THE DIAGENESIS AND REPLACEMENT OF COSMIC DUST IN THE GEOLOGICAL RECORD.

M. D. Suttle[1,2] and M. J. Genge[1,2]. [1]Department of Earth Science and Engineering, Imperial College London, Exhibition Road, London SW7 2AZ, UK. [2]Department of Earth Science, The Natural History Museum, Cromwell Road, London SW7 2BW, UK. Email: *mds10@ic.ac.uk*

Introduction: Fossil micrometeorites are submilimeter cosmic dust grains that fell to Earth in the distant geological past. Having survived atmospheric entry and terrestrial residence these grains were subsequently incorporated into sedimentary rocks and later recovered for analysis [1,2]. Trapped cosmic dust provides a unique resource with which to study the geological history of the asteroid belt; revealing variations in the past dust flux [3] as well as major asteroid break-up events [4]. Simultaneously, fossil cosmic spherules also act as proxies for Earth's upper atmosphere, tracing oxygen concentration over geological time [5]. Despite their significance, the number of fossil micrometeorite collections remains low and their identification and recovery challenging.

In this study we report the discovery of a new fossil micrometeorite collection recovered from 87Ma old Late Cretaceous chalk. This collection demonstrates how diagenetic alteration can result in the formation of pseudomorphic cosmic spherules whose mineralogy is entirely replaced by terrestrial phases.

Methods: To liberate micrometeorites from their host rocks, acid digestion (10% HCl and 6-hour reaction times) and mechanical disaggregation were trialled. The <500µm fraction was then searched by magnetic separation and optical picking of spherical grains. Suspected extraterrestrial particles were analysed using SEM-BSE and EDX techniques.

Results and discussion: Seventy six cosmic spherules were recovered. Pristine S-type and I-type spherules were readily identified as micrometeorites on the basis of characteristic mineralogies, textures and compositions [6]. In addition, an abundance of spherules composed of either hematite or iron silicide were recovered. These spherules contain dendritic crystals and spherical morphologies, attesting to the rapid crystallisation of high-temperature iron-rich metallic and oxide liquids. Furthermore, the presence of spherical cavities, interpreted as voids after the weathering and removal of FeNi metal beads and the presence of irregular rounded cavities, interpreted as vesicles formed by trapped gas during crystallization [7] were also identified. These textures are identical to voids found in modern Antarctic I-type cosmic spherules. As a result, on the basis of textural analysis alone, the hematite and iron-silicide spherules are shown to be I-type cosmic spherules that have experienced complete secondary replacement during diagenesis (fossilization).

Implications: The Cretaceous chalk micrometeorite collection reveals how the identification of fossil micrometeorites demands careful observation of particle textures and comparison against modern Antarctic collections. Criteria cannot simply rely on geochemical analysis as this would have overlooked the many replaced spherules with terrestrial compositions. This discovery also implies that cosmic dust is common within the geological record and likely preserved in most deep-sea sedimentary rocks.

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