MicroXRF Analysis of Astrobiologically-Significant Geological Samples

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PIXL (Planetary Instrument for X-ray Lithochemistry) [1, 2] is a microXRF instrument developed at JPL for the analysis of geological samples relevant to planetary missions. Instruments such as PIXL are able to measure the elemental chemistry of tiny features observed in rocks, such as individual sand grains, veinlets, cements, concretions and crystals. Our breadboard instrument uses a polycapillary to focus a 100 μm-diameter, high-flux X-ray beam on the surfaces of geological samples in air, helium, 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.

MicroXRF provides previously unavailable capabilities in regards to in situ and non-destructive investigation of samples in the context of planetary missions. When applied to textural biosignatures such as stromatolites (macroscopic microbial fossils), microXRF mapping can yield insights into morphogenesis and biogenicity. For example, we can detect variations in elemental chemistry arising from the presence of detrital grains in stromatolites, which may not be apparent in optical and hyperspectral images, and which if spatially constrained may be used to assess biogenicity. We are also able to detect subtle chemical differences in mineral phases and use these to determine the alteration history of rocks. For example, several generations of veining and fluid migration may lead to the formation of concretions and to the replacement of earlier textures on the millimeter to centimeter scale. We are able to map these regions of interest in sub-millimeter resolution, and detect variations corresponding to multiple generations of emplacement even within the same mineral phase.

Our mapping technique also produces large datasets, with high resolution maps typically producing several thousand spectra. These large datasets present problems in terms of the removal of spectral artefacts, the grouping similar spectra, the assignment of these spectra to mineral phases and to other regions of interest, and consequently our ability to rapidly respond to these datasets within mission-relevant timeframes. We are thus exploring techniques to efficiently visualize, correlate and separate our spectral data cubes, including Principal Component Analysis (PCA) and t-distributed Stochastic Neighborhood Embedding (t-SNE).