THE ABSENCE OF NICKEL ISOTOPIC ANOMALY IN IRON METEORITE METAL AND SULFIDE

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Introduction: Evidence for 60Fe (τ1/2 = 1.5 Ma) has been reported in cocrusts and chondrites [1–4], consisting of excesses in 60Ni, in phases with high Fe/Ni. Recent work on iron meteorites, using MC-ICP-MS, indicates a complex picture. Quitte et al. [5] analyzed FeNi and sulfide from iron meteorites and found no 60Ni effects in the FeNi at ±0.3 cu. However, in some sulfides, they found large and correlated effects in 60Ni and s6DNi. In irons, Bizzarro et al. [6] claimed small shifts in 60Ni and 61Ni. Cook et al. [7] showed shifts of ~0.5 cu in 60Ni in several sulfides and up to ~2.4 cu in Mundrabilla sulfide.

In this study, using TIMS, we determined that, for samples of FeNi from 6 iron meteorites of different groups (Bennet County, Bulla Roca, Gibeon, Piñon, Odessa, and Mundrabilla), the 60Ni are the same as terrestrial normal to within ±0.1 cu and s6DNi are normal to ±0.5 cu. For the observed 60Fe/60Fe in FeNi as low as 7 and (60Fe/60Fe) < 2.4 × 10^-9, we expect a deficit in 60Ni of ~0.1 cu, which is not resolvable. The preliminary Ni data [8] on sulfide samples have larger uncertainties, due to low Ni concentrations and possibly some residual mass interference problems (CaF ions). After further purification, the Ni data on sulfide samples from Odessa, Toluca, and Mundrabilla (Fig. 1) show normal Ni isotopic ratios within limits of errors. We do not confirm deficits in 60Ni in sulfides in Mundrabilla or other iron meteorites. The data show no evidence for 60Ni excesses and yield limits on 60Fe/60Fe of <2 × 10^-9.

Fig. 1.

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Introduction: Native Cu in chondritic meteorites is an abundant accessory phase associated with troilite and metal. Ramdohr [1, 2] interpreted its occurrence as the result of exsolution from taenite during cooling. In a recent report, [3] claimed metallic Cu to have formed by shock. No evidence was presented supporting the shock origin nor a chemical mass balance to explain the association of metallic copper with troilite symplectites. We investigated this assemblage in the LL6 chondrite Benguerir to clarify the origin of the assemblage.

Results: SEM and quantitative electron microprobe analyses conducted on the four-phase assemblage, native Cu + troilite + kamacite + taenite, revealed chemical compositions that cannot be produced by exsolution from taenite during a shock event. The native copper grains enclosed in FeNi are usually surrounded by a Ni-poor but Co-rich kamacite. In Ustî Nad Orlici the Ni-poor kamacite contains up to 1.77 wt% Co. No depletion in the adjacent taenite was detected in profiles across taenite-kamacite-copper thus negating formation of both native Cu and cobaltian kamacite by exsolution from taenite. In the LL6 chondrite Benguerir a similar assemblage was encountered. The cobaltian kamacite surrounding the Cu grains were found to be enormously enriched in Co (up to 14.3 wt%) and depleted in Ni. This cannot be explained by exsolution from taenite during cooling nor by a shock-induced heat event. The symplectitic texture of FeS, the unusual enrichment of the kamacite engulfing the native Cu specks in Co, and the lack of Ni diffusion profiles in the neighboring taenite strongly suggests formation of the assemblage through breakdown of a meta-stable complex sulfide species containing Fe, Cu, and Co as major constituents. We envisage a pentlandite-type mineral as a precursor that broke down to this assemblage according to the idealized reaction:

\[(Fe_{0.83}Co_{0.17}Cu_{0.33})_8S_8 \rightarrow 8FeS + 0.33Cu + 0.66(FeCo)\]

Both meteorites belong to the shock stage S2 [4] and no evidence for melting veins or pockets, no recrystallization of troilite and no maskelynite. Furthermore, both troilite and ilmenite grains encountered depict twin lamellae // (10-11) respectively, indicating formation at P < 2 GPa and low post-shock temperature (<200 °C).

Conclusions: This assemblage did not form by exsolution from taenite by shock but rather through decomposition of a meta-stable complex sulfide during low-temperature cooling in the parent body.