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Genetic relationships between spatially associated arsenide and sulphide magmatic ores from the Carratraca Ultramafic Massif (Málaga, south Spain)

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The Carratraca massif is one of the several Iherzolite massifs outcropping in the Serranía de Ronda area, which is located in the westernmost part of the internal zones of the Betico–Rifean Cordillera, part of the Mediterranean Alpine Belt. These massifs are portions of upper mantle emplaced at high temperature in the continental crust and display a top to bottom zoning. They are zoned in three tectono–metamorphic domains i) garnet mylonites to spinel tectonites, ii) granular peridotites and iii) plagioclase tectonites. Between the spinel tectonites (old protolith) and granular peridotites exists a narrow boundary characterised as a recrystallisation/coarsening front and corresponds to a combination of partial melting during lithosphere thinning and fast dynamic cooling (Lenoir et al., 2001). Three ore types occur in these massifs: chromite–Ni arsenide (Cr–Ni) ores, sulphides–graphite (S–G) ores, and chromite (Cr) ores. Only Cr–Ni ores were mined in the past for nickel.

The studied mines are the i) San Agustín (Cr–Ni ores) and ii) El Gallego (S–G ores). The main ore minerals at San Agustín are chromite and nickeline with minor rammelsbergite, gersdorffite, rutile, and some accessory sperrylite and gold, associated with cordierite, ± plagioclase. This type of ore display orthomagmatic textures and, in places, high temperature plastic deformation. The mineralisation occurs as small veins that cross-cut the foliation of the host peridotites, and have been formed by the crystallisation of chromite-carrying immiscible arsenide melt rich in noble metals (Gervilla et al., 1996). At El Gallego (S–G ore) the main mineralogical assemblage is pyrrhotite, petlandite, chalcopyrite, cubanite, chromite, rutile, graphite and minor cobaltite–gersdorffite, nickeline and bismuthotellurides, associated with phlogopite. The mineralisation occurs as veins, partly displaying a stockwork-like pattern, and occur along a fault zone. The San Agustín mine is hosted by spinel tectonites whereas El Gallego mine is located upward in the mantle section and is hosted by garnet mylonites. Previous studies suggest that S–G ores formed later than Cr–Ni ores from residual sulphide liquids segregated after crystallisation of Cr–Ni ores.

In order to calculate the bulk content of major and trace elements, and noble metals, six selected samples were analysed by ICP–MS. The PGEs and Au patterns normalised to chondritic values (Fig. 1) reveal high content of noble metals in the samples. In particular, three samples display a positive anomaly in Pt in agreement with the presence of micron-sized grains of sperrylite (PtAs₂) (Fig. 1), and some alloys consisted mainly of Au (up to 60% wt) and Cu (32% wt), and some Pt (4% wt), Ni (3% wt) in the ore assemblage. This is in contrast to previous results in some samples from the same type of ores which showed negative Pt anomalies and no PGM grains (Fig. 1).

In addition, the As shows a positive correlation with the PGEs content in the samples, in contrast with other semi-metals (Bi, Te) that reveal a negative correlation. However, it's worth to note that the Pt-richest sample (containing 7677 ppb Pt) shows the lowest As content (453 ppm As), but it shows the highest amount of Bi (7.6 ppm) plus Te (9 ppm). This is in accordance with the presence of many micro-grains of bismuthotellurides in this sample. The previous statements suggest that either Pt became concentrated by other semi-metals (e.g. Bi and Te), or segregated earlier from the As-saturated melt in the form of sperrylite, as Helmy's et al. (2013) experimental results show.

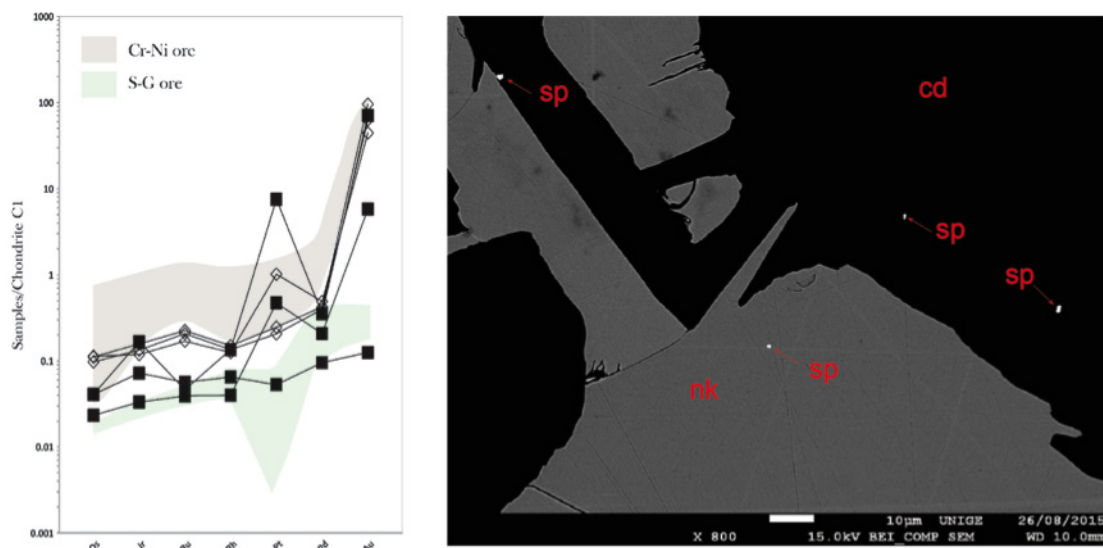


Figure 1. Left image: Chondrite – normalised (Naldrett & Duke 1980) patterns of the samples from San Agustín (open diamonds) and El Gallego (black squares). Data for the Cr-Ni ores and S-G ores from Gervilla et al., 1996. Right image: SEM image of platinum mineral (nk: nickeline, sp: sperrylite, cd: cordierite)

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