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Unmasking the invisible processes of mantle metasomatism: insights from Eastern Australia

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Metasomatism is described as an invisible but often important, if not essential, process that occurs across geological settings from the crust to subduction zones, to the mantle. It's enigmatic and "invisible" nature has provided cover to understanding what is meant when metasomatism is invoked for redistributing volatile elements, concentrating critical metals, or forming new lithological domains in the mantle.

When metasomatism is invoked most authors agree that a metasomatising agent is required to alter the composition of the surrounding rocks, or transport metals and volatiles from one geological setting to another. In the mantle, the metasomatising agent(s) are believed to be either fluids or melts varying in composition from silicate-carbonate rich melts, and CO_2-H_2O rich fluids in oxidised regions. The effects of these melts or fluids are however poorly constrained with limited understanding of the reactions and products of melt-mediated or fluid-mediated metasomatism in the mantle.

To provide granularity and contextualise what is occurring during mantle metasomatism we investigate a suite of mantle xenoliths from eastern Australia. These xenoliths show a progressive change in mineralogy from refractory dunites to amphibole-rich nodules representing a progressive mantle metasomatic trend. We demonstrate here that metasomatism is not a linear reaction with a single agent, but instead multiple episodes of silicate- and carbonate-rich melt metasomatism have occurred.

The east Australian xenoliths show progressive metasomatism beginning with near-complete wehrlitisation from silica-undersaturated melts resulting in Cr-rich amphiboles and clinopyroxenes. Continued in fluxing of carbonate melts results in Ti-rich rims surrounding amphiboles and the formation of magnesite-dolomite rich carbonate pods. Infiltrating carbonate melts form veined networks along grain boundaries that also contain sulfides rich in Cu and Ni.

These first results demonstrate that mantle metasomatism is a multi-episodic, complex process. With the chemical controls on fertilisation dependent on the metasomatising agent(s) composition, reactivity, and infiltration mechanism. For eastern Australia, the metasomatic enrichment of the subcontinental lithospheric mantle was likely essential for the generation of potassic-ultrapotassic Cenozoic volcanism.