GLOBAL POLYGONAL RIDGE NETWORKS: EVIDENCE FOR PERVASIVE NOACHIAN CRUSTAL GROUNDWATER CIRCULATION.
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Introduction: Polygonal ridges networks, lattices of narrow ridges connected at angular junctions, have been documented in narrow regions across the surface of Mars [1-4]. These ridge networks display a diverse array of colors and morphologies, and are likely generated by a variety of causative mechanisms, including the sedimentary or volcanic infilling of fracture networks, or the mineralization of fractures [4]. Among these various formation mechanisms, the mineralization of fractures is particularly worthy of interest because it implies the circulation of liquid groundwater through a substrate, thus potentially contributing to a habitable Martian subsurface at the time of network formation. In the course of previous mapping [1-4], many ridge networks were discovered in the Nili Fossae region of Mars, whose morphologies seemed to suggest an origin by mineralization (**Fig. 1**). These ridges networks consist of mostly light-toned ridges of varying thickness intersecting at a wide variety of angles. Their strikes also did not show any strong orientation preference [3]. Where dissection by deep valleys offers a cross-sectional view, it can be seen that the ridges extend deep into the crust as steep but non-vertical planes [4]. Other types of ridges include the Western MFF ridges, characterized as dark toned and boulder-shedding, with an association with both lava flows and polygonally fractured Medusae Fossae Formation material; Hellas-type ridges, characterized by their consistent thicknesses, regular, polygonal junctures and, similar cell-sizes over wide regions; and Meridiani-type ridges, characterized as flat-topped, arcuate, and splintered along the ridge length [4]. The "Nili-like" ridges were mapped by [4] to be the most widespread type of ridge, found in limited regions across the planet, and likely related to the smaller ridge networks found at the Curiosity landing site. During the course of the first survey, it became apparent that most of the Nili-like ridge locations were localized and often only visible at the highest CTX resolutions, meaning that many instances may have gone unnoticed. In order to find these missing ridge outcroppings, a citizen science initiative was formed through the Zooniverse citizen science platform..

Methods: With the help of the "Planet Four" Zooniverse team, CTX images were divided into small rectangles, and subimages were served to the Zooniverse community. The citizen scientists were given the opportunity to classify the subimage as containing a polygonal ridge network (or not), and additionally given the opportunity to discuss the image on a forum and to tag interesting features with hashtags. Initially, the targeted area of interest was in northern Arabia Terra along the dichotomy boundary; a region including Protonilus Mensae, Deuteronilus Mensae, and Nili Fossae, where ridge networks had previously been found. The participants mapped not only polygonal ridge networks but also fractures and traces of fissures. Based on these results, Zooniverse periodically provided a file containing the center coordinates of all of the CTX subimages containing ridges. The result of this work was a detailed map of ridge networks in northern Arabia Terra (**Fig. 2**). Using the Zooniverse forum functions, one group of citizen scientists continued to map ridges outside of the Zooniverse region of interest, in an area extending across the planet. The result is a global map of Nili-like ridges across the surface of Mars.

Discussion: Nili-like ridges were found to be much more widespread than originally mapped in Kerber et al. [2017], extending across much of the Noachian highlands. On Earth, polygonal fault complexes are common in shallow-marine basins composed of clay, shale, and chalk [6-8]. They are rarely observed in the rock record, but they can be seen in seismic surveys. Polygonal faults are thought to occur in substrates that are not under regional tectonic stress [8]. The faults are thought to occur due to pressurization of water-bearing sediments, causing dewatering and volumetric contraction, or possibly gravity-driven overturn [6-8]. If Mars had an early, active subsurface hydrological cycle, such water-bearing sediments were bound to accumulate. Given enough overburden pressure, polygonal fault systems may have formed due to dewatering, later to be mineralized. The variety of polygonal and chaotically crossing patterns displayed by the Nili-type ridges [3] is typical of fault networks imaged in seismic surveys [8]. At least one terrestrial polygonal fault network is exposed at the surface. This network is located in the Western Desert of Egypt, where calcite veins outlining the polygonal fault patterns can be seen standing in relief over a wide region from space [9].

