



	<b>Experiment title:</b> Wavelength-dispersive X-ray fluorescence spectroscopy of rare-earth elements in extraterrestrial material and deep-Earth diamonds enabled by a highly-curved HAPG crystal optic	<b>Experiment number:</b> ES-1243
<b>Beamline:</b>	<b>Date of experiment:</b> from: 20/09/2022 to: 26/09/2022	<b>Date of report:</b> 21/09/2023
<b>Shifts:</b>	<b>Local contact(s):</b> Alexey Melnikov	<i>Received at ESRF:</i>

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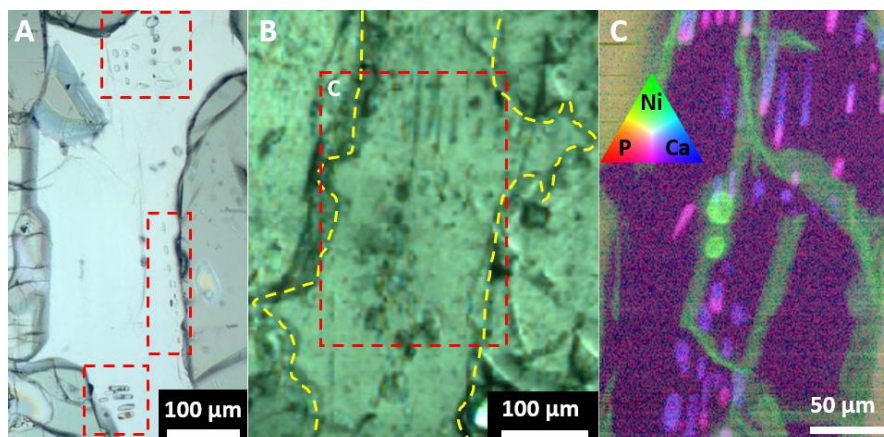
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### Report:

A highly-curved highly annealed pyrolytic graphite (HAPG) crystal was tested as a wavelength diffractive optic for detecting rare-earth elements (REEs) in meteorites NWA 6693 and Tissint. Although the high curvature of the HAPG optic was useful to collect a large solid angle ( $\sim 10^{-1}$  sr), it resulted in unforeseen folding defects in the deposited graphite layer which negatively increased the crystal's mosaicity. The final energy resolution obtained with this optic is comparable with energy-dispersive X-ray fluorescence (XRF) spectroscopy and therefore doesn't provide any benefit.

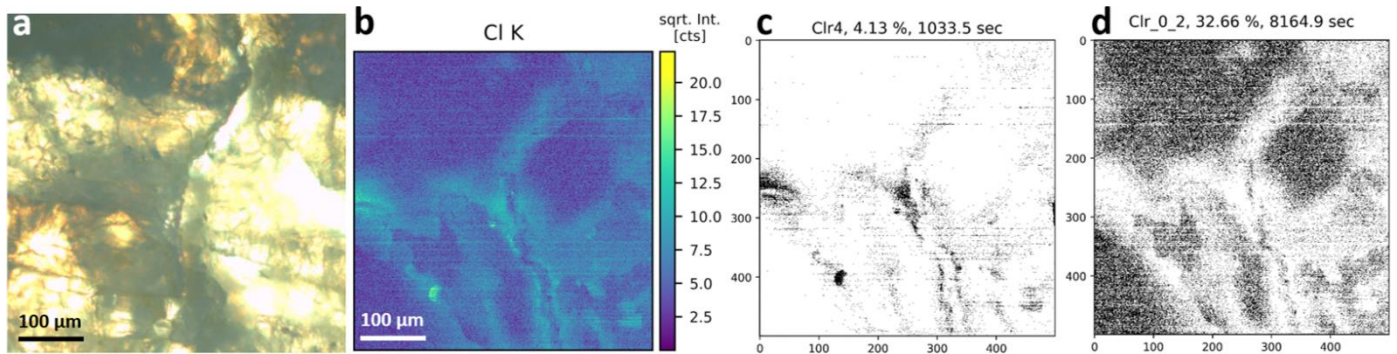
The meteorites NWA 6693 and Tissint were further analysed with confocal synchrotron radiation (SR) XRF to better understand the presence and/or remnants of fluid tracks inside these samples.

