EUROPEAN SYNCHROTRON RADIATION FACILITY

INSTALLATION EUROPEENNE DE RAYONNEMENT SYNCHROTRON

Experiment Report Form

	Experiment title: Confocal micro-XAS/XRF study of rare micrometeorites retrieved from the Sør Rondane Mountains, East Antarctica	**Experiment number**: 26-01-1137
Beamline:	**Date of experiment**: from: 08 Feb 2018 to: 13 Feb 2018	**Date of report**: 14 May 2020
Shifts:	**Local contact(s)**: Dipanjan Banerjee	*Received at ESRF:*

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Report:

Approximately 40,000 metric tons of extraterrestrial materials reach Earth every year (Love and Brownlee, 2003), often as handsized meteorites but mostly in the form of micrometeorites ranging from 10 to 2000 µm in diameter (Rubin and Grossman, 2010). The meteoritic materials recovered from the Earth's surface represent a wide range of Solar System materials and processes, and record discrete intervals of Solar System history (condensation of refractory inclusions such as calcium-aluminum inclusions, aqueous alteration, thermal metamorphism, melting and melt extraction on the meteorite parent bodies, etc.). Unfortunately, the pristine nature of the recovered materials has irrevocably been affected by Earth's atmosphere and hydrosphere, either during their passage through the atmosphere (i.e., melting in the case of micrometeorites or the formation of a fusion crust for larger meteorites) or during their residence at the Earth's surface (i.e., the terrestrial age of a meteorite). Most meteorites are recovered in Antarctica and in hot deserts as finds (e.g., northwest Africa, Oman, Atacama desert). Only approximately one in 30 meteorites (< 5%) is recovered as a fragment from a meteorite fall. Micrometeorites are also found all over the Earth, but the largest collections also derive from hot deserts (e.g., the Atacama desert) or the Antarctic. The micrometeorite particles included in this work were recovered from sedimentary traps near the summits of the Sør Rondane Mountain range, in East Antarctica. Depending on their terrestrial age and place of recovery, extraterrestrial materials will have been affected differently by a multitude of processes. In the case of metal, Fe, Ni-oxyhydroxides can be formed on the parent body, result from atmospheric passage, or develop during terrestrial alteration. While the formation of specific secondary phases (e.g., goethite α-FeO(OH) and maghemite γ-Fe_2O_3) is essentially restricted to weathering processes, other phases such as magnetite (Fe_3O_4) can be formed during several of these stages.

Before the ESRF experiments, laboratory based SEM-EDS and 2D XRF were used to obtain preliminary information. During this experiment, multi-modal analysis combining synchrotron-based confocal XRF and Fe K-edge XAS was used to analyse a large set of meteoritic materials, covering a range of processes and oxidation states. The spectra from Fe-Ni metal (kamacite, taenite), Fe sulfide (troilite), magnetite, and wüstite from (micro-)meteorites and oxidised natural and synthetic reference materials were compared to those of ordinary (H-type) and carbonaceous (CM-type, CK-type) chondrites as well as various textural and chemical types of melted (metal and silicate cosmic spherules) and partially melted (scoriaceous) micrometeorites from the Sør Rondane Mountains collection. In addition to these naturally altered meteoritic materials, a series of arteficially altered ordinary chondrites were included in this experiment. A set of Antarctic ordinary chondrites, exhibiting limited natural alteration, was altered using a climatic chamber at the home institution to test the effects from specific environmental conditions on meteorites. This alteration can be achieved by changing temperature, humity and time in a controlled fashion.

