MICROIMAING SPECTROSCOPY ON MARS WITH CIMMBA, PROPOSED FOR MARS-2020: THE CACHING-SUPPORTING INFRARED MICROIMAGER FOR MINERALOGY AND BIOSIGNATURE ASSESSMENT. B.L. Ehlmann[1,2], J.F. Mustard[3], S. Murchie[4], R. Green[2], P. Mouroulis[2], B. Van Gorp[2], M. Jeganathan[2], Y-H Wu[2], T. Glavich[2], R. Bartos[2], S. Tucker[2], J. Nastal[2], K. Strohbehn[4], D. Blaney[2], J. Boardman[5], J. Farmer[6], W.Fischer[1], J. Grotzinger[1], C.D.K. Herd[7], T. Hoehler[8], J. Hurowitz[9], M.E. Schmidt[10], F. Seelos[4], M. Wadhwa[6], A. Santo[4], J. Ferdosi[2] [1]GPS, Caltech (ehlmann@caltech.edu), [2]JPL/Caltech, [3]Brown Univ., [4]JHU-APL, [5]AIG, [6]ASU, [7]U. Alberta, , [8]NASA-Ames, [9]SUNY-Stony Brook, [10]Brock U.

Introduction: The Caching-supporting Infrared Microimager for Mineralogy and Biosignature Assessment (CIMMBA, "simba") is an arm-mounted imaging system that provides simultaneous fine-scale mineralogy and fine-scale imaging, two of the measurements called for by the Mars 2020 Science Definition Team (SDT). Jointly developed by JPL and APL, CIMMBA's goal is to answer four key science questions that trace to SDT Objectives A, B, and C , which derive from NASA program goals [1]: (1) How pervasive was water on Mars? (2) What was the geologic history and context of potential habitats? (3) What rocks and sediments may preserve biosignatures? (4) What locales are best-suited for sampling to further investigate these questions back on Earth?

CIMMBA couples spatially continuous fine-scale mineralogy and texture to infer origin and history, a significant information-rich step beyond a simple hand lens for *in situ* science and for cache sample selection. "[P]etrology…represents the next leap in our ability" and Objectives A-C "all are either significantly enabled by, or are completely dependent upon, these fine-scale, co-registered observations" [1, p23-24]. Classically done with polarized transmitted light microscopes on prepared thin sections, we have used a CIMMBA-prototype instrument to demonstrate the ability to perform petrologic analyses with imaging spectroscopy, simultaneously identifying Mars-relevant minerals and textures in sediments and natural and prepared rock faces. Due to its sensitivity to water-formed minerals, we hypothesize CIMMBA may reveal that more Mars materials have chemically interacted with water than believed based on currently available types of *in situ* data; moreover, CIMMBA's capability for petrologic analysis permits time-ordering of the aqueous interactions.

Approach: CIMMBA's novel arm-based spectroscopic approach to petrology builds upon the successful strategy of Mars orbiting imaging spectrometers, OMEGA and CRISM, which discovered and mapped rocks containing diverse phyllosilicates, carbonates, and sulfates using visible/shortwave infrared (VSWIR) wavelengths (Fig. 1) [2-4]. Pairing imaging spectrometer mineral maps with high-resolution images, distinct aqueous environments were identified and time-ordered from combined mineralogy, morphology, and stratigraphy [4,5]. Similarly, CIMMBA pairs rapid acquisition of a 75-µm/pixel spectral cube (450-2600nm) with a simultaneous 20-µm/pixel grayscale image over a 2.8-cm × 2.8-cm geologic target and on the same day returns data products to identify minerals and mineral textural relationships (Fig. 2).

