DEGRADED MESAS ON THE EASTERN RIM OF THE HELLAS BASIN, MARS: REMNANTS OF A LARGER MASSIF?

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Introduction: The studied region (~38-45°S, ~90-105°E, Fig. 1) is bordered by Teviot Vallis (in the east), the Hellas basin (west) and Reull/Harmakhis Vallis (north). Southwards it gradually changes into the cratered Promethei Terra highlands [1-4]. This region has a very characteristic set of ~180 m high flat-topped mesas (~30 mesas, areas up to ~5100 km^2; see Table 1). In this work we describe and analyze these and related features and their morphology, and search for possible formation origins [see also 5].

Data and methods: We use the high-resolution data from MEX HRSC camera [6, 7] in conjunction with THEMIS [8] and MOC NA images [9]. Where applicable, HRSC and MOLA digital terrain models (DTMs) and single MOLA tracks [10] were used to obtain information on the topography.

Regional setting: The study area is located on the ~0.0-0.8° eastern rim slope of the Hellas basin and it measures ~350x350 km across, having an area of ~122000 km^2. The terrain immediately around the mesas is smooth or slightly etched, and dissected by numerous fluvial channels as well as linear features, e.g. wrinkle ridges and crisscrossing lineaments, interpreted as dikes [see 5]. The mesa-containing units have previously been mapped as everything from late Noachian to early Amazonian [2-4]. The Hellas region has been frequently studied due to its large amount of volatile-driven features and phenomena [e.g. 11-15]; more detailed studies have shown that the east Hellas rim has been heavily modified by e.g. the evolution of the Morpheus – Reull – Teviot – Harmakhis Vallis complex and their tributaries [16-21] and in larger scale by Hesperia Planum volatile outbreaks [22].

Mesa description: Almost all of the ~30 studied mesas (Table 1) are elongated in the W/NW–E/SE direction, along the regional Hellas rim slope. They rise ~200 m (max. 350 m) above the surrounding plains. The mesas have generally flat tops with no DTM-resolvable features. However, small-scale morphology seen in images shows that the mesa tops exhibit either smooth, hummocky or slightly eroded textures (see all Figures). Several of the largest mesas (areas > 40 km^2) have distinct steps on their summits (Figs. 2, 3b), interpreted to be the remnants of the partly eroded layers within the mesa body. There is no indication of layering on most mesa walls.

The previous geologic maps [2-4] show the mesas as friable eolian, fluvial or possibly volcanic sediments, which may have been locally ice-cemented. [4] map them, similar to isolated pockets in the highlands, as sediment-rich Reull Vallis flood deposits. They also propose that the surrounding plains are younger than the mesa structures; this relation is interpreted the other way around in the adjacent map [2].

Mesa-associated channels: Most mesa margins are heavily scalloped with capes and concave bays (Figs. 2-3). Narrow sinuous depressions originate from many bays, merging downslope together into wider and more subdued channels. They are interpreted to be caused by fluvial run-off leading from the mesas and extending towards the Hellas basin. Judging from the appearance of the mesas associated with the largest channels, the starting point of the channel tends to migrate deeper into the mesa during the inferred channel/mesa evolution. At this stage, additional small tributaries merge with it from channel-parallel mesa lobes.

Some mesa-related channels connecting with Reull Vallis have been embayed by the late stage Reull deposits; other examples show that the mesa material liquidification has in places been younger than the Reull floor materials. This indicates that the material flow from the mesa formations has been activated during several phases of Mars' history. This may have been facilitated e.g. by changes in the climate [23-25] due to changes in the orbital parameters [25-30].

