COLUMBUS CRATER AND OTHER POSSIBLE PALEOLAKES IN TERRA SIRENUM, MARS. James J. Wray[1], R. E. Milliken[2], G. A. Swayze[3], C. M. Dundas[4], J. L. Bishop[5], S. L. Murchie[6], F. P. Seelos[6], and S. W. Squyres[1], [1]Department of Astronomy, Cornell University, Ithaca, NY 14853 (jwray@astro.cornell.edu), [2]JPL/Caltech, Pasadena, CA, [3]U.S. Geological Survey, Denver, CO, [4]University of Arizona, Tucson, AZ, [5]SETI Institute/NASA-ARC, Mountain View, CA, [6]JHU/Applied Physics Laboratory, Laurel, MD.

Introduction: Inferred paleolakes on the surface of Mars are key targets for astrobiology. To date, paleolakes have been identified primarily based on morphologic evidence, including inlet and outlet channels, deltas, and horizontal bedding in closed basins [1-3]. Clay minerals have been identified in some of these settings, but these may be detrital [4]. Other alteration products such as evaporite salts have been elusive in these environments [5].

Here we describe a unique set of finely layered intracrater deposits in northwest Terra Sirenum, in which several types of sulfates are found interbedded with kaolin group clays. These may be sediments precipitated in lakes under a range of pH conditions.

Mineral Identifications: Hydrated minerals are identified and mapped using high resolution CRISM data [6]. Standard atmospheric and photometric corrections were applied to I/F spectra [4]. Spectra shown are ratios between hydrated mineral exposures and areas of low spectral contrast in the same scene. Ratios suppress instrumental artifacts and residual atmospheric bands [4]. We focus on the 100 km diameter crater Columbus (29ºS, 166ºW), which presently has the best CRISM coverage in this region.

Hydrated minerals are present in all eight CRISM targeted images of Columbus. The most common phases are polyhydrated sulfates (Fig. 1) and a kaolin group clay (Fig. 2). Two spectrally distinct polyhydrated salts are observed; the first has absorptions at 1.43, 1.93, and ~2.4 µm, consistent with a Mg-sulfate (e.g., hexahydrite, $MgSO_4{\cdot}6H_2O$; Fig. 1a), whereas the other—distinguished by additional absorptions at 1.19 and 1.75 µm—may be either a different sulfate or a hydrated chloride (Fig. 1b). Gypsum ($CaSO_4{\cdot}2H_2O$) best matches the positions and shapes of most bands, but has absorptions at ~2.2 µm not seen in the CRISM spectrum. Bassanite ($CaSO_4{\cdot}0.5H_2O$) and mirabilite ($Na_2SO_4{\cdot}10H_2O$) are flatter near 2.2 µm. Carnallite ($KMgCl_3{\cdot}6H_2O$) is also spectrally similar to gypsum. Of these candidates, only gypsum has previously been detected from orbit, in the northern circumpolar dunes [7]. Opportunity has also identified Ca-sulfates in Meridiani Planum [e.g., 8].

One small exposure of layered materials has a distinct spectrum with an absorption at 2.26 µm (Fig. 3); the only library spectra [6,9] with this band are those of jarosite ($[K,Na]Fe_3[SO_4]_2[OH]_6$). A second absorption at 2.17 µm in the CRISM spectrum may also be from jarosite, or may indicate a mixture with alunite ($[K,Na]Al_3[SO_4]_2[OH]_6$). Another phase (not shown) seen in even smaller outcrops is characterized by a strong band at 2.1 µm and a 1.93 µm band, most consistent with a monohydrated sulfate. Fe/Mg-phyllosilicates, possibly including nontronite and saponite, are also identified in small outcrops on the floor of Columbus.

Spectra from CRISM multispectral mapping data (100-200 m/pixel) exhibit an Al-OH absorption at 2.2 µm in at least eight other large, degraded craters in Terra Sirenum, possibly due to a kaolin group clay, as in Columbus. In a crater ~400 km east of Columbus, CRISM data reveal alunite and a kaolin group clay [10]. This crater conspicuously lacks the polyhydrated sulfates that are widespread in Columbus.

Morphology and Stratigraphy: The hydrated minerals described above are found in light-toned, layered materials on the floor and inner walls of Columbus. Some surfaces have polygonal fracture patterns consistent with desiccation or dehydration of constituent minerals. On the inner walls, the light-toned materials form a discrete ring that can be traced around ~270º of the crater (Fig. 4). The ring generally consists of layers with polyhydrated sulfates overlying clay-bearing materials, but interbedding of these two compositions is observed (Fig. 5). Stratigraphic relationships confirm that the materials in the ring postdate the formation of Columbus crater. Al-OH spectral signatures in other craters in Sirenum also correspond to light-toned, layered rocks, but the discrete ring is a unique feature of Columbus.

