'WINDOWS' INTO MARS' POTENTIALLY HABITABLE SUBSURFACE IN THE CONTEXT OF NASA'S PERSEVERANCE EXTENDED MISSION. A. Valantinas[1], J. F. Mustard[1] and V. T. Bickel[2]. [1]Brown University, Providence, USA, [2]Center for Space and Habitability, University of Bern, Switzerland.

Introduction: The search for ancient biosignatures on Mars has largely focused on sedimentary environments, because they have preserved the most abundant and diverse evidence of life on Earth [1]. The NASA Mars 2020 Perseverance rover was designed to explore such an environment in Jezero Crater, where it is collecting samples from a fluvial-deltaic system and a paleolake basin [2]. These samples may be returned to Earth by a joint NASA-ESA mission in the 2030s. However, this approach presumes Earth-like lacustrine processes and a robust photosynthesic biosphere [3], which may not be the case. On Earth, the oldest unequivocal signs of photosynthetic life date back to ~3 billion years (Ga) ago [4], but by then, Mars perhaps had already become a cold, dry, and hostile planet [5]. On the other hand, anaerobic microbial life in the subsurface emerged earlier than 3.5 Ga ago on Earth [6] and, if life had started on Mars, could have persisted in Mars before the surface conditions deteriorated [3]. Therefore, exploring the early geologic record of Mars, which is more well preserved than Earth's earliest record, could reveal clues about the origin and evolution of life that are erased on Earth. Fortunately, the Perseverance landing site and its vicinity offer both sedimentary and subsurface targets for astrobiological investigations within driving distance (~20 km).

From its current position on the upper section of the Jezero fan/delta, Perseverance may traverse westward to the crater rim and farther to adjacent plains of Nili Planum (aka 'Midway'[7]). This region exposes ~3.6 Ga old basement rocks that predate the Jezero impact event and belong to the Noachian epoch when groundwater activity was hypothesized to be have been intense, expanding the size of habitable environments [8]. Notably, Nili Planum hosts polygonal ridges (e.g., **Fig. 1**), hypothesized to form through mineralization within fracture zones by hydrothermal fluids and exposed by differential erosion [9–11]. Low temperature hydrothermal systems and circulating groundwater in the Earth's crust are known to harbor diverse and abundant life forms [12]. The ridges may have mineralized and sequestered windows into the deep Martian biosphere and are potential sampling sites for the Perseverance extended mission. Since true global distributions of polygonal ridges on Mars are unknown [13,14], we mapped them using a deep learning-driven approach, which can provide key timing constrains on a global scale. We complement this study with spectroscopic analysis to assess astrobiological potential in Nili Planum and more broadly on Mars.

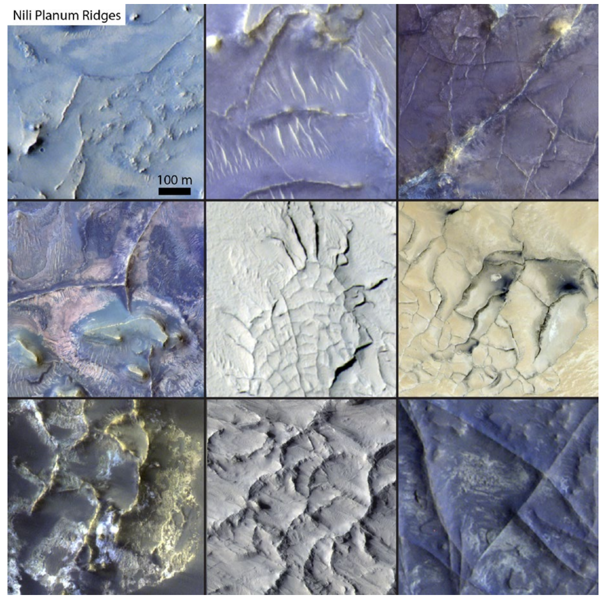

Fig. 1. Polygonal ridges exposed by erosion in Nili Planum (18.2°N, 77.1°E) and other locations on Mars. CaSSIS NPB color composites.

Methods: To map the polygonal ridges across Mars we employed a publicly available object detection architecture (Yolov5x CNN, PyTorch 1.7). We manually annotated 254 polygonal ridges in 134 CTX images from different locations on Mars, following a proven workflow [15]. Each annotation is a rectangular box enclosing a cluster of polygonal ridges in a CTX image. Our detector achieves an average precision of 0.78 in our separate test set with a total of 13 polygonal ridges. We apply the detector to the CTX global mosaic, i.e., a total of 86,546 images, using a well-established processing infrastructure [15] and one NVIDIA RTX 3090 GPU (processing time of ~two months). Each detection was reviewed by a human and in context with the CTX mosaic. We started systematic imaging these sites with the CaSSIS color camera (ESA, TGO).

