Magmatic and metamorphic origin of noble metal nanoparticles in chromite ores

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Chromite ores hosted in the upper mantle section of ophiolites contain (sub)-economic mineralizations of platinum-group elements (PGEs). These noble metals usually form platinum-group minerals (PGM) or are hosted within the structure of Ni-Fe-Cu sulphides, yet little is known about their potential occurrence as nanoparticulate phases. In this study, we used a combination of focused ion beam (FIB) micron sampling with transmission electron microscopy (TEM) to image the nanoscale occurrence of PGEs in chromite ores from Cuba and Mexico. High-resolution observation of Ru-rich pentlandite from unaltered Cuban chromite ores indicate the presence of the following nanoscale phases: (1) idiomorphic, needle-shape (acicular) Ir-Pt nanoparticles up to 500 nm occurring as oriented domains in Ru-rich pentlandite, and (2) nanospherical Ir-Pt inclusions (<250 nm) within pentlandite. These observations point to sub-solidus exsolution of the Ir-Pt alloy from Ru-rich pentlandite. However, the occurrence of nanospherical Ir-Pt inclusions is harder to interpret as the result of exsolution, suggesting the possibility that they formed within the silicate melt before sulfide liquid immiscibility. In contrast, metamorphosed chromitites from Mexico host laurite (RuS_2) inclusions with abundant nanoparticles of Ru–Os–Ir alloys <50 nm in size. In this case, we argue that PGE nanoparticles can be exsolved and grown (or coarsen) from the sulphide matrix during prograde metamorphism, providing an alternative mechanism from the classical high-temperature (magmatic) formation. These two cases illustrate that natural PGE nanoparticles may form and be preserved under magmatic and metamorphic conditions.