LISTWANITIZATION IDENTIFIED ON MARS. D. Mège[1], J. Gurgurewicz[1], M. Massironi[2,3,4], M. Pajola[4], R. Pozzobon[2,4], L. L. Tornabene[5], B. Baschetti[2], S. Douté[6], E. Hauber[7], L. Keszthelyi[8], A. Lucchetti[4], J. Perry[9], F. Seelos[10], A. Pommerol[11], R. Ziethe[12], G. Cremonese[4], N. Thomas[11], [1]Centrum Badań Kosmicznych Polskiej Akademii Nauk (CBK PAN), Warszawa, Poland, dmege@cbk.waw.pl, [2]Dipartimento di Geoscienze, Università degli Studi di Padova, Italy, [3]CISAS, Università degli Studi di Padova, Italy, [4]INAF-OAPD, Italy, [5]Institute for Earth and Space Exploration, Western University, Dept. of Earth Sciences, London, ON, Canada, [6]Université Grenoble Alpes, CNRS, CNES, IPAG, France, [7]DLR, Berlin, Germany, [8]US Geological Survey, Astrogeology Science Center, Flagstaff, AZ, USA, [9]University of Arizona, Tucson, AZ, USA, [10]Johns Hopkins University, Applied Physics Laboratory, Laurel, MD, USA, [11]Universität Bern, Switzerland, [12]M&S Software Engineering, Bern, Switzerland.

Introduction: Listwanite, an assemblage of serpentine, carbonates, quartz and other minerals, is found in obducted oceanic crust, in the context of intense hydrothermal circulation (e.g., [1]). We analyzed CaSSIS, HiRISE, CRISM, and CTX data of the eastern Ladon basin, and found that serpentinization and carbonation of late Hesperian to Early Amazonian ultramafic lava flows is generally consistent with the presence of listwanite ridges.

Study area: The Ladon basin hosts Late Noachian and Hesperian sediments from a multistage drainage system [2], though to have fed a relict groundwater system [3]. Floor-fractured craters (FFCs) formed later, and are filled by a unit that extends beyond them as a graben- and wrinkle-ridge-bearing unit. FFC fracturing has been attributed to magmatic inflation and deflation episodes, perhaps associated with groundwater migration [4, 5]. The study area (Fig. 1) is located in such a unit where three layers are exposed and provide a modelled age of upper Hesperian to lower Amazonian [6].

Datasets and methods: We studied the exposed layers using 3 CaSSIS color infrared images (filters NIR-RED-PAN-BLU, 4.6 m/pixel), 4 HiRISE images (0.25-0.50 m/pixel), 1 CRISM cube (18 m/pixel), and a photoclinometry-enhanced digital elevation model (DTM) of a 2-CTX image mosaic of vertical precision < 1 m [7]. Morphological and structural information was retrieved from both images and topography, and synthesized with composition from CRISM joint VNIR-NIR analysis of TER and MTRDR products [8, 9], in turn, complemented by CaSSIS color analysis. First, CRISM spectral indices [10] were examined to get a general idea of the potential mineralogy at the site. Then, spectra were extracted. The averaged spectrum of three regions of interest (ROI) found to be the most different from this background was ratioed with the background. A mobile average was applied, and the resulting spectra were compared with a library of reference spectra. A K-means spectral clustering technique [11] was applied to a CaSSIS image to identify the dominating spectral classes.

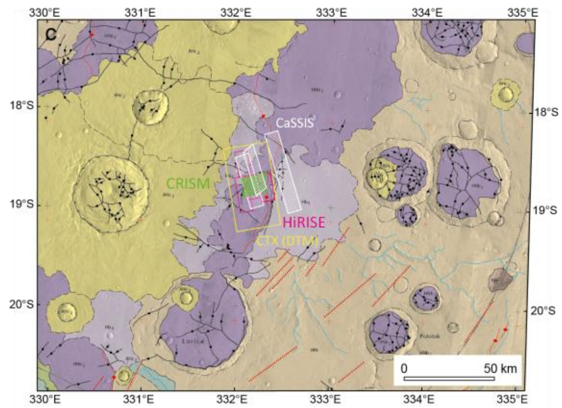

Fig. 1. The study area is defined by CaSSIS, HiRISE, CRISM and CTX coverage. The background map is from [2]; image IDs are given in [6] and the CRISM cube is FRT000128EA.

Results: HiRISE images and the CTX DTM indicate that the two lower of the three exposed layers are altered: one yellowish level and an underlying bright one. The bright unit is observed in low elevation areas, whereas the yellowish one mainly corresponds to NNE-oriented topographic ridges up to 30 m high and their debris slopes. The ridges are capped by the uppermost layer, which has a flow-morphology (Fig. 2).

K-means clustering applied to CaSSIS reveals that the ridges are enriched in ferric-bearing materials, and alteration spreads outward from the ridges. Broad absorptions consistent with pyroxene and olivine are pervasively present throughout the CRISM cube. Notably, dividing by the background spectrum removes these signatures, and results in nearly flat spectrum. Narrower absorptions consistent with serpentine and chlorite coincide with two ROI located in the yellowish unit, in addition to carbonates (probably Mg-rich), and possibly talc, whereas kaolinite group minerals, and perhaps alunite, are detected in the underlying bright unit.