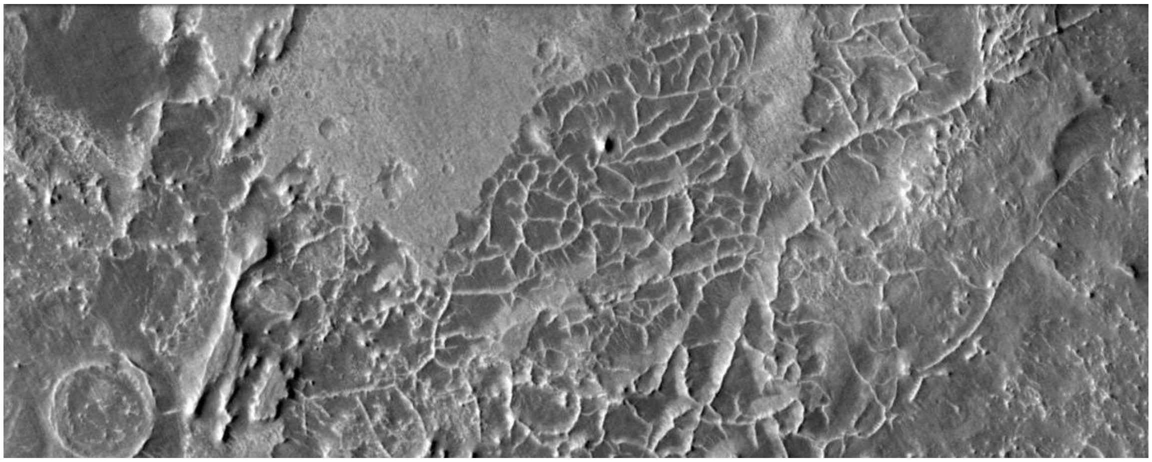

Fig 1. Polygonal Ridges in Northern Arabia Terra, west of Nili Fossae. Google Mars CTX mosaic.

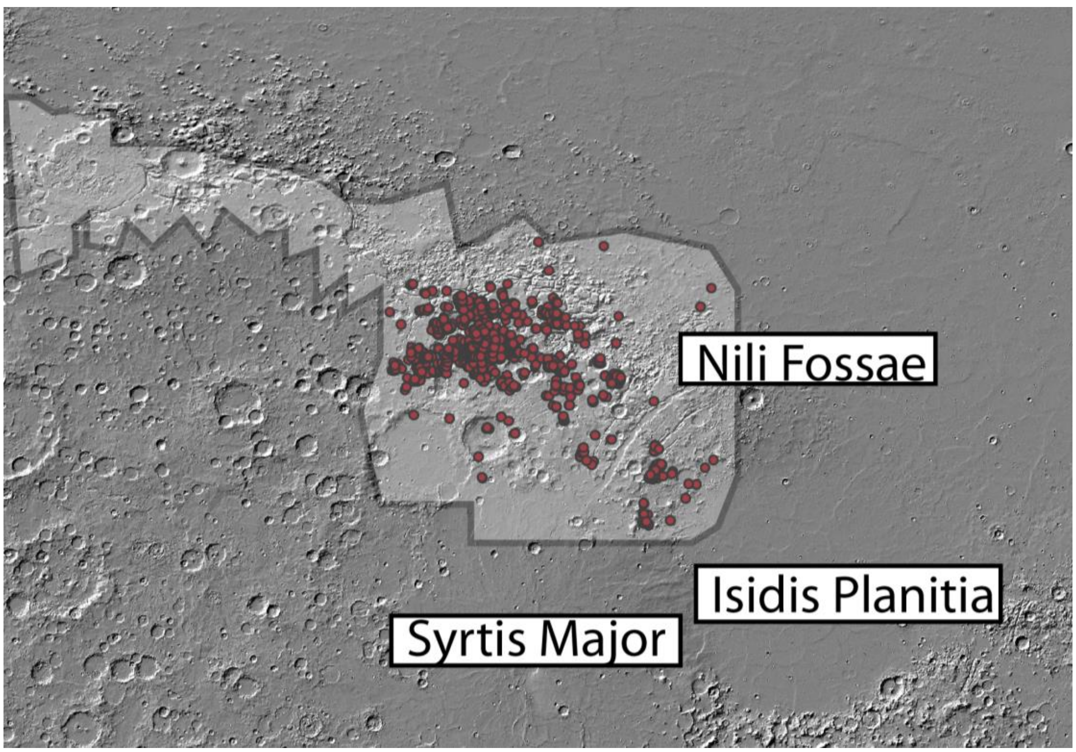

Fig 2. Rough outline of area searched by Zooniverse participants (light grey) and locations where polygonal ridge networks were found (red dots). The ridges clearly being exhumed from the subsurface. They were not associated with glacial terrain, and seemed to be confined to certain stratigraphic layers, similar to the ridges mapped by [8] in seismic surveys of Australia.

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