Onboard Data Processing for Downlink Data Efficiency: CIMMBA's compact design and uniform spectral/spatial response is based on the Moon Mineralogy Mapper (M^3) [7]. A prototype of CIMMBA's imaging spectrometer (Ultra Compact Imaging Spectrometer, UCIS) [8-13] has demonstrated spectral and spatial uniformity, accuracy, and operational efficiency (<10 min/observation) for data collected during lab and field trials, as shown herein (Fig. 1-3). Downlink data volume is managed by onboard

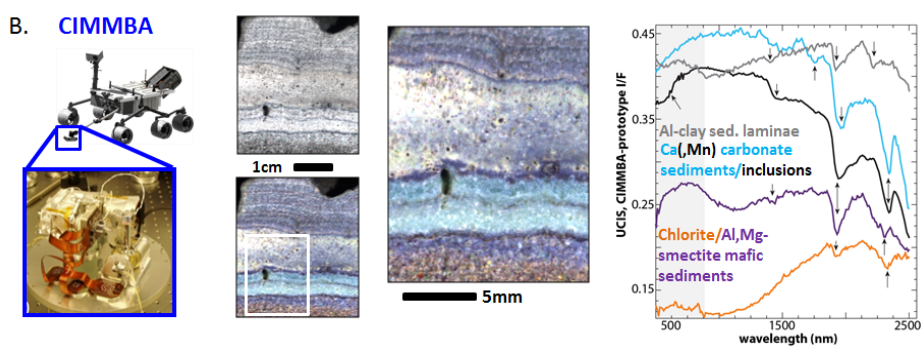

Figure 1: VSWIR imaging spectroscopy from orbit has already enabled breakthrough discoveries in Mars mineralogy, as in the identification of carbonate-bearing rock [6]. We expect CIMMBA to lead to similar breakthroughs at the microscopic level, as here, where single pixel spectra identify distinctive sediment source compositions and two generations of carbonate. VSWIR wavelengths penetrate thin dust and allow mineral identification. Packaging CIMMBA for the Mars 2020 arm represents an evolution in imaging spectrometer design from orbital/airborne to field-based/microscopic.

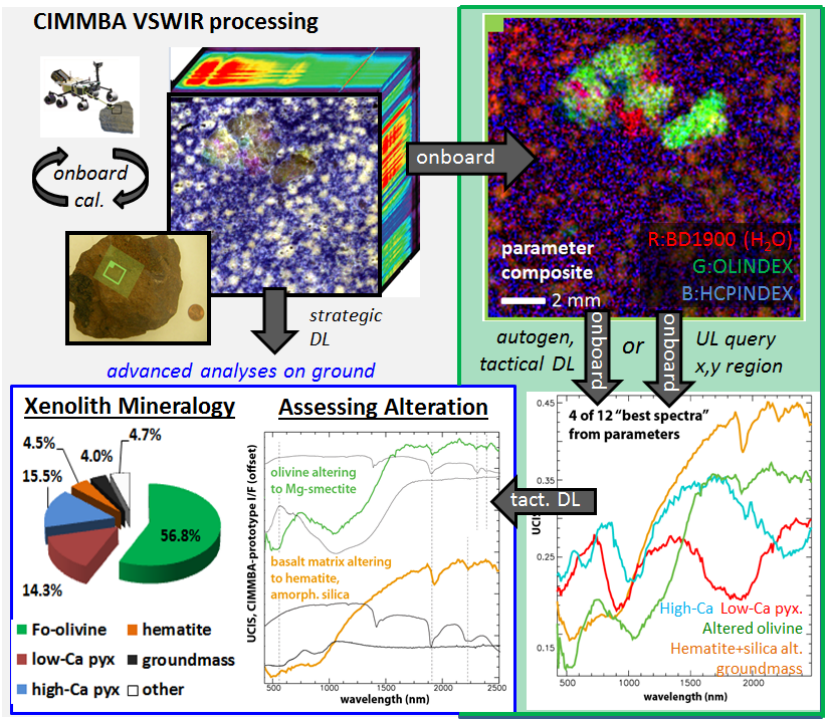

Figure 2: CIMMBA petrology and onboard processing enables rapid discovery. VSWIR image cubes are calibrated to mineral indicator maps onboard so key mineral phases and textures are received with tactical downlink. Here, a xenolith of ultramafic materials (sample of mantle rock) is found within a host rock of altered alkali basalt; areal abundance of phases can be calculated. Even though XRD analyses of this San Carlos basalt showed <2 wt.% clay, hyperspectral data show partial alteration of all olivine to Mg-smectite. The host rock is comprised of fine-grained basalt partially altered to hematite and amorphous silicate.

