Geophysical Research Abstracts
Vol. 19, EGU2017-758, 2017
EGU General Assembly 2017

Time will tell: temporal evolution of Martian gullies and paleoclimatic implications

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Gullies are kilometer-scale alcove-channel-fan systems that occur on steep slopes in midlatitude to polar regions on Mars. To understand the paleoclimatic conditions on Mars, and the role of volatiles therein, the spatio-temporal evolution of gullies must be deciphered. While the spatial distribution of gullies has been extensively studied at a global scale, their temporal evolution has not been quantitatively assessed and is poorly understood. Here we compile a dataset of high-resolution elevation models of gullies on impact crater walls, study the morphology of the gullies and associated landforms, quantify gully size, and date their host craters to constrain their temporal evolution.

We show that gully-size is similar in very young and old craters. However, gullies on the walls of very young impact craters (< a few Myr) typically cut into bedrock and are free of latitude-dependent mantle (LDM; a smooth, often meters-thick deposit of ice and dust) and glacial deposits, while such deposits are evident in older craters. The abundance of LDM and glacial deposits and evidence for multiple generations of gully and glacial activity increases with host crater age. These observations suggest that over time gullies go through obliquity-driven degradation/accumulation cycles controlled by (1) LDM emplacement and degradation and by (2) glacial emplacement and removal, potentially erasing and obscuring gully deposits. In glacially-influenced craters the distribution of gullies on crater walls coincides with the extent of glacial deposits, which suggests that melting of snow and ice played a role in the formation of these gullies. Yet, present-day activity is observed in some gullies on formerly glaciated crater walls. Moreover, in very young craters extensive gullies have formed in the absence of LDM and glacial deposits, showing that gully formation can also be unrelated to these deposits. In these systems gully formation may be dominated by melting of relatively restricted amounts of water ice and snow that collects in gully-alcoves during high obliquity periods and/or by dry CO_2-triggered flows. The dominant processes by which gullies form may thus differ over time, implying that time, in the form of host crater age, should be taken into account when analyzing gully deposits.