Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.35323

# How Deep Is the Origin of Nephelinitic Magmas? Constraints from the Auckland Volcanic Field, New Zealand

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Nephelinitic magmas are commonly interpreted as low-degree partial melts generated in the asthenospheric mantle. Experimental studies of mantle melting in the presence of $CO_2$ support this interpretation, demonstrating an inverse relationship between magma $SiO_2$ and $CO_2$ contents. Because $CO_2$ strongly depresses the mantle solidus and enhances melt stability at high pressure, such $CO_2$-rich, $SiO_2$-poor melts can only form at depths greater than ~150 km. However, several constraints challenge this model. First, eruption of nephelinites requires rapid ascent with minimal interaction with the overlying mantle to prevent chemical re-equilibration. Second, the widespread occurrence of negative K anomalies in alkaline intraplate magmas indicates a source containing amphibole or phlogopite. Because these hydrous phases are unstable in the convecting asthenosphere, this geochemical signature instead implies a contribution from the lithospheric mantle.

To better constrain the origin of the diversity of alkaline rocks, we investigated the volcanism of the Auckland Volcanic Field (AVF; 193–0.5 ka), New Zealand. The AVF is a monogenetic basaltic field spanning the complete compositional range from nephelinite to alkali basalt. Nephelinites are characterized by elevated Gd/Yb ratios, indicative of derivation from a deep, garnet-bearing mantle source. Concurrently, these lavas exhibit a pronounced negative K anomaly, implying the involvement of K-bearing hydrous phases in the source region. In contrast, alkali basalts display systematically lower Gd/Yb ratios, consistent with melting at shallower depths, and they lack a K anomaly. These contrasting geochemical features are difficult to reconcile with a purely asthenospheric origin.

Based on new experimental constraints on partial melting of amphibole-rich metasomatic veins at 2.5 GPa, we propose a dynamic model. Alkali basalts derive from asthenospheric melts that equilibrate near the lithosphere–asthenosphere boundary, whereas nephelinites form by partial melting of hornblendite produced through metasomatism during early percolation of alkali basaltic melts from the upper asthenosphere. Incongruent melting of these amphibole-rich veins generates nephelinitic melts with pronounced negative K anomalies and strong HREE fractionation, consistent with garnet crystallization. This model challenges the assumption that nephelinites necessarily originate at greater depth than alkali basalts and instead highlights the importance of melt–lithosphere interaction in generating intraplate magma diversity.