processing in a CRISM-based data processing unit (DPU). A high-resolution panchromatic microimage and a spectral image cube (28 Mb and 508 Mb, uncompressed) are simultaneously acquired at multiple focus positions of an actively illuminated target and then are z-stacked onboard using a MAHLI-like approach to produce best-focus, single images.

For spectral image cubes, simplified radiometric calibration – possible due to CIMMBA's uniformity – is applied onboard; image cubes are abstracted into "mineral indicator maps" [14] that highlight key minerals and redox variation; and "best-spectra" with strong absorptions are extracted. All data products are compressed and resultant tactical down-link is 0.2 Mb per parameter and <0.02 Mb for the best-spectra compilation, enabling same-day assessment of a target even in worst-case downlink. The full-resolution, focus-merged microimage (4.6 Mb, compressed) is transmitted tactically in most circumstances, and the entire calibrated image cube (299 Mb) is downlinked strategically on longer scales. Onboard storage in the DPU permits querying of key locations for spectra downlink, even prior to whole data set transmission.

Science Utility: CIMMBA's 75 µm/pixel sampling for mineralogy corresponds to the typical size of one fine sand-sized mineral grain. Thus, even complex igneous and sedimentary rocks are effectively monomineralic on a pixel scale or comprised of ≤3 phases, in constrast to integration of a single spectrum over a larger sample area. This has several important consequences: (1) all constituents are easier to identify because their spectra are discretized to particular pixel; (2) in weathered rocks, protolith minerals being altered can often be determined (e.g., Fig. 2); and (3) phases in very low concentrations can be discerned (e.g., 2% clay in cracks bisecting a single olivine grain). Data from CIMMBA would provide a backbone for Mars-2020 efforts, permiting refined characterization of aqueous, habitable environments, time-ordering geologic events via petrologic relationships, and speeding Mars-2020's cache collection.

References: [1] Mustard, J.F. et al., 2013, SDT report [2] Bibring et al., 2006, Science [3] Mustard et al., 2008, Nature [4] Murchie et al., 2009, JGR [5] Ehlmann et al., 2009, JGR [6] Ehlmann et al., 2008, Science [7] Green et al., 2011, JGR [8] Van Gorp et al., 2011, SPIE Proc. [9] Van Gorp et al., 2012, SPIE Proc. [10] Van Gorp et al., submitted [11] Blaney et al., 2012, Plan. Inst. Wkshp [12] Blaney et al., 2012, AGU [13] Sanders et al., 2013, AGU [14] Viviano et al., this conf.
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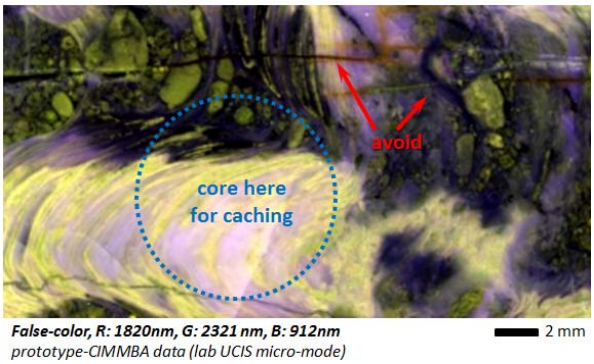

Figure 3: Where to core and cache, exactly? CIMMBA-prototype data show stromatolite growth textures mineralized in sedimentary hematite and carbonate, which could preserve organics; however, a mineralized crack shows where later fluids contaminated the rock and may have destroyed organics