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The miaskitic-to-agpaitic transition in the Pilanesberg alkaline complex, South Africa

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Agpaitic rocks are highly peralkaline nepheline syenites in which the high field strength elements (most notably Zr and Ti) are hosted in complex Ca-Na-F-Cl bearing silicate minerals rather than in common zircon, titanite and ilmenite characterizing miaskitic rocks. The processes that lead from a miaskitic to an agpaitic crystallization regime in alkaline magmas are poorly understood, and may be important for enrichment and transport of economically interesting elements (Zr, Rare Earth Elements) in alkaline intrusions.

The Mesoproterozoic Pilanesberg alkaline complex, South Africa, comprises several distinct intrusions of syenite and peralkaline nepheline syenite, which intruded into their volcanic cover. A mildly peralkaline ((Na+K)/Al \approx 1.04), medium- to coarse grained nepheline syenite in the outermost ring of the complex ("white foyaite"), has a distinct interstitial mineralogy consisting of amphibole (Na-Ca amphibole cores overgrown by arfvedsonite), aegirine (in part with elevated Zr), magnetite, fluorite, apatite, sodalite and a sequence of Ti-bearing minerals from miaskitic assemblages with titanite and ilmenite, through aenigmatite and astrophyllite to lorenzenite, rinkite, bafertisite and jinshajiangite. Zirconium remained hosted in pyroxene almost to the end of this evolution, when hilairite crystallized as the only Zr-silicate mineral in the rock. The initial stage of the miaskitic-to-agpaitic transition (from titanite- and ilmenite- to astrophyllite-bearing assemblages) was driven by increasing peralkalinity of an interstitial, residual silicate melt, caused by growth of alkali feldspar and nepheline. Chemographic modelling suggests that the later part of the evolution, with a change from astrophyllite- through aenigmatite- to lorenzenite-bearing assemblages, and finally to crystallization of hilairite, involved increases also in oxygen fugacity and water activity, and probably marks the consumption of the final interstitial silicate melt, and separation of a late magmatic, halogen-bearing aqueous fluid.

