Re-Os Isotope Evidences of Multiple Melting Events in the Ojén Ultramafic Massif

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INTRODUCTION.

Of the applicable radiogenic systems, the ^{187}Re- ^{187}Os system is arguably the most sensitive to the long-term removal/storage of mafic crust from the fertile/depleted convective mantle. Its usefulness stems from the fact that Re, the parent element (^{187}Re → ^{187}Os: λ=1.666 x 10^{-11} yr^{-1}), is preferentially enriched in basaltic melts during the formation of the mafic crust, while Os is highly compatible and is retained in the residual depleted mantle. Consequently, the evolution of the ^{188}Os/^{187}Os of the convective mantle must reflect the extent of long-term exchange between variably depleted mantle reservoirs.

Re and Os also are highly siderophile elements (HSE), meaning that they strongly prefer metal or sulphides over silicates. Thus, alloys and sulfides are the main phases that control the budget of Re and Os in the mantle. Both elements may occur in tiny Fe-Ni sulfide minerals and in Platinum-Group Minerals (PGM), which consist mainly of Platinum-Group elements (PGE: Os, Ir, Ru, Rh, Pt, Pd; and Re). The high Os contents and low Re/Os of many PGM enable rapid, precise measurement of ^{187}Os/^{188}Os by *in situ* Laser ablation-ICPMS.

Of particular interest is the study of the Re-Os systematics in PGM from chromite-rich rocks found in the mantle section preserved in ultramafic massifs of orogenic peridotites and ophiolite complexes. These chromite-rich rocks, commonly called chromitites, are usually enriched in PGM, many of which have Os as a major component [e.g. Os-Ir alloys; erlichmanite (OsS_2), osarsite (OsAsS), laurite $(Ru,Os)S_2$]. Their Os-isotope composition may be representative of the large volumes of the convective mantle that would need to be melted to accumulate these concentrations of Cr and PGE (Marchesi et al., 2010). Therefore, *in situ* analysis of Re-Os isotopes in PGM hosted by chromitites potentially provides the most robust information on the Re-Os systematics of the mantle.

The age distributions of Os-rich PGM, determined by projection of their Os isotope ratios to a model for the compositional evolution of the convective mantle, should provide a record of high-degree melting events, and can be used, for example, to discriminate between continuous *vs* episodic mantle melting.

In the current communication we attempt to decipher multiple events of melting in the orogenic lherzolite massif of Ojen. To reach this goal we have studied *in situ* the Re-Os isotope systematics of Os-rich PGM from a set of chromititite occurrences (Gutierrez-Narbona et al., 2003). We show that these chromitites record a quite variable Os-isotope signature, as evidence of multiple mantle melting events preserved in the host peridotite prior to the formation of the chromitite. In addition, we present evidence that PGM in chromitites can act as “tape recorders” of melting events that take place in the upper mantle and that were not preserved in the peridotites that host the chromitite bodies.

PETROLOGICAL BACKGROUND.

The Ojén ultramafic massif.

The Ojén ultramafic massif lies within the internal zone of the Betic chain (southern Spain). It forms part of a belt of ultramafic outcrops representative of Sub-Continental Lithospheric Mantle (SCLM), which wraps around the northen and southern margins of the Alboran Sea (the westernmost part of the Alpine belt), and also includes the large massif of Ronda, and small massif of Carratraca on the south coast of Spain, and the complex of Beni Bousera in northern Morocco.

The Ojén body is the second largest (after Ronda) exposure of ultramafic rocks in the Serranía de Ronda. It covers an area of about 70 km^2 and, like the other two ultramafic massifs (Ronda and Carratraca), shows petrological zoning. This consists of (1) a central zone with a *plagioclase tectonite domain* composed of plagioclase-rich lherzolite hosting tabular dunite bodies which transitionally grades to plagioclase-rich lherzolite via a zone of harzburgite. (2) *granular peridotite domain* made up of olivine-rich lherzolite and harzburgite with subordinate pyroxenite, formed by re-equilibration of the pre-existing spinel tectonites with partial melts and infiltrated melts. This granular domain also records a younger partial melting event associated to a porous flow melt percolation process with different stages of percolation at different melt/rock ratios, recorded by the formation of a narrow recrystallization front that separates it from an external unit made of (3) spinel (± garnet) tectonite domain. The later domain is composed of spinel and garnet–spinel peridotite which represents a residue of the unmodified Proterozoic lithospheric mantle (see Marchesi et al., 2009 and references therein for more details).

Characterization of the PGM- bearing chromitites in the Ojen Massif.

