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Automated µXRF workflow for efficient characterization of large micrometeorite collections: application to the Antarctic Belgica Mountains

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MicroX-ray fluorescence spectrometry (µXRF) enables rapid, non-destructive elemental mapping of micrometer-sized geological particles [1]. However, extracting bulk compositions from thousands of individual grains remains challenging. Manual outlining of particles is time-consuming, operator-dependent, and limits reproducibility, restricting µXRF largely to an initial screening tool prior to more detailed analyses [2,3].

Here, we introduce a standardized, efficient workflow that combines µXRF mapping with automated particle recognition and compositional extraction, transforming µXRF into a quantitative tool for large populations of particles. The developed workflow integrates Bruker ESPRIT Feature software to automatically delineate individual particles directly from µXRF maps and determine their bulk elemental composition. In addition to automated particle counting and size determination, the method also enables immediate classification of particles based on user-defined compositional thresholds, allowing rapid identification of compositional clusters within large datasets.

We apply this workflow to more than 9000 micrometeorites (ranging from 38 to 2000 µm in size) recovered from the Belgica Mountains, Antarctica. We evaluate optimal analytical conditions for different particle size ranges to ensure accurate compositional determination across the entire size spectrum. The automated feature extraction provides a robust size distribution for the collection and enables rapid discrimination between terrestrial and extraterrestrial material based on elemental criteria.

This approach significantly accelerates the characterization of large micrometeorite collections while minimizing operator bias and improving reproducibility. By standardizing the µXRF-based particle analysis, this method enhances comparability between collections, hence granting access to the full statistical power of large extraterrestrial dust datasets and opening new possibilities for population-level studies of cosmic dust flux and parent body diversity. Moreover, the versatility of the presented workflow makes it applicable to a wide range of large particle collections of similar size ranges, including microfossils or minerals such as garnets or zircons.

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