A NEW VIEW OF MARS AQUEOUS ALTERATION: FIRST RESULTS FROM THE MARS ORBITAL CATALOG OF CHEMICAL ALTERATION SIGNATURES (MOCCAS)

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Introduction: Aqueous minerals are a prime target for Mars exploration, and as such have been under much scrutiny from orbital and roving missions. The latter provide in-depth investigations but highly localized in space and geologic age, while the former only provide a coarse view of the mineralogy but at a global spatial and temporal scale. Orbital investigations have uncovered thousands of locations on Mars with aqueous mineral deposits, of all major Earth types: salts, hydroxides, hydrous clay and clay like minerals. Piecing together all these data into a coherent, global timeline for water at Mars has been tedious however, and few refinements have been made since the established paradigm of Mars's waning activity around the Noachian [e.g. 1,2]. One important limitation has been the heavily disrupted nature of the oldest terrains on Mars. Another one has been the difficulty in providing a global repository of aqueous deposits on Mars at the orbital scale.

Dataset: Here we report on the completion of the MOCCAS (*Mars Orbital Catalog of Chemical Alteration Signatures*) project. A decade of mapping hydrated minerals on Mars at the sub km resolution, using principally the OMEGA/MEx and CRISM/MRO imaging spectrometers [3,4], now provides a global view of aqueous alteration at Mars. The approach here is hybrid between the early mapping works [1,5], and subsequent cataloging projects [6,7,8]. This new vectorial database combines detailed spectral analysis providing the aqueous mineralogy, with high resolution spatial mapping for morphologic context and global scale distribution. The detailed methodology and goals of MOCCAS are further described in [9].

Results: We present early results from this dataset which provide a new view of Mars alteration:

1. A statistically significant sample (100,000s deposits) globally at Mars which reveal the blanketing nature of Mars's Noachian alteration. Likely an order of magnitude more than established thus far.
2. New regions of extensive aqueous alteration with areas in par with those well studied thus far (e.g. Mawrth Vallis Plateaus, Nili Fossae, Sinus Meridiani).
3. Regional scale trends in Mars's alteration showing coupling between geologic/topographic context and composition.

Collectively, these early results show that Mars's alteration is still largely un-investigated, and there exist several regions of particular interest which would warrant further study and in-situ exploration. Several such example regions are shown here and will be presented.

Featured altered regions:

1. Hellas Planitia basin. The western lower margin of Hellas Planitia exhibits blanketing alteration consisting of hydrated silica and localized alunite sulfate deposits. They are interpreted as late stage (Hesperian) acidic alteration, perhaps as a mixture of thin films and intermittent spring outflows. The lower reaches of this margin exhibits erosional windows into sedimentary clays and sulfates. There is evidence at Hellas for a large sea then shallow ponding then salt domes.

2. Southern Tyrrhena Terra. This area exhibits the highest concentration of aqueous clay deposits which are found systematically in layered units draping pre-existing topography (craters and uplifted buttes from the Hellas impact event). These are interpreted as sedimentary deposits, perhaps as pediments or linked to a possible Hellas sea. The uplifted buttes are rich in higher temperature phases: chlorites, prehnite, carbonate, talc and perhaps amphiboles.

3. Circum Chryse margin. This margin exhibits layered clay sediments over a range of 100s meters elevation, over the entire southern arc of Chryse. These will be explored by the ExoMars rover, either at Mawrth Vallis Plateaus or Oxia Planum. Their origin is debated, from dryer pediments, to an intersecting water table, to a palustrine setting in contact with a northern sea.

4. The southern polar sulfates of Mars. While the northern peri polar gypsum deposits are well documented [e.g. 10,11], only scattered sulfate detections had been made in the south. Systematic mapping of southern peri polar latitudes shows in fact that a large sulfate unit exists there too. Preliminary studies show that there is only loose correlation with the morphology and geologic units, which might indicate a recent, surficial origin. Gypsum is not always the main sulfate there. Its mode of formation may therefore differ from that of the north polar region.

Perspectives. A systematic, regional-scale investigation of Mars using the MOCCAS dataset is underway which aim is to provide insight on the diversity of alteration settings at Mars. The database itself is being refined to integrate, for each deposit, the geologic age from [12], while the largest deposits will have esti-

mates of their thicknesses (when possible) and modal abundances (*see companion abstract* [13]). These will help interpret the regional diversity, and be used to study the global scale distribution of clay minerals at Mars.

