# Atmospheric Entry Dynamics and Textural Evolution of Micrometeorites

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An estimated 40,000 tonnes of extraterrestrial dust enter the Earth's atmosphere annually [1]. During atmospheric transit, frictional heating induces severe evaporative and ablative mass loss; consequently, only ~10% of this material survives to reach the surface as micrometeorites [2]. The structural and textural alterations of these particles are strictly controlled by atmospheric entry parameters, specifically entry velocity, entry angle, and size, in conjunction with their precursor composition [3,4].

To evaluate the thermal history of these particles, this study investigated 1,032 cosmic spherules recovered from deep-sea sediments in the Central Indian Ocean Basin. By integrating petrological data with entry heating simulations from the Chemical Ablation Model (CABMOD), the textural evolution of silicate-dominated spherules was analyzed. A systematic classification was implemented, categorizing barred textures into tabular, platy, and radial configurations, and porphyritic textures into equant, skeletal, and chain arrangements [3].

The emergence of these distinct morphologies is governed by the thermodynamic balance between peak heating relative to the precursor liquidus temperature and the subsequent undercooling required for crystallization. Particles heated below the liquidus temperature primarily form scoriaceous or equant porphyritic textures. In contrast, overheating destroys existing nuclei; subsequent undercooling produces barred textures, while extreme overheating yields glassy spherules. Quantitative modeling indicates that particles up to 400 µm entering at an escape velocity of 11 km/s with moderate zenith angles (50°–70°) are likely to form barred textures due to overheating of ~100°C above the liquidus. Steeper entry angles and higher velocities drive extensive melting, favoring glass formation. Furthermore, heating regimes exceeding 2400°C result in >90% ablation, preventing spherule formation entirely. Evaluating these textural modifications provides a reliable framework to determine the precise atmospheric entry conditions of micrometeorites.

**References:**

[1] Love SG, Brownlee DE (1991) Heating and thermal transformation of micrometeoroids entering the Earth's atmosphere. Icarus 89(1):26–43.

[2] Genge, M. J., Van Ginneken, M., & Suttle, M. D. (2020). Micrometeorites: Insights into the flux, sources and atmospheric entry of extraterrestrial dust at Earth. *Planetary and Space Science*, *187*, 104900.

[3] Singh, V.P., Rudraswami, N.G. (2025) Textural evolution of S-type micrometeorites. *Prog Earth Planet Sci* **12**, 36

[4] Rudraswami NG, Shyam Prasad M, Dey S, Plane JMC, Feng W, Carrillo-Sánchez JD, Fernandes D (2016) Ablation and chemical alteration of cosmic dust particles during entry into the earth's atmosphere. Astrophys J Suppl Ser 227:15.