LARGE IRON SPHERULES FROM THE TRANSANTARCTIC MOUNTAINS: WHERE IS THE NICKEL?

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We studied 27 large (>400 µm) iron-type (I) cosmic spherules (made essentially of magnetite and wustite) representative of the Transantarctic Mountains collection [1], together with 5 G-type (G) spherules (made of iron oxides and silicates in similar proportions). They were characterized by magnetic and density measurements, SEM imaging and microprobe analysis of polished sections. Presence of metal is easily detected by magnetic hysteresis (which enables discrimination from magnetite) while density is less useful due to variable porosity (from 1 to 50 % based on image analysis). Only two I spherules contain large metal beads, while several other show obvious signs of recent expulsion of such metal beads. These two types are wustite-rich (around 80%). One spherule contains a OsIr bead (6 µm in diameter) while 18 spherules contain disseminated Pt-rich submicrometric inclusions (mostly in magnetite). We studied the partitioning of Ni and other trace elements between metal, wustite and magnetite using EMPA. These phases show strongly decreasing affinity for Ni, leading to nearly Ni-free magnetites (down to 0.2 wt% NiO). The average Ni ratio for metal/wustite and wustite/magnetite are 50 and 1.7, respectively. Submicron sized grains of a Ni-rich phase (likely NiO) are frequently observed at the contact between the two oxide phases. This partitioning associated with the likely expulsion of Ni-rich metal beads during atmospheric flight would explain why I spherules appear on average poorer in Ni than chondritic kamacite, based on analyses of wustite and magnetite. Preferential evaporation of Ni is not apparent as the periphery of the spherules is systematically richer in Ni than the center.

On the other hand, Ni/Co ratio are on average similar to those of chondritic kamacite (ca. 10), and this ratio does not change drastically from metal to wustite and from wustite to magnetite, as well as from the center to the periphery of the spherule. Large (>400 µm) kamacite grains or aggregates should therefore be the main precursor of our spherules. Even accounting for Ni subtraction by Ni drainage in the metal beads and expulsion or undersampling of submicron Ni-rich phases, we do not have clear evidences for a taenite precursor (that has Ni/Co >100). We suspect a precursor grain (kamacite vs taenite) size effect.

Lack of external EDS detection of Ni is not a criteria to exclude an extraterrestrial origin for an iron oxide spherule, as most I spherules exhibit an external magnetite layer. Instead we propose that terrestrial I-like spherules can be distinguished based on the absence of wustite (in the interior of the spherule), which is ubiquitous and conspicuous (at least 20 vol%) not only in our I spherules but also in much smaller ones [e.g. 1-3].

Some wustite-rich G type spherules appear to form a continuum with I spherules, and are thus likely the product of melting of metal+silicates+oxides aggregates in variable proportions. This mixing is also signed by significant amount of Cr, Si, Al and Mg in I spherules (in magnetites up to 1.3, 0.5, 0.4 and 0.3 oxide wt%, respectively). We may have a G-type with a metal core, although this metal is nearly entirely weathered.