Mesa wall disintegration: The straighter mesa rim segments with no channels exhibit often one of the found distinct wall degradation styles, which generally occur on different mesa sides, with some overlap. *1)* The south-facing slopes tend to have prominent debris aprons, extending up to 1 km away. The apron is smooth and featureless on a large scale, but close-up images reveal it to be either lineated or heavily etched (Fig. 4). *2)* The north-facing mesa flanks tend to have only weak or no aprons at all. Instead they exhibit large separate and seemingly intact material bodies at the foot of the slope. These usually lie at 200-400 m distances from the mesa tops laterally; vertical analysis is not possible due to DTM resolution limits. We interpret the blocks to be remnants of fallen material detached from the mesa. MOC NA images reveal that the largest fallen blocks exhibit lineations parallel to the mesa walls (Fig. 4a). This can be explained by any of the following scenarios: *a)* prior, during or as a result of falling, the blocks have fractured along these lines due to zones of weakness in the mesa top edge and the block itself, *b)* blocks have been eroded post-emplacement along the lines, *c)* the lineations represent the layered structure of the mesa body itself (this would indicate that the large, somewhat intact blocks slide/topple down the mesa flank, which results in rotation; the previously horizontal layers are now visible from above), *d)* or a combination of the above.

Conclusion and Discussion: When reconstructing the geologic evolution of the study area and the whole eastern Hellas rim region, we need to assess the importance of the smoothened mesas. The similarity between the mesas and their apparent lack elsewhere outside the study area shows that they are the result of one sequence of events occurring only in that particular area. Furthermore, the scalloped nature of the mesa flanks, the existence of the channels running away from them, the erosion of the immediate surroundings of the mesas and the mesa locality shows that they are in fact erosional remnants of a single larger construct.

We suggest that this mesa system, now consisting of several separate units, is actually a remnant of a more wide-spread depositional unit. This is a possibly glacier-related massif, which at some point in Martian history covered much of the area studied.

References: [1] Potter (1976) *USGS*, map I-941. [2] Price (1998) *USGS*, map I-2557. [3] Leonard & Tanaka (2001) *USGS*, map I-2694. [4] Mest & Crown (2002) *USGS*, map I-2730. [5] Kostama et al. (2007) *this conference*. [6] Neukum et al. (2004) *ESA-SP 1640*, 17-35. [7] Jaumann et al. (2007) *PSS,* in press. [8] Christensen et al. (2003) *Science 300*, 2056-2061. [9] Malin et al. (1992) *JGR 97*, 7699-7718. [10] Smith et al. (2001) *JGR 106*, 23689-23722. [11] Scott et al. (1995) *USGS,* map I-2461. [12] Carr (1996) Water on Mars, 229 p. [13] Crown et al. (2004) *2nd Early Mars Conf.*, #8027. [14] Crown et al. (2005) *LPSC 36*, #2097. [15] Crown et al. (2005) *JGR 110*, E12S22. [16] Crown & Mest (1997) *LPSC 28*, p. 269. [17] Mest & Crown (2001) *Icarus 153*, 89-110. [18] Bleamaster & Crown (2004) *LPSC 35*, #1825. [19] Kostama et al. (2006) *LPSC 37*, #1649. [20] Kostama et al. (2007) *JGR*, in press. [21] Lahtela et al (2007) *Icarus,* in review. [22] Ivanov et al. (2005) *JGR 110*, E12S21. [23] Head et al. (2003) *Nature 426*(6968) 797-802. [24] Milkovich & Head (2004) *LPSC 35*, #1342. [25] Haberle (2004) *LPSC 35*, #2010. [26] Imbrie (1982) *Icarus 50*, 408-422. [27] Laskar & Robutel (1993) *Nature 361*, 608-612. [28] Touma & Wisdom (1993) *Science 259*, 1294-1297.[29] Laskar et al. (2004) *LPSC 35*, #1600. [30] Kreslavsky & Head (2004) *LPSC 35*, #1201.

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Table 1. Mesa parameters (lengths, widths and areas have been measured from HRSC data, heights and volumes from MOLA).

