Geological analysis of Ganymede using Digital Elevation Models

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Abstract

The surface of Ganymede is characterized by dark and light terrains. Light terrain, covering two thirds of the surface, is retained to be younger and resulted from resurfacing events, likely correlated to a global expansion of Ganymede [1]. It is typically characterized by several sets of subparallel troughs and ridges, called grooves. They highly modify the dark terrain and the other pre-existing features. Since these areas display two different superposed spacing scales, grooves have been interpreted as the product of extensional tectonism [2] and two different faulting styles have been recognized (horst-graben and domino) [3]. Nevertheless, the stratigraphical relationship, the required conditions to the grooves' origin and the tectonic mechanisms are still objects of debate. In preparation of the ESA Juice Mission, we are producing DEMs of extended areas of the surface of Ganymede, using both Galileo and Voyager imagery. We use the open-source suite of tools NASA Ames Stereo Pipeline (ASP) [4], by using the photoclinometry-based "shape-from-shading" (SfS) tool. Since SfS needs an input DEM generated preferably with stereo images, and we do not have such data in this area of Ganymede, we used the methodology proposed by Lesage et al. 2021 [5]. Figure 1 shows an example of Digital Elevation Model using a Galileo image (EDR 2878r, with a resolution of 151 m/px) of Anshar Sulcus (167.40° E, 11.50° N). The DEM clearly shows the height variations of the ridge and trough systems included in the study area. These novel Digital Elevation Models can provide new insights on the geological processes of Ganymede. Acknowledgments GM acknowledges support from the Italian Space Agency (contract ASI/2018-25-HH.0). References [1] Pappalardo R.T., et al., 2004. Jupiter: The Planet, Satellites and Magnetosphere, 2:363. [2] Prockter L.M. et al.,2010. Space Sci Rev 153:63-111 [3] Pizzi A. et al., 2017. Icarus 288: 148-159 [4] Beyer, R. A. et al., (2018), Science, 5. [5] Lesage E. et al. (2021), Icarus, 114373.

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Introduction

The forthcoming ESA mission JUpiter ICy moons Explorer (JUICE) will investigate the Jovian satellites Europa, Callisto and Ganymede, providing new knowledges concerning the evolution and habitability of these icy worlds. Ganymede, the largest one, has a fractured icy crust overlying a subsurface ocean. Its surface is characterized by dark and light terrains. Light terrain, covering two thirds of the surface, is thought to be younger and resulting from resurfacing events, likely correlated to a global expansion of Ganymede. It is typically characterized by several sets of subparallel troughs and ridges, called grooves. They highly modify the dark terrain and the other pre-existing features. Since these areas display two different superposed spacing scales, grooves have been interpreted as the product of extensional tectonism, and two different faulting styles have been recognized (horst-graben and domino). Nevertheless, the stratigraphical relationships, the required conditions to the grooves' origin and the tectonic mechanisms are still objects of debate.

