INCLUSIONS IN THE METAL OF ALH85085: NEW CLUES TO A CONDENSATION ORIGIN?

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Inclusions in chondritic metal have been studied as possible tracers of the evolution of their host phase [1,2]. In H-chondrites and the reduced CV3 chondrites Leoville and Efremovka, these consist of chromite, phosphates and silica/silicates that we believe to have been formed from the precipitation as simple oxides of Cr, P and Si initially in solid solution in the Fe-Ni, and to have evolved chemically in the course of metamorphism. In order to assess the origin of these solid solutions, our study has been extended to the metal of Renazzo [3]. In this meteorite we found pure silica and silicate round inclusions, some of them possibly vitrous, together with a chromium sulfide (possibly daubreelite) and chromites. The most striking feature, however, was the homogeneity of the metal grains within one chondrule with respect to both their inclusions and their dissolved Cr and P contents. This led us to infer that chondrule formation might have been responsible either for the integration of P, Cr, and Si into Fe-Ni, or, if solid solutions were produced as a result of condensation in the solar nebula, for reequilibration of the metal grains within one chondrule. A logical next step was to study metal in ALH85085, as this meteorite appears related to Renazzo and bears features that are believed to derive from nebular processes.

Metal in ALH85085 is more abundant than in any other chondritic assemblage (with the possible exception of Bencubbin-Weatherford): >20 vol% [4,5]. A significant fraction of the grains contain measurable amounts of dissolved Cr or P and some of them also Si up to 11 wt% (this work). This metal is believed to be the product of nebular condensation [5,6]. Little is known about the condensation of the highly Si-enriched grains: this might require either local high pressures or a fractionated nebula [7,8].

Only a small percentage of the grains bear inclusions (<5%). The most abundant of these consist of troilite blebs containing various amounts of Cr: these can be very small (<1 μm) and widespread in the metal or larger (up to a few μm) and less numerous. Metal grains bearing these inclusions show a strong similarity with those of Bencubbin [8]. We believe the unusual aspect of this troilite-metal association could result from the cooling of a liquid containing S, Fe, Ni and Cr, formed from the reheating of Fe-Ni grains containing various amounts of dissolved Cr and surrounded by a troilite coat, possibly in the same annealing period that converted martensite to plessite in the >10 wt% Ni grains [6]. Silica/silicate inclusions are also fairly frequent: these appear round, and, like the Cr-bearing troilite, small (<1 μm) and widespread or larger (up to a few μm) and less numerous: such a feature shows a clear similarity with some metal grains of Renazzo [3].

The type and distribution of the most abundant inclusions in the metal grains of ALH85085 thus clearly confirms the relationship between this meteorite and the Renazzo-Bencubbin group. However ALH85085 also presents distinctive features that may shed some light on the diversity of Fe-Ni when not processed in chondrules or processed in very distinctive environments. (1): Presence of scarce phosphate (merrillite) inclusions. Up to now phosphates in metal have been observed in ordinary chondrites [1] or in reduced CV3 chondrites [2], but not in Renazzo in which P in the metal was only found in dissolved form, nor in Bencubbin where it occasionally builds schreibersite inclusions. The coexistence in the same meteorite of both oxidised and reduced P in metal points to the wide range of oxido-reduction conditions experienced by the different grains of the object. (2): A Si-rich (6 wt%)
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A grain has been observed to contain a ~3μm euhedral inclusion (Fig. 1) consisting of (approx., in wt%) SiO₂: 45, CaO: 45, Al₂O₃: 4.5, FeO: 4 and TiO₂: 1.8; a composition that could account for an Al and Ti enriched wollastonite. (3) Another Si-rich grain (7 wt%) shown on Fig. 2 bore another small (0.5 μm) inclusion containing Ca and Si (indicated by arrow), together with two larger (~1x2-3μm) inclusions (grey on picture) consisting in a Fe-Cr-phosphide (approx., wt%: Fe:50, P:22, Cr:21, Ni:4, Mn:3). The existence of such a phosphide had already been reported [9] and its composition appears fairly constant. (4) An intermediate between this Fe-Cr-phosphide and schreibersite has also been found in a grain containing 1 wt% Cr and no detectable dissolved Si, but small numerous silica inclusions.

We find it very unlikely that Ca-silicates could have been formed out of metal. On the contrary, the composition of the larger one points to an origin as a high temperature condensate. These condensates would subsequently have been trapped in the highly Si, P and Cr rich metal condensing in the same region or at the same epoch. The few grains we now observe would have evolved little since, and especially not have been changed in the chondrule formation process, whereas the grain containing the intermediate phosphide and silica inclusions instead of dissolved Si would have undergone at least a partial transformation. Such grains might have been preserved in ALH85085 as this meteorite probably represents material that was able to accrete during a higher temperature, perhaps earlier, epoch than is recorded in most chondrites [5]. In view of this interpretation, it appears unlikely that chondrule formation could be, as a rule, responsible for the formation of the solid solutions. On the contrary, we believe a wide range of Si-, P- and Cr-containing metal originates from condensation, and chondrule formation acts as an homogenization process. In such a case, the presence in their chondrule precursor of one or a few Si-rich grains such as the ones observed in ALH85085 could account for the occasional chondrules displaying a very large abundance of silica inclusions, together with a fairly high Cr and P content such as chondrule I2 in Renazzo [3]. Homogeneisation during chondrule formation might, moreover, explain why most metal grains seem to depart from the condensation curves with respect to their P- and Cr-content.

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