

Pyroxene metasomatism facilitates scandium recycling in East Gondwana, Antarctic

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Mafic-ultramafic intrusions represent the primary source of global scandium (Sc) resources, typically originating from fertile mantle sources in arc systems. While fluid and melt metasomatism are widely recognized as crucial mechanisms for Sc enrichment in the mantle, key aspects including the precise composition of these metasomatic agents and their operating conditions remain poorly understood. To address these knowledge gaps, we conducted a comprehensive investigation of Sc recycling processes using clinopyroxene (Cpx) and orthopyroxene (Opx) chemistry from charnockites and mafic granulites in East Antarctica's Prydz Bay Belt. Our findings reveal a multi-stage Sc recycling pathway within the accretionary belt, initiated by reduced carbonate and silicate melt metasomatism that significantly enriches Sc in the mantle. This enrichment process is followed by post-peak decompression melting at 800-1000°C and 6.5-12.8 kbar, which triggers arc magmatism and facilitates Sc partitioning into Opx and Cpx. The subsequent exhumation stage involves interaction with an external hydrous, sulfur- and phosphorus-rich oxidized melt, leading to Sc release into the melt phase. Based on these observations, we establish a comprehensive model for Sc recycling in accretionary orogens, highlighting three critical controlling factors: (1) mantle interactions with carbonate and silicate melts, (2) oxygen fugacity variations, and (3) the synergistic effects of metasomatism, arc magmatism, and decompressional exhumation processes.