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Zinc and magnesium in micrometeorite chrome spinel crystals: tracing parent-body processing, atmospheric entry, and terrestrial alteration

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Micrometeorites constitute a major fraction of the extraterrestrial material accreting to Earth. Due to their small size, these particles are highly susceptible to melting during atmospheric entry and to post-depositional terrestrial weathering [1]. Refractory, weather-resistant chromite ($FeCr_2O_4$), and more broadly chrome spinel, commonly survives these processes as a relict phase in micrometeorites and the geological record, where it serves as a proxy for the flux of extraterrestrial material to Earth [2]. However, parent-body metamorphism, atmospheric heating, and terrestrial alteration may modify its composition, complicating interpretation.

In this study, we found that zinc (Zn) and magnesium (Mg) are useful as elemental tracers of Cr-spinel alteration in micrometeorites from the Transantarctic Mountains and Sør Rondane Mountains (Antarctica). Micrometeorites were sectioned and characterised by SEM-EDS after optical extraction and μXRF preselection. Cr-spinel-bearing cross-sections were mapped by LA-ICP-TOF-MS. Additionally, Cr-spinels extracted by dissolution from H5 chondrite El Hammami and previously published data of micrometeorite Cr-spinels [3] were used for comparison.

Uniformly Zn-enriched Cr-spinels likely reflect recrystallisation in the parent body [4]. Atmospheric entry produces a distinct symmetrically developed transition zone surrounding Cr-spinel grains, reflecting partial re-equilibration with the melt. An asymmetric intrusion of Zn along surfaces of the grain exposed to the environment is observed, consistent with terrestrial alteration. Magnesium systematics further distinguish alteration processes; Cr-spinels from H5 chondrites cluster around 2.8 wt% MgO (max. 5.4 wt%), whereas micrometeoritic chromites display significantly higher MgO contents (2-16 wt%; [3]), consistent with Mg enrichment during atmospheric entry [5].

By distinguishing Zn and Mg signatures associated with terrestrial weathering, atmospheric heating, and parent-body metamorphism, this study refines the interpretation of micrometeoritic Cr-spinel chemistry. The constraints improve the reliability of Cr-spinel as a tracer of the extraterrestrial flux and enhance its application in reconstructing interactions between the Solar System and Earth in deep time.

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