ANALYSIS OF SINUOUS RIDGES IN THE ARGYRE PLANITIA, MARS, USING HIRISE IMAGES AND MOLA DATA.

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Introduction: A suite of sinuous ridges with dendritic and braided morphologies forms an anastomosing network around the southern Argyre basin in the southern hemisphere of Mars (Fig. 1-2). Past research has led to several proposed modes of origin for the ridges including sand dunes [e.g. 1-2], wrinkle ridges (tectonic ridges) [3], spits/baymouth bars [1], lava flow fronts [3], exhumed igneous dikes [4], inverted fluvial channels [5], and glacial eskers [e.g. 5-11].

Analysis of the sinuous ridges using currently available imagery and datasets provides further insight into the geologic history of the Argyre region. Here we use early imagery from the Mars Reconnaissance Orbiter (MRO) High Resolution Imaging Science Experiment (HiRISE) camera (resolution up to 0.25 m/pixel), and Mars Orbiter Laser Altimeter (MOLA) datasets from the Mars Global Surveyor mission to further characterize and constrain the processes involved in formation of the sinuous ridges. We argue that, when considered together, the characteristics of the ridges are consistent with terrestrial eskers and that the ridges most likely formed from melt water flowing under pressure within or beneath a glacier or large ice mass in a tunnel or sub-ice stream bed.

Characteristics: In planform, the Argyre sinuous ridges vary from dendritic and braided forms to relatively straight, solitary features with an average sinuosity of ~1.2 [10]. MOLA data indicates that the ridges range from ~1-4 km in width, ~10-300 m in height, and have side slopes of ~20-30º. Individual ridge segments vary in length from <1 km to >120 km. Ridge crests frequently transition from sharp-crested to rounded or flat-topped.

Portions of several ridges exhibit layers or beds (Fig. 3A). Analysis of HiRISE and MOLA data reveals that individual layers near the crest of ridge A (Fig. 2) have roughly the same elevation on both sides of the ridge suggesting that layers are most likely horizontal.

HiRISE images resolve large boulders, some >8 m in diameter, in layers and on the surface of ridges (Fig. 3B). However, it is unclear if the boulders, particularly angular ones, are eroding out of layers of indurated material or represent transported particles.

In several locations, ridges appear to lie in troughs that are several kilometers wide and mantled with finer sediment (Fig. 4).

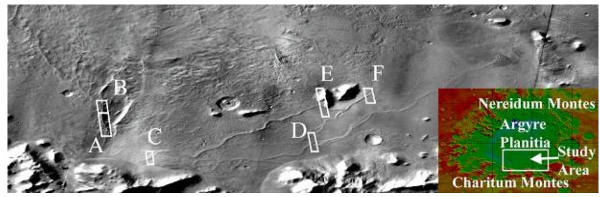

Figure 1: MOLA elevation map (lower right) and Themis day IR mosaic of the study area. White boxes indicate the locations of HiRISE images: A) PSP_001904_1245, B) PSP_003916_1245, C) PSP_003183_1235, D) PSP_001640_1240, E) PSP_005596_1245, and F) PSP_001508_1245.

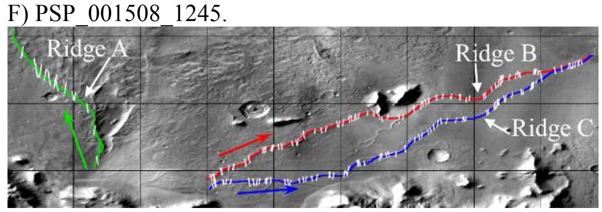

Figure 2: Location of three ridges imaged by HiRISE, ridges A, B, and C (colored lines), on a Themis day IR mosaic. White lines indicate the location of MOLA PEDR tracks. Colored arrows indicate the direction along the ridges that profiles were plotted in Figure 5.

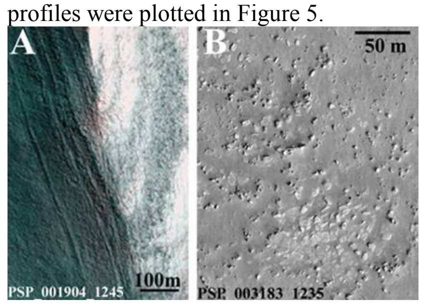

Figure 3: (A) Layers in a HiRISE color image. (B) Large boulders may be eroding out of indurated layers.

Topographic profiles across and along ridges A, B, and C (Fig. 2) were derived from MOLA PEDR tracks. In several locations the adjacent surface elevation differs, sometimes by 10s of meters, on either side of the ridge indicating that the ridges are often oriented across slopes (Fig. 4B). The elevation of the surrounding surface was then averaged and plotted as a function of distance along the extent of the ridge revealing that the ridges cross topographic divides (Fig. 5). If the regional topography has remained stable since ridge formation, the tendency for ridges to cross topography suggests formation by a pressurized flow, rather than a gravity driven flow (open river channels). Analysis of

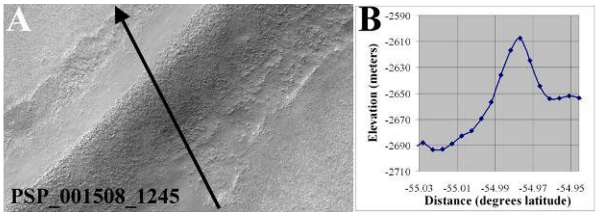

Figure 4: A) Example of a ridge located within a trough. B) A profile across the ridge from MOLA PEDR data. The arrow indicates the location and direction of the profile.

