Possible New Constraints on Gully Formation in Nirgal Vallis from High Resolution Thermal Inertia Data

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Background: For the geological interpretation of small scale landforms on Mars a good understanding of local thermophysical properties of the observed area is of key importance. Thermal inertia is the key parameter that dominates the thermal behaviour of the upper few centimeters of a surface. Principally it controls how the surface material stores and conducts heat. Thermal inertia is defined as $I = (k\rho c_p)^{\frac{1}{2}}$, where k denotes the thermal conductivity, ρ the bulk density and c_p the specific heat capacity and is measured in $Jm^{-2}K^{-1}s^{-\frac{1}{2}}$, subsequently referred to as *tiu*. Via the thermal conductivity, which has the greatest influence on the thermal inertia, the average grain size of the material can be estimated [1]. Therefore studying thermal inertia data can provide clues on how far a surface is dominated by fine grained dust or by bigger sized rocks.

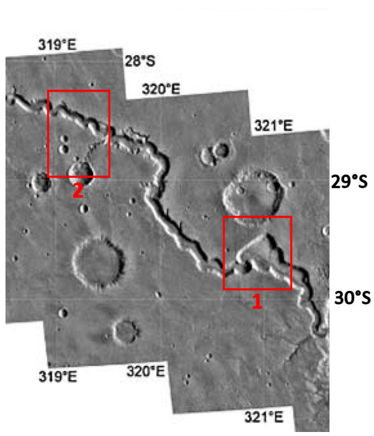

Figure 1: This map shows a part of Nirgal Vallis with the selected study areas 1 and 2.

Numerical model: We calculate thermal inertia from THEMIS nighttime infrared data (100 m/pixel) by using a thermal model with a layered subsurface which derives diurnal temperature cycles for given latitude, thermal inertia, season. We use nighttime infrared data to minimize the thermal effects of varying surface albedo and sun facing slopes. These effects have dissipated throughout the night and hence thermal inertia is the dominant parameter controlling the surface temperature at night [2, 3]. Other ancillary parameters such as dust opacity, bulk density or heat capacity are kept constant and have been chosen according to commonly used literature values [3].

Results: We derived thermal inertia data for the selected two study areas (THEMIS images *I08584006* and *I08222011* respectively) where gullies are observed [4] to examine the upper parts of the valley walls with regard to gully formation. MOC-NA images shown in Figures 2a and 2b are located in the study areas 1 and 2 (Figure 1) respectively. They indicate that gullies in the examined areas apparently originate slightly below an upper layer interpreted as bedrock. We use thermal inertia data in combination with visible imagery to further characterize the lower borders of this material with regard to gully formation.

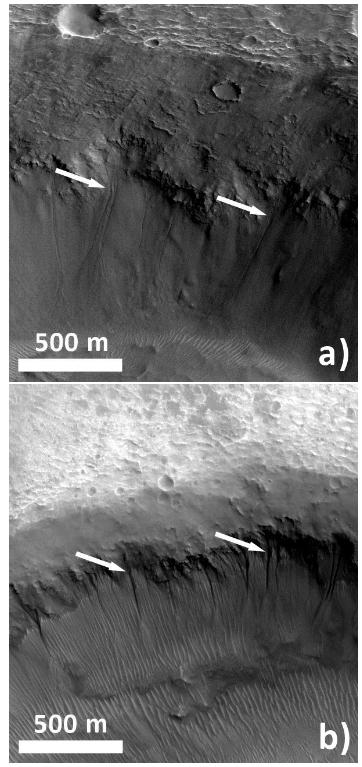

Figure 2: These sections of MOC-NA images M07/02005 (a) and E17/00132 (b) show parts of the northern valley walls where gullies occur.

