THE HUYGENS-HELLAS GIANT DIKE SYSTEM ON MARS: IMPLICATIONS FOR LATE NOACHIAN-EARLY HESPERIAN VOLCANIC RESURFACING AND CLIMATE EVOLUTION. J. W. Head[1], L. Wilson[2], J. Dickson[1], G. Neukum[3] and the HRSC Team. [1]Dept. Geol. Sci., Brown Univ., Providence RI 02912 USA, [2]Environ. Sci. Dept, Lancaster Univ., Lancaster LA1 4YQ, UK, [3]Inst. Geol. Wissenschaften, Freie Univ. Berlin, Malteserstrasse 74-100, 12249 Berlin, Germany.

Introduction: On Mars, the presence of linear volcanic vents, narrow graben (the surface manifestation of near-surface dike intrusion) [1], and narrow linear ridges (the erosional remnants of near-surface dike systems) [2] represent the best evidence for the nature and distribution of dike systems. We report here on the discovery and documentation of a laterally and areally extensive set of narrow ridges that are interpreted to be the near-surface manifestation of a major dike system emplaced in the Late Noachian-Early Hesperian period of Mars history and associated with one of the most widespread magmatic and volcanic events in the history of Mars. Hesperian ridged plains (Hr) are "broad planar surfaces, rare lobate deposits, and long, parallel linear to sinuous mare-type (wrinkle) ridges.." interpreted as "Extensive lava flows erupted with low effective viscosity from many sources at high rates..". The paucity of distinctive flow fronts that might confirm a volcanic origin, and the weakness of secondary evidence to support a volcanic origin (such as the presence of wrinkle ridges) has led to some uncertainty in the origin of Hr (5). Furthermore, in regions where volcanic edifices are observed (e.g., Hesperia Planum) there is evidence for pyroclastic activity, rather than effusive volcanic activity, playing a major role (e.g., 6, 7). Because of its global distribution and significance in the history of Mars, we have undertaken a regional and global assessment of Hr as a means to assess evidence for the thermal, volcanological and climatic evolution of early Mars (e.g., 8, 9). In the course of examination of exposures of Hr in the area north and east of Huygens Crater (Fig. 1), we discovered a series of linear ridges associated with Hr. We used MOLA, MOC, THEMIS and HRSC data to trace the surface exposure of these ridges and characterize their nature and relationship to other units.

The Nature and Distribution of the Linear Ridges: At least fourteen exposures of narrow linear ridges comprising two major ridge systems have been detected (Fig. 1). Each ridge system is broadly arcuate to slightly sinuous in its surface pattern and remarkably consistent in character over its lateral extent, which although discontinuous, extends for distances of 575 and 700 km, perhaps extending further in the subsurface. The nature of the ridges is remarkably consistent over their length, as revealed in THEMIS and HRSC data. The width of the ridges range from ~400-800 meters but is typically ~600 meters. The height of the ridges, as revealed by numerous MOLA PEDR profiles, averages less than ~30 meters. The broad ridge seen in the THEMIS and HRSC images is caused by flanking erosional debris surrounding a thin central ridge. The ridge system does not change detailed character as a function of local topography. As ridge segments climb broad wrinkle ridges or descend into craters their width and height remain virtually unchanged. The general shape of the ridge strike is linear, but in regional view it is broadly arcuate. Locally the ridge can meander slightly, but there is no evidence to date for multiple ridges, braiding, bifurcation, sinuosity or tectonically disrupted patterns along strike. The ridge is in contact with several southern upland geological units [4]. The ridges are seen to be both superposed/cross-cutting these plains units and embayed by them. Impact craters and their ejecta are superposed on the ridges as well as cut by them. In some cases there is evidence that lateral emplacement of ejecta took place subsequent to the ridge formation, as ejecta is preferentially piled up in the vicinity of the ridge.

