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# The role of sulphur in siderophile and chalcophile element enrichment of the lithospheric mantle: constraints from Kaapvaal mantle xenoliths and high-pressure partial melting experiments of S±C-bearing eclogite

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## ABSTRACT

Sulphur- and carbon-bearing melts play an important role as metasomatic agents within the cratonic mantle lithosphere. While carbon-bearing melt metasomatism has been linked to various lithosphere enrichment processes including, diamond formation and kimberlite magmatism as part of the deep carbon cycle, information about the behaviour of sulphur during metasomatism and partial melting is less well constrained. Sulphide minerals predominantly host the mantle platinum group element (PGE), siderophile and chalcophile element budgets, and their behaviour during melting controls the movement of these economically important metals. Here I present a case study of eclogite and peridotite metasomatism by sulphur±carbon-bearing fluids/melts by comparing new experimental work with geochemical, stable isotopic and petrologic investigations of sulphide-bearing eclogite and peridotite xenoliths from several key kimberlite occurrences on the Kaapvaal craton, South Africa. The experiments conducted from 2 to 3.5 GPa and 1050 to 1300 ºC on sulphur±carbon-bearing eclogite compositions demonstrate that the critical factors concerning the mobility of sulphur in upper mantle eclogite are the degree of partial melting and the compositions of the resulting melts. Pure sulphide melt is shown to be largely immobile within the MORB-like eclogite system unless aided by more fluid-mobile carbonate±silicate melts at these upper mantle conditions. Sulphur is effectively mobilised as immiscible sulphide liquid melt pools within $CO_2$-free basaltic-andesite melts and as dissolved elemental sulphur within intermediate carbonate-silicate melts at >15 % partial melting of the mixed volatile-bearing eclogite compositions. Comparative investigations of eclogite and peridotite xenoliths show that the metasomatic precipitation of secondary sulphide is intimately linked to metasomatism of the host silicate assemblage. The sulphide minerals are exceptionally redox sensitive and contain variable PGE contents with characteristic I-PGE/P-PGE fractionations, which are controlled by the compositional character of the metasomatic melt/fluid. Specifically, the xenoliths investigated here show evidence for several contrasting depth-dependent, and sometimes location-specific, metasomatic events which may have affected both the Kaapvaal cratonic lithosphere as well as the craton above. Moreover, this study demonstrates that metasomatic enrichment of the cratonic lithosphere by sulphur±carbon-bearing fluids/melts has resulted in isotopic heterogeneities and the addition of new minerals such as sulphide and potentially also diamond since the Archean.



KEYWORDS: base metal sulphide; lithospheric mantle; mantle redox; metasomatism; oxygen isotopes; peridotite; platinum group elements; sulphur isotopes