PIXL: Planetary Instrument for X-ray Lithochemistry on Mars 2020.
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Introduction: Measuring the chemistry of rocks is one of the fundamental tools for geological and astrobiological exploration of rocky planets. Accordingly, almost every mission to the surface of Mars has included an X-ray fluorescence (XRF) spectrometer for investigating rock and soil chemistry. However, previous instruments had relatively low spatial resolution (e.g. 17mm beam diameter for Alpha Particle X-ray Spectrometer on the Mars Science Laboratory's Curiosity rover), which limited the ability to correlate chemistry with fine scale textures and microstructures. In contrast, the Planetary Instrument for X-ray Lithochemistry (PIXL) is a microfocus XRF instrument that will be able to investigate abundances and distribution of elements at submillimeter scales, enabling chemical measurements to be accurately tied to individual grains, crystals, veins, cements, concretions and laminae. These fine scale observations will enable much more detailed assessment of past environments and the potential for preservation of microbial biosignatures.

PIXL uses polycapillary optics to focus X-rays to a 100 micron diameter spot on a sample surface. The focusing optic also produces high X-ray flux, which means PIXL can measure the chemistry of a target very rapidly. For example, a PIXL breadboard analysis of the BHVO2 basalt detects most major and minor elements at 0.5 wt% in 5 s (Figure 1). To detect many trace elements, PIXL needs only 30 s to 2 min.

Scanning the beam reveals chemical variations across a target surface. To ensure the measured chemistry is unambiguously tied to the textural features in the targets, PIXL has an optical fiducial system (OFS) co-aligned with the X-ray beam. The OFS includes a color Micro-Context Camera, and an LED illuminator that projects a reference pattern onto the target. A prototype, operating in simulated Mars atmosphere, has demonstrated PIXL's ability to produce science data products within the practical constraints of the 2020 rover mission: from rapid line scans or spot analyses of the key rock components, to hyperspectral element maps, or sensitive trace element measurements of individual features.

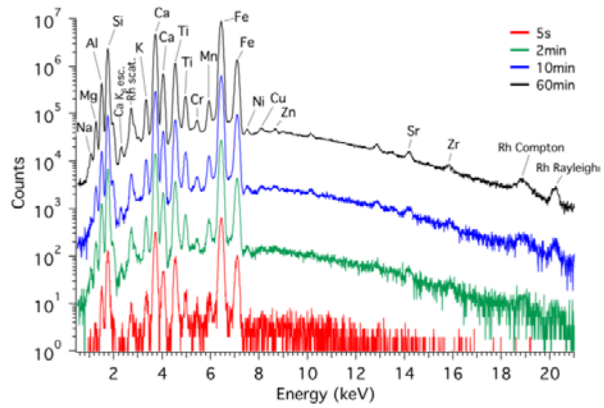

Figure 1: PIXL spot analysis of BHVO-2: in 5 seconds, most major and some minor elements are detected, sufficient for basic classification and comparison between different rock components. In 2 minutes, many trace elements are detected. All trace elements are detected with high precision and accuracy in one hour. Multiple short spectra can be summed for a highly sensitive bulk analysis

Measurement Strategies and Operations: PIXL has flexible measurement modes to suit target complexity and available time: a coarse prospecting mode for rapid assessment of a broad area; line scanning or grid modes with varying coverage and density, and a long dwell point analysis mode for maximum sensitivity. To strike a balance between speed and sensitivity, PIXL employs "Adaptive Sampling": an autonomous mode for real-time data analysis and experiment modification to ensure at least one longer integration for each different rock component encountered in an experiment. PIXL is also relatively tolerant to surface roughness. Several millimeters of topographic relief can be tolerated with little or no effect on the overall quality of our geochemical data or images. For calculations of absolute abundance, we can correct for distances up to several cm using the scattered Bremsstrahlung. This array of measurement modes is carefully designed to take full advantage of PIXL's capabilities while adapting to science opportunity and operational constraints.

The combined effect of PIXL's speed, sensitivity, resolution, coverage/ targeting, and measurement flexibility allows PIXL to provide insights to habitability and biosignature potential both efficiently and effectively. For example, having high spatial resolution minimizes the amount of time searching for searching for "just-so" locations needed to measure the chemistry of small features. High spatial resolution also minimizes the problem of confounding dust and rock coatings, because only very small patches of clean rock are needed to make an uncontaminated measurement.

PIXL Science: PIXL will enable detailed geochemical assessment of past environments, habitability and biosignature preservation potential. PIXL will also provide the capability to detect potential chemical biosignatures such as "reduction spots" [1]. Detecting these requires separate detailed measurement of the chemistry of spot vs. matrix; an easy feat for PIXL. A map (Figure 2) or simple line scan across the target reveals the presence of this potential biosignature in a single measurement sequence. PIXL will also enable detailed geochemical characterization of other types of potential biosignatures. A compelling terrestrial example is shown in element maps of 3.45-billion-yr-old stromatolites (Figure 3). The microscale distribution of Fe and Ca revealed void-filling, Fe-rich, dolomite cements—these cements highlight the presence of fenestrae (voids formed in shallow sediment, commonly associated with microbial mats), proving that carbonate was not a late diagenetic replacement phase but instead was a sediment whose deposition was almost certainly influenced by microbes [2]. PIXL can make equivalent measurements on Mars, enabling recognition of potential biosignatures and providing a detailed geochemical basis for selection of a compelling set of samples for return to Earth.

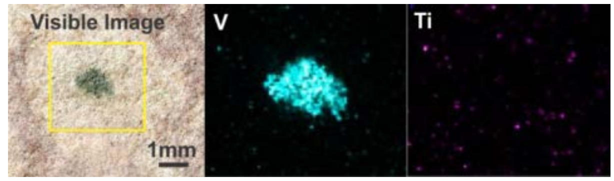

Figure 2 PIXL element maps reveal a potential chemical biosignature: a vanadium-enriched microbial reduction spot in sandstone. Sample courtesy S. Spinks.

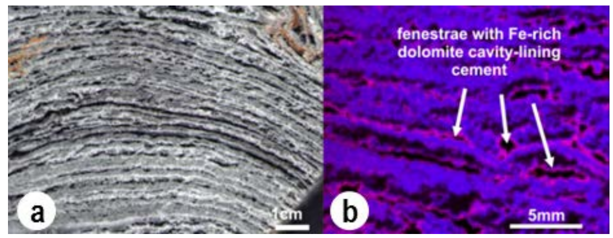

Figure 3: Element maps enable biogenic interpretation of Early Archean stromatolites: (a) visible image. (b) PIXL prototype element map (Blue = Ca, Pink = Fe) of stromatolite texture shows Fe-rich dolomite cements that grew into fenestrae (voids - black areas, now chert-filled), indicating sedimentary origin of carbonate and microbial influence on texture (Allwood et al. 2009).

References:

[1] Spinks, S.C., Parnell, J., Bowden, S.A. (2010), *International Journal of Astrobiology*, doi:10.1017/S1473550410000273.

[2] Allwood, A.C., Grotzinger, J.P., Knoll, A.H., Burch, I.W., Anderson, M.S., Coleman, M.L., Kanik, I. 2009. *Proceedings of the National Academy of Sciences, 106,* 9548-9555