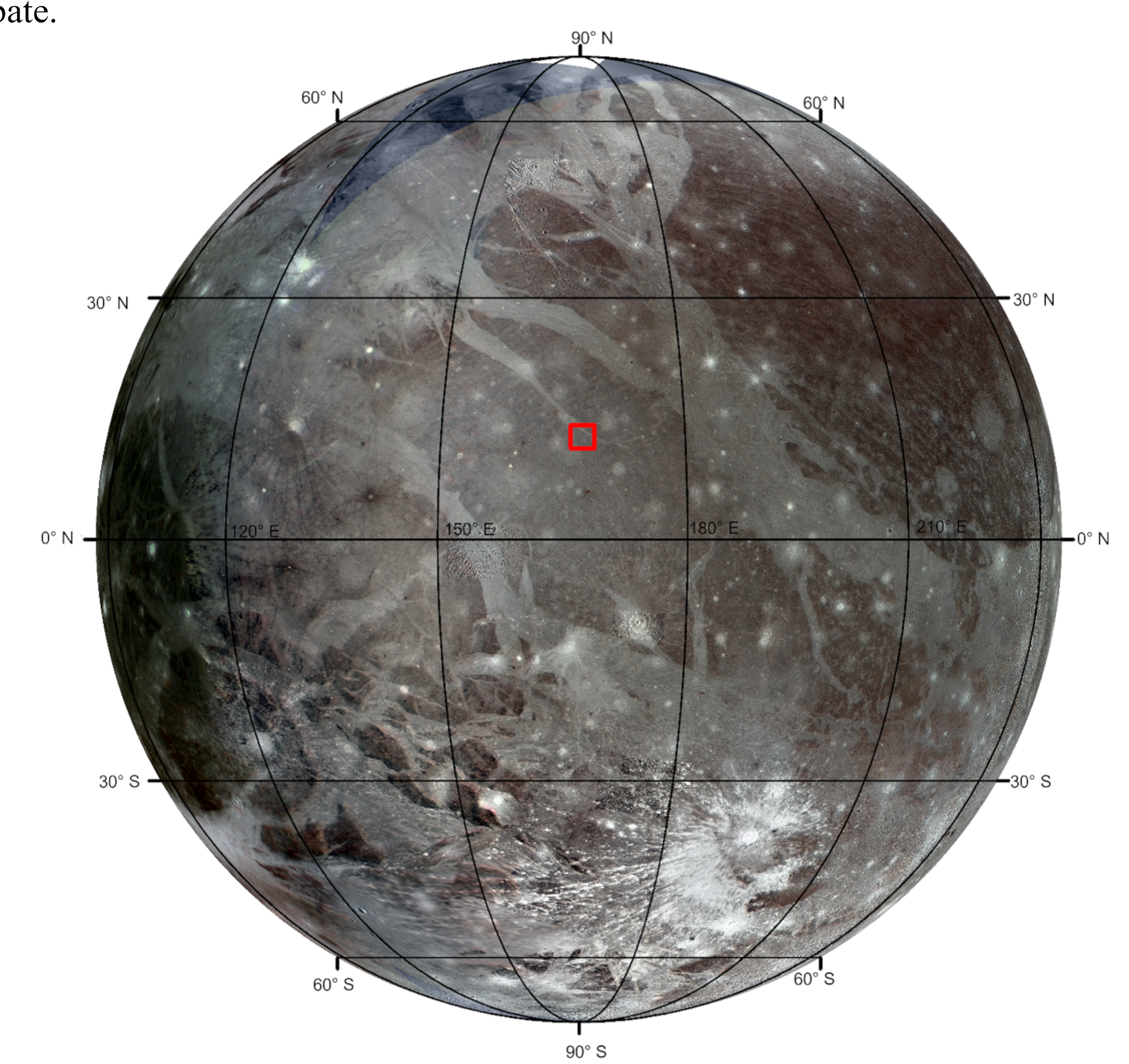

Fig. 1
Ganymede Voyager and Galileo Global Mosaics (courtesy by the Lunar and Planetary Institute).
The red polygon outlines the study area.

Methods and results

We analysed an area located in the Anshar Sulcus region, centred at 12°N, 167°E, characterized by the presence of both grooved and dark terrains. We produced a novel DEM (Digital Elevation Model) to observe the relative elevations of the main features in the study area. We used Galileo imagery named 2878r (152 m/px), properly calibrated, filtered, and georeferenced using the Integrated Software for Imagers and Spectrometers (ISIS4). The DEM of the study area has been produced by using the open-source suite of tools NASA Ames Stereo Pipeline (ASP). We applied the photoclinometry-based "shape-from-shading" (SfS) tool to produce the Digital Elevation Model. Since SfS needs an input DEM generated preferably with stereo images, and we do not have such data for this area, we applied the methodology proposed by Lesage et al. 2021.

