doi:10.1017/S143192761900518X
Microsc. Microanal. 25 (Suppl 2), 2019

Analytics on the FIB: ORION-SIMS and the Discovery of a Unique Chondrite-like, Precambrian Impactor

Matthew R. Ball[1*], Richard J.M. Taylor[1], Joshua F. Einsle[2], Jean-Nicolas Audinot[3] and Richard J. Harrison[1]

[1.] Department of Earth Sciences, University of Cambridge, Cambridge, UK.
[2.] Department of Earth Science and Engineering, Imperial College, London, UK.
[3.] Advanced Instrumentation for Ion Nano-Analytics (AINA), MRT Department, Luxembourg Institute of Science and Technology (LIST), Belvaux, Luxembourg.
* Corresponding author: mb977@cam.ac.uk

The Helium/Neon Ion Microscope (HIM/NIM) has become a powerful tool for ultra-high-resolution imaging and nanofabrication. However, unlike the scanning electron microscope (SEM), there is a lack of analytical capabilities on the HIM/NIM which can exploit this extreme resolution. Secondary Ion Mass Spectrometry (SIMS) is a powerful tool for trace element and isotope analysis which is highly surface sensitive and can reach lateral resolutions of up to 50nm with a traditional beam chemistry. There have been large strides in developing the SIMS technique on the HIM/NIM [1]. Here we use the Ne beam of the ZEISS ORION FIB as a primary beam for microanalysis with an attached magnetic sector SIMS detector. This yields lateral resolutions limited only by fundamental probe-matter interaction, down to sub 10nm [2].

Meteorite impacts occur throughout the geological record, however, the destruction of craters and impactors by Earth surface processes has hindered their study. The nature of impactors can be uniquely identified using inter-element platinum group element (PGE) ratios [3]. This has typically been based on inductively coupled plasma mass spectrometry (ICP-MS) of bulk rock samples following a preconcentration step, which is necessarily devoid of spatial context and requires large sample sizes of several grams [4]. Here we address the twin problems of context free analysis and analysis of small volumes through the application of neon-focused-ion-beam-secondary-ion-mass-spectrometry (Ne-FIB-SIMS) to an ejecta blanket deposit. This reveals both the first measurements of a Chondrite-like parent body for which the breakup age must predate 1.177Ga and the first contextualized measurements of PGE concentrations taken directly from the extraterrestrial phase itself.

The Stac Fada deposit, an ejecta blanket deposit in NW Scotland, contains abundant impact lapilli, round agglomeration of grains thought to form within the ejecta blanket, falling out as the cloud energy dissipates in the same way as volcanic lapilli. Traditionally, bulk samples of this rock would be used to extract low level (ppb) enrichment of the PGEs through the methods outlined above. Here we use a correlative microscopy approach to measure the concentration and interelement ratios of the PGEs by direct microanalysis of the extraterrestrial phase (Figure 1).

We identify the meteoritic component carrier phase from chemical and backscatter electron images from the SEM and target these using the Ne-FIB-SIMS. The high spatial resolution (sub 10nm) and high sensitivity of the Orion SIMS allows us to directly image PGE micronuggets within this intergranular phase (Figure 1e). Using two standards to account for the matrix effect (the NIST 610 glass and the Bonn Sulfide II), we quantify the concentrations and inter-element ratios of the PGEs using a 'useful yield' approach. Using the volume fraction of the samples which are composed of this PGE enriched phase from the large field of view microscopy, we show that the entire PGE budget of the samples can be explained using this phase, which is enriched by up to four orders of magnitude relative to the continental crust.

Both the CI (solar abundance) normalised concentrations and the interelement ratios of the PGEs demonstrate that the impactor came from a chondritic parent body, whilst the interelement ratios identify it as a previously undescribed body. This methodology also opens the door for more detailed direct study of PGE concentration and distribution within PGE ore deposits [5].