NWA 6693 was found in Morocco near Amazraou during May 2010 and is classified as an ungrouped achondrite (i.e. melted/differentiated meteorite) with an igneous texture. Most of our understanding of the earliest magmatism in the Solar System is based on these achondrites which were derived from asteroids that underwent melting. Approximately 13 wt% of bulk NWA 6693 material consist of Na-rich feldspar and is the host material of trapped liquid in the form of bubbles and parallel trails of microinclusions. Most of these fluid inclusions are rich in the Ca, P-rich mineral merrillite  $\text{Ca}_9\text{NaMg}(\text{PO}_4)_7$ . **Figure 1** shows an example of these fluid bubble tracks and detected P, Ni and Ca XRF signals at beamline ID13. The Ca, P-rich and Ni-rich bubbles have shown to be rich in Ce and Nd.

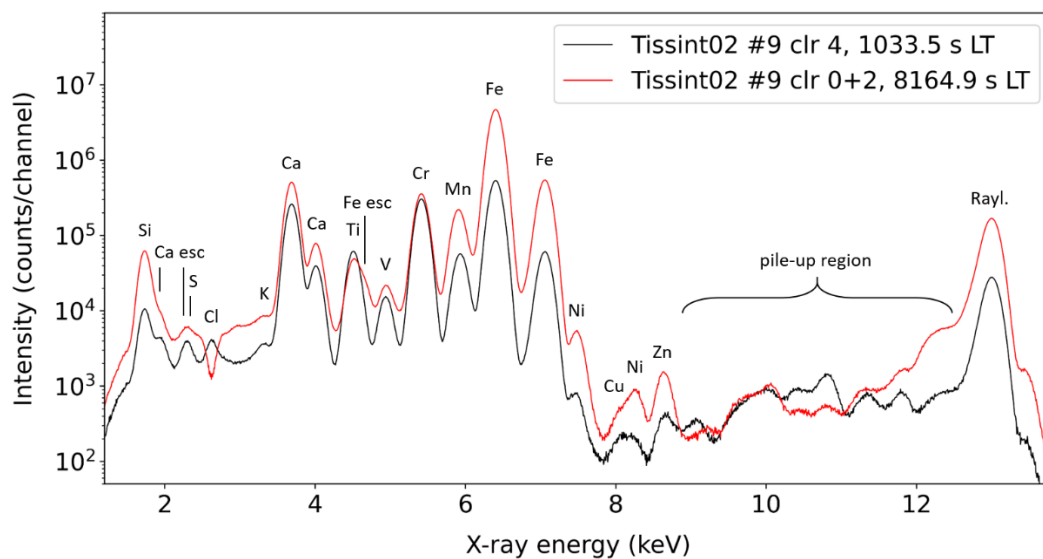


**Fig. 1** (A) Reflected-light microscopy of parallel-oriented fluid tracks (red boxes) inside feldspar of the NWA 6693 meteorite. (B) NWA 6693 feldspar region analysed at the low-energy (13 keV) beamline ID13 (ESRF), 2D XRF map is indicated with a red box. (C) RGB image of **P**, **Ni** and **Ca** showing the presence of Ca, P-rich fluid bubbles and Ni-rich bubbles and vein structures. Based on fluorescent L-line detection, the Ca, P-rich and Ni-rich bubbles have shown to be rich in Ce and Nd.

The Tissint meteorite was found in Morocco in 2011 and is the 5<sup>th</sup> and last observed fall of Martian material. The matrix is highly fractured and penetrated by numerous dark shock veins. The latter was analysed for REEs and chlorine. Although no REEs were detected, chlorine was found to be present along the shock veins (**Figure 2**) which has been positively correlated with water in literature studies. The surrounding rock material was found to contain no chlorine. The SRXRF spectra of both chlorine-rich and chlorine-absent regions are presented in **Figure 3**.



**Fig. 2** (A) Microscope image of the analysed dark shock vein region inside Tissint. (B) Confocal SRXRF map of chlorine, (C) K-means cluster of the chlorine-rich regions, (D) K-means cluster of the chlorine-absent regions.



**Fig. 3** SRXRF sum spectra of the chlorine-rich cluster (along the dark shock vein, black curve, 1033.5 s total acquisition time) and the chlorine-poor cluster (rock material surrounding the shock vein, red curve, 8164.9 s total acquisition time).