MICROXRF INVESTIGATION OF ASTROBIOLOGICALLY SIGNIFICANT SAMPLES

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Introduction: We are developing micro-focus X-ray fluorescence instruments for examining fine scale chemical variations in rocks and soils. MicroXRF instruments can measure the elemental chemistry of tiny features observed in rocks, such as individual sand grains, veinlets, cements, concretions and crystals. In the context of planetary missions, microXRF instruments will enable detailed insights into past habitability and the preservation of biosignatures.

PIXL (Planetary Instrument for X-ray Lithochemistry) [1, 2] was developed at JPL and has since been selected for flight on the Mars 2020 rover science payload. Our breadboard instrument uses a polycapillary to focus a 100 µm-diameter, high-flux X-ray beam onto the surfaces of geological samples in air, helium, a vacuum or simulated planetary atmospheres. The X-ray beam produced by the focused X-ray source yields extremely high fluorescent X-ray count rates, enabling the measurement of major and minor elements in 5-10 seconds. By rastering the beam between spots, we are able to accumulate thousands of spectra and produce centimeter-scale maps of the fine-scale elemental chemistry of a surface in minutes to hours of operation. If we integrate for 1 to 2 minutes per spot, we can perform a sensitive trace element analysis.

MicroXRF investigation of Mars rocks and terrestrial biosignatures: While exploring different measurement and data analysis strategies, such as line scans and adaptive sampling, we are using the capabilities of our breadboard instrument to solve terrestrial research problems. We have successfully operated this instrument for thousands of hours while examining Martian meteorites (e.g. Figure 1), alteration of terrestrial volcanic and sedimentary rocks, stromatolites and other textural and elemental signatures of microbial life (e.g. Figure 2). We are also exploring Principal Component Analysis (PCA) and t-distributed Stochastic Neighborhood Embedding (t-SNE) as tools to rapidly visualize and analyse the large data cubes produced by our instruments [3].

References:

[1] Wade, A. L., Hodyss, R. P., Allwood A. C., Gao N. and Kozarczek K. (2013) *NASA Tech Briefs*
[2] Allwood A., Wade L., Hurowitz J., Hodyss R. and Flannery D. (2014). Seeking Ancient Microbial Biosignatures With PIXL on Mars 2020. *American Geophysical Fall Meeting 2014*.
[3] Thompson, D., Ravi Kiran R., Allwood, A., Altinok A., Estlin T. and Flannery D. (2014) Smarter Instruments, Smarter Archives: Machine Learning for Tactical Science. *American Geophysical Fall Meeting 2014*.

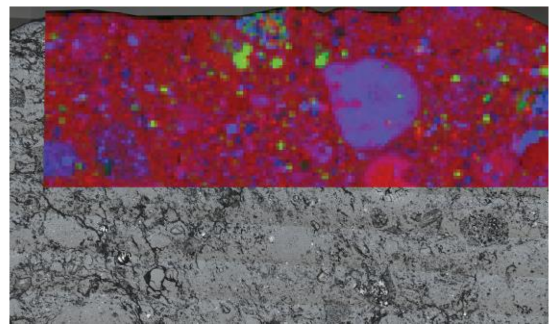

Figure 1. RGB image created from Fe (red), K (green) and Ca (blue) microXRF element maps overlaid on a reflected light image of Martian meteorite NWA 7533. The entire field of view is ~20 mm. The instrument was operated at 28 kV and 40 uA. We used a 100 µm step size and integrated for 30 seconds at each step.

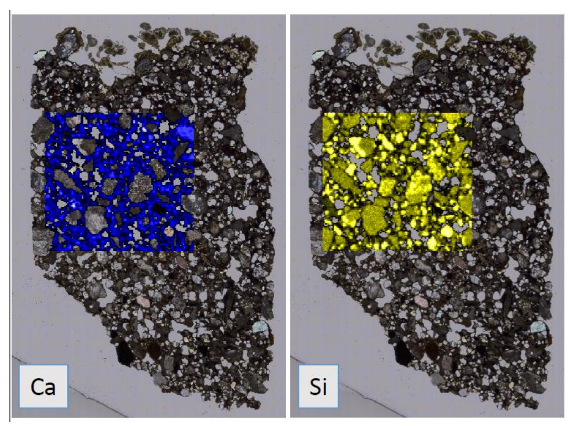

Figure 2. MicroXRF Ca and Si element maps overlaid on a transmitted light photomicrograph of a microbialite-encrusted, carbonate-cemented sandstone. The entire field of view is ~20 mm. The instrument was operated at 28 kV and 40 uA. We used a 100 µm step size and integrated for 15 seconds at each step.