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Reconstructing Paleozoic Variations in Extraterrestrial Flux Using Fossil Micrometeorites

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The flux of extraterrestrial material to Earth is governed by asteroid-belt breakup events and cometary debris. These materials generate everything from large impact structures to micrometer-scale cosmic dust, the latter dominating the extraterrestrial mass flux [1-3]. Until recently, fine-grained material was assumed not to survive geological timescales, limiting reconstructions of past dust flux to indirect proxies such as iridium enrichments, ^{3}He anomalies, or relict chrome-spinel grains.

The extracted fossil micrometeorites (MMs; 10–2000 μm [4]) derive from stratigraphically constrained Cambrian (~500 Ma) and Late Permian (~254 Ma) sequences and are compared with populations from the Mid-Ordovician (~470 Ma) and Late Devonian–Early Carboniferous (~360 Ma). Micrometeorites were recovered using an optimized acid dissolution protocol [5] and classified based on textural and mineralogical criteria [6]. Results are compared with existing data from chrome-spinel grains, previously applied as robust proxies for cosmic dust.

All intervals are dominated by particles <125 μm. The Cambrian, Late Permian, and mid-Ordovician contain similar abundances (~10 MMs/kg), while the Early Carboniferous shows higher values (~20 MMs/kg). I-type spherules predominate in these intervals. The Late Devonian exhibits higher abundances (~22 MMs/kg) and is enriched in I- and G-type spherules, although S-types persist despite weathering. Elemental and triple-oxygen isotope analyses allow parent-body affinities to be assessed and extraterrestrial input quantified.

These results indicate measurable changes in MM abundance and compositional diversity within and between intervals, consistent with temporally variable dust flux and evolving parent-body contributions. Fossil micrometeorites provide a direct, stratigraphically resolved record of extraterrestrial accretion, enabling reconstruction of asteroid belt evolution and potential cometary contributions through deep time. This approach establishes MMs as a robust archive tracking long-term Solar System dynamical processes and their interactions with Earth system.

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