mesa	central coordinates		maximum span (km)			areas (km^2)		volumes (km^3)	
#	lat (N)	lon (E)	length	width	height	mesa	mesa+apron	mesa	mesa+apron
1	-40,13	96,25	28	6	0,12	87,7	117,8	9,9	14,2
2	-40,67	95,50	5	4	0,12	10,6	14,4	1,1	1,5
3	-40,66	97,96	54	8,5	0,175	286,0	375,0	72,9	92,8
4	-40,77	97,25	15	9,5	0,195	53,8	65,1	11,6	14,4
5	-40,95	97,42	4,8	0,6	0,11	2,0	6,1	0,2	0,8
6	-40,46	98,11	26	3	0,12	48,9	89,1	4,6	8,6
7	-40,62	98,37	3	0,8	0,03	2,4	4,3	0,1	0,1
8	-41,14	98,60	7,6	1	0,12	4,4	10,6	0,3	0,8
9	-40,79	98,78	7,2	6,4	0,2	24,6	33,6	2,7	4,6
10	-40,73	98,93	3,2	1,8	0,105	3,8	6,7	0,2	0,5
11	-40,60	98,97	8	0,4	0,13	3,9	9,1	0,1	0,5
12	-41,85	100,11	185	52	0,26	3470,4	5147,2	1305,8	2273,1
13	-41,66	98,18	9,5	3,8	0,19	17,5	24,8	3,8	5,2
14	-42,34	100,28	6,6	1,8	0,065	9,5	12,4	0,7	0,9
15	-42,48	99,49	3,7	1,6	0,065	6,1	10,9	0,4	0,9
16	-42,35	99,46	4,8	1	0,1	3,4	5,2	0,2	0,4
17	-42,50	99,27	3,7	2,4	0,125	5,3	9,1	0,5	0,8

18	-42,30	99,30	6,2	1,8	0,09	7,7	11,1	0,6	0,9
19	-42,16	98,56	29	4,8	0,145	93,0	119,5	9,4	13,6
20	-42,27	98,36	9,2	3,5	0,14	19,6	28,2	2,3	3,3
21	-42,21	98,00	27	8	0,15	114,1	144,8	18,1	23,8
22	-42,72	98,65	1,6	1	0,14	1,5	4,5	0,1	0,5
23	-42,32	97,84	2,6	0,8	0,12	1,2	5,0	0,1	0,5
24	-42,69	97,50	1,8	0,6	0,03	0,6	2,0	0,0	0,0
25	-41,91	97,72	3,5	1,2	0,224	4,2	8,2	0,5	1,2
26	-41,80	97,05	14	2,8	0,14	21,2	35,6	4,7	8,0
27	-41,61	96,95	11	1,8	0,165	15,8	21,4	3,1	4,0
28	-41,74	95,98	2,8	1,2	0,175	2,0	4,6	0,3	0,7
29	-41,19	95,97	37	24	0,2	395,6	450,2	101,8	116,9
30	-41,73	93,38	28,5	15,2	0,3	241,4	293,5	73,8	85,8
31	-41,63	93,01	6,2	3,2	0,125	14,1	19,9	1,7	2,6
32	-42,44	93,25	8,7	3,5	0,24	23,0	37,4	2,5	5,4
33	-42,31	93,07	11	3,2	0,195	20,6	28,1	2,0	3,1
34	-43,14	98,07	5,8	2,8	0,15	8,9	14,9	1,4	2,2

