Exploring sedimentary micrometeorite traps in Western Greenland

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Flore Van Maldeghem[1]

Collaborators: Steven Goderis[1], Willem Vandoorne[2], William Robert Hyde[3], Philippe Claeys[1]

[1]Archaeology, Environmental Changes and Geo-Chemistry, Vrije Universiteit Brussel, Brussels, Belgium
[2]Into the Arctic, Ghent, Belgium.
[3]Department of Geology, Lund University, Sölvegatan 12, Lund 223 62, Sweden

Introduction: Each year, large amounts of extraterrestrial material arrive on earth, varying from large-scale projectiles to a continuous influx of cosmic dust and micrometeorites (< 2 mm). The study of extraterrestrial material offers insights in the first stages of the evolution of the protoplanetary disk using material accessible on earth, the effect of the extraterrestrial input on the global geochemical budget, and the effect on the preservation and evolution of life [1]. The study of micrometeorites refines the source regions in the Solar System for material arriving on Earth today. Cosmic dust comes from a variety of meteorite parent bodies existing in the Solar System, today but also in the geological past. This extraterrestrial material complements expensive sample-return missions to primitive asteroids and comets. Large accumulations of micrometeorites were discovered in high-altitude sediment traps in the Transantarctic and Sør Rondane Mountains in Antarctica [2-4]. Pits and joints in high-altitude rock surfaces can trap extraterrestrial particles through direct infall and different concentration mechanisms [2-4]. These deposits do not only contain micrometeorites but also capture particles formed during larger events, such as airbursts and impacts [5-6]. Based on the wide variety of extraterrestrial materials recovered in only a handful of sedimentary traps across Antarctica, the potential to find new and unexpected types of cosmic dust, not only in Antarctica but also in the Arctic is promising. Each sedimentary trap is characterized by a distinct exposure history, comparing collections sampled in the Arctic to those from Antarctica [2-4], hot deserts, and urban environments [7] is valuable for understanding the concentration mechanisms behind the accumulation of cosmic dust and detecting possible variations in the composition of the extraterrestrial flux with time. It should be emphasized that cosmic materials have not been collected from Arctic sedimentary deposits, but only from Greenland snow and ice mostly in the 1990s [8]. This was before the mechanisms and processes that lead to the accumulation of large volumes of extraterrestrial dust in Antarctica were fully understood.

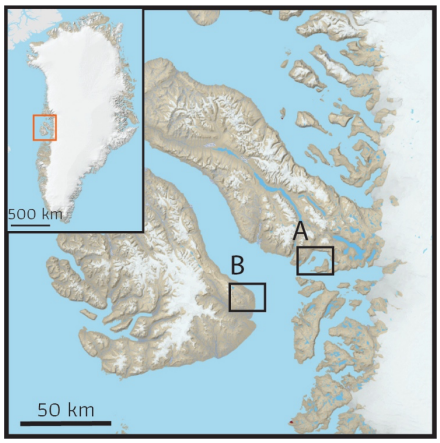

Figure 1: Sample localities.

Scientific aims: The main goal of this project is to study micrometeorites and/or cosmic spinel grains from similar types of sedimentary deposits in the Arctic. This first recovery of unique extraterrestrial material from sediment traps in Greenland enables the characterization of this modern-day collection through state-of-the-art analytical techniques and comparison to similar material from Antarctica. This approach will document cosmic events in the North Pole area over the last few Myr and track possible changes in the extraterrestrial flux over extended geological timescales at the global scale.

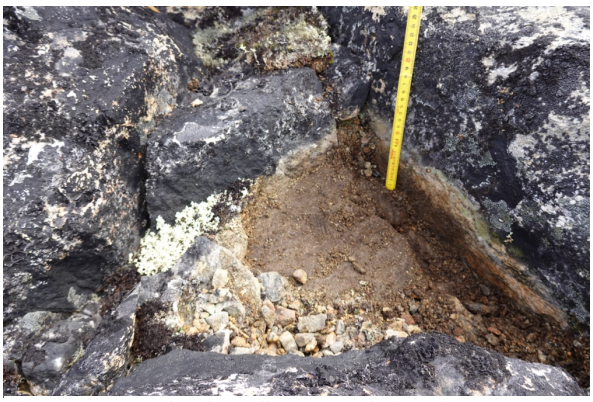
Figure 2: Example of a sediment trap in location A.

Results and discussion: During a field campaign in the summer of 2023, S.G., W.R.H., W.V., and F.V.M. gathered approximately 80 kg of sediment and samples for cosmogenic nuclide dating from two different locations in the Disko Bay area in Western Greenland. First, we sampled 3 sites in the southeast of the Nuussuaq peninsula close to the village Qeqertaq (Figure 1A). The lithologies in this area consist of Precambrian orthogneiss [9]. Second, we sampled 2 sites on the southeast coast of Disko

Island (Figure 1B). This area consists of plagioclase-phyric and aphyric tholeiitic basalts and plagioclase-phyric and aphyric basaltic andesites deposited as subaerial lava flows approximately 60 Ma ago [10]. Both areas were covered by the Greenlandic Ice Sheet in the last 18 Myr and periodically became ice-free [11], creating high-altitude areas suitable for sediment traps (Figure 2).

