Deep Recycling of Carbon During Subduction

While most of the subducted H_2O is recycled at shallow and subarc depths, carbon is less readily mobilized and susceptive to complex redox processes involving CO_2 in solids, fluids and melts, elemental carbon, Fe- and Si- carbides, and methane. In this talk, I review the various ways of recycling carbon during subduction and present a spectrum of possible reaction products in the mantle.

Metamorphic reactions liberate <20% of the subducted CO_2 to the subarc region (Connolly 2005, EPSL). Larger amounts might be mobilized through (sediment) melting. Although the wet pelite solidus is only shifted by 30-50 ^{o}C (at 3 GPa) with carbonates, the latter remain stable with melts that are saturated in a H_2O+CO_2-fluid. Complete dissolution of carbonates requires temperatures above any predicted subduction geotherm. The melting of carbonated sediments yield CO_2-rich phonolites to 5 GPa but carbonatites at higher pressures. The silicate melts become increasingly potassic with pressure, and the alkali-rich carbonatites have their highest K/Na at 8 GPa, decreasing with pressure until they become sodic with the disappearance of residual cpx at ~16 GPa.

What may happen when carbonated pelite derived melts migrate into the mantle is illustrated in Central Italy: in this case, it can be experimentally demonstrated that hybridization of ultrapotassic phonolitic melts with ~2 wt% H_2O and ~6 wt% CO_2 in the mantle results in the primitive parents of the ultrapotassic kamafugite suites which have ~43 wt% SiO_2. Hence, despite a crustal isotopic signature of C, O, and Sr in these rocks, the CO_2 of the Italian magmatism does not stem from assimilation in the crust (as almost generally agreed upon) but from melts derived from subducted marine carbonates mixed with pelagic clays and then reacted in the mantle.

The migration of CO_2-bearing fluids and melts into the mantle may lead to a redox-shock. Where high liquid/mantle ratios prevail, carbonatites rest in their oxidized form and may only freeze in relatively cold lithospheric keels where they form metasomatic zones prone to generate kimberlites in the context of a much later remelting event. Where the redox-capacity of the oxidized crust-derived material is sub-equal to the reduced mantle, iron carbides are to be expected. The eutectic in the Fe-Ni-C system is at lower temperatures than the mantle adiabat, leading to the distinct possibility that such zones entrained in global mantle convection will contain ~1% of eutectic Fe-C-melt.

When the amount of subduction derived CO_2 is small compared to the redox capacity of a metal bearing reduced mantle, diamond will form, but diamond itself is not truly reducing at high pressures. The most extreme reducing case leads to moissanite (found together with diamond), which isotopic signature implies involvement of organically derived carbon. Moissanite (SiC) only forms at f_{O2} <6-8 log units below iron-wustite and coexists with mantle silicates that have an X_{Mg} of 0.995-0.998. Our calculations show that a fluid or melt with a bulk, which is slightly more reduced than the CO_2-H_2O-tieline in C-O-H, may evolve to ultra-reduced residual C-H-rich fluids through removal of CO_2 (through carbonate precipitation) followed by removal of H_2O (through hydrous silicate formation). As SiC may only be in grain scale equilibrium with the mantle and requires a protracted fluid-fractionation, we propose that SiC is generally a low temperature phase formed from originally already reducing fluids involving organic carbon and hence subduction.