ABSOLUTE DUNE AGES AND IMPLICATIONS FOR THE TIME OF FORMATION OF GULLIES IN NIRGAL VALLIS, MARS.

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Introduction: The observation of gullies in high resolution images suggests that liquid water may have been present on Mars in the recent past [1]. Some debris fans of gullies superpose dunes and patterned ground; this and the lack of impact craters and dust covers as well as the fresh-looking appearance indicate a relatively young age of the gullies, possibly less than 1 Ma [1]. Age determinations by crater count methods are diffcult due to the limited area of the small-scale gully features and the lack of impact craters on fresh-appearing gullies. The estimated ages from superposition on relatively young surface features (dunes, patterned ground) and from proposed climatic conditions range rom less than 6 Ma [2] to 1 Ma [1] and within the last 10^5–10^6 years [3, 4] up to formation under present day conditions [5, 6].

In this study we derived the absolute age of gully features superposing dunes from crater frequency measurements on high-resolution MOC-imagery in Nirgal Vallis. This gives us an upper limit age of the gullies in this mid-latitude region on Mars.

Nirgal Vallis: Nirgal Vallis is located at 318°E and 29°S in the cratered highlands. The valley has a total length of about 670 km and debouches in the Uzboi Vallis. Crater counts on the small valley area on Viking Orbiter images indicate a Noachian age of about 3.78 Ga [7] (Figure 3) for Nirgal Vallis.

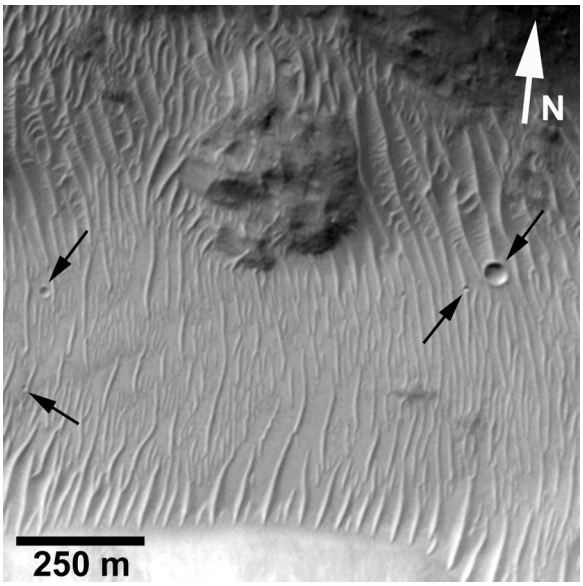

Figure 1. Craters superpose the dunes (E0101142).

Dunes: Most parts of the flat valley floor of Nirgal Vallis are covered by dunes. These are transverse dunes, which are characterized by a transverse direction of the dunes to the prevailing winds. The wavelength between the individual dunes varies from 10 to 120 m. Small impact craters on the dunes clearly (Figure 1) show that these dunes are inactive under present day conditions.

Gullies: Gullies in Nirgal Vallis are widespread features. From 88 high resolution MOC-NA images, which cover the valley 35 images (40%) show gullies. The occurrence of gullies in Nirgal Vallis is the only cluster on Mars at lower latitudes of <30° [1] and nearest the equator. They occur almost throughout the entire length of the valley and are situated on poleward-facing slopes only. Almost all gullies in Nirgal Vallis superpose small dunes (Figure 2).

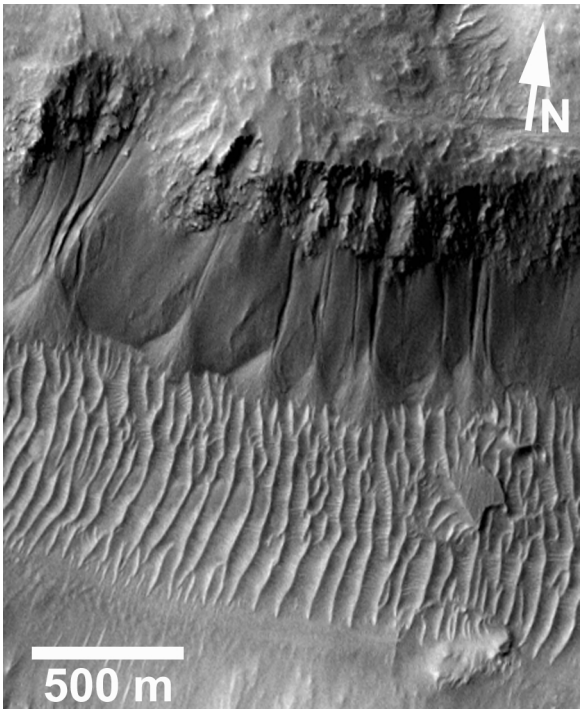

Figure 2. Gully aprons superpose the dunes (E0501789).

Methodology: For accurate crater size frequency distribution statistics we investigated all 88 MOC - NA images with image resolutions between 1.4m and 6m (Subphases M00-R02), which cover the valley floor of

Nirgal Vallis. Several images could not be used or the analysis due to image errors, image quality, secondary craters or the lack of dunes. 69 images have been mapped and used for crater counts. The dune surfaces have been mapped in each image for crater measurements in these areas.

