Cosmic Dust Flux During the Quaternary: The Record of Large Scoriaceous and Unmelted Micrometeorites From the Transantarctic Mountains Collection

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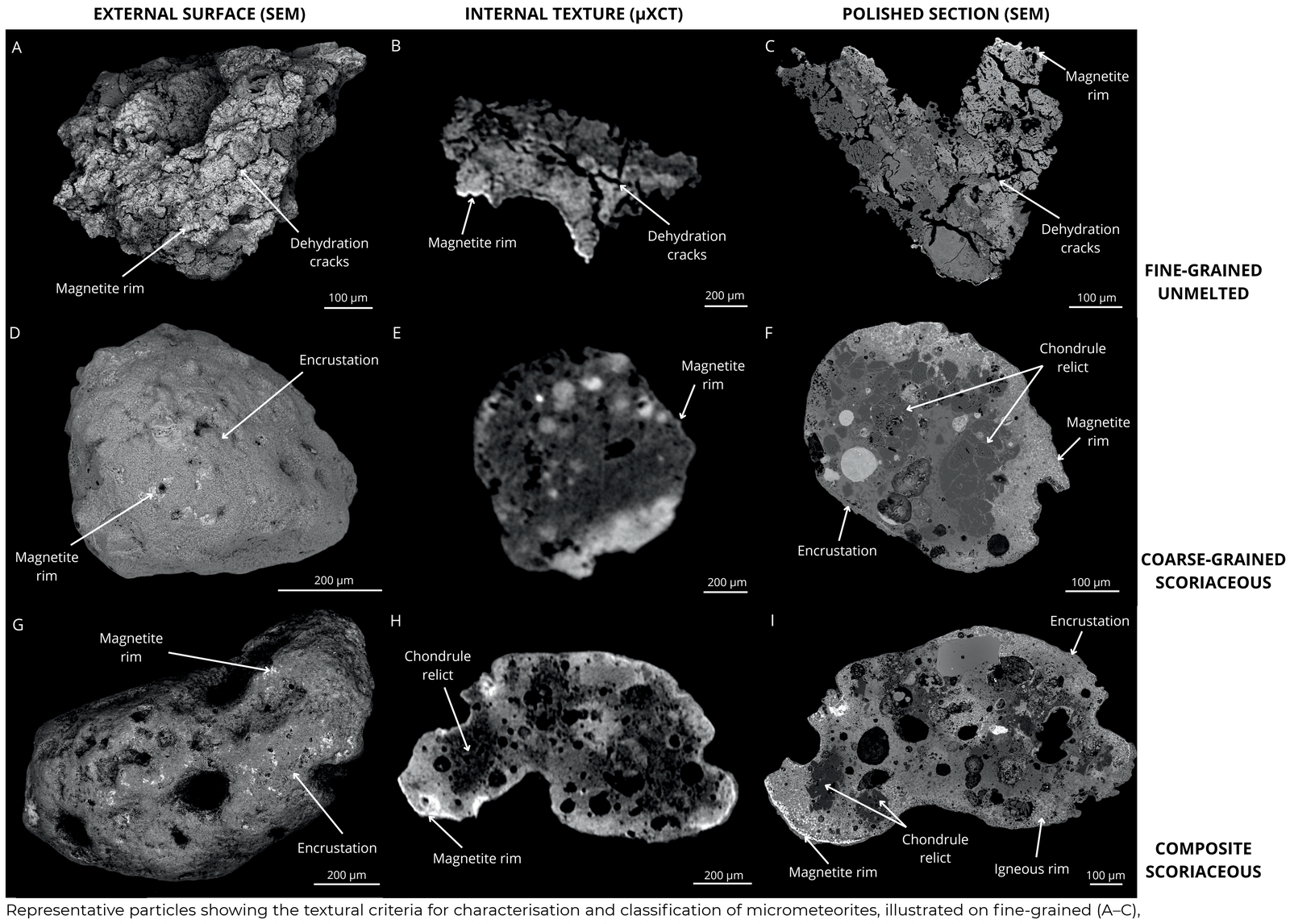
1. RATIONALE

Micrometeorites are **interplanetary dust particles** representing the dominant fraction of extraterrestrial material accreted by Earth [1]. Most melt during atmospheric entry, whereas rarer unmelted and scoriaceous micrometeorites partly **preserve primary mineralogical and textural characteristics**. Previous estimates of micrometeorite size distribution and mass flux rely mainly on fully melted Transantarctic Mountains (TAM) cosmic spherules [2]. Here, we study **207 scoriaceous and unmelted micrometeorites** to constrain **atmospheric entry mass loss** and the micrometeorite **mass flux over the Quaternary**.

