

GEOCHEMISTRY AND ORIGIN OF METAL IN AUBRITES; I. Casanova¹, K. Keil², and H.E. Newsom¹. (1) Department of Geology and Institute of Meteoritics, University of New Mexico, Albuquerque NM 87131, USA. (2) Planetary Geosciences Division, Department of Geology and Geophysics, SOEST, University of Hawaii at Manoa, Honolulu HI 96822, USA.

Introduction. The study of aubritic metal can provide important clues about the origin and magmatic evolution of the enstatite achondrite parent body(ies). We have studied the metal present in aubrites with the aim of constraining ideas about their igneous and metamorphic history. In this group of differentiated meteorites, metallic Fe,Ni occurs as fine-grained particles of several microns to a few mm in size (commonly referred to as matrix metal, [1]), and as large nodules of up to 2 cm in diameter. Microprobe analyses of over 200 different metallic grains reveal no correlation between composition and dimension, suggesting that the sizes of Fe,Ni particles in aubrites represent different degrees of comminution, and not chemically different populations.

Thermal history. Previous authors determined apparent cooling rates of taenite grains in the brecciated matrix and in a pyroxenitic clast of Norton County [1]. If we take into account the effect of phosphorous [2], the cooling rates for the analyzed aubritic metal could be on the order of 5-50 deg/Ma, thus implying a long cooling history for the aubrite parent body. Our calculations of apparent cooling rates for taenite-bearing metal particles in three different aubrites (Norton County, ALH 84007 and ALHA 78113; Fig. 1) are in good agreement with previous results. However, a recent study suggests that the presence of Si can substantially increase the estimated cooling rate (e.g., 1 wt.% Si in a 89.7 wt.% Fe - 9.2 wt.% Ni - 0.1 wt.% P alloy increases the cooling rate by a factor of approximately 2.5) [3]. Therefore, the actual cooling rate of aubritic metal may be estimated as follows: 1-10 deg/Ma (apparent) x 3-6 (effect of 0.05 wt.% P) x 2.5 (effect of 1 wt.% Si) = 7-150 deg/Ma. This interval is roughly three times larger than the cooling rate values reported in previous estimates [1]. The 7-150 deg/Ma range in metallographic cooling rates implies burial depths of approximately 50 km (for 7 deg/Ma) to <10 km (for 150 deg/Ma) in a parent body of 100 km in radius, at an initial temperature of 1000 °C, assuming thermal conductivities like those of silicate materials [4]. Therefore, it is possible that metal particles in aubrites equilibrated at a variety of depths (<10-50 km) in their parent body. Although this argument does not constitute by itself evidence for the hypothesis of breakup and reassembly of the aubrite parent body [1], it offers an alternative interpretation for the apparently small range of cooling rates of aubrites when the joint effects of Si and P are considered. Perryite (Ni,Fe)₈(Si,P)₃ [5] commonly appears as an exsolution product in metallic Fe,Ni from aubrites, parallel to the (111) direction of the kamacite host [6]. The study of the compositions of perryite grains in the light of the sub-solidus Fe-Ni-Si phase diagram [7] suggests that the previously reported [1] Fe-poor and Fe-rich perryites in Norton County might be indicative of materials that equilibrated at different temperatures (between approximately 450 and 1000 °C), and were subsequently mixed together in the Norton County breccia. This would require substantial differences in cooling rates for metal nodules with Fe-poor and Fe-rich perryites. Such interpretation is, in principle, consistent with the different equilibration temperatures suggested by the nickel contents of taenite-bearing metal inclusions discussed earlier. The most important limitation to the understanding of perryite compositions using the proposed approach arises from the lack of information about the effect of a few weight percent P in the crystallization of Fe-Ni-Si alloys (perryites in Horse Creek, Mt. Egerton and Norton County contain 2.4-5 wt.% P). This requires the study of the Fe-Ni-Si-P quaternary phase diagram and, until some information on this complex system is available, the interpretations given above can only be considered as an approximation to the potential significance of perryite exsolution in the thermal history of aubritic metal.

Metal Segregation. The abundances of Ni, Au, Re and Ir in the silicate fraction of aubrites decrease with increasing metal/silicate partition coefficient of the element (Fig. 2). This observation is indicative of metal segregation (upon melting) occurring in the aubrite parent body. At the present stage of this study, no definitive interpretation can be given to the large variation of the abundances of siderophile elements in aubritic silicates [8]. These large compositional ranges might reflect (1) variations in metal/silicate partition coefficients, and/or (2) a very heterogeneous distribution of the metal prior to or during the main melting episode. The large variability of the contents of Si in solid solution in aubritic metal might be indicative of local variations in oxygen fugacity [6] and, consequently, very different metal/silicate partitioning behavior for the same element may be found in a single parent body with variable local equilibrium conditions. An alternative possibility to explain

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such variation is that, upon melting of the aubrite precursor material, the metal segregated and concentrated heterogeneously in different parts of the parent body. As a result of this, the silicates from zones with higher amounts of metal would become depleted in siderophiles to a larger extent than those from areas with relatively less metal. The understanding of this scenario opens new questions about the efficiency of the metal segregation process in the aubrite parent body (*i.e.*, the likelihood of formation of isolated metal pods as opposed to a metallic core).

Core Formation. The different possibilities for the origin of aubritic metal were discussed in an earlier work [9]. Fractional crystallization of a metallic magma would induce large variations in the concentrations of certain siderophiles [10]. The aubritic metal inclusions analyzed in this work and others [8,9], show siderophile element/Ni ratios within a factor of 5 with respect to CI abundances, except for Cr which displays a strong depletion (approximately 500 times with respect to CI composition; this may be attributed to preferential partitioning into Cr-rich sulfide phases characteristic of aubrites, such as daubréelite and caswellsilverite). Therefore, the possibility that the studied metal nuggets represent fragments of a fractionally crystallized core can, in principle, be ruled out. This does not necessarily imply that the aubrite parent body did not undergo a core formation process. In fact, the observed low abundance of metal (generally < 4 wt.% [6]) and the previously discussed correlation of the siderophile element contents in the silicates with their increasing siderophile affinity (metal/silicate distribution coefficients) suggest that metal segregation was an extensive process in the aubrite parental material and that, as a consequence of this, some of the metal might have sunk efficiently to form a small (unsampled) core.

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