[1] T Wirtz et al. Applied Physics Letters **101** (2012), p. 041601-5.
[2] D Dowsett and T Wirtzm Analytical Chemistry **89** (2017), p. 8957-8965.
[3] S Goderis, F Paquay and P Claeys in "Impact Cratering: Processes and Products", eds. G R Osinski and E Pierazzo, (Wiley-Blackwell, New York) p.223-239.
[4] H Plessen and J Erzinger, Geostandards Newsletter **22** (1998), p. 187-194.
[5] The authors would like to acknowledge ZEISS for instrument access.

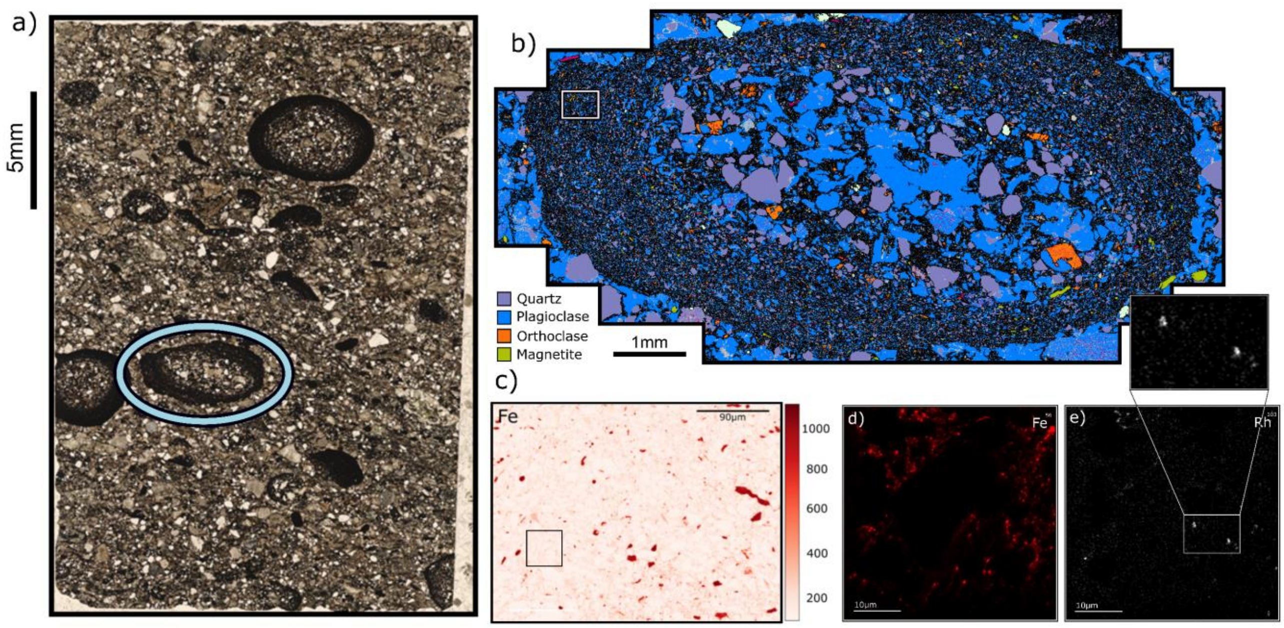

Figure 1. Division B of the Stac Fada mapped using: a) transmitted light b) inset, showing several oblate accretionary lapilli, both whole and broken. b) ZEISS Mineralogic Mining (an automated mineralogy package built off a SEM-EDS) c) inset, showing the coarse grained, predominantly quartz and feldspar core of the lapilli, surrounded by a finer scale rim, containing quartz, feldspar and magnetite. c) SEM-EDS mapping at the Fe Kα edge d) and e) inset, showing iron rich magnetite grains as well as a low-level iron enrichment between the mineral grains of the lapilli rim. d) Ne-SIMS rastered ion microprobe mapping at mass 56, Fe, showing the low-level iron enrichment between grains in the lapilli rim. e) Ne-SIMS rastered ion microprobe mapping at mass 103, Rh. The Rh micronuggets can be directly correlated to the iron rich regions in d) which can be spatially located to the interstitial matrix material between fine mineral grains within the accretionary lapilli rims. Multiple maps from the same regions are used for quantification.