The Significance of Fe exchange between Metal and Silicate minerals in mafic clasts from the howardites Kapoeta and Winterhaven.

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Introduction: Metal in achondrites may be derived either from chondritic precursors or during redox exchange reactions with the oxidized (silicate) portions of the sample [1]. The intrinsic diversity of assemblage within polymict achondrites of the HED suite (polymict eucrites, polymict diogenites, howardites and mesosiderites) requires that any metal located must be constrained both compositionally AND by lithological (textural) location if its origin is to be interpreted. The lithological components of polymict achondritic breccias (such as howardites) include a variety of igneous and metaigneous rock types including olivine bearing pyroxenites, a great variety of basaltic (or mafic) lithologies and SiO2 oversaturated assemblages and glasses [2]. These lithologies are dominated by silicates with a variety of oxides also present. In many lithic clasts and in the breccia derived from them, however, both metal and sulfides appear either as inclusions in minerals or as minor phases. The presence of metal implies that the oxygen fugacity at the time of formation of the assemblages was at or below the iron-wustite buffer and the metal is dominantly Fe^{o} supporting that implication [3]. The minor element content of achondrite metal includes both Ni and Co in varying abundances suggesting an affinity with 'chondritic' metal although the specific meteoritic source of the metal remains unclear [4]. Here we study systematic Fe-Ni-Co variations in metal to develop a metal oriented reduction exchange indicator for comparison with Fe-Mn-Mg variations in silicate in tight coexistence with the metal phase.

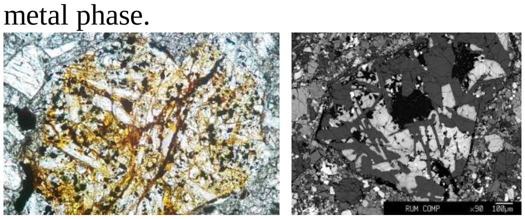

Figure 1: Metal bearing mafic clasts B9 and MM4 from Kapoeta AMNH3924-2

Results: The samples studied are unbrecciated, or thoroughly recrystallized mafic clasts from 2 howardites. Kapoeta howardite is very well known for its intrinsic heterogeneity and the variety of lithic (mafic) components occurring in it [5] including metal bearing lithic clasts; and Winterhaven, [6] a 2002 discovery, notable for unusual compositional trends in the silicate and oxide assemblages [7] that appears to have strong re-equilibration signatures with affinities to the metamorphic overprinting seen in mesosiderites [8] and has relatively abundant clasts in which metal and sulfide coexist with silicates.

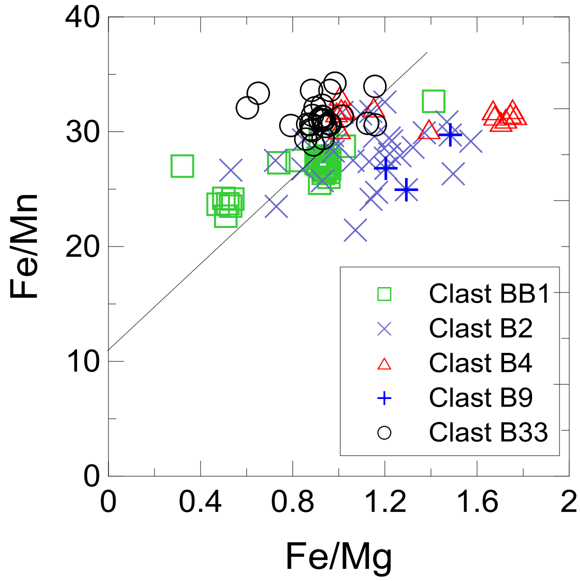

Figure 2: Fe-Mn-Mg of Pyroxene grains from individual clasts in Kapoeta.