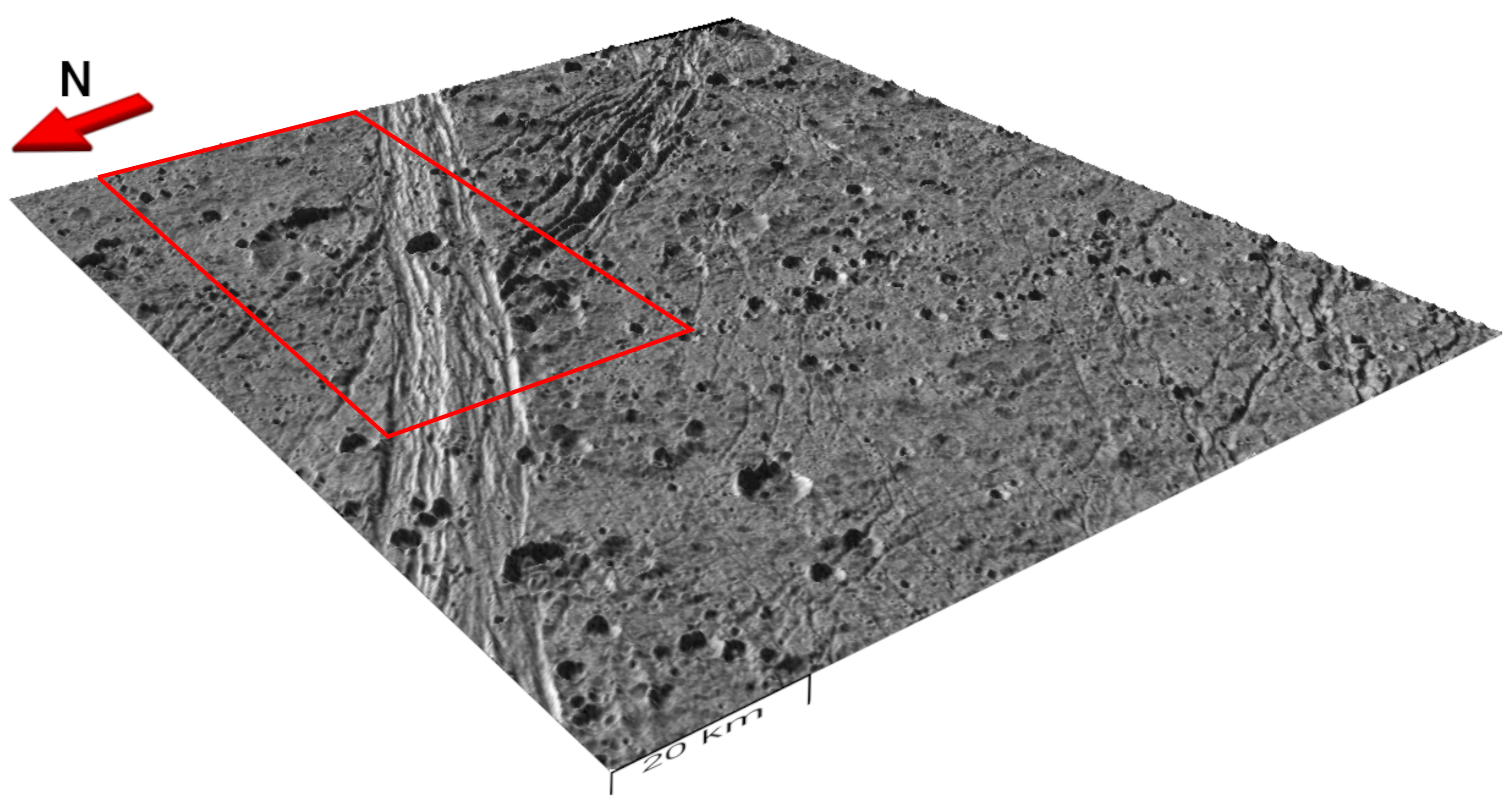

Fig. 2
Digital Elevation Model of the study area in 3D view.

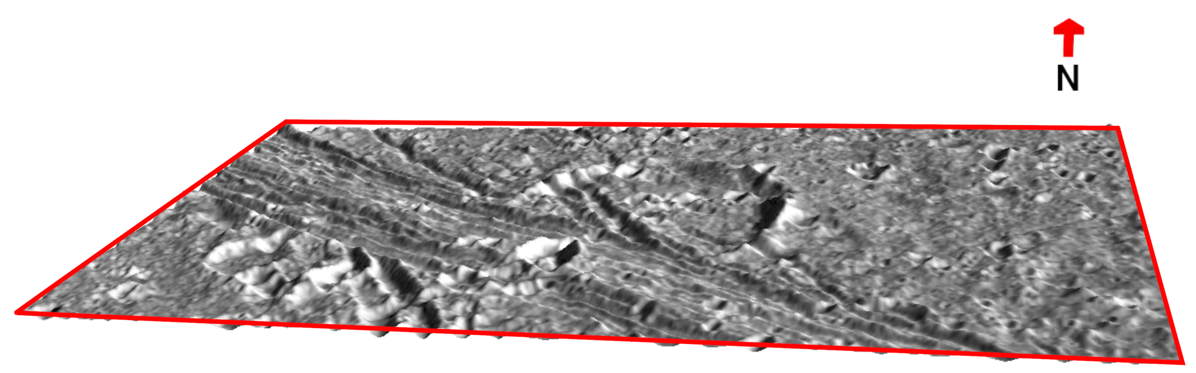

Fig. 3
Digital Elevation Model in 3D view of the study area (inset box of Fig. 2).

Discussion

To support the upcoming ESA mission JUICE, we are producing Digital Elevation Models of the areas covered by Galileo imagery data. The Digital Elevation Models may provide critical information concerning the three-dimensional relationship between forms and processes of the surface of Ganymede, such as the formation processes of the grooved terrains and associated furrows. Furthermore, from the Digital Elevation Models, several topographic data can be extrapolated, such as the surface roughness and topographic cross-sections (e.g., Figs. 4b and 4c). In particular, the roughness is an expression of the surface height variation over a given spatial horizontal scale, that provides geological and geomorphological insights of the investigated area. These datasets can be used to understand how the topography is influenced by endogenic and exogenic processes, allowing the identification of regions of scientific interest.