Discussion: The detected mineralogical assemblage in the yellowish unit is consistent with serpentinization and carbonation of ultramafic lava flows. However, this fails to sufficiently explain the mechanical ridge strength. Similar listwanite ridges, with comparable spectral shapes, are provided by ASTER multispectral data [6] and are composed of serpentine and carbonates reinforced by quartz. We suggest that the yellowish ridges in the Ladon basin are also listwanite ridges. Quartz has no diagnostic absorptions in the CRISM spectral range.

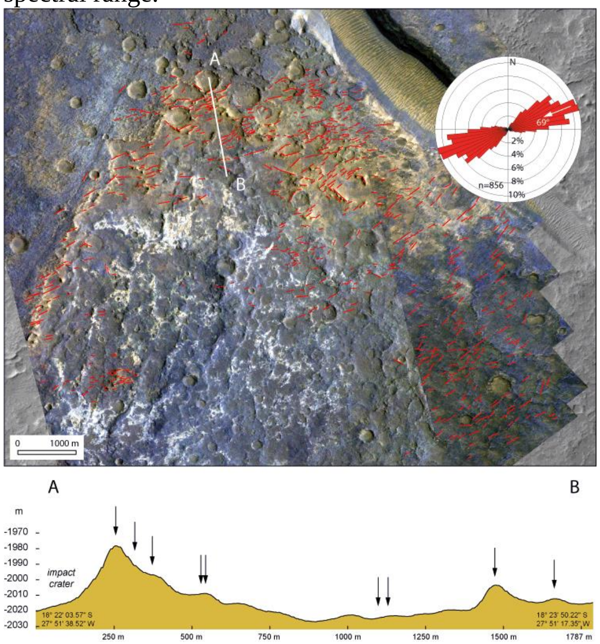

Fig. 2. Location and orientation of yellowish ridges (in red) in two of the studied CaSSIS images (background image is CTX), and example of a topographic profile across ridges (arrows). Vertical precision < 1 m. North on top. Main graben trend in the area is parallel to ridge trend, although the graben seen here is oriented NW-SE.

The composition of the bright unit, when compared to the yellowish, may be explained as decreasing hydrothermal alteration downward, if not simple alteration from the presence of groundwater. This suggests that the heat source was more likely on top of the altered unit, i.e. in the uppermost lava flow. The source of the hydrothermal fluids was more likely a Hesperian or older water reservoir underneath [3, 12]. Structural control of ridges and their alignment with the main graben trend suggest ridge formation as fractures in extensional regime, similar to Oman listwanites [1], with associated intense alteration and perhaps thermomechanical erosion owing to high emplacement temperature of ultramafic flows [13]. Fig. 3 summarizes the proposed listwanitization mechanism within the Ladon basin.

Conclusion: Data analysis suggests that listwanite ridges formed in the eastern Ladon basin. Listwanitization had not been identified on Mars in earlier works. Serpentinization and carbonation is interpreted to result from alteration of ultramafic flows provided by hydrothermal fluids sourced from an underlying groundwater reservoir, with heat from emplacement of an overlying ultramafic flow.

Acknowledgments: CaSSIS is a project of the University of Bern funded through the Swiss Space Office via ESA's PRODEX program, and also supported by the Italian Space Agency (ASI) (ASI-INAF agreement no. I/018/12/0), INAF/Astronomical Observatory of Padova, and the Space Research Centre PAS (CBK PAN) in Warsaw. The HiRISE, CRISM and CTX datasets were provided by the Planetary Data System (PDS).

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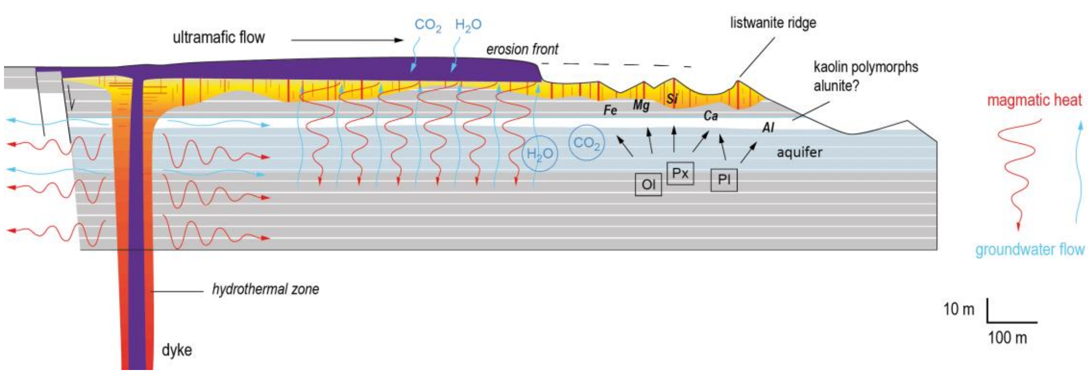

Fig. 3. Proposed explanation for listwanitization in eastern Ladon basin, constrained by the present work [6].