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Serpentinization and carbonation of pristine continental ultramafic rocks and applications to the oceanic crust; H_2O-CO_2 alteration of dunites and re-distribution of Ni-Cu-PGE in sulphide deposits

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Here, we document carbonation and serpentinization within a suite of ultramafic rocks from a continental setting. These ultramafic rocks vary from pristine dunites to varying degrees of serpentinization which locally penetrates the ultramafic complex. Hence, it allows us to observe a number of delicate serpentinization and carbonation reactions, otherwise lost during more extensive alteration or tectonic events. We use a multi-disciplinary approach using petrographic, EPMA, thermodynamic modelling and geophysical data to reveal how the initial stages of serpentization and carbonation in dunites affects the distribution of economic to sub-economic deposits of Ni-Cu and PGE. The data can then be applied to oceanic crust.

The samples are dunites and poikilitic wehrlites from the Reinfjord Ultramafic complex, Seiland Igneous Province Northern Norway. The complex formed through crystallization of picritic melts in the lower continental crust. The dunites contain small amounts of interstitial clinopyroxene, sulphides and spinel, with local enrichments in Ni, Cu and PGE. Late magmatic CO_2-H_2O-S fluids reacted with the dunite forming clots of amphibole + dolomite + sulphides + enstatite, reaction rims of enstatite + dolomite, and inclusions trails of dolomite + enstatite + magnetite + CO_2 fluid. Thermodynamic modelling reveals that these textures formed at pressures of >12 kbar and temperatures 850-950 °C, which would be consistent with the late magmatic history of the Reinfjord complex. The clots and reactions have local association with enrichments in gold-rich PGMs.

A second stage of alteration involved H_2O-dominated fluids. These formed predominantly lizardite serpentinization, as is often concentrated within highly localized fracture zones. Thermodynamic modelling shows that these formed <400°C, after the complex had been exhumed towards the surface of the crust. Local and more pervasive serpentinization interacted with the earlier formed carbonate bearing assemblages leading to the formation of serpentinite, native copper and symplectites of brucite + calcite.

The two processes of carbonation and serpentinization re-distribute key economic elements. Understanding these processes will be vital for understanding the formation of ocean floor ore deposits. Density, magnetic and geophysical data, combined with petrographic and chemical data, show variations in serpentinization, which can be locally intense. The combination of these data sets may help resolve km scale anomalies within the Reinfjord intrusion and potentially in offshore ultramafic rocks.