THE HELLAS BASIN ON MARS: FURTHER EXPLORATION OF ITS ANOMALOUS SHAPE. G. Komatsu[1,2], T. Ruj[1,2], H. Miyamoto[3], J. M. Dohm[3], J. Ormö[4], and K. Kurosawa[5], [1]International Research School of Planetary Sciences, Università d'Annunzio, Viale Pindaro 42, 65127 Pescara, Italy (goro@irsps.unich.it), [2]Dipartimento di Ingegneria e Geologia, Università d'Annunzio, Viale Pindaro 42, 65127 Pescara, Italy, [3]The University Museum, University of Tokyo, Hongo 7-3-1, Bunkyo-ku, Tokyo 113-0033, Japan, [4]Centro de Astrobiologia, INTA-CSIC, Spain, [5]Planetary Exploration Research Center, Chiba Institute of Technology, 2-17-1 Tsudanuma, Narashino-shi, Chiba 275-0016, Japan.

Introduction: The origin of the Hellas basin on Mars has long been considered to be from a large impact [1], which makes it, respectively, the largest (~1700 km) relatively well-preserved impact basin on Mars and the 2nd largest in the Solar System after the South Pole–Aitken basin on the Moon [2]. Nevertheless, its formational process and subsequent modification have not been well understood. For example, the basin has been debated to be the result of an oblique [3] or doublet impact [4]. Here, we investigate the formational process (including post-impact modification and degradation) of the impact basin on the basis of its morphometry and geology.

Morphometric and geological characteristics: The 3.99 Ga [5] or possibly > 4.0 Ga [6] multi-ring Hellas basin in the southern hemisphere of Mars has been modified, in part, by igneous activity which resulted in the formation of volcanic provinces such as Syrtis Major to the north, Tyrrhena-Hadriaca to the northeast, and Malaea Planum to the south [e.g., 7]. Modification of the basin due to tectonism could have also been important. The basin's geomorphology has also gone through intensive post-impact modification and degradation over time, e.g., basin infilling and rim lowering [e.g., 8, 9], through fluvial, lacustrine, periglacial/glacial, aeolian, mass wasting processes. Nonetheless, its primary form is still preserved.

Here, we use MOLA topography maps (**Figs. 1, 2**) to investigate the main morphometric characteristics of the Hellas basin. The basin is strongly asymmetrical approximately in the west-east (or WNW-ESE) direction. The notable morphometric properties giving it its asymmetric appearance include: (1) ellipticity (~1.3), 2) deeper western basin floor (-8 km below the Martian datum), and 3) steeper western inner rim (**Fig. 2**).

The elliptic shape may partially be owing to erosion and sedimentation in the eastern part of the basin. Clearly expressed in the topography, this included slope retreat related to the formation of major channels, Dao and Hamakhis Valles [10, 11]; the channels incised the eastern basin slope and transported and deposited sediments along the eastern margin of the basin floor.

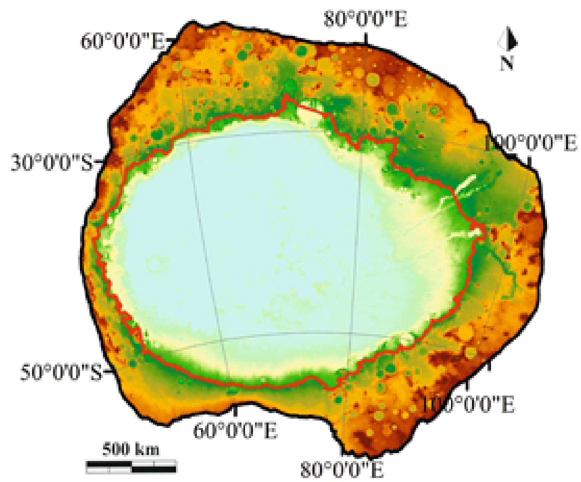

Fig. 1. MOLA topography of the Hellas basin on Mars. Two elevation levels (750 m—black and -4000 m—red) outline the shape of the basin. In particular, the lower one clearly shows its ellipticity. (Orthographic projection centered at 71° E, 41° S)

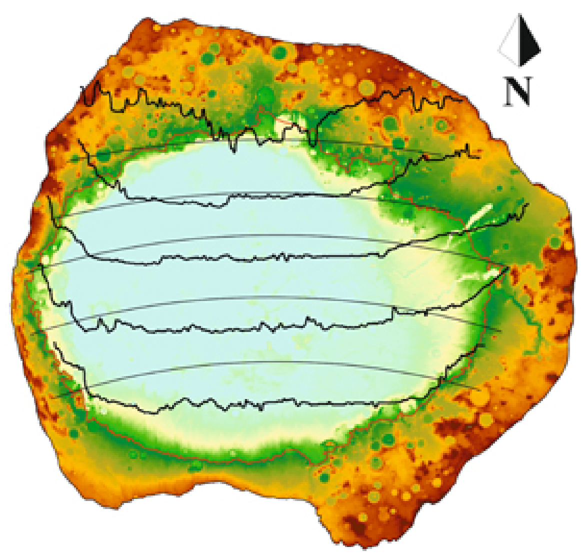

Fig. 2. Cross-sectional MOLA topographic profiles of the Hellas basin. Note the steeper western slope of the basin compared to the eastern slope.

