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Quantitative micro-XRF analysis of micrometeorites: evaluation against EPMA and analytical limitations

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Micrometeorites represent a continuous influx of extraterrestrial material to Earth and accumulate in diverse environments such as Antarctica, deep-sea sediments, Greenland, and urban rooftops. In addition to modern collections, fossil micrometeorites preserved in ancient sedimentary rocks provide a long-term archive of the past extraterrestrial flux. Their classification relies firstly on both morphological and internal textural features that help characterize them. Secondly, geochemical characterization for elemental composition and isotopic studies helps in the micrometeorite classification [1,2]. Conventional in-situ geochemical workflows require embedding of individual particles in epoxy and polishing to expose internal sections prior to e.g. scanning electron microscopy (SEM) and electron probe microanalysis (EPMA) or Secondary Ion Mass Spectrometry (SIMS). While effective, this preparation step is destructive and limits the preservation of the original whole particle. Here, we evaluate micro-X-ray fluorescence spectrometry (µXRF) as a rapid, non-destructive alternative for bulk elemental characterization, as it allows elemental analysis of intact micrometeorites without extensive sample preparation, sectioning or polishing, enabling high-throughput geochemical screening while preserving particle integrity. High-resolution element maps were produced with the Bruker M4 Tornado Plus µXRF instrument at VUB using a 20 µm spot size and variable acquisition times ranging from 2 to 100 ms per pixel. We then systematically compare quantitative µXRF data with EPMA results to assess analytical accuracy and precision, limits of detection, and potential matrix effects across different micrometeorite types. Our results demonstrate that µXRF provides robust bulk compositional data for major and minor elements which helps to effectively distinguish micrometeorite types prior to destructive preparation. While EPMA remains essential for detailed *in-situ* micrometer-scale analysis, µXRF offers a powerful complementary tool for rapid classification of a large sample set and for sample selection for subsequent detailed analyses. The integration of non-destructive µXRF screening with established morphological approaches and microanalytical techniques enhances efficiency, preserves rare material, and enables statistically robust characterization of micrometeorite collections, strengthening both modern and fossil cosmic dust studies.

References:

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