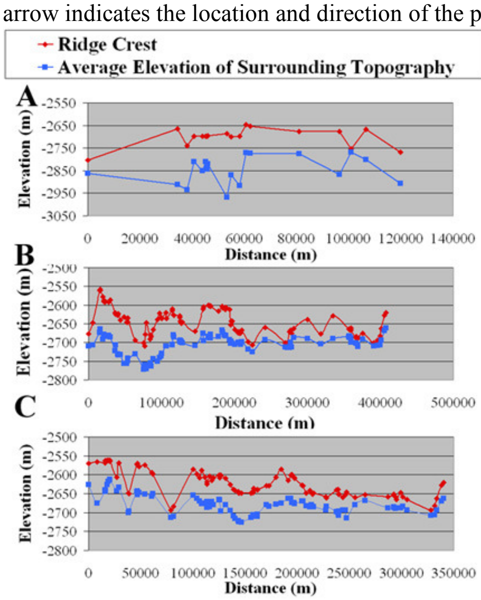

Figure 5: Elevation of the ridge crest and surrounding surface along A) Ridge A, B) Ridge B, and C) Ridge C. Arrows in Figure 2 show the direction of profiles along each ridge.

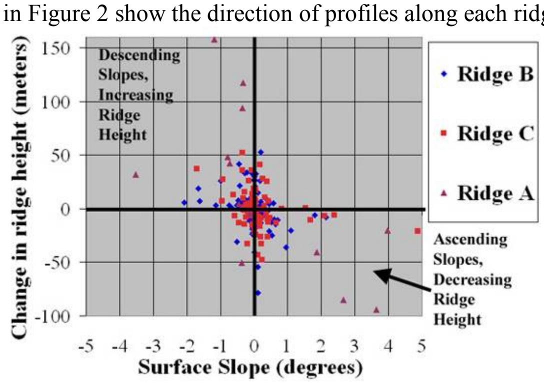

Figure 6: Relationship between changes in ridge height and surrounding surface slope between successive MOLA tracks along each ridge. Negative numbers indicate a decrease in ridge height on the y-axis and descending slopes on the x-axis.

other sinuous ridges in Argyre and the nearby Dorsa Argentea Formation have revealed similar results [e.g. 8-9, 11]. The elevation of the ridge crest was also plotted as a function of distance revealing that the height of the ridge varies along its extent (Fig. 5). To understand the relationship of ridge height to the surrounding terrain, the change in ridge height between successive MOLA tracks along each ridge was plotted against the slope of the surrounding surface (Fig. 6). For slopes >1º, ridge height generally increases with descending slopes and decreases with ascending slopes.

Discussion: We re-evaluate the sinuous ridge formation hypotheses to determine which one(s) can reasonably account for the ridge characteristics discussed in this study. The results of this analysis are summarized in Table 1. The characteristics of the Argyre ridges are consistent with sub-ice fluvial processes and the ridges most likely represent terrestrial esker-like features. Terrestrial eskers have similar morphologies and planview distributions, cross topography, may contain layers, and may lie within troughs, often referred to as Nye channels or tunnel valleys, which form from melt water erosion into subglacial bedrock or sediments [12]. Terrestrial eskers also typically increase in height on descending slopes and decrease in height on ascending slopes due to changes in viscous heating and the resulting melting and freezing of melt water [13].

If the Argyre sinuous ridges are eskers, they indicate that this portion of Argyre Planitia was at the margin of a large ice deposit [e.g. 5-9, 13]. Sequences of layers may indicate the influence of cyclic or seasonal changes [12] and the nature of some eroding beds suggest possible induration. Glaciolacustrine deposition may also have been involved. The esker hypothesis is further supported by potential glacial landforms identified in the surrounding area [e.g. 6, 14-15].

Hypothesis	Morphology	Braided/ Sinuosity	Horizontal Bedding	Troughs	Cross Topography
Sand Dunes	Maybe	No	No	No	Yes
Wrinkle ridges (tectonic ridges)	Yes	No	No	No	Yes
Spits/ Baymouth bars	Maybe	No	Yes	No	Yes
Lava Flow Fronts	Yes	No	Yes	Maybe	Yes
Exhumed Igneous Dikes	Yes	No	No	Maybe	Yes
Inverted Fluvial Channels	Yes	Yes	Yes	Maybe	No
Glacial Eskers	Yes	Yes	Yes	Yes	Yes

Table 1: Summary of analysis. A "yes" or "no" is used to indicate which formation mechanisms are consistent with the ridge characteristics discussed in this study.

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