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The role of assimilation and volatiles in the formation and metal enrichment of magmatic sulfide ores: constraints from experimental petrology and application to the Noril'sk-Talnakh ore deposits (Russia)

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Most of the intrusions in the Noril'sk-Talnakh region (Siberia) are hosted in thick sedimentary sequences including abundant evaporitic and terrigenous sedimentary rocks. Three mafic-ultramafic intrusions in this region contain unusually thick massive sulfide deposits that constitute one of the world's largest economic concentrations of Ni, Cu and PGE. The interaction of Siberian magmas with sulfate and organic matter-rich sedimentary rocks has been proposed as a mechanism for the origin of these remarkable sulfide deposits. Here we fully investigate the interaction and reaction paths, by means of experiments at magmatic conditions and by thermodynamic modeling. We demonstrate how the assimilation of sulfate and organic matter in mafic-ultramafic magmas affects magma composition, crystallization and sulfide saturation. We identify the conditions that favored assimilation and ore formation in Noril'sk-Talnakh intrusions and conclude that the assimilation of sulfate-rich rocks enriched Siberian magmas in sulfur, while the carbonaceous rocks ensured the reduction of the oxidized sulfur and the segregation of exceptional amounts of sulfide melt.

One of the consequences of the assimilation of organic material is the formation of an abundant fluid phase in the mafic magma. Our experimental work shows that the strong association between sulfide melt and fluid phase may have a major control on both the mobility and the metal enrichment of the sulfide melt. The fluid phase seems to play a critical role on the accumulation of the sulfide liquid by facilitating the coalescence of those sulfide droplets that are attached to gas bubbles. The experiments also reveal that the presence of a fluid phase consumes the sulfide melt concentrating metals in it. This process may have occurred during the formation of Norilsk-Talnakh sulfide ores and could explain the decreasing sulfide content and increasing metal content from the bottom to the top of the intrusions, i.e. from S-rich, PGE-poor massive sulfides at the base, to disseminated sulfides at intermediate levels and to S-poor, PGE-rich ores in the upper part.