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Ni and Co content of chondritic metal

We have made a detailed study of the metal phases in some chondrites. Axon and Goldstein have reported[1] microprobe measurements of the Ni and Co contents at the interfaces between contiguous α and γ phases in seven metallic particles of high Co content from Apollo 14 and 15 lunar soils. The three particles of highest Co content had α phase in contact with clear homogeneous γ phases (Fig. 1), whereas the particles of lower Co content (Fig. 1) had Widmanstätten spindles of α phase in a matrix of high Ni γ phase in a manner analogous to that observed in certain Ni-rich ataxite irons. Axon and Goldstein have expressed the view that the Co contents of these particles are "higher than the meteorites of similar structure" and that they must have come from a different source.

In two instances, Olivenza (LL5) and Khanpur (LL5), we have encountered spindle-like exsolutions of the high-Co α phase in a matrix of high-Ni–high-Co γ phase. The α–γ interface values for the two meteorites are plotted together with measured bulk compositions in Fig. 1. It can be seen that the meteoritic metal is similar in structure and composition to the lunar soil particles, although the interface composition of the meteoritic γ phase shows less enrichment of Ni. In terms of the binary Fe–Ni equilibrium diagram, the LL5 metal seems to have γ-phase interface compositions appropriate to $\sim$410 °C, in contrast to the value of $\sim$350 °C observed for the lunar material.

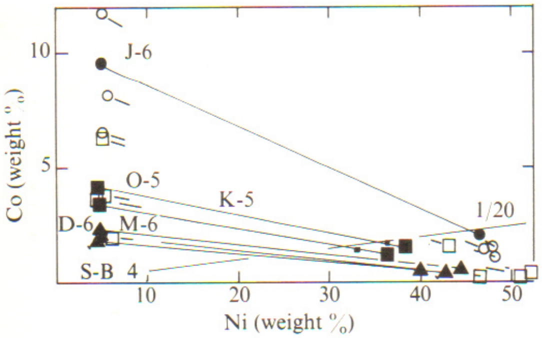

Fig. 1 Interface compositions for α and γ phases in the metal of LL chondrites (solid symbols) compared with high cobalt metal in lunar soils (open symbols). Circles, Clear γ phases; squares, ataxite type structures; triangles = zoned γ phases. J, Jelica; O, Olivenza; K, Khanpur; M. Mangwendi; D, Dhurmsala; S-B, Soko-Banja. Number, petrological grade of LL chondrites.

Figure 1 also includes α–γ interface values for Jelica (LL6). In this meteorite the α phase is extremely rare. When the α and γ phases are contiguous in Jelica, however, the γ phase is clear and compositionally unzoned, and in this case the bulk composition of the metal is almost coincident with the reported γ-phase composition. The bulk metal compositions for Khanpur, Olivenza and Jelica have a Co–Ni ratio of 1: 20 (Fig. 1). This represents the cosmic abundance ratio of the two elements. Therefore, the bulk Ni–Co contents of the metal phases in these three LL chondrites are consistent with a Prior's Law relationship in which iron partitions between the metal and silicate phases, whereas the more noble elements Ni and Co concentrate exclusively in the metal. The bulk composition of the metal is first established according to Prior's Law, and the distribution of Ni and Co between the α and γ phases is then controlled by tie-line relationships in the Fe–Ni–Co ternary equilibrium diagram. The lower part of Fig. 1 contains data for Mangwendi (LL6), Dhurmsala (LL6) and Soko-Banja (LL4). In each of these instances the α phase is contiguous with a compositionally zoned γ phase.

None of the samples in Fig. 1 shows visible signs of reheating in the metal phases. They are all observed falls, free from terrestrial corrosion and ablation heating. The silicate portions of these samples have been examined by Sears and Mills[2] who have given details of identification.

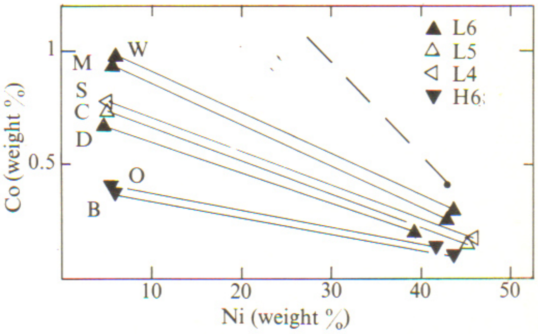

Fig. 2 Interface compositions between α and zoned γ phases in L and H chondrites. The broken line represents the lowest line of Fig. 1. W, Wold Cottage; M, Mauerkirchen; S, Saratov; C, Crumlin; D, Durala; O, Ogi; B, Butsura.

The same criteria were used to select an array of H and L chondrites from Sears' and Mills' samples. The results are shown in Fig. 2. The Ni content of the α phase is essentially the same in both Figs 1 and 2, but there is a distinct Co hiatus of about 1% between the LLα (Fig. 1) and the Lα phases (Fig. 2). There is also a marked change in the slope of the Ni–Co tie-lines between Figs 1 and 2, as may be seen from the broken line in Fig. 2, which represents part of the lowest tie-line (Soko-Banja) of Fig. 1.

No metallurgical reheating effects were observed in the samples shown in Fig. 2, but the kamacite (α phase) in both Wold Cottage (L6) and Mauerkirchen (L6) contained minor ε-shock transformation of the type that Axon and Boustead[3] have shown does not alter pre-existing compositions at α–γ interfaces. Within the limits of this investigation, no consistent differences emerged between the petrological grades L4, L5, L6. Any hiatus between the Co contents of α metal in H and L chondrites is, however, much less pronounced than that between L and LL chondrites. In contrast, the silicate compositions seem to show the reverse effect.

Reheating or shock-heating effects were identified in the metal from three of the samples from ref. 2 that are not plotted in Fig. 2. They are: Holbrook (L6), (α=5.8 Ni, 1.15 Co; γ=29.0 Ni, 0.45 Co); Gambat (L6), (2.86, 0.86; 16.2, 0.26), and Tennasilm (L4) (3.98, 0.75; 25.6, 0.25). Lines joining the α and γ compositions in these reheated samples of metal cross the assembly of Fig. 2 at a steep angle. It is noteworthy that the interface data for the metal in these reheated L chondrites are similar to those reported by Goldstein *et al.*[4] for two-phase α–γ or α–plessite structures in metal from Apollo 17 soils.

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