NORTHERN-HEMISPHERE GULLIES ON MARS – DISTRIBUTION AND ORIENTATION FROM THE EVALUATION OF HRSC AND MOC-NA DATA.

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Introduction: Gullies show morphologic features that indicate the presence of a flowing liquid during their forming process [1]. However, the current climate in the northern hemisphere of Mars does not allow the existence of substantial amounts of liquid water for a long time. Therefore, the exploration of particular young landforms, such as gullies is a valuable tool for understanding the most recent climatic history of Mars.

In order to complement and complete an earlier survey conducted by Balme et al. (2006) [2] for the southern hemisphere, we evaluated HRSC [3] and MOC-NA [4] data covering the northern hemisphere for analysing geographical and latitudinal distribution, geological context and orientation of gullied slopes. Constraining such parameters helps to shed light upon the formation mechanisms of gullies on Mars, as preferred latitudinal regions or orientations strongly indicate the influence of insolation and/or climatic conditions.

Generally, HRSC and MOC-NA are very different camera concepts. While the MOC-NA instrument provides a very high spatial resolution with low coverage of the planetary surface, HRSC has a wide coverage with a lower but sufficient resolution capable of detecting gullies if atmospheric conditions are favourable. In combination, these two datasets provide a balanced basis for our study on gullies in the northern hemisphere.

MOC-NA results: Out of 21,042 MOC-NA images (0°-90°N) we detected 3195 gullies in 311 images. All these gullies are located between 30°N and 76.6°N (Fig.1), with a significant increase of frequency between 35°N and 55°N. The maximum of 4.1 gullies/1000 km² is situated between 40°N-45°N. Most gullies found in this survey are located on the slopes of impact craters (n=2594, 81.2%). Gullies in graben structures and fretted terrains amount to approx. 11.7% (n=373). The remainig gullies are located at isolated knobs and hills (n= 228, 7.1%). Gullies positioned at crater walls show orientation trends towards northwest and southeast. However, the orientation of gullies changes with latitude (Fig.2). Between 30°N and 40°N 61.9% (n=635) of the gullies are situated on poleward facing slopes. Between 40°N and 50°N 69.4% (n=819) of all gullies are located on equator-facing slopes. Due to the small number of gullies at crater walls observed north of 60° (n=89, 3.4%) we binned all gullies north of 50°N into one group spanning a latitude band of 50°N-80°N with n=386 (14.9 %). 67.3% (n=261) of these gullies occur on slopes facing the equator.

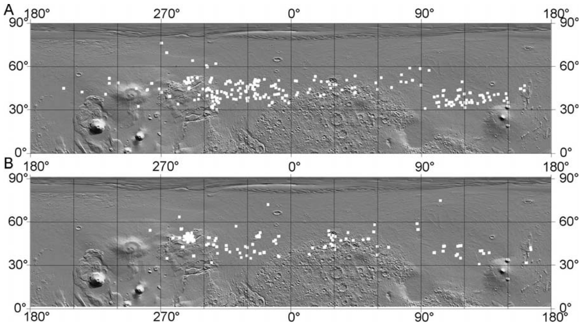

Figure 1: Distribution of gullies in the northern hemisphere. White dots mark single gullies. (A) Gullies found in MOC-NA survey. (B) Gullies found in HRSC survey.

HRSC results: In 50 of 230 evaluated HRSC image strips we identified 2293 gullies. All gullies occur between 30.8°N and 74.9°N (Fig.1). The area between 35°N and 55°N shows gully densities higher than 0.1 gullies/1000 km² with a maximum situated between 45°N and 50°N (0.36 gullies/1000 km²). As for the MOC survey all gullies could be attributed to one of the three major groups of geological settings: 65.5% (n=1502) of the identified gullies in the HRSC survey are located on slopes of impact craters. Gullies in graben structures and fretted terrains constitute 26 % (n=597), to which the Mareotis Fossae population contributes significantly (n=580, 97.1%). Gullies formed at isolated knobs and hills constitute 8.3% (n=190) of all gullies. Gullies in small depressions constitute only 0.2% (n=5). The orientation of gullies located at crater walls is relatively widespread with a trend towards northeast. However, similar to our MOC survey, the orientation of gullies changes with latitude (Fig.2): between 30°N and 40°N most gullies (n=327, 77.3%) are situated on poleward-facing slopes. Between 40°N and 50°N 587 gullies (68%) occur on slopes facing the equator. Due to few gullies found north of 60°N (n=8, 0.5%) we binned in a comparable way as we did it for the MOC survey all gullies north of 50°N into one group (n=219, 14.6%). These gullies were mostly located on northeast-facing slopes, but there are also some occurrences pointing in other directions. In this latitudinal bin, 327 gullies (77.3%) are situated on slopes facing the pole.