References: [1] Bibring J.-P. et al. (2006) Science, 312, 400-404 [2] Fassett C. and Head J. (2011) Icarus, 211, 1204-1214 [3] Bibring J.-P. et al. (2004), ESA SP, 1291, 75-95 [4] Murchie S. et al. (2007) JGR, 112, E05S03 [5] Poulet F. et al. (2007) JGR, 112, E08S02 [6] Carter J. et al. (2013) JGR, 118, 831-858 [7] Murchie S. et al. (2009) JGR, 114, E00D06 [8] Ehlmann B. et al. (2011) Nature, 479, 53-60 [9] Carter J. (2017) *LPSC 48*, Abstract #2231 [10] Langevin Y. et al. (2005) Science, 307, 1584-1586 [11] Massé M. et al. (2010) Icarus, 209, 434-451 [12] Tanaka K. et al. (2014) PSS, 95, 11-24 [13] Poulet F. et al. (2018) *this conference.*

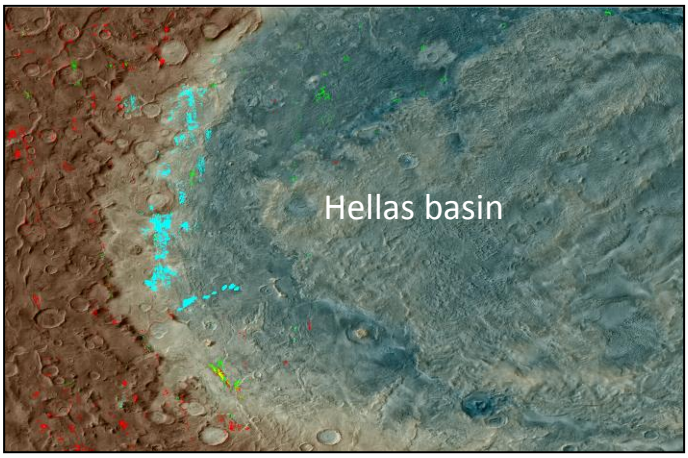

Figure 1. Extensive surficial alteration within Hellas basin. *Cyan: Hydrated silica. Green: sulfates (inc. alunite). Red: clays. Yellow: clays + sulfates.*

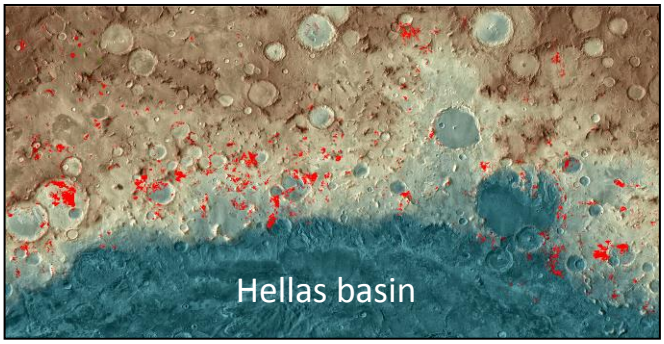

Figure 2. Sedimentary clays (*red*) in southern Tyrrhena Terra / northern margin of Hellas Planitia.

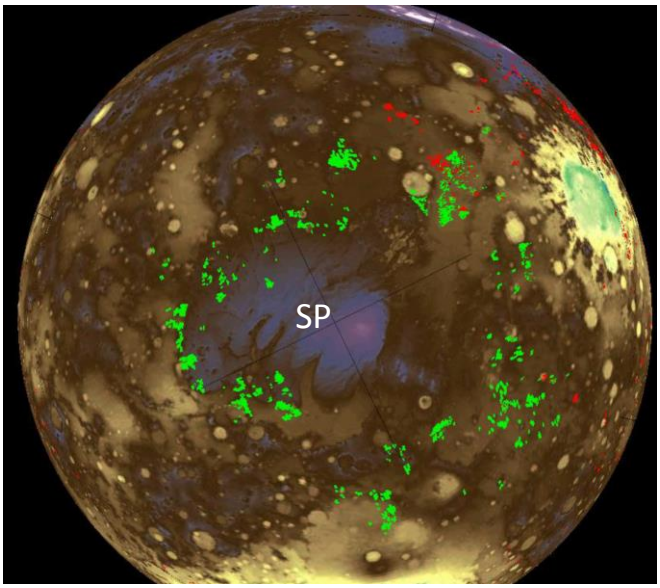

Figure 4. The south polar sulfates (*in green*) of Mars.

Figure 3. Clay rich (*in red*) margin of Chyrse Planitia.