Sulphide Mineralogy in Peridotite Xenoliths from the Calatrava Volcanic Field (Central Spain)

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INTRODUCTION.

Mantle-derived xenoliths in volcanic rocks are significant sources of information on the composition and physicochemical processes that accounted in the sub-continental lithospheric mantle. In these rocks, sulphides are common accessory opaque minerals. They typically belong to the Ni-Fe-S and/or Cu-Fe-S systems and play the main role in controlling the budget of many siderophile elements (Ni, Fe and Cu) as well as highly siderophile elements (HSE), that is to say platinum-group elements (PGE), Au and Re (e.g. Arculus and Delano 1981; Alard et al., 2000; Yue and He 2008). In peridotite xenoliths, sulphides are usually found as inclusions or interstitial in silicates (e.g. Shindo et al., 2009). Thus, based on their textural position, morphology and chemistry, different populations of sulphides related with primary mantle processes or secondary metasomatism may be recognized (e.g. Hattori et al., 2002).

In this work we have carried out a detailed petrographic study on sulphide inclusions using reflected light microscopy, and analyzed numerous back-scattered electron images of sulphides from a set of mantle-derived xenoliths from the Calatrava volcanic field (central Spain). Based on the petrographic study we recognized different generations of sulphides which were interpreted to be result of the different metasomatic events that have affected the lithospheric mantle beneath central Spain (Ancochea and Nixon, 1987; Villaseca et al., 2010).

GEOLOGICAL SETTING.

The Campos de Calatrava Volcanic Field (CCVF) covers an area of about 500 km^2 near the cities of Ciudad Real and Puertollano, in the central-south part of Spain. From a geological point of view, this Cenozoic volcanic field intrudes into the easternmost branch of the Hercynian Iberian massif. The volcanic field comprises more than 200 volcanic centers (Ancochea, 1982). The formation of this volcanic field is related with eruption of ultra-potassic to more Na-rich alkaline magmas ~8.7-0.7 million years ago (Ancochea, 1982). All the volcanic edifices are monogenetic, suggestive of small and short-lived shallow magma chambers. Most of the volcanoes are strombolian cones but more than 50 hydromagmatic tuff rings or maars have been also reported. Here we focused our study on the peridotite xenoliths from two of the volcanic centers: the El Aprisco maar and the Cerro Pelado scoria cone.

DESCRIPTION OF THE XENOLITHS.

Peridotite xenoliths are all spinel-bearing varieties. They appear as fragments in the pyroclastic deposits of the two aforementioned volcanic centers. They are rounded medium-size samples (from 5 to 45 cm in diameter) which show no evidence of alteration or host basalt infiltration.

Nine of the studied xenoliths are lherzolite and only one wehrlite. Mantle xenoliths from the El Aprisco center tend to have more orthopyroxene than clinopyroxene whereas those from Cerro Pelado are richer in clinopyroxene, even wehrlitic in composition. Although present in accessory amounts, the studied peridotite xenoliths usually have interstitial volatile-rich minerals indicative of modal metasomatism: amphibole in samples from El Aprisco center, and phlogopite in those from the Cerro Pelado maar. Only one xenolith is an anhydrous lherzolite. The wehrlite shows trace amounts of phlogopite included in poikilitic clinopyroxene.

According to Villaseca et al. (2010) the studied xenoliths are records of a metasomatized, moderately fertile mantle beneath central Spain. However, differences in mineralogy and geochemistry between the peridotite xenoliths of both volcanic centers suggest that their original mantle sources were affected by different metasomatic agents. The enrichment in LREE, Th, U and Pb and the negative anomalies in Nb-Ta in clinopyroxene and amphibole from xenoliths of El Aprisco indicate that the metasomatic agent was probably a subduction-related melt. In contrast, a relative enrichment in MREE in clinopyroxene from xenoliths of Cerro Pelado center suggests that the metasomatic agent was probably an alkaline melt chemically similar to the host undersaturated melts.

