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Solubility of carbon in diamond-saturated granite melt in subducted crust: implications for carbon transport to the deep mantle

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Subducted altered oceanic crust and sediments carry carbon in the form of carbonate and/or graphite/diamond to the mantle. Subduction zone fluids are fundamental transport agents for modulating the exchange and recycling of material, such as carbon, between Earth's surface and mantle reservoirs. This deep carbon cycle is important for constraining the evolution of climate at geological timescale of tens of millions of years, the formation of diamonds in the subducted crust and mantle, as well as processes controlling the chemical evolution of the Earth's interior. Previous experiments using synthetic materials have shown that, under oxidizing conditions (i.e., in the presence of a CO_2-rich fluid and/or carbonates and absence of graphite/diamond), intermediate to hot subduction zones can produce carbon-bearing silicate to carbonatitic melts that may recycle most subducted carbon back into the mantle wedge, arc magmas and atmosphere.

To constrain the capacity of carbon recycling during subduction under reducing conditions (i.e., absence of CO_2-rich fluid and carbonates), we have experimentally re-homogenized natural diamond-bearing melt inclusions present in ultrahigh pressure garnets of felsic rocks from Erzgebirge. These inclusions represent former diamond-saturated felsic melts produced during the deep subduction of crustal material, and hence provide information on the solubility of reduced carbon in felsic melts at sub-arc depths. NanoSIMS analyses of the diamond-saturated glasses provide CO_2 concentrations of 500-2000 ppm, an order of magnitude lower than CO_2 contents in CO_2- and carbonate-saturated melts. This indicates that, under reducing conditions, most subducted carbon sinks into the deep mantle even in hot subduction zones such as the Cascadian and Aleutians systems. Therefore subducted sediments rich in organic matter will retain most of the carbon in the form of diamond beyond sub-arc depths. This study shows that the amount of carbon that subduction zone fluids do transport can be directly measured from the study of appropriate natural samples. It also suggests that in a significant percentage of present subduction zones, subducted carbon sinks into the deep mantle instead of being directly recycled back to the continental lithosphere and atmosphere.