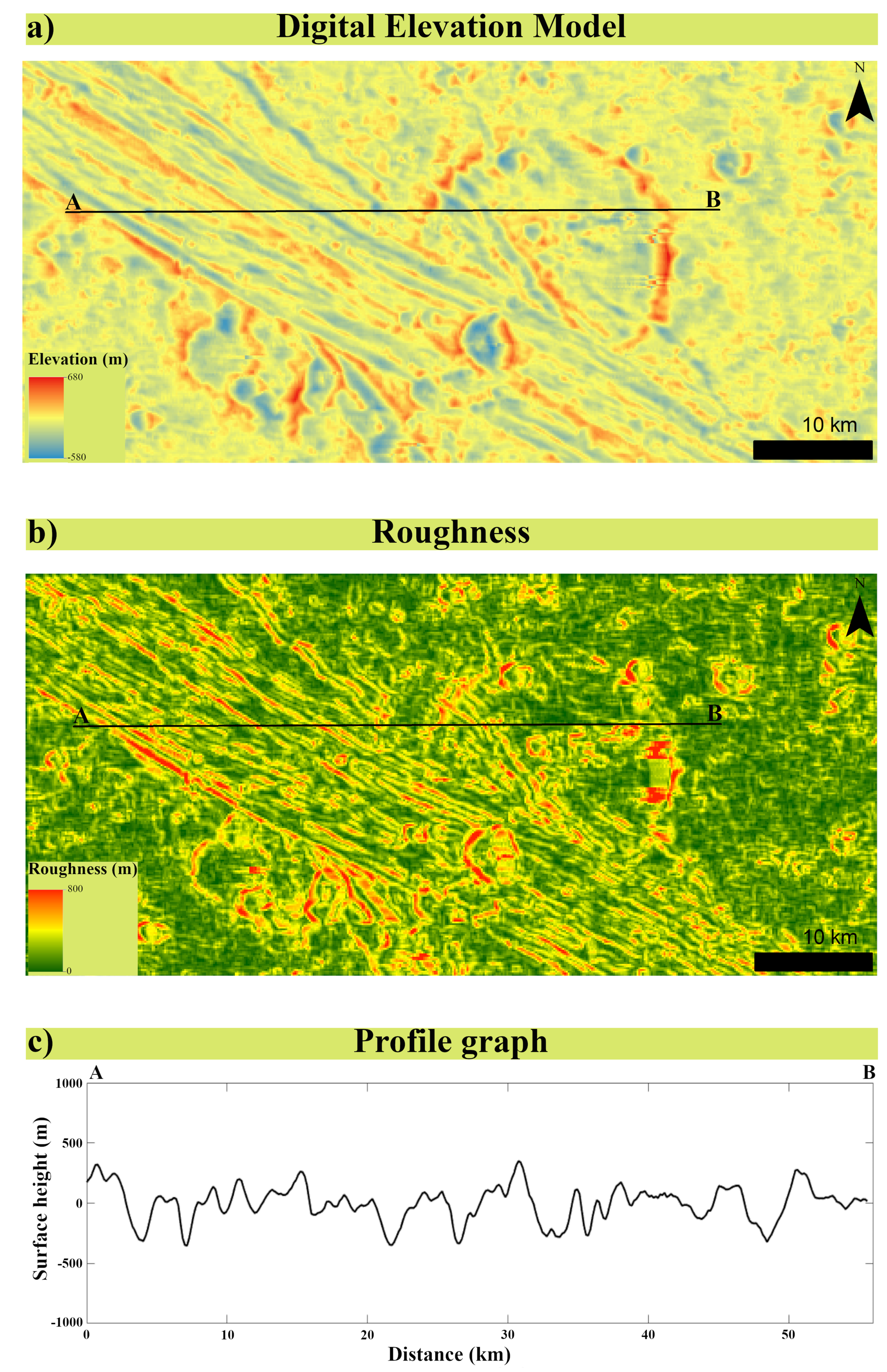

Fig. 4 a) Digital Elevation Model of the study area (inset box of Fig. 2); b) Roughness map of the DIgital Elevation Model in a); c) Topographic cross-section, whose groundrack is shown in Figs. 4a) and 4b) (black lines).

Acknowledgements and References

G.M., acknowledges support from the Italian Space Agency (contract ASI/2018-25-HH.0).

[1] Pappalardo R.T., et al., 2004. Jupiter: The Planet, Satellites and Magnetosphere, 2:363.
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