MARTIAN LAKE PLUMBING: MINERALOGY, MORPHOLOGY, AND GEOLOGIC CONTEXT OF HYDRATED MINERALS IN TERRA SIRENUM.
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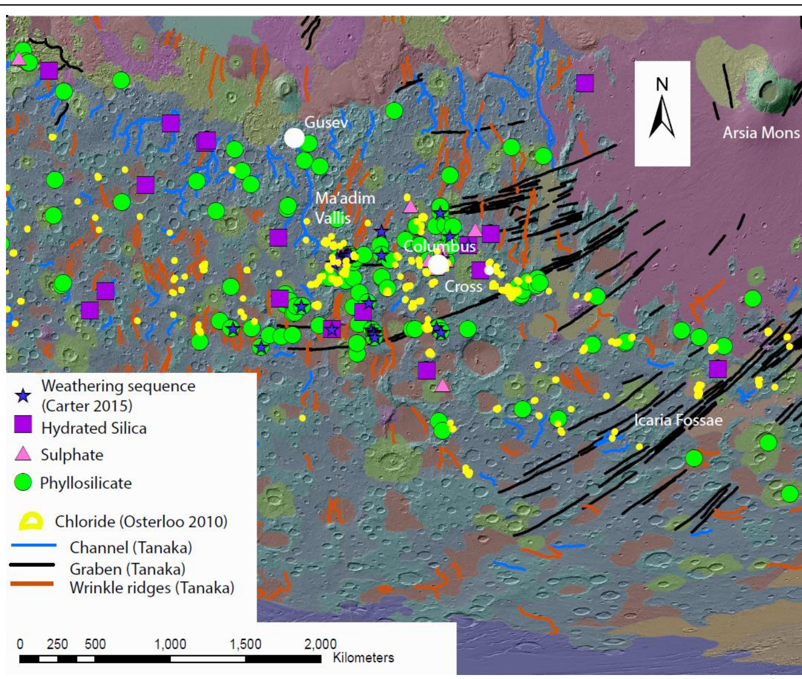
Introduction: Over the last decade, remote sensing and imaging instruments on a variety of missions (TES, OMEGA, THEMIS, CRISM, CTX, HiRISE) have produced and are still producing a rich dataset for geological and mineralogical interpretation of the surface of Mars. One location that has emerged as a region of interest, mineralogically and geologically, is Terra Sirenum. Located on the southwestern flank of the Tharsis region, it has been influenced by volcanic activity as well as pre- and post- Tharsis tectonic activity [1]. Several palaeolakes dot the region, including the large Eridania basin [2, 3], and it is an area of predicted groundwater upwelling [4, 5]. Diverse, secondary minerals have been identified in Terra Sirenum, including widespread chloride deposits [6], sulphates (including acid sulphates alunite and jarosite) [7, 8, 9], and Fe/Mg as well as Al-rich phyllosilicates [10]. Hydrated silica [7] and carbonate deposits [11] have also been detected, although they are rare.

Secondary minerals are key to understanding the history of water chemistry on Mars. Studying the spatial relationships between minerals allows us to better understand the overall "plumbing" of this region—investigating the connectivity between possible sources of water and soluble ions that formed the salt deposits. Here, we look at the distribution of mineral detections, the morphology and stratigraphic relationships to one another and volcanic and tectonic processes. We also consider mass balances in understanding the origin of the mineral-bearing deposits. This comprehensive study will improve current estimates for the quantities of chlorides and sulphates transported by water on Mars.



Fig, 1: Map of the Terra Sirenum region showing the distibution of secondary mineral detections and their spatial relationship with surface features.

Methods: We use VSWIR (visible-shortwave infrared) and TIR (thermal infrared) remote sensing datasets to understand the mineralogy and lithification (via thermal inertia) and corresponding high resolution imagery (HiRISE (25 cm/pixel) and CTX (6m/pixel)) to understand the geologic nature of the deposit. We have built an ArcGIS project incorporating previously published mineral detections [6, 7, 8, 9, 10, 11], mineral maps [OMEGA, 12; TES, 13], geological maps [1, 2] and hydrological maps [4, 5], as well as primary datasets (HiRISE, CTX, THEMIS). Multispectral CRISM and THEMIS data (updating Osterloo chloride detections) are processed in IDL/ENVI and 3-colour stretched products are imported to ArcGIS. Multispectral CRISM data are used in conjuction with lower spatial resolution OMEGA data to map the distribution of Fe/Mg phyllosilicates, Al phyllosilicates, sulphates, and carbonates. For geological interpretation, we focus on regions where chloride, sulphate, and phyllosilicate minerals are found in close proximity.

For mineral deposits which appear to fill low-lying areas (eg. chlorides, some sulphates), the areal extent allows a first-order approximation of the deposit volume, especially if the depth is constrained either by exposed stratigraphy or if stereo images are available to build a DEM. We explore constraints on the amount of chloride stored in such deposits, using order of magnitude estimation.

