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Tracing impact plume fractionation using Fe-Mg isotopes: insights from the late Eocene Popigai impact event

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The late Eocene (37.8–33.9 Ma) was marked by accelerated global cooling [1] and an increased influx of extraterrestrial material. This includes one of the largest Cenozoic asteroid impacts leading to the Popigai structure, Siberia [2]. Radiometric dating constrains the impact to 35.7±0.2 Ma [2]. The globally distributed ejecta layer associated with the Popigai impact has been documented at numerous low-latitude marine sites, characterized by microkrystite-rich material, clinopyroxene-bearing spherules, shocked quartz, and iridium anomalies [3]. The crater's ejecta includes diverse lithologies of Archean-Proterozoic crystalline basement rocks overlain by a sedimentary succession [4].

This study presents the first application of Fe and Mg isotope systematics to reconstruct the evolution of the Popigai impact plume through the analysis of target lithologies, proximal impactites, and distal ejecta. All samples were dissolved, Fe and Mg separated by ion-exchange chromatography, and isotope ratios measured by MC-ICP-MS. The dataset includes six impact breccias and suevite fragments drilled within the Popigai crater (Fig. 1A–B), 30 clinopyroxene-bearing spherules recovered from Indian Ocean ODP cores [3] (Fig. 1C–E), and ~8,000 distal "pancake" spherules, which are flattened, altered impact spherules partially to completely coated by Ni-spinel [5], recovered from three Italian sections [6,7] (Fig. 1F–H).

By combining iron and magnesium isotopic data across this sample suite, we aim to provide insights into the links between target lithologies, spherule formation, and isotopic evolution, while also tracing how ejecta transform with distance from the impact site and how variations in fractionation and temperature may reflect different conditions during spherule formation in distinct parts of the impact plume.

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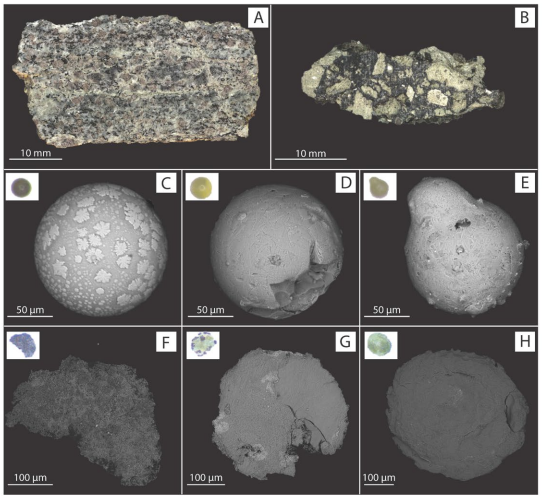

Figure 1. (A) XRF image of a breccia gneiss fragment from the Popigai impact area. (B) XRF image of a suevitic fragment from the same impact area. (C–E) Backscattered electron images of clinopyroxene spherules from ODP709C. (F–H) Backscattered electron images of "pancake" spherules from the Italian sections, completely to partially coated by Ni-rich spinels. The small white boxes in the corners show optical microscope images of the spherules to highlight their color variations.