Origin of the Linear Ridges: Of the several processes that might be responsible for the ridges, we find that the most likely origin is related to dike emplacement events, caused by the propagation of magma-filled cracks in the crust, to form long linear fractures filled with magma that solidifies and can leave a surface ridge following exhumation (e.g., 10). Dikes are generally vertical or near vertical in nature, cross terrain irrespective of topography, are in the range of meters to hundreds of meters in width, are extremely linear and often broadly curving, and can extend in the near subsurface for thousands of kilometers (e.g., 1, 10-12). The geometry and extent of the ridges provides important constraints on the nature of the dikes and the eruption conditions that might have accompanied their emplacement. The broad ridge in lower resolution images is typically ~600 m across and the details revealed in high-resolution images suggest that the surface exposure of the ridge crest is 50-100 m. This implies that the actual width of the dike at depth might range up to ~200 meters. These values indicate that the depth from the original surface to the top of the dike would range from zero (the part that erupts) to as much as 1000-1500 m [1]. If, for example, an eruption was active along a 5 km long segment of the dike (less than 1/100th of the total dike length), the rise speed of mafic magma in a dike ~100 m wide could be up to 20 m/s, and the volume flux (velocity x width x length) could be up to 10 x 10^6 m^3/sec [12]. Flows erupting from such vents would travel over flat to gently sloping terrain for hundreds to thousands of km [12], or in rougher topography, pond in local to regional lows such as craters, burying the vent and the associated eruptive products in the process. In summary, on the basis of models of the ascent and eruption of magma on Mars and the structure of its crust (e.g., 1, 12), dike widths of this magnitude are likely to involve very high effusion rate and high volume eruptions, in the range of those typical of flood basalts on Earth. These models are completely consistent with the patchy nature of Hr plains in the cratered uplands and the dearth of individual flow fronts.

Summary and Conclusions: Two major low, narrow broadly arcuate linear ridges in the region of western Terra Tyrrhena northeast of Huygens crater cross Noachian terrain for distances of hundreds of kilometers irrespective of topographic and geologic unit changes. The longest of these is over 750 km in length, is remarkable in its continuity and consistent nature, and its exposure relationships. We find that an origin of these ridges as the surface manifestation of near-surface magmatic intrusions (dikes) is the most plausible. The consistent width, vertical orientation, linear continuity, and broad linear-arcuate nature are all consistent with dike emplacement. Detailed, along-strike stratigraphic relationships show that the ridges cut some Hesperian-aged ridged plains but are embayed by others. We thus interpret these features to be associated with the emplacement of the nearly globally distributed Early Hesperian ridged plains. Hesperian plains have previously been interpreted to have been emplaced volcanically, but the lack of clearly identifiable flow fronts and the presence of mantling sediments has often led to alternative hypotheses. The width and geometry of these dikes is consistent with very high effusion rate, high volume flood basalt eruptions, emplacement events that would result in the volcanic flooding of rough Noachian cratered terrain topography, likely leaving little evidence of flow fronts. The current nature and consistent exposure of the ridges strongly argues that they have been exhumed, with overlying material up to several hundred meters thick being removed. The present topographic relationships imply that exhumation was a very efficient process, and thus that the removed layer must have been very volatile-rich and fine-grained, susceptible to sublimation, possible aqueous erosion and eolian redistribution. The close linkage in time of the valley networks characterizing the dissected terrain and the emplacement of the volcanic plains suggests that volcanic degassing into the atmosphere may have changed the climate sufficiently to cause deposition and erosion of a volatile-rich cover.

