

The effect of liquidus undercooling on the crystallisation pathways of peralkaline magmas: Insights from clinopyroxene zonation and implications for metallogenesis.

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Highly sodic peralkaline magmas can reach hyper-enrichment in critical metals including rare earth elements (REE). We explore clinopyroxene zoning to track the evolution of peralkaline magmas and the mechanisms that trigger critical metal mineralisation, focusing on the Mesozoic Benolong Volcanic Suite in eastern Australia, which includes a zirconium + hafnium + niobium + tantalum mineralised subvolcanic sill. Major and trace element analysis of clinopyroxene across the volcanic field tracks continuous magma differentiation from diopside-hedenbergite to aegirine, associated with progressive enrichment of rare metals. Crucially, aegirine in the mineralised trachyte becomes sector-zoned and depleted in critical metals, which instead partition into latest-stage eudialyte. Association with vesiculated portions of the sill suggests that sector zoning is the product of undercooling which may be driven by degassing. Because volatiles increase the solubility of critical metals in silicate magmas, we suggest retention of volatiles and dynamic crystallisation conditions drive enrichment of critical metals in the Toongi deposit. Our data show that pyroxene chemistry and zoning can help track fertility in critical metals in peralkaline magmas.

