50th Lunar and Planetary Science Conference 2019 (LPI Contrib. No. 2132)

2636.pdf

EVIDENCE FOR CHEMICALLY DISTINCT WATERS FORMING SULPHATES AND CHLORIDES IN TERRA SIRENUM, MARS.

E. K. Leask[1], B. L. Ehlmann[1, 2], M. M. Dundar[3], [1] California Institute of Technology,1200 E California Blvd., Pasadena, California, 91125, [2] Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, California, 91109, [3] Indiana University Purdue University Indianapolis, 723 W. Michigan St., Indianapolis, Indiana, 46202.

Introduction: Terra Sirenum, a region in the ancient southern highlands of Mars (southwest of the Tharsis volcanics) is unique in its density and diversity of orbitally-identified hydrated mineral deposits [1, 2, 3]. It contains a large number of chloride deposits [4, 5], sulphate minerals (gypsum, bassanite, kieserite, alunite, jarosite), clays (Al-rich as well as Fe/Mg clays), carbonate, and hydrated silica. Here, we conduct a thorough survey of CRISM data in the region, and use image and topography data to investigate the geological context of these diverse mineral detections in order to better understand the sources of water and ions that created these secondary minerals, and their spatial/temporal relationships. We find that sulphate and chloride detections are decoupled, and likely from independent water sources, indicating that there were either spatially distinct water reservoirs, or they occurred at different times.

Methods: For this work, we use published chloride detections from Osterloo et al. 2010 (verified with THEMIS 875 DCS strips), a global CTX mosaic [6], HiRISE imagery where available, MOLA and HRSC data for relative elevation information, and CRISM targeted image cubes (110) and mapping tiles for mineral identification. We use an algorithm based on [7] to assign a probability of belonging to a certain mineral class to each pixel; for each image, the resulting spectra and spatial patterns are verified manually. We use this technique as a method to identify rare minerals (small clusters of similar pixels), which could be missed using standard techniques such as band depth maps. Mineral detections are overlain on high-resolution imagery (CTX and HiRISE) and elevation data to interpret their geologic context.

Results and Interpretations: Figure 1 depicts the locations of all CRISM images in the Terra Sirenum study area and the minerals detected therein, along with previously reported chloride detections.

Clays. Clay minerals are widespread at a wide range of elevations (see green and cyan markers, figures 1, 2). Most of the clay mineral detections are Fe/Mg clays, identified by their strong 2.3-um metal-hydroxide absorption (e.g. [8]); Al-rich clays with a characteristic band centre at 2.2 um tend to be found either with sulphate minerals (e.g. Cross crater, Columbus crater), or at elevations above proximal Fe/Mg clays (e.g. [9]).

Chlorides. Chloride deposits (yellow markers, as identified by [4]) are also widespread and at a wide variety of elevations. They are most often found in local topographic lows, but are not observed within the regional deep basins (e.g. Columbus crater, Eridania palaeolake system). Instead, 2/3 of the chloride deposits appear to be "perched"—located in a local topographic low in the highlands, but above a deeper crater. Many deposits (~1/2) have sinuous features in high resolution imagery (CTX, HiRISE where available). High-quality CRISM data is available for 1/3 of the region's chloride deposits. At the scale of CRISM resolution, we do not observe any accessory carbonate or sulphate minerals associated with any of the chloride deposits. Instead, Fe/Mg clays are found proximal to
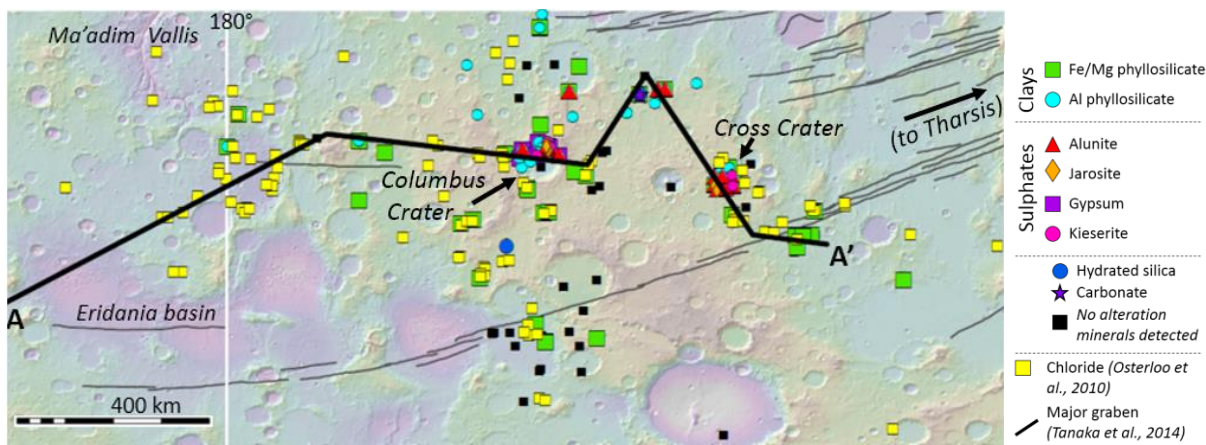
Figure 1: Hydrated mineral distribution in Terra Sirenum. Background is colourised MOLA (-500-3500 m). Location of cross section in Fig. 2 shown (A-A').
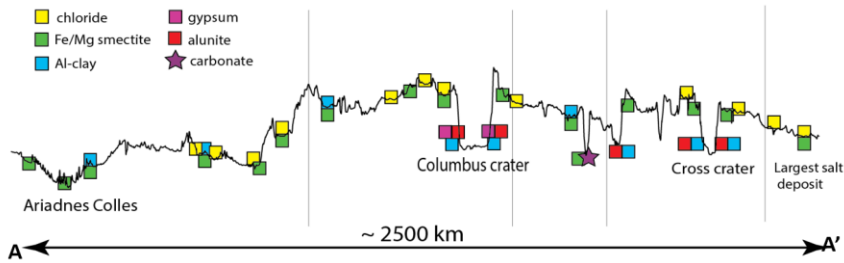
Figure 2: Regional cross section showing relative elevation of hydrated mineral deposits. (Alunite deposit between Columbus and Cross craters is newly identified).