Initially, 800 g of sediment was examined. The collected sediment is washed and sieved into different size fractions (<63 μm, 63 – 125 μm, 125 – 200 μm, 200 – 400 μm, 400 – 800 μm, 800 – 2000 μm). Afterwards, a magnetic separation is applied using a handheld magnet. Micrometeorites are extracted optically under a binocular microscope and imaged using a secondary electron microscope coupled to an energy dispersed spectrometer (SEM-EDS) for a first qualitative chemical characterization. The initial survey led to the identification and characterization of 61 micrometeorites. 16 cosmic spherules between 100 and 200 μm were identified from 1.6 kg of sediment. 45 cosmic spherules between 63 and 100 μm were identified from 800 g of sediment. A first comparison can be made with other micrometeorite collections. Exposure ages for Antarctic collections for sedimentary traps are dated to ca 2 – 4 Ma and result in 1 micrometeorite per gram of sediment [3]. Urban micrometeorites are collected from rooftops that accumulated material for 1 – 3 years, resulting in 0.01 micrometeorite per gram of sediment [12]. The preliminary results for the Greenlandic collection give 0.1 micrometeorite per gram which could match to exposure ages of ca 100 ka. This must be confirmed with the exposure ages.

Future work: The next steps for the Greenlandic micrometeorite collection include firstly to process more sediment. This will increase the number of micrometeorites, that will be petrologically and chemically characterized. The next steps are to use this information to identify the parent bodies and thoroughly compare the Greenlandic collection to other micrometeorite collections. Another important step will be to determine the exposure ages of the sediment traps and see how the Greenlandic collection fits in the broader micrometeorite research. The preliminary results have been presented at two conferences to the scientific community, and piqued the interest of potential collaborators. Once these next steps are carried out, a manuscript will be prepared to characterize the Greenlandic collection.

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References

[1] Schmitz B., Farley K.A., Goderis S., Heck P.R., Bergström S.M., Boschi S., Claeys Ph., Debaille V., Dronov A., van Ginneken M., Harper D.A.T., Iqbal F., Friberg J., Liao S., Martin E., Meier M.M.M., Peucker-Ehrenbrink B., Soens B., Wieler R., and Terfelt F., An extraterrestrial trigger for the mid-Ordovician ice age: dust from the breakup of the L-chondrite parent body, Sci. Adv. 5 (9), eaax4184, 2019.

[2] Rochette P., Folco L., Suavet C., van Ginneken M., Gattacceca J., Perchiazzi N., Braucher R., Harvey R. P., Micrometeorites from the Transantarctic Mountains, PNAS 105 (47), 18206 – 18211, 2008.

[3] Goderis S., Soens B., Huber M. S., McKibbin S., van Ginneken M., Van Maldeghem F., Debaille V., Greenwood R. C., Franchi I. A., Cnudde V., Van Malderen S., Vanhaecke F., Koeberl C., Topa D., Claeys Ph., Cosmic spherules from Widerøefjellet, Sør Rondane Mountains (East Antarctica), Geochim. Cosmochim. Acta 270, 112-143, 2020.

[4] Van Maldeghem F., van Ginneken M., Soens B., Kaufmann F., Lampe S., Krämer Ruggiu L., Hecht L., Claeys Ph., Goderis S., Geochemical characterization of scoriaceous and unmelted micrometeorites from the Sør Rondane Mountains, East Antarctica: Links to chondritic parent bodies and the effects of alteration, Geochim. Cosmochim. Acta 354, 88-108, 2023.

[5] van Ginneken M., Goderis S., Artemieva N., Debaille V., Decrée S., Harvey R.P., Huwig K., Hecht L., Yang S., Kaufmann F.E.D., Soens B., Humayun M., Van Maldeghem F., Genge M.J., Claeys Ph, A large meteoritic event over Antarctica ca. 430 ka ago inferred from chondritic spherules from the Sør Rondane Mountains, Science Advances 7, eabc1008, 2021. [6] Soens B., van Ginneken M., Chernonozhkin S., Slotte N., Debaille V., Vanhaecke F., Terryn H., Claeys Ph., Goderis S, Australasian microtektites across the Antarctic continent: evidence from the Sør Rondane Mountain range (East Antarctica), Geoscience Frontiers 12 (4), 01153, 2021.

[7] Genge M. J., Larsen J., van Ginneken M., Suttle M.D., An urban collection of modern-day large micrometeorites: Evidence for variations in the extraterrestrial dust flux through the Quaternary, Geology 45 (2), 119 -122, 2017.

[8] Robin E., Michel-Levy N. C., Bourot-Denise M., Jéhanno C., Crystalline micrometeorites from Greenland blue lakes: their chemical composition, mineralogy and possible origin, Earth Planet. Sci. lett. 97, 162-176, 1990.
[9] Garde A. A., Steenfelt A., Precambrian geology of Nuussuaq and the area north-east of Disko Bugt, West Greenland, Geological survey of Denmark and Greenland bulletin 19, 2009.
[10] Pedersen A. K., Larsen L. M., Pedersen G. K., Lithostratigraphy, geology and geochemistry of the volcanic rocks of the Maligât Formation and associated intrusions on Disko and Nuussuaq, Paleocene of West Greenland, Geological survey of Denmark and Greenland bulletin 40, 2018.
[11] Thiede J., Jessen C., Knutz P., Kuijpers A., Mikkelsen N., Norgaard-Pedersen N., and Spielhagen R., Millions of Years of Greenland Ice Sheet History Recorded in Ocean Sediments. Polarforschung. 80(3), 141–159, 2011.
[12] Jonker G., van Elzas R., van der Lubbe J. H. J. L., van Westrenen W., Improved collection of rooftop micrometeorites through optimized extraction methods: the Budel collection, Met. Planet. Sci. 58, 4, 463 – 479, 2023.