Oblique impact hypothesis: The above-mentioned morphometric characteristics of the Hellas basin, if not entirely due to post-impact modification and degradation nor an impact by an asymmetric dumbbell shaped bolide, are consistent with an oblique impact from the west (or WNW). The ellipticity (~1.3) of the Hellas basin with its longer axis orientated along the west-east (or WNW-ESE) direction implies that the impact occurred at an angle < 30° (for a high cohesion target) [12]. Impact experiments, although at much smaller scales, illustrate the effect of an oblique impact on the crater cross-section (**Fig. 3**). The uprange side of the transient crater is steeper than that of the downrange side, and the crater floor depth shallows significantly toward the downrange side.

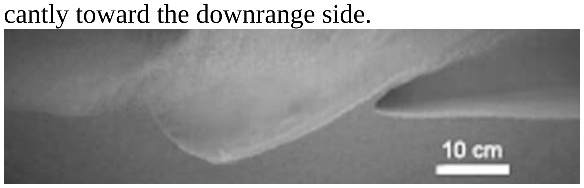

Fig. 3. Cross-section of a transient crater forming process due to an oblique impact experiment (projectile from the left) [13].

Multiple impact hypothesis: Investigators have argued for a history of multiple impacts to explain the oblong shape of the Hellas basin [4, 14]. A bigger impact, for example, may have resulted in the western part, while a smaller one in the eastern part. Compared to most large Martian impact basins such as Argyre and Isidis, the Hellas basin lacks a distinct gravity anomaly in its central part (**Fig. 4**). Instead, a relatively weak positive gravity anomaly is observed in the basin's eastern part, possibly associated with the putative eastern impact. The main drawback of this hypothesis is the absence of crater rims between the two impact sites. If Hellas's shape stems from multiple impact cratering events (including those possibly associated with an original fragmented bolide into a cluster of projectiles), then post-impact modification must have been significant enough to destroy the crater rims.

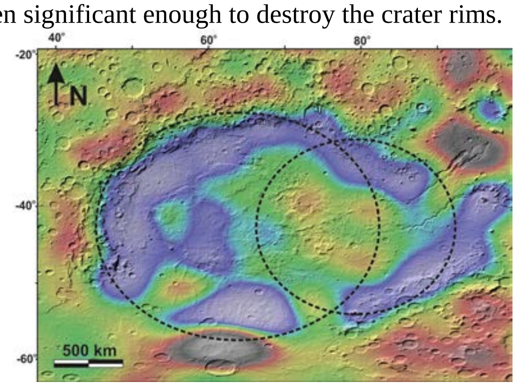

Fig. 4. The free-air gravity map of the Hellas region [15]. Two circles mark the approximate positions of the hypothesized double impacts. (Equirectangular projection)

Linking to a giant impact?: Recently, a giant impact hypothesis was proposed to explain the origin of both Phobos and Deimos [16]. It encompasses a giant impact on Mars by a relatively large planetary body (i.e., about one-third of Mars), which may have formed the Borealis basin and ejected a large amount of debris into orbit about the planet. Subsequently, the debris coalesced and formed at least one large satellite and smaller ones. The largest satellite is estimated to have had a mass of about 10^{19} kg [16]. This putative large inner satellite is hypothesized to have fallen back to Mars after about 5 Myr due to the tidal pull of the planet, with the two outer Phobos and Deimos, maintaining orbits about Mars [16]. One possible scenario may be that the falling satellite was disrupted into multiple parts due to tidal force (depending on the strength of the satellite), and thus causing a cluster of impacts on the surface at low angles.

Conclusions: The Hellas basin on Mars is characterized by its unique morphometry, including: (1) ellipticity, (2) deeper western basin floor, and (3) steeper western inner rim. These features are consistent with an oblique impact from the west [3] or multiple impacts [4]. The new hypothesis regarding the origin of Phobos and Deimos [16] may shed light on the formation of the Hellas basin. However, the timings of the giant impact and the fall back of the large satellite are not explained in the hypothesis. The Hellas impact is estimated to have occurred at about 3.99 Ga [5] or > 4.0 Ga [6], and further evaluation of this scenario must take into account the critical timing issue, among other possible exogenic- (e.g., channel formation highlighted above) or endogenic-driven (mobile lithosphere [e.g., 17]) processes during and subsequent to the Hellas impact.

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