

Copper-rich alteration of micrometeorites collected near Calama, Atacama Desert

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This study investigates terrestrial alteration of micrometeorites using copper concentrations as a tracer. We analysed micrometeorites from the Atacama Desert near Calama, Chile, 25 km from the Chuquibambilla mine, world's largest open pit copper mine. Bulk sediment μ XRF analysis performed at AMGC revealed a copper-rich composition. To study the micrometeorite flux and preservation in a hot desert, sediment was sampled from a 1 m² surface at 2 cm depth, using 500 g in this study. 500 particles in total were extracted across multiple size fractions between 2 mm and 63 μ m. The major element composition of these particles is mapped using μ XRF and 173 promising spherules were selected for SEM-EDS imaging and analysis, while 9 were selected for further oxygen isotope analysis.

SEM-EDS revealed well-preserved S-type (14), I-type (5), G-type (12) micrometeorites, showing typical micrometeorite texture like magnetite dendrites in a glassy matrix (G-type), metal beads (I-type) and olivine crystals inside glassy matrix (S-type). These spherules show bulk copper content up to 14 wt% (2.79 wt% average), with Cu-bearing phases observed as rounded inclusions on polished sections ranging from the nm-scale up to a few μ m, or as homogeneous replacement of single-phase spherules. The copper-minerals range from covellite (CuS), bornite (Cu₅FeS₄), and chalcopyrite (CuFeS₂), with minor contributions of As and Sb, which has not been described in literature as a typical weathering feature of micrometeorites.

Triple-oxygen isotope analysis using SIMS (Figure 1) assessed parent body origin and atmospheric entry effects. The $\Delta^{17}\text{O}$ vs $\delta^{18}\text{O}$ plot [1] shows spherules of major micrometeorite groups. Most particles link to carbonaceous chondrites, and one I-type falls between the TFL and ordinary chondrite fields. Five spherules (without copper) plot near the TFL ($\sim \delta^{17}\text{O} = 0.52 \times \delta^{18}\text{O}$ [2]), suggesting a terrestrial overprint. Remarkably, five Cu-bearing spherules preserve partial extraterrestrial oxygen signatures. Their textures combined with their major composition and isotopic data suggest that those spherules could have an extraterrestrial origin while showing Cu-rich terrestrial weathering.

References: [1] Suavet et al. (2010) Earth Planet. Sci. Lett. 293:313-320. [2] Clayton (1993) Annu. Rev. Earth. Planet. Sci. 21:115-149. [3] Thiemens and Brenninkmeijer (1995) Geophys. Res. Lett. 22(3):255-257.

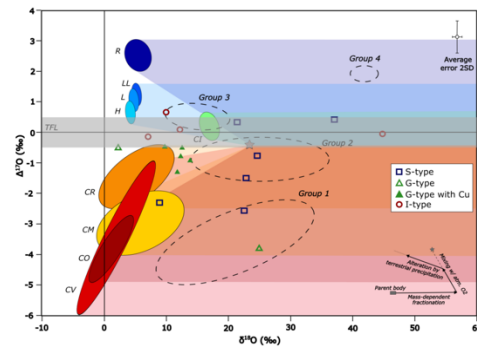


Figure 1: Triple oxygen data by SIMS of the micrometeorites plotted with $\delta^{18}\text{O}$ (‰) versus $\Delta^{17}\text{O}$ (‰). S-, G-, and I-type micrometeorites are plotted in the figure in relation to the micrometeorite groups and meteorite parent body sources. The solid line and grey rectangle represent the TFL ($\sim \delta^{17}\text{O} = 0.52 \times \delta^{18}\text{O}$; [2]). The star represents the present average atmospheric isotopic composition of oxygen around the stratosphere-mesosphere transition ($\delta^{18}\text{O} \sim 23.5\text{‰}$ and $\delta^{17}\text{O} \sim 11.8\text{‰}$; [3]). The plot is adapted from [1]. The average error is 2SD.