

A POTENTIAL ORIGIN FOR ^{16}O -POOR COSMIC SPHERULES: A NEAR-EARTH SOURCE AND PARENTAGE WITH CY CHONDRITES. M. Van Ginneken¹, S. Goderis², R. Maeda^{2,3}, P. Wozniakiewicz¹, M. Genge⁴, L. Folco⁵, M. Suttle⁶, A. Yamaguchi⁷, S. Decré⁸, ¹Centre for Astrophysics and Planetary Science, School of Physical Sciences, University of Kent, United Kingdom (m.van-ginneken@kent.ac.uk), ²Department of Analytical, Environmental and Geo-Chemistry, Vrije Universiteit Brussel, Belgium, ³G-time laboratory, Université Libre de Bruxelles, Belgium, ⁴Impacts and Astromaterials Research Centre, Department of Earth Science and Engineering, Imperial College London, United Kingdom, ⁵Dipartimento di Scienze della Terra, Università di Pisa, Italy, ⁶School of Physical Sciences, Open University, United Kingdom, ⁷National Institute of Polar Research, Japan; ⁸Belgian Geological Survey, Royal Belgian Institute of Natural Sciences, Belgium.

Introduction: Micrometeorites are extraterrestrial dust-sized (< 2mm) particles surviving atmospheric entry and represent the main part of the flux of extraterrestrial matter reaching the Earth's surface [1]. Micrometeorites are classified according to the degree of heating suffered during atmospheric entry [1]. Cosmic spherules (hereafter CSs), the melted endmember of micrometeorites, account for ~70% of all micrometeorites. Almost complete melting during atmospheric entry erases the primary features of the precursors of CSs (i.e., mineralogy and petrology), thus preventing an identification of their parentage by comparison with meteorites.

Recent studies have shown that oxygen isotopes are an efficient tool to identify the parent bodies of CSs, as well-characterized chondrite groups exhibit distinct $\delta^{18}\text{O}$ and $\delta^{17}\text{O}$ values [3, 4]. Three factors control the oxygen isotopic composition of CSs during their atmospheric entry: 1/ the oxygen isotopic composition of the precursor, 2/ mass dependent fractionation, due to evaporation during melting of the particles that shifts values toward higher $\delta^{18}\text{O}$, and 3/ mixing with atmospheric oxygen that pulls towards tropospheric values. The precise contribution of these processes to the final oxygen isotopic composition of CSs has yet to be estimated. Although most CSs are parented with known chondrite groups, approximately 10% are depleted in $\delta^{16}\text{O}$ and show relatively high $\Delta^{17}\text{O}$, which are not consistent with known chondritic materials. This ^{16}O -poor material supposedly form a group termed isotopic Group 4, contrasting with Group 1 related to CV/CO/CM chondrites, Group 2 related to the CR chondrites and Group 3 to ordinary chondrites [3]. Although the CSs in the Group 4 could potentially be related to intensely aqueously altered ^{16}O -poor unmelted micrometeorites [5], these micrometeorites represent ^{16}O -poor nebular material from a reservoir that has yet to be formally identified.

A key to deciphering the parent body of Group 4 CSs may lie in a particular subset of porphyritic olivine (Po) CSs. Indeed, about 14% of Po CSs, named Cumulate Porphyritic Olivine (CumPo) CSs, exhibit textures testifying to settling of olivine crystals during atmospheric deceleration [6]. This unusual texture

suggests these particles entered the Earth's atmosphere at velocity of ~16 km s⁻¹, which corresponds to orbital eccentricities >0.3, which is higher than most asteroidal dust bands. Planetary or secular perturbations of dust orbits over the recent geological past (<800 kyr) may be responsible for the increased eccentricity of dust particles and, thus, the formation of CumPo CSs. However, we cannot exclude that these particles instead originated from a parent asteroid that is not present in meteorite collections, similar to CSs belonging to the isotopic Group 4.