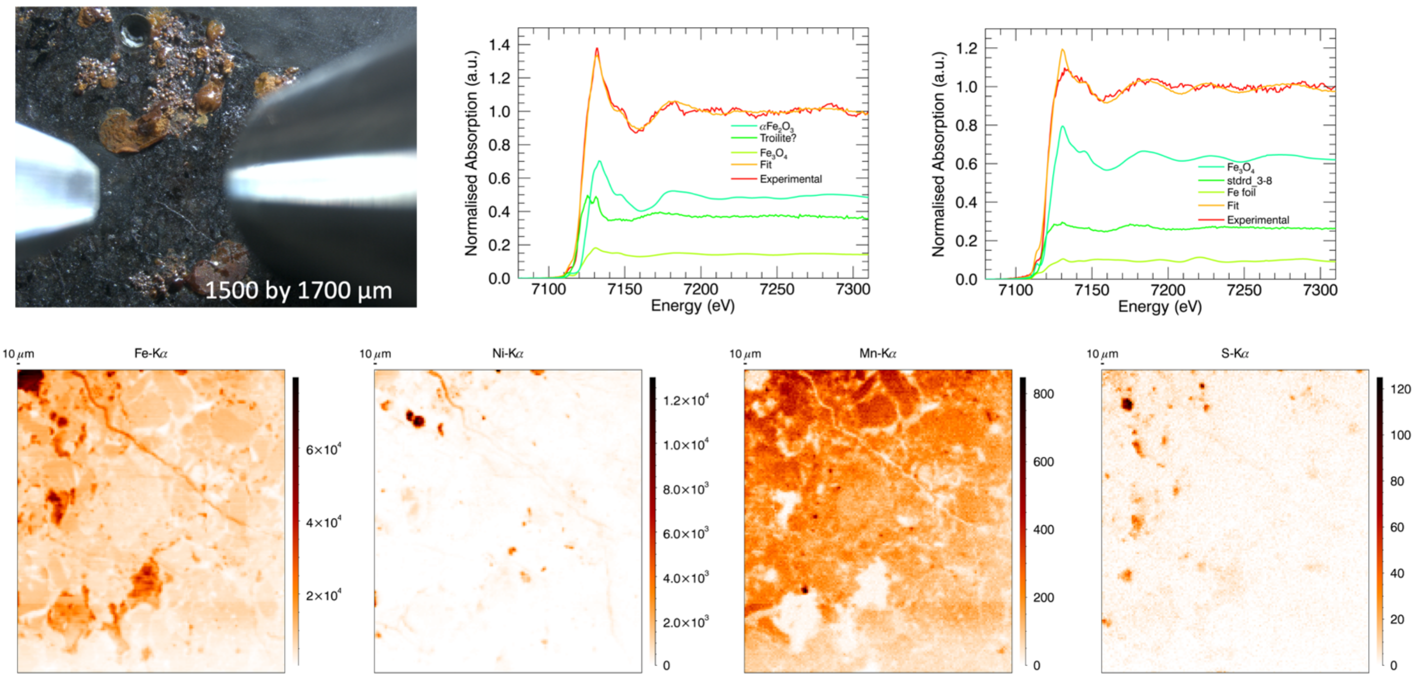

Fig.1 Overview of XRF scans and selected Fe K-edge XAS spectra (10 µm steps) performed on an arteficially altered meteoritic sample recovered from the blue ice fields surrounding the Sør Rondane Mountains.

The obtained results are in excellent agreement with the predicted occurrence of Fe-bearing phases in the experimentally altered meteorite samples. In Fig. 1, the presence of Fe-oxyhydroxides (hematite α-Fe_2O_3) is clearly identified in the XAS spectra, despite the prevalent presence of troilite, an iron sulfide generally removed quickly during terrestrial weathering. Overall, the obtained data indicate the abundance of a wide range of Fe species, from FeNi metal and sulfide to hematite, goethite and magnetite. As time is a crucial parameter in the alteration experiments, additional synchrotron campaigns will be requested and organised at the ESRF to obtain similar data for meteorite samples exposed to comparable temperature and humidity conditions in the climate chamber, but for a longer period of time (e.g., 2 years relative to the 6 months in this campaign). Once the full set of data is collected, a peer-reviewed Q1 paper will be written summarizing the full extent of results obtained during these two beam line campaigns. In the meantime, the collected data on individual micrometeorite particles will provide valuable information on the internal structure of these particles and serve as a guideline to select regions of interest for additional geochemical analysis to constrain the nature of these particles (e.g., oxygen isotope analysis using SIMS to identify the precursor meteorite body).