2. METHODS

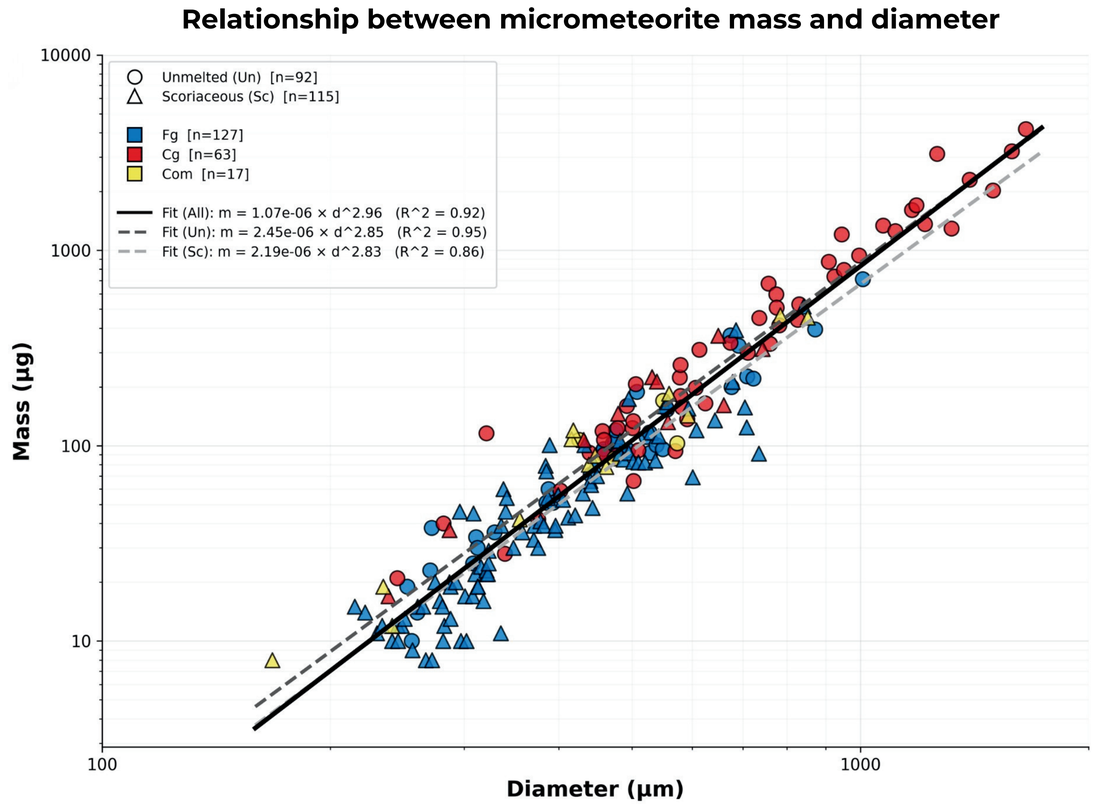
Mass was measured using a **microbalance**, while particle **size** was determined by **scanning electron microscopy** (SEM). **Backscattered electron** (BSE) **images** provided textural criteria for the identification of unmelted and scoriaceous micrometeorites. X-ray computed microtomography (**µXCT**) provided a non-destructive, 3D textural classification into **fine-grained** (Fg, crystal size <1 µm), **coarse-grained** (Cg, crystal size >1 µm), and **composite** (Com, coarse-grained chondrule fragments set in a fine-grained matrix) micrometeorites, cross-checked by SEM imaging of **polished sections** from a subset of representative particles.



Representative particles showing the textural criteria for characterisation and classification of micrometeorites, illustrated on fine-grained (A–C), coarse-grained (D–F), and composite (G–I) examples, imaged by external surface (SEM), internal (µXCT), and polished section (SEM).