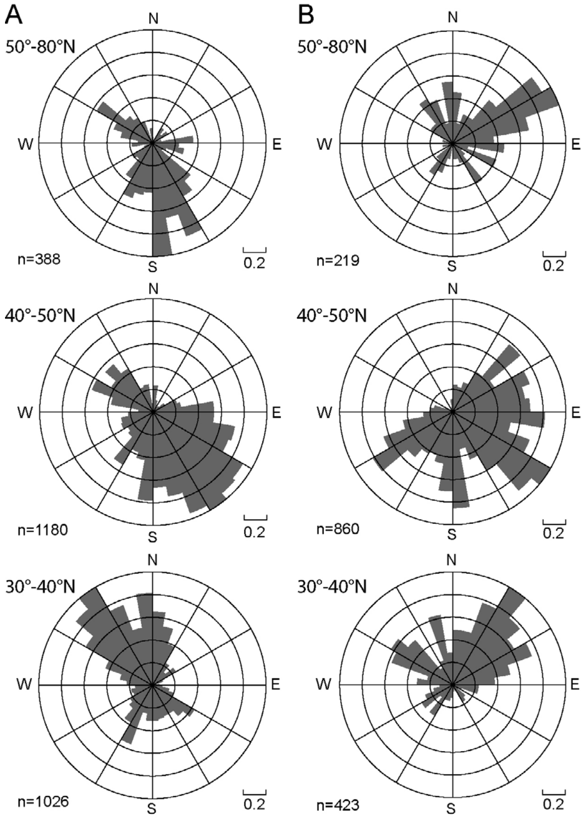

Figure 2: Orientation of crater-wall gullies split by latitude. (A) Gullies found in MOC survey. (B) Gullies found in HRSC survey.

Comparison of MOC-NA and HRSC surveys: With respect to orientation data, a difference of the two surveys becomes apparent: between 50°N and 80°N gullies detected in MOC-NA survey occur preferentially at S and SE facing slopes, while gullies detected in the HRSC survey are mostly situated at NE-facing slopes (Fig.2). A detailed inspection of gullies between 50°N and 80°N explains why some were detected and others not by the different cameras.

As expected most of the gullies identified in HRSC imagery (95.3%) were simply not covered by MOC-NA. 3.3% were not seen because of unfavorable illumination conditions (i.e., sun elevation, phase angle) and only 1.4% of HRSC gullies could also be identified on MOC-NA imagery.

A small number (13.6%) of gullies identified in the MOC-NA survey were not seen in the HRSC survey due to disadvantageous atmospheric conditions (e.g., dust). 22.4% of the MOC-NA gullies were not identified in the HRSC survey due to the lack of HRSC data. However, most MOC-NA gullies (63.9%) could not be detected in the HRSC survey due to their small size.

Disscussion: The distribution in mid latitudes, the high frequencies of gullies on isolated knobs and hills as well as the change of gully orientation at 40°N are consistent with the formation models based on water ice accumulation from the atmosphere. Berman et al. (2005) [5] as well as Balme et al. (2006) [2] interpreted comparable observations in the southern hemisphere to show that climate is one of the key controls in gully formation. The model of Costard et al. (2002) [6], where sources of gullies depend on accumulation and melting of near-surface ground ice during phases of higher obliquity, is in good agreement with our results and the observations of Balme et al. (2006) [2], which are also based on MOC-NA and HRSC data. Both the calculated latitudinal temperature distribution and the predicted seasonal thawing at slopes with pole-ward orientation in the lower latitudes and accumulation of water ice and thawing at slopes of all directions in higher latitudes are consistent with our observations. Therefore we suggest that the most likely formation mechanism of Martian gullies appears to be correlated with water ice accumulation from the atmosphere.

Conclusions:

- High gully frequencies between 35°N and 55°N as well as the orientation dependence on latitude with a change of preferred gully orientation at 40°N indicate that gully formation strongly depends on deposition of water ice and insolation.
- Furthermore, all our observations are consistent with the gully formation model proposed by [6]. Our survey appears to be a promising basis for developing this model on a global scale.
- High frequencies of gullies on isolated hills are difficult to associate with the groundwater formation thesis.
- On the technical side, differences in orientation data between 50°N - 80°N show the importance for the using of different datasets, i.e. high resolution/ low coverage and low resolution/ high coverage, for this type of hemispheric surveys.

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