ACIDIC ENVIRONMENTS IN COLUMBUS CRATER, MARS: IMPLICATIONS FOR HABITABILITY.

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Introduction: Several studies have suggested a significant water availability on ancient Mars that produced water bodies fed by surface runoff, precipitation or groundwater. Most of those studies have focused on the distribution and possible origin [1-2] of those water bodies. However, the geochemistry of these lakes is and the implications for habitability is not well known. Columbus crater was previously proposed as a candidate groundwater-fed paleolake [3]. A hydrated mineral-bearing deposit that consists of interbedded sulfates and phyllosilicates was identified in the northern part of the crater [3] and the upwelling of groundwater and near-shore evaporation was the suggested origin for those minerals. In this study, we use new CRISM MTRDR data to provide a more detailed mineral identification and constrain the chemical conditions and the nature of habitable environments in Columbus crater.

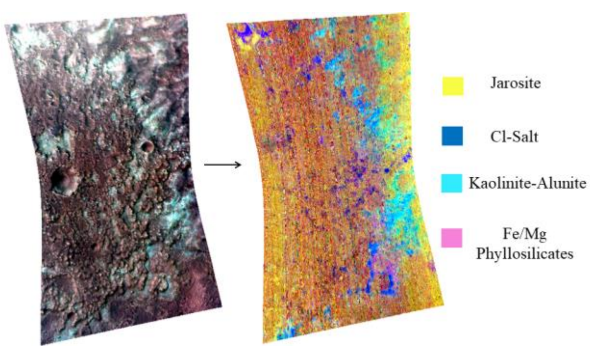

Figure 1: *HRL000062B6_07_IF181J image. Left) False color. Right) HYS (R:MIN2250, G:BD2250, B:BD1900r2) composite showing the mineral phases.*

Methods: Minerals were identified in twelve TRR3 and one MTRDR images acquired by CRISM (Compact Reconnaissance Imaging Spectrometer for Mars). Spectral parameters and RGB composites [4] were used to identify distinct spectral units (Figure 1). The spectra from these units (Figure 2) were compared with CRISM and USGS spectral libraries to find the best mineral match based on the absorption bands.

Results: The two major mineral units in the crater are kaolinite and Fe/Mg sulfates, but other clays and salts are also present. Kaolinite is the most common mineral (present in 12/13 images, Figure 3), and was identified by bands at 1.4/1.9 µm and a doublet at 2.17/2.2 µm [5]. Fe/Mg-phyllosilicates are also present in association with the kaolinite in about half the

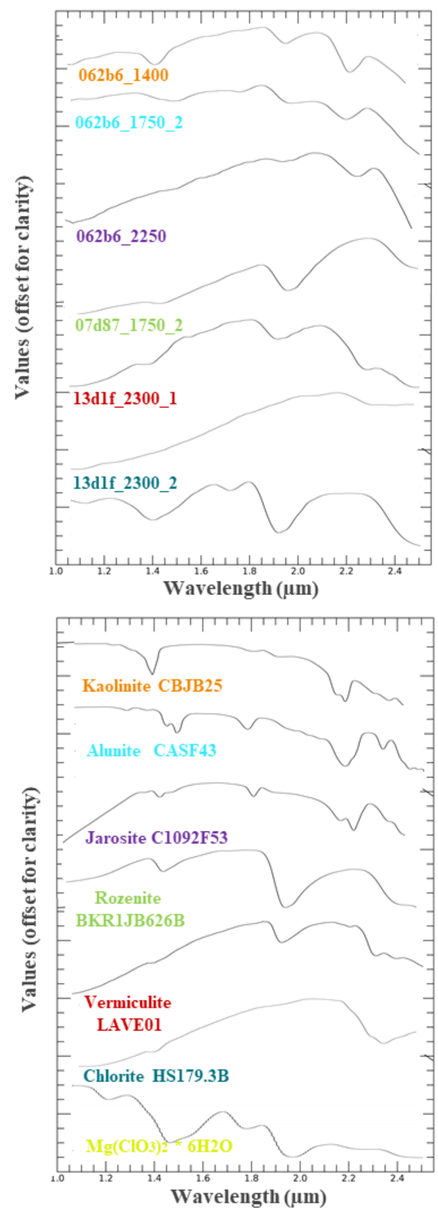

Figure2: *Spectral comparison. Top) Extracted spectra from Columbus crater . Bottom) CRISM and USGS specimens.*

