CHROMITES IN COSMIC SPHERULES: A UNIQUE PERSPECTIVE ON THE EXTRATERRESTRIAL FLUX TO EARTH

F. Van Maldeghem[1]*, B. Soens[1,3], M. van Ginneken[2], R. Maeda[1,3], C. Cordier[4], M. Suttle[5], L. Folco[6], A. Yamaguchi[7], Ph. Claeys[1], S. Goderis[1]

[1]AMGC, Vrije Universiteit Brussel, Brussels, Belgium (*Flore.Van.Maldeghem@vub.be). [2]Center for Astrophysics and Planetary Science, School of Physical Sciences, University of Kent, Canterbury, UK. [3]Laboratoire G-Time, Université libre de Bruxelles, Brussels, Belgium. [4]CNRS, IRD, IFSTTAR, ISTerre, Université Grenoble Alpes, Grenoble, France. [5]School of Physical Sciences, The Open University, Milton Keynes, UK [6]Dipartimento di Scienze della Terra, Università di Pisa, Pisa, Italy. [7]National Institute of Polar Research, Tokyo, Japan.

Introduction: Chromite ($FeCr_2O_4$) is a mineral phase with a spinel structure found in different types of rocks across the planet and our solar system, including meteorites and micrometeorites [1]. Because of their strong resistance to weathering, chromite grains can survive in sedimentary successions in the stratigraphic record and advance our understanding of the variability of the extraterrestrial flux through time [2]. However, a full understanding of the origin of these sedimentary chromite grains and potential alteration processes requires detailed in situ analysis. A full characterization of individual chromites is necessary to comprehend what processes or reservoirs sedimentary spinels trace and how their abundance changes over time. Here, we characterize 27 chromite-bearing cosmic spherules (175-1000 μm) from two different Antarctic micrometeorite collections.

Methodology: Twenty-three of the studied particles belong to the micrometeorite collection from the Transantarctic Mountains (Antarctica), and four particles are from the Sør Rondane Mountains (Antarctica) collection [3-4]. In total, 52 individual chromite minerals ranging in size from 5.3 to 120 μm are identified among these 27 cosmic spherules. Each micrometeorite was polished and their cross-sections were imaged using a JEOL JSM-IT300 scanning electron microscope equipped with an energy-dispersive X-ray spectrometer at the Vrije Universiteit Brussels (Belgium). All 27 micrometeorites were studied using a JEOL JXA-8200 electron microprobe analyzer at the National Institute of Polar Research (NIPR) in Tokyo (Japan). Both the individual chromite grains and groundmass were targeted to refine the parentage and alteration history of these cosmic spherules. A subset of 14 micrometeorites was selected for oxygen isotope analysis using a Cameca IMS 1207 ion microprobe at the Centre de Recherches Pétrographiques et Géochimiques (CRPG) in Nancy (France). Triple-oxygen isotope ratios are obtained for chromite minerals larger than 10 μm and the matrix of the cosmic spherules.

Results and discussion: Based on the bulk oxygen isotope composition, we recognize one particle with a carbonaceous chondritic parentage ($\Delta^{17}O \approx -2.28$ ‰ and $\delta^{18}O \approx -4.46$ ‰), one particle with ambiguous parentage ($\Delta^{17}O \approx 0.09$ ‰ and $\delta^{18}O \approx -6.82$ ‰) and 12 particles deriving from ordinary chondrite-like material ($\Delta^{17}O \approx 0.80 – 1.49$ ‰ and $\delta^{18}O \approx 3.06 – 11.69$ ‰) [5]. In five particles with an ordinary chondrite origin, the chromite minerals (15 – 30 μm) have deviating $\delta^{17}O$ and $\delta^{18}O$ values suggesting these minerals could have been affected by alteration during atmospheric entry resulting in a shift to higher $\delta^{18}O$ - values and are neoformed. Seven particles with ordinary chondrite parentage have values similar to chromites previously identified in cosmic spherules [6] and suggest a pristine nature. However, the observed difference between the two types of chromites was not observed by Rudraswami et al. [6]. This study confirms the presence of chromite minerals mainly in particles with an ordinary chondritic parentage, while particles with MgAl spinel grains are usually associated with micrometeorites deriving from carbonaceous chondritic parent bodies [7]. Spinel group minerals can therefore be an additional parameter to identify the parent body of a micrometeorite.

Conclusion: Chromite is present in many types of extraterrestrial material, including cosmic spherules [1]. We identified 52 individual chromite minerals in 27 cosmic spherules from the Transantarctic and Sør Rondane Mountains (Antarctica). Seven micrometeorites with an ordinary chondritic origin contain pristine chromites with oxygen isotope values similar to the matrix. The chromite minerals in the five other particles have deviating $\delta^{17}O$ and $\delta^{18}O$ values suggesting these minerals were altered and even neoformed during atmospheric entry and terrestrial residence.

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