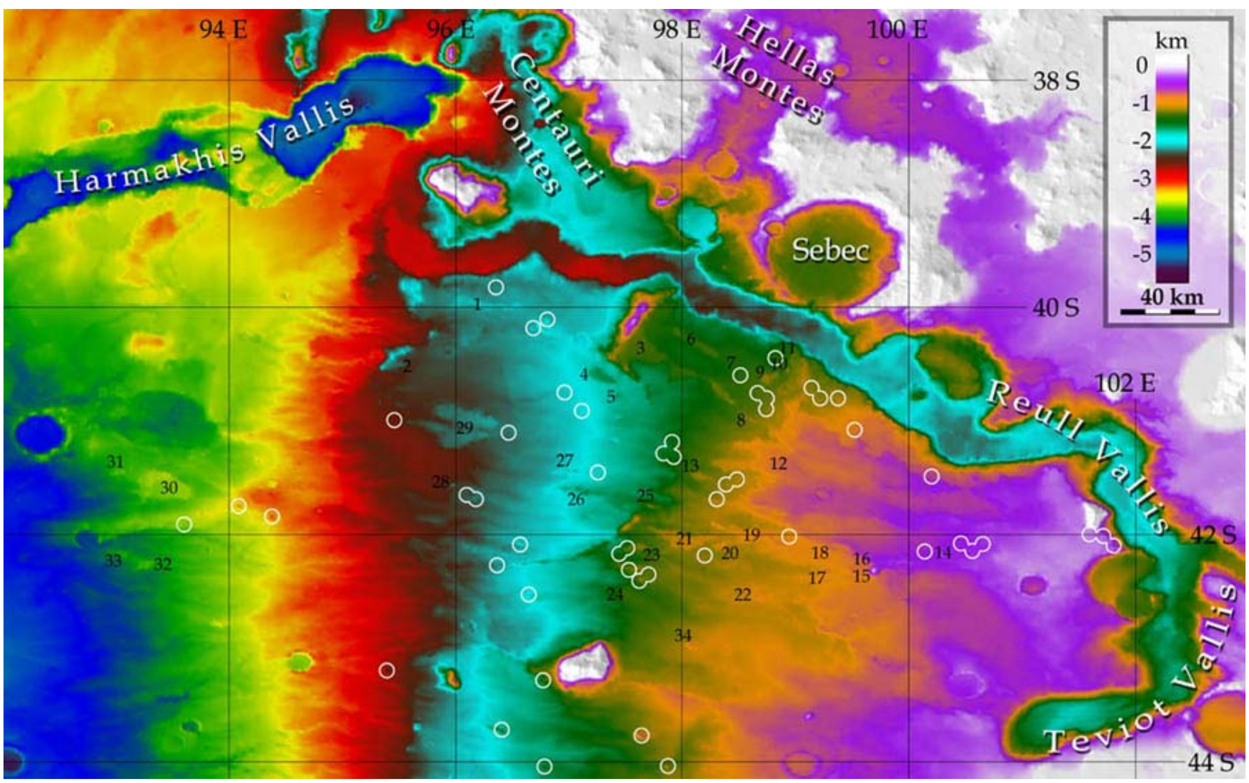
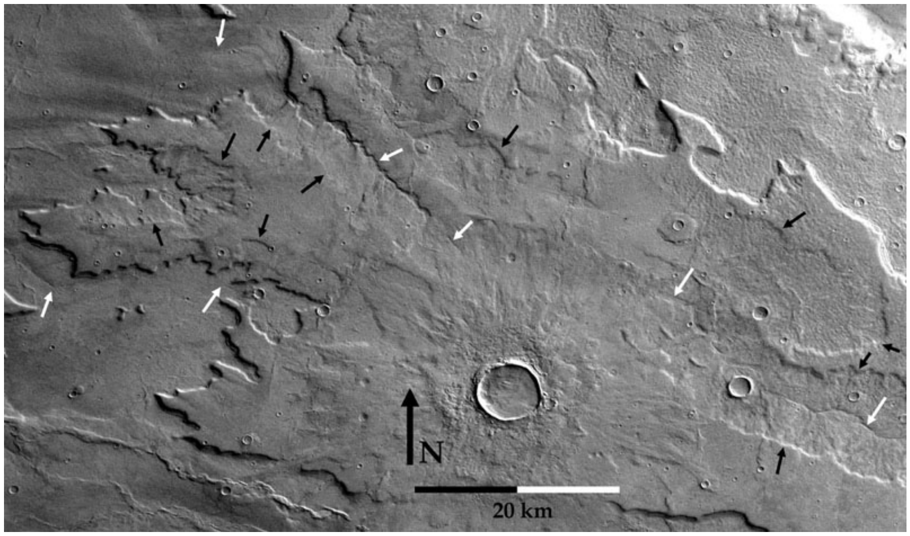


Figure 1. Distribution of the mesas in the studied region, numbered to allow their identification in other Figures and Table 1. Also shown are the knobs and buttes (in the centers of the white circles), which may be heavily degraded remnants of mesa material. However, their absolute identification is not possible with current resolution data.

Figure 2 (top of next page). The western end of mesa #12 seen in HRSC orbit 506 nadir image (image center: 41.4°S, 99.2°E). Black arrows point to steps on the mesa top, indicating its layered structure. White arrows point to the channels cutting into the mesa, creating much of the scalloped outline and continuing downslope.