Methods: We randomly selected 17 Po CSs from the Sør Rondane Mts. Micrometeorite collection. Samples were sectioned and studied using a scanning electron microscope. We then carried out a minimum of three oxygen isotope spot analyses on each particle using a Cameca IMS 1270 at the Centre de Recherches Pétrographiques et Géochimiques (CRPG) of Nancy, France. Major element composition of individual mineral phases of the CumPo CSs was carried out using a JEOL JXA-8200 electron microprobe at the National Institute of Polar Science, Japan.

Result: Based on their internal texture, nine particles in our selection can be classified as CumPo CSs, whereas the rest are normal Po CSs. The latter exhibit $\delta^{18}\text{O}$ and $\delta^{17}\text{O}$ values consistent with the isotopic Groups 1 and 2.

The finer grained portion of the CumPo CSs is highly vesicular, whereas the coarse grained is devoid of vesicles. Four CumPo CSs exhibit values consistent with Groups 1 and 2, whereas five exhibit ^{16}O -poor values consistent with the isotopic Group 4. Furthermore, the CumPo CSs belonging to Group 4 exhibit mineralogical and geochemical characteristics that are rare or not observed in other silicate-rich CSs, with an almost complete lack of magnetite and frequent S-rich metal inclusions and/or droplets. Olivine in the ^{16}O -poor CumPo CSs is consistently Ni-poor (< 0.5 wt%).

Discussion: That all five Group 4 CumPo CSs have the same magnetite-free, sulphide-rich natures suggests they sample a consistent precursor material with a mineral assemblage distinct from those derived from CM1, CM2, CR2 and OC precursors.

The Ni-poor nature of olivine in CumPos may be the result of a parent material with a Ni-poor bulk composition or reducing conditions during atmospheric entry [7]. Such conditions could be generated by the removal of indigenous oxygen by degassing of S or carbonaceous material. The relatively low oxygen fugacity suggested by the Ni-content of olivine is further supported by the lack of magnetite. Additionally, the relatively fine-grained vesicular portion of the particles is reminiscent of the μ Po CSs, which form by the decomposition of phyllosilicates and carbonaceous matter during atmospheric heating [8]. Based on these criteria, we argue that the precursors of the CumPo CSs belonging to isotopic Group 4 are S-rich hydrous carbonaceous dust particles.

Recent studies of the newly established CY carbonaceous chondrite group have shown that it is particularly S-rich compared to other carbonaceous chondrite groups [9]. Furthermore, assuming an increase of ca. 10 ‰ in $\delta^{18}\text{O}$ values due to mass dependent fractionation and limited mixing with atmospheric oxygen due to predation of O_2 by degassing of S and C, the original oxygen isotopic values of the Group 4/CumPo CSs falls on the CM-CY line, albeit at slightly higher $\delta^{18}\text{O}$ and $\delta^{17}\text{O}$. A parentage with CY chondrites could also explain the hydrous nature of the parent material. As a result, CY chondrites represent at present the best match in terms of petrological, geochemical, and isotopic properties to Group 4/CumPo CSs.

Finally, a recent study on CY chondrites has shown that these exhibit an unusually short cosmic-ray exposure age, suggesting a near-Earth source consistent with a Near-Earth Object [9]. This also is compatible with high orbital eccentricities suggested by the unusual textures of CumPo spherules [6].

Conclusion: We analyzed a set of 17 Po CSs, of which 9 are CumPo CSs. Among these CumPo CSs, 5 exhibit ^{16}O -poor oxygen isotopic compositions and a consistent lack of magnetite and frequent S-rich metallic inclusions. Based on these criteria, a parentage with the newly defined CY carbonaceous chondrite group is likely. We suggest that about 10% of CSs reaching the Earth surface have a near-Earth origin that is rare in meteorite collection, demonstrating the importance is fully characterizing the flux of micrometeorites to understand the composition of the Solar System.

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