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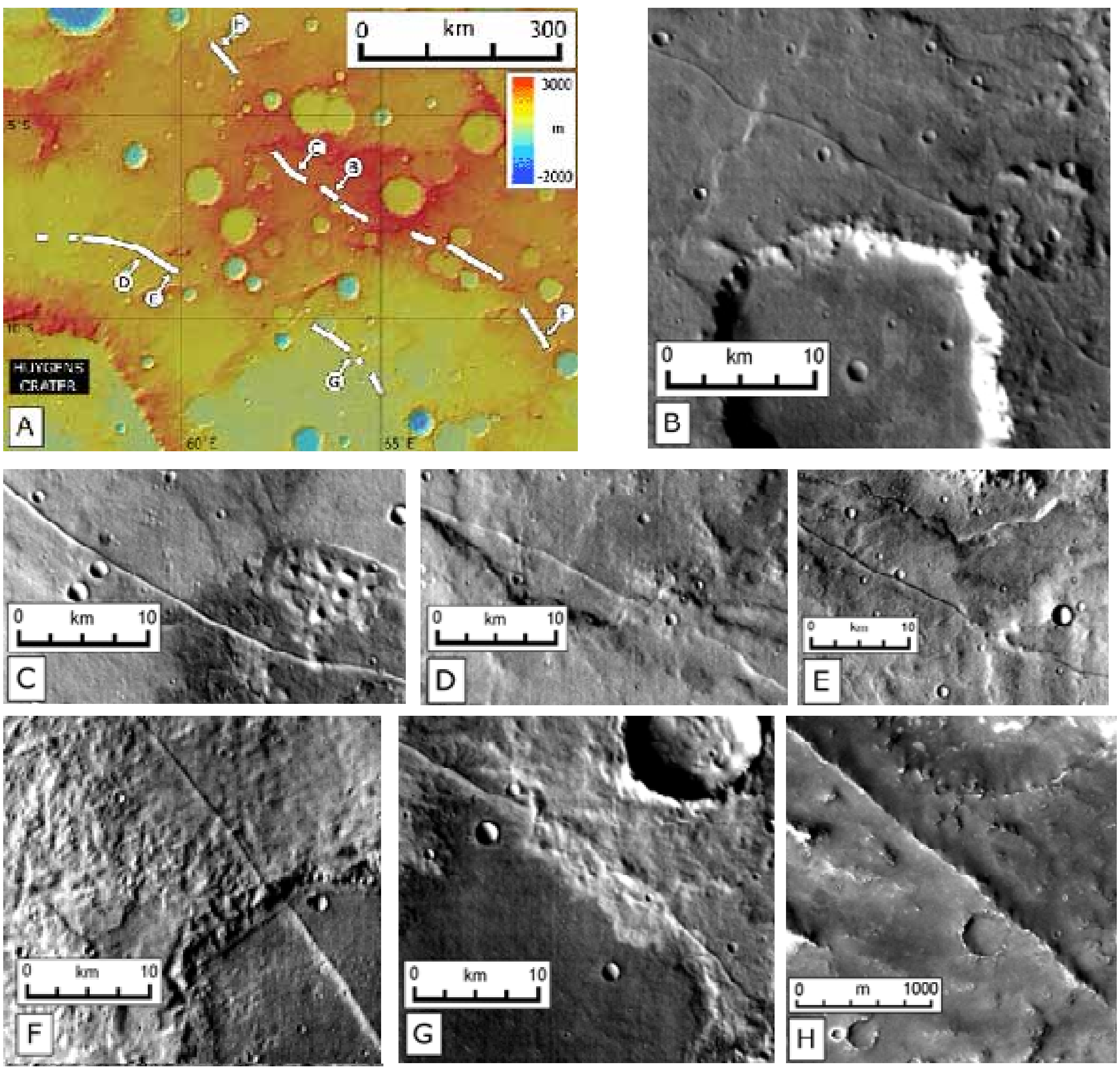

Fig. 1. A) Distribution of ridges (thick lines) northeast of Huygens crater. B) Ridge crosses rim of an ancient 18 km rectangular crater. C) Typical character of the ridge system showing narrow and linear behavior. D) Ridge cutting across wrinkle ridges with a superposed impact crater with a pedestal-like elevated ejecta deposit. E) Ridge, knobs and associated flow-like lobes. F) Lack of deflection as the ridge passes across crater rim crest and down onto crater floor. G) Central portion of ridge covered by lobate ejecta from crater in upper right. H) MOC image of linear ridge. Note sharpness of ridge crest and material along sides of ridge, responsible for making it appear broader in the lower resolution THEMIS images (B-G).