Results: Global mapping resulted in over 1,200 unique ridge cluster detections, representing the first consistent and global catalog of polygonal ridges on Mars. Polygonal ridges are found primarily in Noachian highland terrains (**Fig. 2**). Interestingly, ~20% of all detections are associated with younger Amazonian volcanic terrains, which may be glacial in origin. While only ~2% of all detections fall in the impact geologic units (as defined by [16]). We also report several ridge hotspots in Gordii Dorsum, Arsia Mons, Meridiani Planum, Hellas Planitia, Nili Fossae and Nepenthes Mensae (**Fig. 3**). Our detections in Nili Fossae region confirm the results of previous studies [17]. Of interest are new detections near the dichotomy boundary in Gordii Dorsum and Nepenthes Mensae regions because this area may have been in contact with a putative northern ocean [18].

Furthermore, we have covered ~70% of Nili Planum in high quality CaSSIS VNIR data (4 band multispectral, @4.5 m/px). Complete mapping and multispectral analysis will provide new information on the ridge composition and 3-D structure in Nili Planum and offer new targets for the Perseverance team.

Future work: We will complement the CaSSIS data with archived CRISM hyperspectral data for mineralogical mapping and HiRISE high-resolution images for morphological analysis. We will also use the NASA RELAB facility at Brown University to acquire spectral measurements of analog materials for comparison.

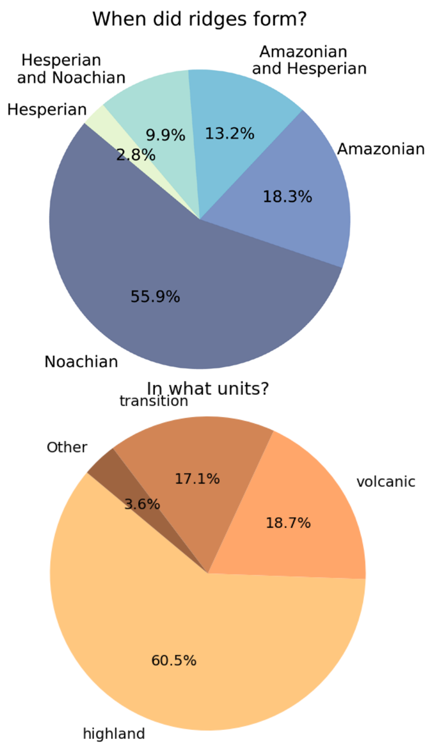

Fig. 1. Pie charts for over 1,200 polygonal ridge clusters detected in our study. The geologic ages and units derived from [16].

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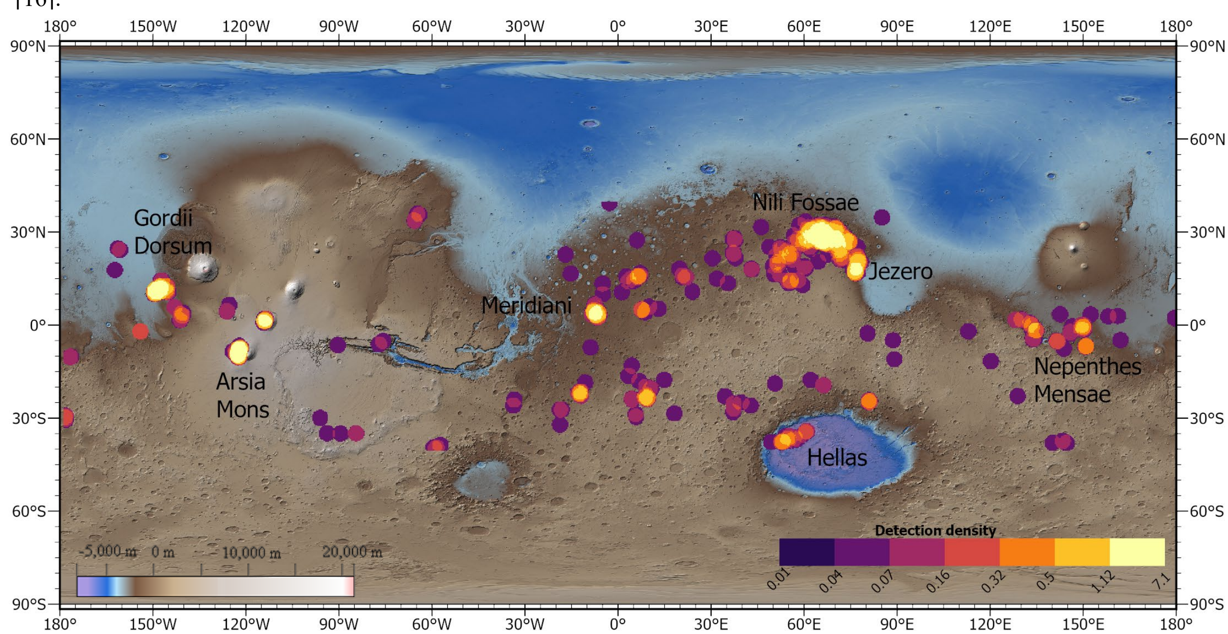

Fig. 3. Global distribution of >1200 exhumed polygonal ridges on Mars as identified by a neural network. MOLA in the background.