the chloride deposit in every place where CRISM data is available (including multispectral mapping tiles). Where the relationship is clear, the Fe/Mg clays under-lie the chloride deposits. Since clay minerals are relatively impermeable, it may be that these chloride deposits preferentially formed where clay minerals prevented efficient drainage of surface waters.

We find that these observations (local lows, widespread elevation distribution, sinuous features) are consistent with a local surface water source for the chloride deposits, rather than groundwater upwelling. A deep groundwater source is not consistent with the lack of observed deposits in regional deep basins, nor with those observed at high elevations. Order of magnitude estimates indicate that a layer of typical Martian basalt [10] <10 cm thick across the study area would contain enough chloride to form the observed deposits; leaching of basaltic material by surface waters could therefore reasonably concentrate the amount of chloride observed. A lack of association between chloride deposits and other salts (carbonates, sulphates) suggests that these deposits result from different hydrologic reservoirs, separated by space and/or time. Note that a lack of observed sulphate/carbonate at the orbital scale does not mean that no accessory salts are present with the chlorides in this region; only that they are not sufficiently concentrated/abundant at the surface to be observed at this scale.

Sulphates. Unlike clays and chlorides, orbital detections of sulphate minerals in this region are limited to a few locations, typically around the edges of deep basins. While our survey did not find any additional kieserite or gypsum outside of previously-reported deposits in Columbus [3] and Cross [11, 12] craters, we did find a small number of additional alunite deposits within the study area, in craters in the northern part of our study area; see Figs. 1, 2.

The observed sulphate deposits are restricted to deep basins, rather than being widespread through the highlands; this is consistent with a deep groundwater source, rather than surface water runoff. Order of magnitude estimations indicate that a layer of typical Martian basalt <0.5 mm thick over our study area (or 1-2

km^3) contains enough sulphur for the observed deposits (assuming the deposits are 1 m thick). Therefore, sufficient sulphur ions could easily have been leached from the rock to generate the observed deposits—either through widespread low-level leaching and concentration in a deep subsurface reservoir, or through intense focused leaching along fluid pathways. A concentrated sulphur source (such as a buried evaporite or pyrite body) is not required to explain the observed deposits. The presence of alunite in these deposits indicate that some of the sulphur-bearing waters were also acidic; on Earth, such sulphurous and acidic systems are often connected to a magmatic reservoir.

Conclusions: While Terra Sirenum has a large concentration of both chloride and sulphate orbital mineral detections, these are decoupled in space and/or time. Chloride deposits are most consistent with surface runoff of relatively sulphate-free waters (since no accessory sulphates were observed from orbital data). Chlorides are not observed in deep basins; this may be due to (1) post-depositional resurfacing/remobilization; (2) small volumes of water that did not spill over into deep craters; (3) lack of Fe/Mg clay to provide an impermeable substrate; or (4) they are present, but not detectable in deep basins due to intimate mixing with sulphates or other minerals with strong absorptions in the visible-shortwave infrared part of the spectrum.

On the other hand, sulphate minerals are restricted to deep crater basins; this distribution suggests a deep groundwater source. In our ongoing work, we are investigating plausible formation scenarios to determine how these separate hydrological reservoirs could evolve, and conducting further detailed analysis to determine whether it is possible to ascertain the relative ages of these different processes.

References: [1] Ehlmann, B.L. and Edwards C.S. (2014) *Am.Min., 42,* 291-315. [2] Leask, E.K. et al. (2017). *LPSC XLVIII,* #2609. [3] Wray, J.J. et al. (2011) *JGR:Planets, 116,* E01001.[4] Osterloo, M.M. et al. (2010) *JGR, 115,* E10012. [5] Glotch, T.D. (2010), *GRL, 37,* L16202. [6] Dickson, J.L. (2018), *LPSC XLIX,* #2480. [7] Dundar, M. et al. (2019) *LPSC L,* (# TBD). [8] Bishop, J.L. et al. (2008), *Clay Min., 43, 1.* [9] Carter, J. et al. (2015) *Icarus, 248,* 373-382. [10] Schmidt, M.E. et al. (2018) *JGR Planets, 123,* 1649–1673. [11] Swayze, G.A. et al. (2008) *AGU, 89(53),* Abstract P44A-04. [12] Ehlmann, B.L. et al. (2016) *Am.Min., 101,* 1527-1542.