BLACK SHALE PARTIAL MELTING EXPERIMENTS PROVIDE INSIGHT INTO S, C, AND CU ASSIMILATION PROCESSES IN DULUTH COMPLEX, MINNESOTA

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Black shale assimilation is the most plausible trigger mechanism for the formation of the magmatic Ni-Cu-PGE deposits in the 1.1 Ga Duluth Complex, Minnesota. The Duluth Complex magmas assimilated large proportion of S from the footwall black shales of the Paleoproterozoic Virginia Formation, which enhanced sulfide saturation in the magmas. Consequently, the sulphide deposits occur systematically close to the footwall rocks and are often associated with abundant Virginia Formation xenoliths. The details of the mode of S transport during the assimilation are not fully understood. Both fluid and melt phases are likely to mobilize S during contact metamorphism and partial melting of the black shale, but the relative contributions of these different media have not been constrained yet.

We collected a pristine Virginia Formation black shale sample outside the thermally affected contact aureole of the Duluth Complex and conducted partial melting experiments at 2 kbar, 700–1000 °C. These P-T conditions are in agreement with conditions estimated for the footwall rocks and Virginia Formation xenoliths in the Duluth Complex. The experiments revealed that incipient subsolidus dehydration of hydrous silicates at 700 °C leads to mobilization of majority of S, C, and Cu into the fluid phase. Mass balance calculations indicate that in addition to S, large portion of Cu in the Duluth Complex deposits could also derive from the Virginia Formation via fluid transportation. Subsequently, Cu-rich sulphide melt and Cu-Ni-bearing pyrrhotite droplets form at 1000 °C, when silicate melt becomes the dominant phase. Cu and Ni from the fluid and silicate melt partition into these droplets providing a mechanism of initial concentration and extraction of the chalcophiles during (partial) assimilation of the wall-rock. The sulphides are typically attached to fluid bubbles at 1000 °C, which enhances assimilation from the footwall by buoyant transport.