processes started at that time during Earth’s history. Finally, such a model could equally be applied to post-Archaean Mg-K mafic magmas that emplaced in late- to post-orogenic settings and share close similarities with Archaean sanukitoids, including a wide geochemical diversity.

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