Figures 3a and 3b show thermal inertia data for these study areas in which area 1 (Fig.3a) is located in the eastern part of the valley close to Uzboi Vallis and area 2 (Fig.3b) is located further west and more upstream (Fig1). Figure 3a (*I08584006*) shows a wider section of the valley with adjacent smooth plains. Thermal inertia of the plains range from approximately 250 to sometimes 400 *tiu* and therefore indicate a certain degree of consolidation. In the interior of a small crater in the left part of Figure 3a thermal inertia show values less than 200 *tiu* which we interpret as fine grained materials transported and deposited into the crater by aeolian processes. Within the valley the

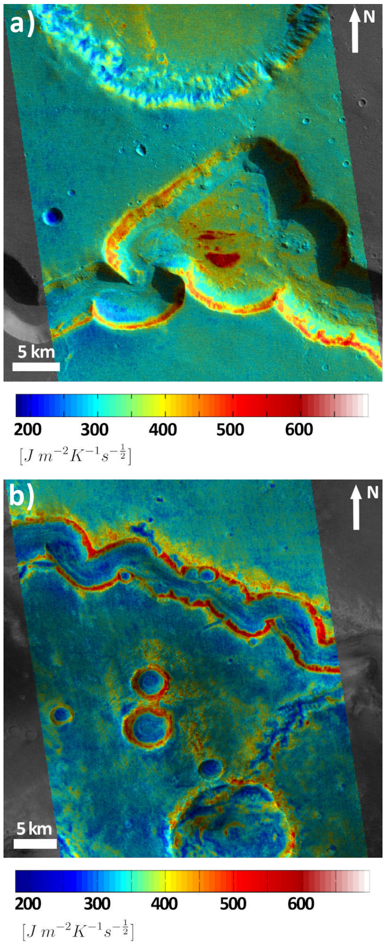

Figure 3: Thermal inertia data for the two study areas in Nirgal Vallis (THEMIS images I08584006 and I08222011).

data show high thermal inertia material for the entire part of the studied southern walls and also for a large part of the northern walls. Thermal inertia values for this material are approximately 600 to 650 *tiu*. Considering visual imagery e.g. in Figures 2a and 2b we interpret this unit as mostly a mixture of bedrock and fine grained materials such as a dust cover over a bedrock exposure. Additionally, areas of rocky debris may contribute to these mixtures of materials producing the observed thermal inertia values. The central valley floor appears to be rather rough with thermal inertia of ≈ 400 *tiu* and also exhibits features of high thermal inertia (≈ 600 *tiu*) which we interpret as possible bedrock outcrops covered by dust or areas covered with larger sized rocks or boulders. Further west of these features, the floor appears more smooth with values of ≈ 250 to 300 *tiu*. The second study area (Fig. 3b) shows high thermal inertia material (≈ 600 *tiu*) in the upper parts of the valley walls in most of the study area. In contrast to study area 1 high thermal inertia material apparently extends slightly into the smooth plains north of Nirgal Vallis. Thermal inertia data for these smooth plains are between 350 and 400 *tiu* and are therefore close to those of study area 1. The plains south of the valley show thermal inertia in the same range, but appear to be more structured especially in the vicinity of impact craters. High thermal inertia material with values of ≈ 500 to 550 *tiu* is also present in the walls of these craters. In contrast to study area 1 the floor of this part of the valley appears to be smooth with thermal inertia values ranging from ≈ 200 to 350 *tui*. Therefore this material is probably less blocky than the plains and covered with rather fine-grained materials. Summarizing our thermal inertia data supports the interpretation that the competent layer shown in visual images of the study areas (Figs.2a and b) is resembled by the observed high thermal inertia material in the most upper part of the walls. Hence from our thermal inertia data we conclude that this bedrock is probably covered by fine dust which decreases the apparent thermal inertia to the values observed. Main theories of gully formation include melting of surface ice/snow [5] and groundwater seepage [6]. One main argument for groundwater related processes is that many of them originate 10-100 m below the local surface [6], like the gullies in Nirgal Vallis. However, gully formation on Earth (debris-flow, fluvial) depends on the abundance of loose and unconsolidated material (e.g.,[7]), which was also proposed as one prerequisite for gully formation on Mars [8]. Our results show that gullies in Nirgal Vallis originate slightly below a competent layer interpreted as bedrock and erode into unconsolidated material. This indicates that the origin point of gullies on slopes in Nirgal Vallis rather depends on the location of consolidated/unconsolidated material (bedrock/talus) and is not an argument for groundwater processes.

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