The structural and compositional characteristics of the Ojén chromitites are similar to those of podiform chromitites that usually occur in the mantle tectonite of ophiolitic complexes. The chromitite bodies are small,

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extending over a few square meters and they occur in the form of schlieren and pods sporadically distributed in the plagioclase tectonite domain. The PGM-bearing chromitite bodies (Cr-ores of Gervilla and Leblanc 1990, and Gervilla et al., 2002) occur in three localities: *Arroyo de los Caballos*, *Cerro del Águila*, *Cañada del lentisco* and *Cerro del Algarrobo* (Gutiérrez-Narbona et al., 2003). Among these chromitite occurrences only chromitites from the Arroyo de los Caballos (so-called ARC, CAB and ACA) and Cerro del Águila (CDA) carried PGM with an appropriate size (≥ 5 µm) to allow useful *in situ* Re-Os analysis.

Re-Os ISOTOPES SYSTEMATICS.

We have measured the Os-isotope compositions of PGM *in situ* using a Laser-ablation microprobe coupled to an ICPMS (LA-MC-ICPMS). Most of the analyzed PGM are single grains of Os-rich laurite with associated Os-Ir alloys and/or irarsite (Gutiérrez-Narbona et al., 2003).

The chromitite occurrence ARC carries PGM with $^{187}Os/^{188}Os$ from 0.1198 to 0.1270 (average = 0.1241 ± 0.002; 2σ; n= 26) and $^{187}Re/^{188}Os$ from 0.0001 to 0.02 (average = 0.019 ± 0.004). $T_{MA} \approx T_{RD}$ model ages vary from 0.16 to 1.20 Ga.

The chromitite occurrence CAB has PGM with a very similar $^{187}Os/^{188}Os$ between 0.1215 and 0.1261 (average = 0.1240 ± 0.0014; 2σ; n= 8) and $^{187}Re/^{188}Os$ between zero and 0.001 (average = 0.0005 ± 0.0004). $T_{MA} \approx T_{RD}$ model ages vary from 0.29 to 0.94 Ga.

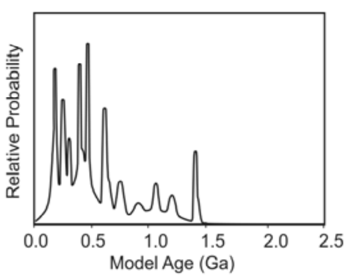

fig 1. T_{RD} (Re depletion) model ages of PGM from the Ojén chromitites calculated relative to Enstatite Chondrite Reservoir (ERC).

The third occurrence, the Arroyo de los Caballos locality (ACA), has PGM with a similar isotopic composition. $^{187}Os/^{188}Os$ ranges from 0.1182 to 0.1271 (average = 0.1227 ± 0.0014; 2σ; n= 7) and $^{187}Re/^{188}Os$ from 0.0001 to 0.0036 (average = 0.0013 ± 0.0015). $T_{MA} \approx T_{RD}$ ranges from 0.15 up to 1.4 Ga.

In marked contrast to chromitites from the Arroyo de los Caballos locality, those from Cerro del Águila are characterized by PGM with a more radiogenic Os-isotopic composition. The seven PGM analyzed show a range of $^{187}Os/^{188}Os$ between 0.1256 and 0.1275 (average = 0.1265 ± 0.0007; 2σ; n= 7), and $^{187}Re/^{188}Os$ from zero to 0.0027 (average = 0.001 ±0.001). $T_{MA} \approx T_{RD}$ are younger, ranging from 0.09 to 0.36 Ga.

MULTIPLE EVENTS OF PARTIAL MELTING.

The PGM from the Ojén chromitites are characterized by significant variability of $^{187}Os/^{188}Os$ and low $^{187}Re/^{188}Os$ at the scale of chromite bodies (and thin section). This variability, already observed in chromitites from both continental and oceanic areas (e.g., Marchesi et al., 2010; references therein), is generally interpreted as the result of multiple events of partial melting in the upper mantle.

As the Os content of a single micrometric PGM grain derives from a mantle region that was at least several m^3 in size, the variable Os composition of PGM in the Ojén chromitite would reflect the sampling of mantle sources on the 10-100 m scale. Therefore, large volumes of upper mantle would need to be melted to accumulate appreciable amounts of the incompatible Os (together with the other PGE), to produce the PGM-enriched chromitites at Ojén.

The fact that the parental melt(s) of the Ojen chromitites inherited the Os-isotopic signature of a mantle source that already had undergone multiple episodes is more prominently indicated by the wide range of Os model ages, which vary from Mesoproterozoic (1.40 Ga) to Cretaceous (90 Ma). Partial melting events younger than Panafrican (>0.5 Ga) have not been recorded the peridotites of the neighboring (equivalent) Ronda Massif (Marchesi et al., 2009 and references therein). This suggests that the PGM of chromitites are "tape recorders" of melting processes not already preserved in the peridotite. This observation is important if we wish to interpret the complete evolutionary history of the upper mantle in any given locality.

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