images, based on a band at 2.3 µm [6], and were identified using D2300 parameter. A possible chlorite signature with a broad band near 2.32 µm and strong red spectral slope occurs just in one image and also appears to be related to the kaolinite. Salts within the crater are most consistent with various Fe/Mg and Al-sulfates. Fe/Mg-sulfates are most consistent with the Fe(II) sulfate rozenite, but could also be consistent with Mg-sulfate or a mixture of these phases. These sulfates are always present with kaolinite. Alunite has also been identified in several patches between the sulfate and kaolinite units, suggesting a possible relationship with the kaolinite maybe as a result of alunitization of the phyllosilicate. We have also identified localized signatures of jarosite in the one MTRDR image based on the doublet at 2.2 µm and overtones of water. Lastly, we have also identified a unique spectral signature potentially consistent with a Mg-Cl-salt [7] or a mixture of the Cl-salt and gypsum based on distinctive absorption bands at 1.75 µm and a triplet between 1.4-1.5 µm. This mineral is present in four of the thirteen images processed.

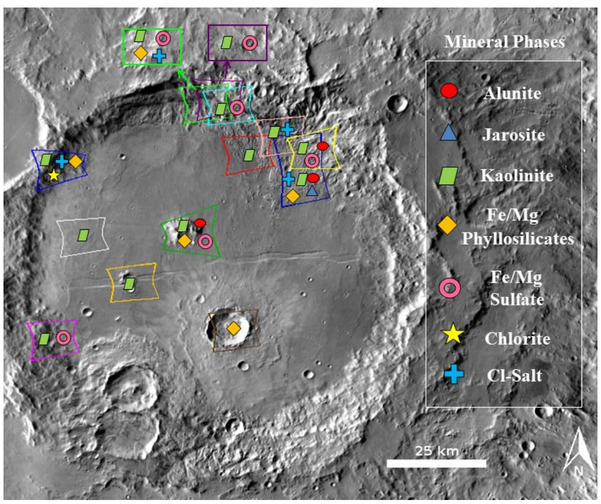

Figure 3: *Mineral distribution in Columbus crater.*

Discussion: The presence of Al and Fe(II/III)-sulfates in Columbus Crater suggests that at least some acidic and S-rich fluids were present at some point within the crater. Kaolinite can also be produced under mildly to very acidic conditions. On Earth, this mineral assemblage can be present in several different environments with these chemical conditions, and additional stratigraphic investigations will be required to determine which is the most likely. These deposits could be produced by acidic sulfate waters generated by oxidation of sulfides [8-10]. On the other hand, this deposit could correspond to high sulphidation epithermal environments or to advanced argillic hydrothermal alteration in porphyry type deposits, but none of those kind of deposits have been explicitly detected yet on Mars. This assemblage is also consistent with upwelling of acidic groundwater or upwelling and oxidation of neutral Fe-bearing groundwater. In either case, the groundwater could have been enriched in K, $SO4^{2-}$, Al, Mg and Fe and later concentrated in a playa environment by evaporation [11], as hypothesizd previously by [3]. This hypothesis is supported by observations of bedding within the sulfates and phyllosilicates, filled fractures potenttially produced through the upwelling of groundwater, and polygonal patterns consistent with evaporites.

However, the presence of Fe/Mg phyllosilicates along with kaolinite in the crater could also be consistent with a weathering profile produced via pedogenic alteration, as observed elsewhere southern highlands [12]. Indeed, a similar mineral assemblage of Al and Fe/Mg-clays and Fe and Al-sulfates is present at Mawrth Vallis [10], where they are proposed to have been produced via Fe/S redox cycling and evaporation in surficial ponds and groundwater seeps on top of a clay-rich and poorly drained weathering profile [13]. Thus, a lowland wetlands-type environment could have been present within Columbus Crater, or at the margins of the lake. An intermediate scenario is that the wetlands/pedogenic environment transitioned to a shallow lacustrine environment to deposit the sulfates.

Implications for habitability: In any of the above scenarios, sulfates and other salts suggest that the physico-chemical conditions were likely present for sustaining S-driven microbial ecosystems, while also preserving biosignatures as there are both mesophilic and acidophilic microbes that can use sulfate as a terminal electron acceptor in dissimilatory sulfate reduction (reducing sulfate while producing sulfide as a waste product). [14]. In closing the water availability evidentiated in the water overtones present in all the spectra, the geochemical compounds, and the pH conditions together all suggest that Columbus crater likely contained the metabolic requirements to support the growth and mantenaince of a microbial ecosystem.

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