Implications: The observed assemblages of sulfates, kaolinite, and other minor phyllosilicates occurring in finely bedded rocks inside closed (crater) basins are reminiscent of terrestrial acid-saline lake precipitates [11]. The sulfates identified in Columbus (most likely Mg, Ca, and Fe) are similar to those observed in Meridiani bedrock by the Opportunity rover, interpreted to have formed in playa lakes [8]. Sulfates such as jarosite and alunite imply highly acidic solutions, but the presence of Fe/Mg-smectite suggests that pH may have varied. There are no well-preserved fluvial networks in this region, so Columbus and other adjacent possible paleolakes may have been fed by groundwater.

Minerals precipitated from a paleolake would provide a direct record of conditions in the lake. Fossils have been found in acid-saline lake deposits on Earth [12], suggesting that these environments are not only habitable, but that their evaporitic sediments are capable of preserving biosignatures. Therefore, the possible paleolakes in Terra Sirenum are compelling sites for future surface exploration.

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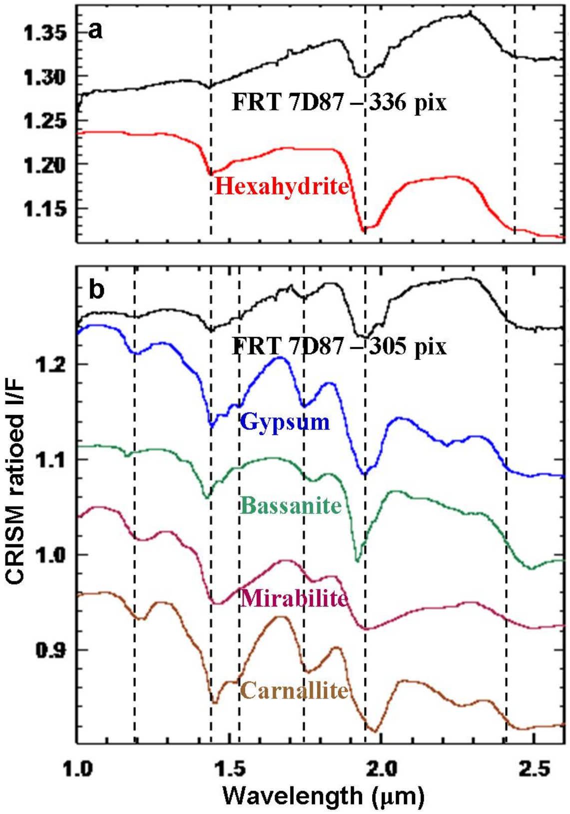

Figure 1. CRISM spectra (black) of two different polyhydrated salts (a and b) along with library spectra [6,9] of candidate minerals; see text for discussion.

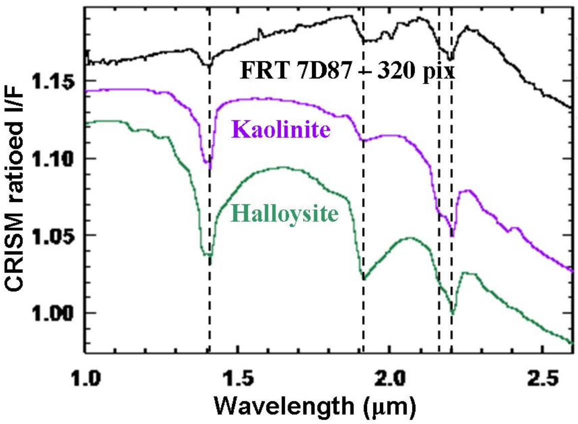

Figure 2. CRISM (black) and library spectra of kaolin group clays.

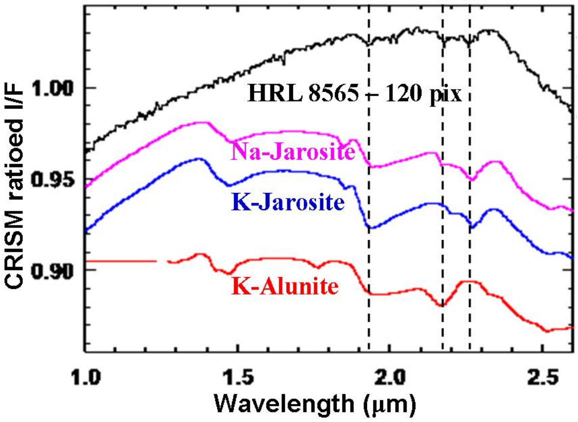

Figure 3. CRISM (black) and library spectra of low-temperature jarosite-alunite group minerals.

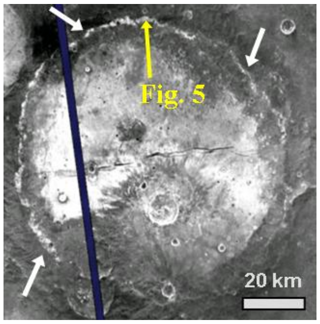

Figure 4. THEMIS Night IR mosaic shows warm (indurated) materials in a ring (arrows) around the inner walls of Columbus.

Figure 5. Clay/sulfate interbedding (HiRISE PSP_005851_1510).