To determine the absolute model age and the last active phase of the dunes, respectively, we utilized the martian impact cratering model of [8] and the polynomial coeffcients of [9] to represent the isochrones in form of the cumulative crater size frequency distribution given for a certain age (crater production function). The uncertainty of the absolute age for young surfaces (<2 Ga) are roughly a factor of two [8].

Results: We have dated the age of the dunes for four main image resolutions seperately and also for all resolutions together, because of the different recognizable crater diameters due to the different spatial image resolutions. Due to possible inaccuracy we determined a best fit age and in addition an upper limit age for all classifications. The upper limit age was determined by using the largest crater diameter bin and an assumed larger crater diameter bin. The best fit absolute model ages range from 140,000 to 380,000 years and the upper limit ages range from 390,000 years to 1.4 Ma (Figure 3 and Table 1).

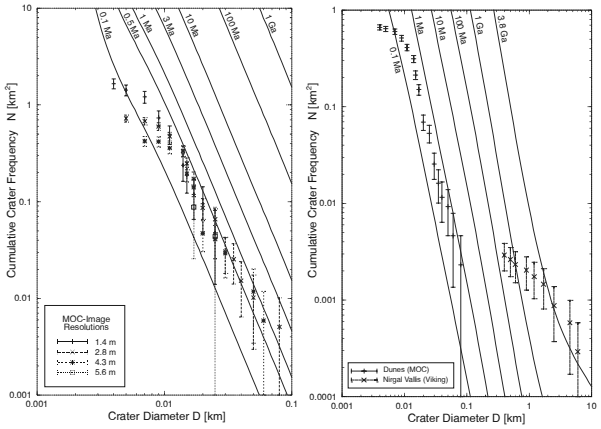

Figure 3. (Left) Crater statistics results for the individual image resolution classifications. (Right) Crater statistics results for all image resolutions together and for the valley as measured on Viking images [7].

Image Resolution (m/pxl)	Dune Area (km^2)	Crater Number (>10m)	Model Age Ma (best fit)	Model Age Ma (upper limit)
1.4	42.13	31	0.256	0.317
2.8	197.06	118	0.384	1.363
4.3	170.20	71	0.283	0.691
5.6	22.78	2	0.139	0.293
all	432.17	222	0.327	0.621

Table 1. Summary of crater statiscs

Discussion: The last active dune phase could be a consequence of higher atmospheric pressures in recent geological times, possibly due to high obliquity phases of Mars [10]. The absolute model ages are in agreement with obliquity models of [11] in which obliquities of more than 30° may have been reached in the last 3 Ma. The last phase of more than 30°-obliquity at around 300,000 years [11] correlates well with the best fit absolute model ages for dune activity.

Under present climatic conditions the particle sizes which most easily moved on Mars by saltation are about 100 µm in diameter (fine sand) [12]. The exact particle sizes of Martian dunes are unknown, but the large dark intracrater dune fields in the southern hemisphere may consist of fine sand [13] and may be active under present day conditions. If the small dunes in Nirgal Vallis consist of coarser particle sizes than the dark dunes, higher atmospheric pressure is required for dune movement. At higher atmospheric pressures winds of sufficient strength could be reached to move larger particle sizes such as medium- or coarse-grained sand.

Conclusions: The crater counts on dunes in Nirgal Vallis for determining the absolute age of dune activity show absolute model ages around 300,000 years for the best fit and less than 1.4 Ma for the upper limit. The estimated error is less than a factor of 2 [8]. These ages indicate a very recent (in geological times) dune activity in this region, possibly due to higher atmospheric pressures caused by higher obliquity.

The relative age relations of gully aprons superposing the dunes imply that the gullies are younger than the dunes. Therefore the gullies must have been formed after the last acitive phase of the dunes and are younger than 3 Ma, possibly less than 300,000 years. The gully formation may have started and/or continued when the climatic conditions changed and the dune activity in Nirgal Vallis ended. This age determination of dunes by crater counts confirms the suggested young ages of the gullies.

References: [1] Malin M. C. and Edgett K. S. (2000) *Science, 288,* 2330–2335. [2] Costard F. et al. (2002) *Science*, *295*, 110-113. [3] Lee P. et al. (2001) *LPS XXXII,* Abstract #1809. [4] Christensen P. R. (2003) *Nature*, *422*, 45-48. [5] Hoffman N. (2002) *Astrobiology*, *2*, 313-323. [6] Reiss D. and Jaumann R. (2003) *Geophys. Res. Lett.*, *30* (6), 1321. [7] Reiss D. (2001) *Unpublished Master Thesis*, Georg-August-Universität Göttingen [8] Hartmann W. K. and Neukum G. (2001) *Space Sci. Rev.*, *96*, 165-194. [9] Ivanov B. (2001) *Space Sci. Rev.*, *96*, 87-104. [10] Fanale et al. (1982) *Icarus*, *50*, 381-407. [11] Laskar J. et al. (2002) *Nature*, *419*, 375-377. [12] Greeley R. et al. (1980) *GRL*, *7*, 121-124. [13] Edgett K. S. and Christensen P. R. (1994) *JGR*, *99*, 1997-2018.