Metal and pyroxene points were selected in both generally unbrecciated mafic clasts from Winterhaven and Kapoeta. In addition, a rectangular position array was analyzed over same area to assess heterogeneity distribution. The pyroxene analyses in lithic clasts are further distinguished between "far from metal" section and "close to metal" grains. The exchange of Fe between the pyroxene and iron metal during either magmatic or reduction processes can be seen in metal Fe-Ni-Co ratios and pyroxene Fe-Mn signature [9] [10]. Pyroxene in several Kapoeta and Winterhaven clasts has variable Fe/Mn both within individual clasts and from clast to clast. Figure 2 and 3 indicate both magmatic Fe/Mg AND Fe-loss trends seen as trajectories towards the origin of the graph. Metal in clasts from Winterhaven have variable abundances of pure Fe^o reduced from the coexisting silicates (Figure 3). Similar results are seen in Kapoeta.

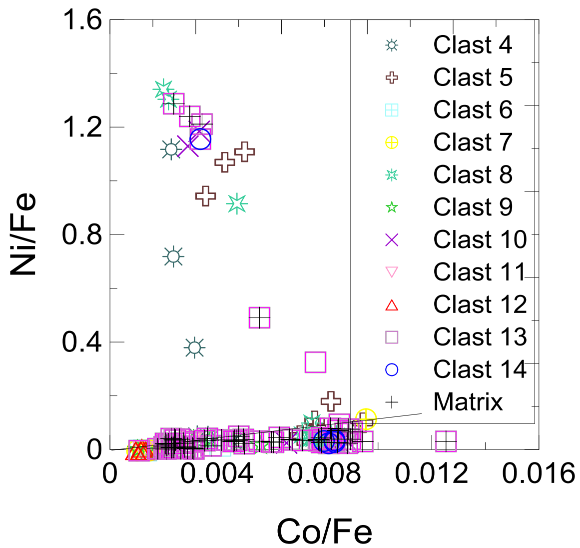

Figure 3: Matrix and lithic clast metal from Winterhaven showing Fe-Ni-Co values.

Discussion: The presence of metal in mafic clasts from howardites such as Kapoeta and Winterhaven reflects the low oxygen fugacity at which the clast equilibrated. However, the presence Ni-Co rich metal AND Ni-Co poor metal suggests different origins for each. The near surface of Vesta was clearly subjected to intense bombardment [11] resulting in impact generated melts containing generally chondritic metal (Ni-Co bearing). Whether the Ni-Co rich metal in the observed lithic clasts is of impact origin remains to be demonstrated, but seems a likely origin. Documenting siderophile trace element variations between individual lithic clasts (or the lack of them) will be needed to further constrain this hypothesis. The alternative that some of this is metal derived from the earliest segregation of the known large core of Vesta during the planetary differentiation so characteristic of this planetoid cannot yet be fully ruled out, but seems unlikely in view of the multi-stage history that must be responsible for the formation of the regolith of the body. Again trace element analysis of individual metal grains in clasts will be needed to identify any trend related to planetary scale metal differentiation. In contrast, pure Fe^0 implies a very different origin possibly unrelated to the early Vestan differentiation. Low Ni-Co metal dominates in many clasts and typically varies internally within the clasts. None of these metal grains appear to be absolutely pure Fe^0 as expected from simple reduction of silicate FeO. Instead mixing trends between a 'chondritic' and a pure Fe^0 end-member. Clearly some Ni-Co bearing metal is present in all cases but is diluted by the subsequent addition of Fe^0 presumably by reduction from adjacent silicate.

Conclusion: The combination of the non-magmatic variation of Fe/Mn in lithics reducing overall Fe/Mn below values of 35-40 seen in bulk howardites and several clasts with the observed Fe^0 enrichment of metal grains in these same unbrecciated clasts provides compelling evidence for exchange of iron between the silicates and metal phases during the genesis of the source lithologies or for metamorphic overprints on the howardites breccias. The timing of these events whether following initial planetary differentiation, post regolith formation, or both, remains to be determined.

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