SULPHIDE MINERALOGY.

Several grains of sulphides ranging between <1 to 500 µm in diameter were identified in 8 polished rock-blocks representative of the peridotite xenoliths from the El Aprisco and Cerro Pelado (Fig. 1). Based on reflected light microscopy and EDS spectra obtained by means of VPSEM, three main different sulphides were distinguished: pentlandite (Pn), pyrrhotite (Po) and chalcopyrite (Cp).
Although some grains of pentlandite and pyrrhotite were found as single inclusions the most common assemblage is made up of pentlandite and pyrrhotite in some cases with chalcopyrite (> 80% of the identified grains) in both lherzolite and wehrlite xenoliths (Figs. 1a-c). The morphology of the inclusions (usually < 50 µm in diameter) varies from euhedral to rounded and bleb. Singularly, the grains found within olivine tend to be rounded

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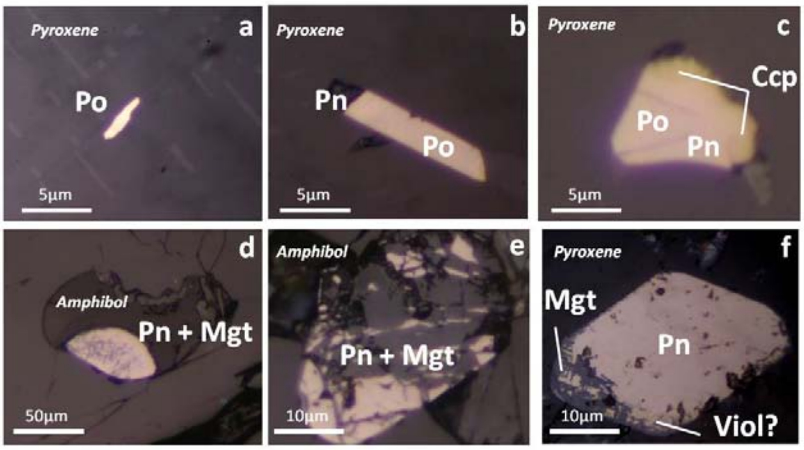

fig 1. Images (reflected light) of sulphide assemblages in the peridotite xenoliths of the Calatrava volcanic field. Images a-b are unaltered sulphides included within pyroxenes; images d-f are altered sulphides associated with metasomatic amphibole (d-e) or connected with late fracturing affecting to anhydrous silicates (f). Po: pyrrhotite, Pn: pentlandite, Ccp: chalcopyrite, Mgt: magnetite, Viol: violarite.

whereas those hosted by pyroxenes frequently are euhedral and occur oriented along the cleavage planes of the host pyroxene (Figs. 1a-b). Frequent acicular-like grains of pentlandite were also found between olivine grains. Some grains hosted by metasomatic, interstitial hydrous silicates show evidence of alteration, such as replacement by magnetite (Figs. 1d-e). Similar evidences of alteration were observed in some inclusions within strongly fractured olivine or pyroxene in which pentlandite is also replaced along its rims by violarite (?) (Fig. 1f).

CONCLUSIONS.

The identified sulphide mineralogy in the peridotite xenoliths from the Calatrava volcanic field is typical of that of moderately fertile mantle peridotite (e.g. Wang et al., 2009). Euhedral to rounded sulphides included within anhydrous silicates (i.e. olivine and pyroxene) may be interpreted as early trapped sulphide melts rich in Fe, Ni and to a lesser extent in Cu. The fact that some of the grains show rounded shapes or occur oriented along cleavage planes of the pyroxene (Figs. 1a-b) suggest that they were trapped by growing silicates (Fig. 1a). On the other hand, the replacement of these S-poor sulphides to magnetite or S-poor sulphides (e.g. violarite) when they are associated with metasomatic hydrous silicates suggests that these sulphides, like their original host silicates (i.e. olivine and pyroxene) were affected by the metasomatic event.

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