The misleading role of carbonatites in the deep volatile cycle

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Kimberlite and carbonatite magmas intruding cratonic lithosphere are considered the deepest probes into Earth's mantle. In this setting their co-existence is commonly interpreted to represent a primary melting sequence of carbonated peridotite at >150 km depths, possibly as deep as the transition zone. The carbon involved in this magmatism is thought to be either of primordial origin or derived from recycled oceanic crust.

To better understand carbon fluxes beneath cratons and their role in the deep carbon cycle, we have studied kimberlite dyke swarms and associated carbonatite intrusions of the North Atlantic craton in West Greenland. Our new Nd-Hf-Pb isotope data suggest that both magma types were derived from a common convective upper mantle source. Moreover, the absence of hallmark recycled oceanic crust signatures such as highly radiogenic Pb and decoupled Nd-Hf isotope systematics are indicative of a primordial mantle origin of the carbon involved in Greenland kimberlite and carbonatite magmatism. Based on phase relationships and geochemistry, including carbon isotopes, we identify Greenland kimberlites as near-primary melts (-6 to -4‰ $\delta^{13}C$). The intrusive carbonatites (-4 to -2‰ $\delta^{13}C$), however, represent mixtures of cumulus crystals and liquid. The kimberlites and carbonatites appear to be linked by a two-stage fractionation process that commenced at uppermost mantle depths. First, liquidus olivine+phlogopite were removed from kimberlitic carbonate-silicate melts at high-T, leading to residual carbonate-rich melt fractions. Second, upon continued ascent into the cratonic crust and cooling, these carbonate-rich melts precipitated calcite+dolomite along with minor olivine+magnetite. Rayleigh carbon isotope fractionation modelling suggests that 70-to-90 vol% of mantle-derived carbonate involved in this deep magmatism is now captured in the intrusive carbonatite bodies. Thus, it appears that CO_2 outgassing associated with kimberlite and carbonatite magmatic activity is volumetrically insignificant compared to global basaltic magmatism, and that carbonatite intrusions represent a major cache of primordial mantle carbon.