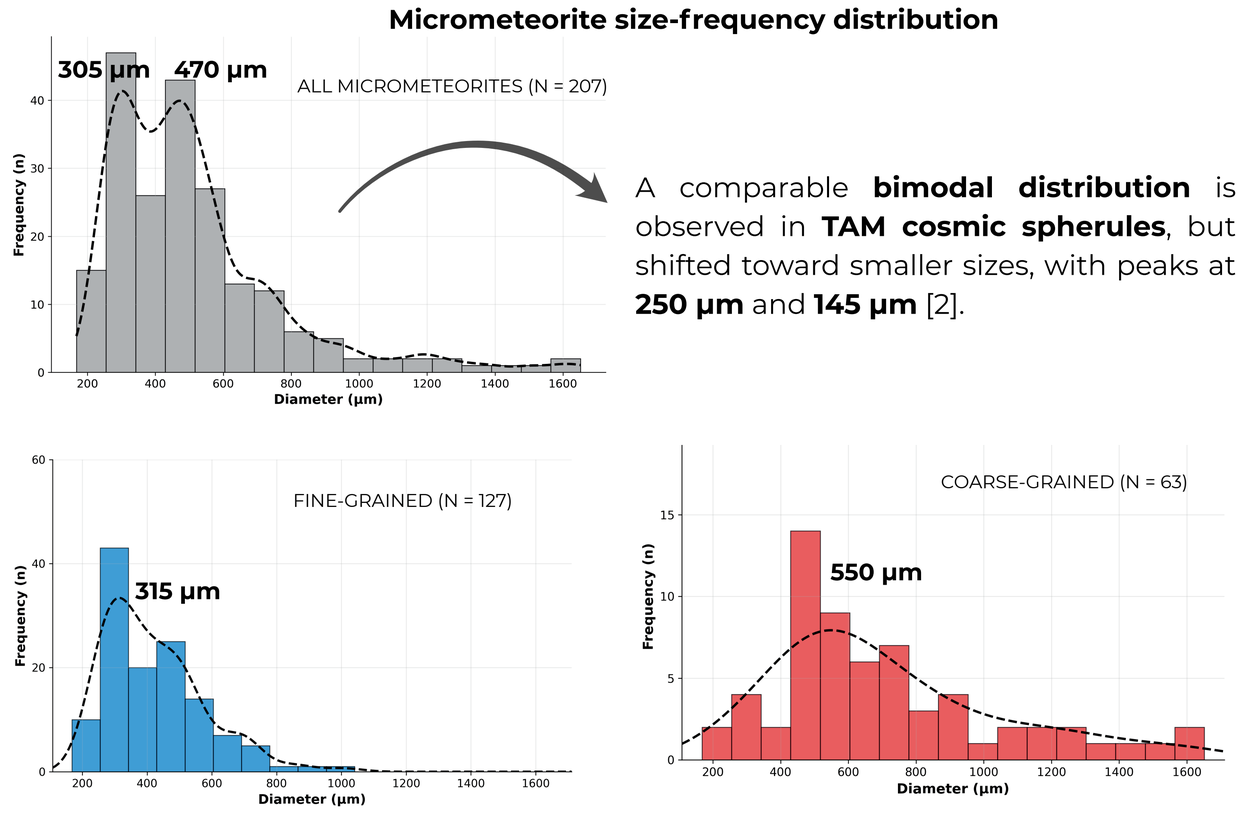
3. RESULTS

Relationship between micrometeorite mass and diameter



- Equivalent spherical diameter: ~170–1650 µm; mass: ~10–4200 µg. **The size–mass relationship** is described by a power-law: $\mathbf{m_{(\mu g)} = 1.07 \times 10^{-6}\ d_{(\mu m)}^{2.96}}$
- The full dataset is robustly described by a single empirical relationship despite compositional and atmospheric-processing heterogeneity (R^2 = 0.92).
- Bulk densities typically range from 1000 to 3000 kg/m³, overlapping CI and CM carbonaceous chondrites.

Micrometeorite size-frequency distribution



A comparable **bimodal distribution** is observed in **TAM cosmic spherules**, but shifted toward smaller sizes, with peaks at **250 µm** and **145 µm** [2].

- **Bimodality** likely reflects **two end-member material populations** with contrasting physical properties and fragmentation behaviour during dust production in space.
- **Fine-grained** particles do not exceed ~1 mm, consistent with hydrated, matrix-rich materials with **friable and porous textures**.
- **Coarse-grained** particles, dominated by **mechanically robust**, dry or weakly hydrated minerals, preferentially survive as larger particles.

4. DISCUSSION

1. The **size shift** between TAM unmelted–scoriaceous micrometeorites and cosmic spherules can be plausibly explained by the **size–mass reduction** produced **during atmospheric entry heating**.
2. Using the **empirical size–mass relationship derived in this study**, the diameters of the corresponding peaks in the two TAM distributions were converted into their respective masses, yielding a first-order **average mass loss of ~87%** for particles undergoing complete melting.
3. Accounting for this inferred mass loss, we convert the TAM cosmic spherule surface flux [2] and derive a first-order, time-averaged **pre-atmospheric mass flux of ~12,000 (±6,000) t yr^{-1} over the Quaternary**.
4. This estimate should be considered an order-of-magnitude approximation, but is broadly comparable with numerical models [3,4], suggesting that Earth has received a **relatively stable input of micrometeorites** over the last few million years.

KEY POINTS

2
LITHOLOGICAL END-MEMBERS
reflected in the size distribution

~87%
ATMOSPHERIC ENTRY MASS LOSS
during complete melting

~12 kt/yr
PRE-ATMOSPHERIC MASS FLUX
broadly stable over the Quaternary

References: [1] Love, S. G., & Brownlee, D. E. (1993). Science, 262, 550–553. [2] Suttle, M. D., & Folco, L. (2020). J. Geophys. Res.: Planets, 125(2), e2019JE006241. [3] Rojas, J., et al. (2021). Earth Planet. Sci. Lett., 560, 116794. [4] Carrillo-Sánchez, J. D., et al. (2020). Icarus, 335, 113395.

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