GEOCHEMISTRY OF PALLASITE OLIVINES AND THE ORIGIN OF MAIN-GROUP PALLASITES.

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Main-group pallasites (PMG) are mixtures of iron-nickel metal and magnesian olivine thought to have been formed at the core-mantle boundary of an asteroid [1]. Some have anomalous metal compositions (PMG-am) and a few have atypically ferroan olivines (PMG-as) [2]. PMG metal is consistent with an origin as a late fractionate of the IIIAB iron core [2]. Most PMG olivines have very similar Fe/Mg ratios, likely due to subsolidus redox reaction with the metal [3]. In contrast, minor and trace elements show substantial variation, which may be explained by either: (i) PMG were formed at a range of depths in the parent asteroid; the element variations reflect variations in igneous evolution with depth, (ii) the pallasite parent asteroid was chemically heterogeneous; the heterogeneity partially survived igneous processing, or (iii) PMG represent the core-mantle boundaries of several distinct parent asteroids [4, 5]. We have continued doing major, minor and trace elements by EMPA and INAA on a wider suite of PMG olivines, and have begun doing precise oxygen isotope analyses to test these hypotheses.

Manganese is homologous with Fe^{2+}, and can be used to distinguish between magmatic and redox processes as causes for Fe/Mg variations. PMG olivines have a range in molar 1000*Mn/Mg of 2.3-4.6 indicating substantial igneous fractionation in olivines with very similar Fe/Mg (0.138-0.148). The Mg-Mn-Fe distributions can be explained by a fractional crystallization-reduction model; higher Mn/Mg ratios reflect more evolved olivines while Fe/Mg is buffered by redox reactions with the metal. There is a positive association between Mn/Mg and Sc content that is consistent with igneous fractionation. However, most PMG olivines fall within a narrow Mn/Mg range (3.0-3.6), but these show a substantial range in Sc (1.00-2.29 µg/g). Assuming fractional crystallization, this Sc range could have resulted from ~65% crystallization of an ultramafic magma. This is inconsistent with formation at the core-mantle boundary of a single asteroid [4].

One alternative is that the PMG are fragments of several asteroids, and these could have had different initial Sc contents, Mn/Mg and differences in igneous history. Our preliminary O isotope data and those of [6, 7] do not support this, although the coverage of PMG olivines is incomplete.

The PMG-as Springwater is not easily fit in any scenario. Its olivine has among the highest Mn/Mg suggesting it is one of the most evolved, but the lowest Sc content suggesting it is the least evolved. The O isotopic composition of Springwater olivine is the same as that of other PMG. Thus there is no indication that it represents a distinct parent asteroid.

Our preliminary O isotopic data favor a single PMG parent asteroid. In this case, the olivines are more likely melt-residues, and that the parent asteroid was initially heterogeneous in chemical, but not isotopic, composition.

References: [1] Mittlefehldt et al. (1998) Reviews in Mineralogy 36, chp. 4. [2] Wasson & Choi (2003) GCA 67, 3079. [3] Righter et al. (1990) GCA 54, 1803. [4] Mittlefehldt (1999) LPS XXX, #1828. [5] Mittlefehldt (2005) MAPS 40, A104. [6] Greenwood et al. (2006) LPS XXXVII, #1768. [7] Ziegler et al. (2006) LPS XXXVIII, #1894.