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Caught in the act: CO_2 production in the Hawaiian mantle

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High ascent rates of silica undersaturated, alkaline, small-volume melts such like kimberlites or melilitites may be caused by the exsolution of carbon dioxide from the rising magma, with the production of the CO_2 propellant being attributed to the interaction of carbonate melts with mantle minerals, especially orthopyroxene (Opx), (Ref. 1,2). In such a model, carbonate liquid reacts with Ca-poor pyroxene to form Ca-rich pyroxene (Cpx) and CO_2. Indirect evidence for this reaction is the observance of primary Opx inclusions in kimberlite olivine that are surrounded by the reaction products Cpx, CO_2 and carbonated glass, but with no trace of primary carbonate melt (Ref. 2). Here, we present a combined EPMA-TEM study on < 1mm-sized carbonatitic mantle xenoliths from Salt Lake Crater (SLC), Oahu, Hawaii, which documents the interaction of Ca-dominated carbonate melts with (i) Ca-poor pyroxene and (ii) garnet to form Ca-rich pyroxene and garnet, respectively. Regarding (i): primary Opx in contact with mantle-derived carbonate (± phlogopite) displays a reaction rim of Cpx, magnetite and possibly titanite. Also, primary Ca-poor Cpx may react with carbonate, leading to Ca-rich and Ca-poor Cpx domains. Regarding (ii), we observe mantle garnet showing partial dissolution resulting in a porous "cauliflower" texture with diffuse shapes that we attribute to reaction with Ca-carbonate melt.

The presence of carbonate melts/fluids within the Hawaiian mantle plume is important because of their effects on (auto)metasomatic processes, degree of partial melting, the composition of melts, mantle conductivity and plume rheology. Our direct observation of Ca-carbonate melts/fluids in the mantle beneath Hawaii complements abundant indirect evidence including: (i) Ca-Sr isotope signatures in Hawaiian (pre)shield lavas suggesting recycled carbonate-sediments in the source (Ref. 3) (ii) high-density CO_2 inclusions of metasomatic origin in SLC mantle xenoliths (Ref. 4, 5) and (iii) their association with micro-diamond and carbonate (Ref.6), (iv) trace-element signatures including supra-chondritic Nb/Ta and Zr/Hf ratios in SLC lavas (Ref. 7,8) and (v) the nephelinitic/melilitic composition of the SLC melts requiring a deep, carbonated source (Ref.9).

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