Results: Preliminary results indicate that all secondary mineral detections are concentrated between ~20-40°S and 185°E-150°W. Lack of detection in the north could be attributed to dust cover (TES global dust map), but the same is not true beyond 40 S. Some detections are clustered along large tectonic features (fossae; see Fig. 1), but only in the midlatitude regions. The Icaria Fossae to the south has a similar level of targeted CRISM coverage, but many fewer secondary mineral detections.

The different types of mineral deposits tend to be found in different places; as noted in [6], chloride deposits are often on the inter-crater plains, while detections of phyllosilicates and sulphates are concentrated around crater edges. Part of this may be a result of a sampling bias, where CRISM targeted images are often focused on crater edges where the best 'fresh' exposures are expected, as opposed to THEMIS' more widespread coverage.

A site with chlorides, sulphates, and phyllosilicates detected within a small area is identified in Fig. 2. It is located at the head of Ma'adim Vallis, north of Eridania palaeolake, and is near tectonic fracturing. Using high-resolution imagery, we will attempt to unravel the relationship between these different alteration phases.

We can use the aforementioned mapping results to provide bounds on the quantities of minerals present. For example, the polygons of Osterloo [6] indicate a surface expression of ~6000 km^2 of chloride salt in this region. If we assume that the deposits are at least 10 cm thick (thermal skin depth), perhaps up to 10 m thick (scarp exposures), this yields a salt volume estimate of about 0.6-60 km^3. If we assume that the deposits are about 25% chloride [14], this gives ~ 0.15 to 15 km3 ($3x10^{11}$ to $3x10^{13}$kg; $5x10^{12}$ to $5x10^{14}$mol) of pure salt (for reference, the Dead Sea on Earth contains about $3x10^{13}$kg of NaCl). We think the chloride at Terra Sirenum may come from a magmatic source, given its proximity to known volcanic regions; from Earth literature, volcanic gases associated with basaltic lavas have ~0.1 mol% Cl [15]. This means that ~$5x10^{15}$ to $5x10^{17}$mols of lava (10^{15} to10^{17}kg, assuming enstatite-like molecular mass) would be required to produce the observed amount of chloride. Using an estimate [16] for the lava volume associated with Tharsis, this known volcanic region contains ~ 10^{21}kg of lava. Therefore, the emplacement of Tharsis volcanics could easily account for the chlorides detected at the surface by the Osterloo survey.

Future Work: We are looking to understand the distribution of secondary mineral deposits in Terra Sirenum—how and when they were formed, where the materials came from (*in situ* or allochthonous), and the implications for Martian hydrogeology. We will use the results of this project to provide bounds for geochemical modelling of Martian ion transport systems, to better understand this water, nutrient (ion), and energy-rich environment of Mars' past.

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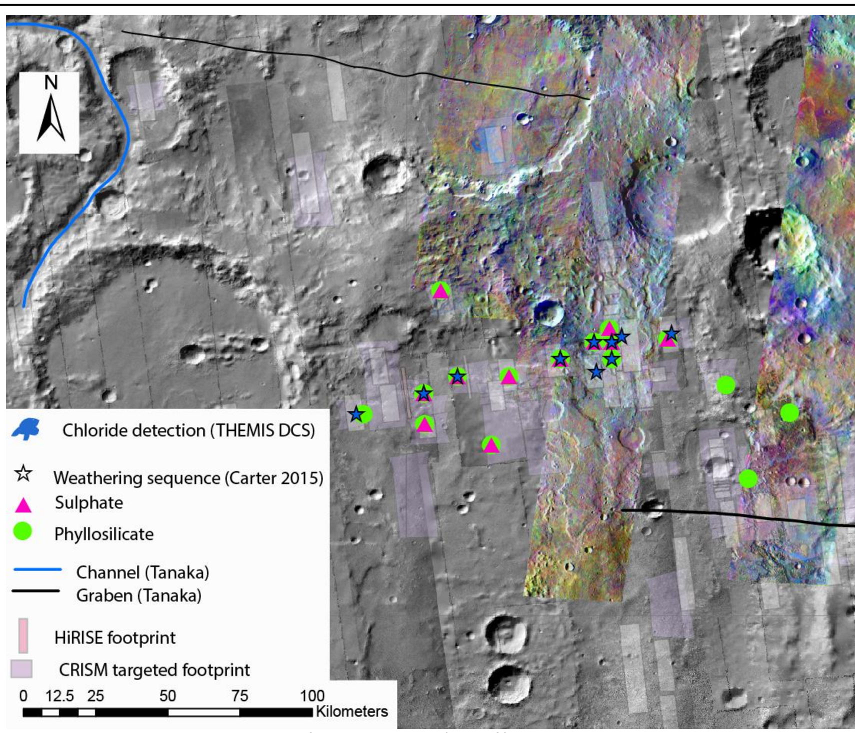

Fig. 2: Example site near the head of Ma'adim Vallis (top left) with chloride, sulphate, and phyllosilicate detections. THEMIS 875 DCS images (chloride deposits are bright blue) are overlain on a CTX mosaic.