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The role of dehydration of subducted serpentinites in the genesis of gold-rich magmatic-hydrothermal ore deposits

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INTRODUCTION

Here we present a geochemical study of whole-rock concentrations of gold and other noble metals (Ir, Ru, Rh, Pt and Pd) in subducted serpentinites and their dehydration products, i.e. chlorite harzburgites, from Cerro del Almirez (southern Spain). The Cerro del Almirez massif exposes the arrested front of antigorite breakdown in high-pressure subducted serpentinites (Trommsdorff et al., 1998; Padrón-Navarta et al., 2011), which is one of the most important reactions that generate fluids in subduction zones (Ulmer and Trommsdorff, 1995). Hence, the concentrations of precious metals, including gold, in these rocks constitute a unique opportunity to evaluate the impact of serpentinization, subduction metamorphism and serpentinite dehydration on the metal budget of subducted mantle, and to constrain the role of serpentinite-derived fluids in the transfer of metals to the mantle wedge. We show that gold has been significantly partitioned into fluids released by the dehydration of serpentinites, thus providing a firm natural evidence of gold endowment in the source of arc magmas that may form gold-rich deposits. Additionally, we provide a direct application of our results to explain the source of gold in epithermal deposits currently under exploitation in southern Spain.

GEOLOGICAL BACKGROUND

Several ultramafic bodies are enclosed within metasediments in the upper section of the Nevado-Filábride Complex, the lowermost tectono-metamorphic unit of the Internal Zones of the Betic Cordillera (S. Spain). The Cerro del Almirez massif is the largest (~ 2 km^2) of these bodies and consists of ~ 200-m thick foliated antigorite serpentinites, with or without diopside, underlain by ~ 200-m thick chlorite harzburgites with granofels, spinifex-like or recrystallized texture. Chlorite serpentinites and antigorite-chlorite-orthopyroxene-olivine rocks locally form a (< 10-m thick) transitional zone between antigorite serpentinites and chlorite harzburgites (Padrón-Navarta et al., 2011). Minor lithologies are cm- to m-thick clinopyroxenites, meter-scale metadunites, titanian clinohumite-olivine veins and eclogitic (rodingite) boudins.
The transition between antigorite serpentinites and chlorite harzburgites at Cerro del Almirez is discordant to the serpentinite foliation and marks the front of antigorite breakdown to olivine + orthopyroxene + chlorite at ~ 1.8 GPa (~ 50-60 km depth) and 650 °C (Trommsdorff et al., 1998; López Sánchez-Vizcaíno et al., 2005; Padrón-Navarta et al., 2011). Serpentinization of the Cerro del Almirez ultramafic rocks occurred at the seafloor (Alt et al., 2012) and was followed by Alpine subduction to eclogite-facies conditions triggering the breakdown of antigorite in the Middle Miocene (~ 15 Ma) (López Sánchez-Vizcaíno et al., 2001). Finally, the ultramafic rocks of Cerro del Almirez were emplaced over enclosing metasediments along a major shear zone in transpressional regime (Jabaloy-Sánchez et al., 2015), and they were exhumed at high rate (~ 1.2 cm/yr^{-1}) during the Middle Miocene to Pliocene overall convergence between Europe and Africa (López Sánchez-Vizcaíno et al., 2001).

RESULTS

The noble metal concentrations (platinum-group elements –PGE- and Au) in the Almirez serpentinites and chlorite harzburgites are generally comparable to those of Depleted MORB Mantle (DMM). Ruthenium in these rocks is slightly enriched relatively to Ir and Rh, as well as Pd relative to Pt. Noble metal concentrations in the Almirez rocks are rather heterogeneous except in diopside-bearing serpentinites that show low variability. Contents of Ir, Ru, Rh and Au in diopside-lacking and diopside-bearing serpentinites are similar, opposite to Pt and Pd that are generally more abundant in the latter. Spinifex-like chlorite harzburgites have PGE contents and fractionations similar to serpentinites; however, one of these samples is particularly rich in Pt and Pd (PPGE). Interestingly, Au in spinifex-like chlorite harzburgites is commonly less abundant than in serpentinites and is negatively fractionated relative to Pd, contrary to serpentinites. Recrystallized chlorite harzburgites are also relatively depleted in Au and have noble metals contents similar to spinifex-like chlorite harzburgites but are normally more fractionated.

DISCUSSION AND CONCLUSIONS

Variations of PGE in the Almirez serpentinites are in agreement with experimental results of mantle melting. However, diopside-bearing serpentinites have higher Pt and Pd abundances than diopside-lacking serpentinites and DMM, suggesting that these rocks gained PPGE after melting, probably during subduction.

Low-T seafloor serpentinization of diopside-lacking serpentinites by relatively S-poor fluids increased gold concentrations to notably higher Au/S values than in diopside-bearing high-T serpentinites, perhaps in concurrence with late seafloor weathering. In both serpentinite types, precipitation of hydrothermal sulfides on the seafloor triggered Au deposition due to loss of sulfide S in the fluid. However, high-T serpentinization was not responsible of the gold endowment in diopside-bearing serpentinites but this enrichment likely occurred during subduction by incorporation of pyroxenite sulfides, similar to Pt and Pd.

Relative depletion of gold in dehydrated chlorite harzburgites supports that antigorite-breakdown in subducted serpentinites released fluids rich in Au. These fluids were likely able to transfer gold, and possibly other metals, to the mantle wedge of the upper plate, i.e., the allochtonous Alboran Domain. This process may explain the origin of gold-rich hydrothermal deposits in the eastern Betic Cordillera. In this scenario, subduction and dehydration of serpentinites may have enriched in gold the subcontinental lithospheric mantle (SCLM) of the Alboran Domain, which later underwent partial melting and melt infiltration triggered by the well-documented Cenozoic asthenospheric upwelling in the western Mediterranean. Melting of the SCLM of the Alboran Domain -pre-enriched in gold by slab fluids liberated via subduction of Nevado-Filábride serpentinites- likely led to the formation of metal-rich magmas. These magmas may then have evolved to Neogene calcalkaline melts that separated fluids responsible of gold epithermal mineralization in southeastern Spain.

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