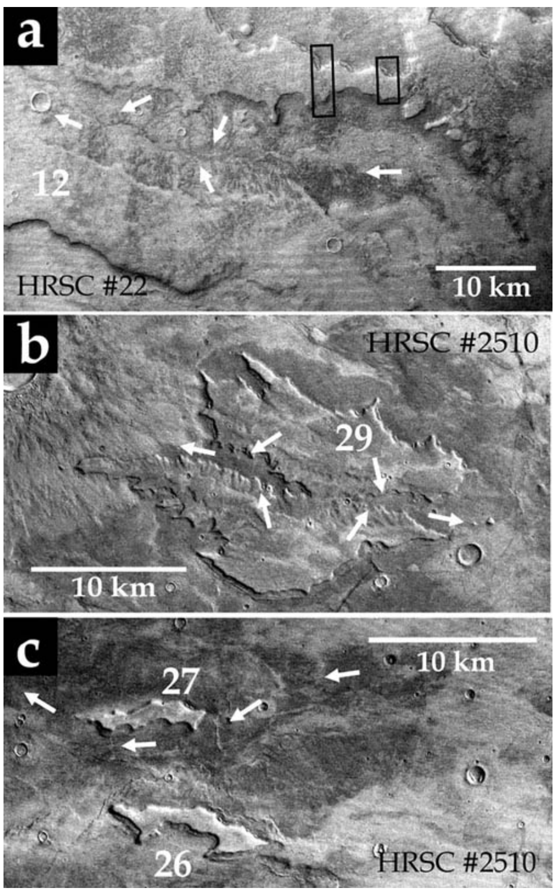


Figure 3. Mesa-cutting channels (arrows: flow direction, boxes: Fig. 4 locations). **a)** Tributaries originate from gullies and join with the central channel of mesa #12. Image center: 41.7°S, 100.2°E. **b)** Gullies etch the top of mesa #29, causing its layered structure and scalloped edges. A narrow E-W cut has been created on its both sides. Image center: 41.0°S, 96.0°E. **c)** Mesas #26 and #27 separated by a channel originating from the edge of mesa #12. Center: 41.5°S, 97.1°E.

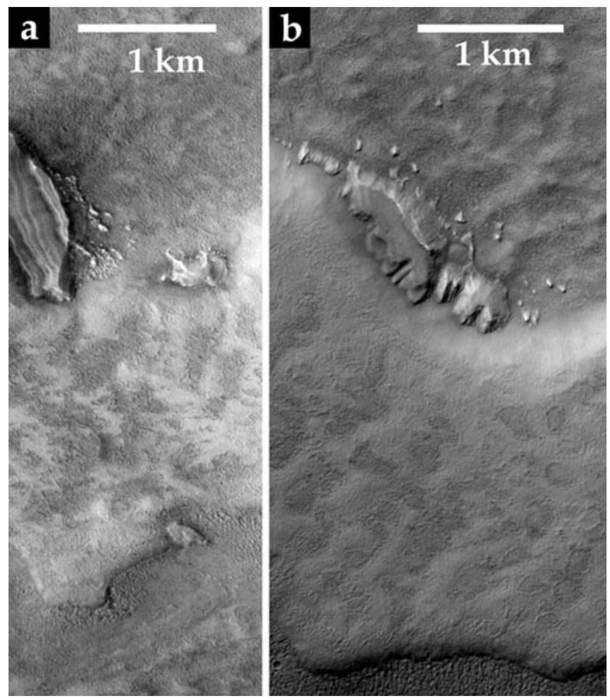


Figure 4. Details of mesa #12 falloff material characteristics (locations shown in Fig. 3). **a)** The layers of the block (top left) are parallel to the mesa wall, indicating that they are a primary feature of both the block and the mesa body. MOC NA S0702871. **b)** Blocks cut by ‘troughs’ perpendicular to the mesa wall. MOC NA R1702372. Both images show typical mesa debris aprons with etched textures in their southern edges (image bottoms), and the mesa tops (lower halfs of the images) with brighter superposing material revealing a darker and eroded surface beneath.