Revising the geological mapping of Mars

by Marco Pantaloni, Roberto Graciotti, Lucia Marinangeli, Matteo Massironi

The geological map is a unique graphical tool that summarises through colours and symbols, the complex evolution of a planet. It requires the combination of many different characteristics of the studied rock sequences including lithology, stratigraphy and structural deformation to reconstruct the variation of environments and climates through time. Although based on the same basic principles as on Earth, planetary geological - geomorphological mapping has some peculiarities which need to be addressed in order to standardize the technical and scientific approach.

The standards of planetary cartography have long been based on principles defined in the 1970s during the Apollo missions, while recently it is emerged the need to develop new cartographic guidelines in the light of advances in the understanding of geological processes that shape planetary surfaces. Furthermore, the plethora of new data derived from recent space missions and the possibility of identifying resources to be used in situ in view of permanent stations on the Moon and eventually Mars accentuate this need. This was recently faced by the USGS, which since the Apollo Era has continuously produced geological mapping of the surfaces of other planets and by a network of European scientific institutes involved in the pilot project H2020-PLANMAP (https://planmap.eu/).

In this framework, the Geological Survey of Italy, ISPRA, recently started a collaboration with the Italian Space Agency (ASI), the National Institute of Astrophysics (INAF) and the Universities of Chieti, Cagliari, Naples Federico II, Padua, Perugia and Jacobs University of Bremen. The aim of the project is the attempt to apply the cartographic standards rules used in the Italian Geological Mapping Project (CARG Project) for the realization of geological and geomorphological maps at various scales of detail even in the planetary environments. Thanks to the excellent coverage of high-resolution images of HiRISE (High Resolution Imaging Science Experiment) and the availability of medium and high resolution DTMs of some specific sectors of its surface, the applicability of the cartographic guidelines, published by the Geological Survey of Italy in the "Quaderni" series (http://www.isprambiente.gov.it/it/progetti/suolo-e-territorio-1/progetto-carg-cartografia-geologica-e-geotematica/linee-guida), is being tested. In this preliminary phase of the work, has been tested the production of geological and geomorphological maps of some sample areas of planet Mars.

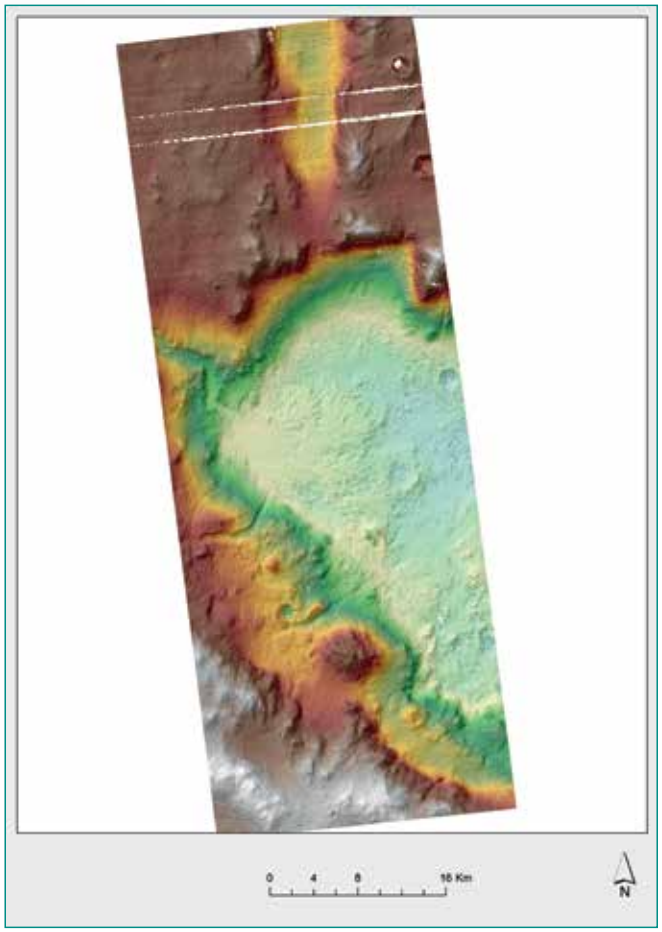

Fig. 1 - Topographic map of the western part of Eberswalde crater on Mars, chosen as a test area for the object of this study

The standards of planetary cartography have long been based on principles defined in the 1970s during the Apollo missions, while recently emerged the need to develop new cartographic guidelines in the light of advances in the understanding of geological processes that shape planetary surfaces. The plethora of new data derived from recent space missions and the possibility of identifying resources to be used in situ in view of permanent stations on

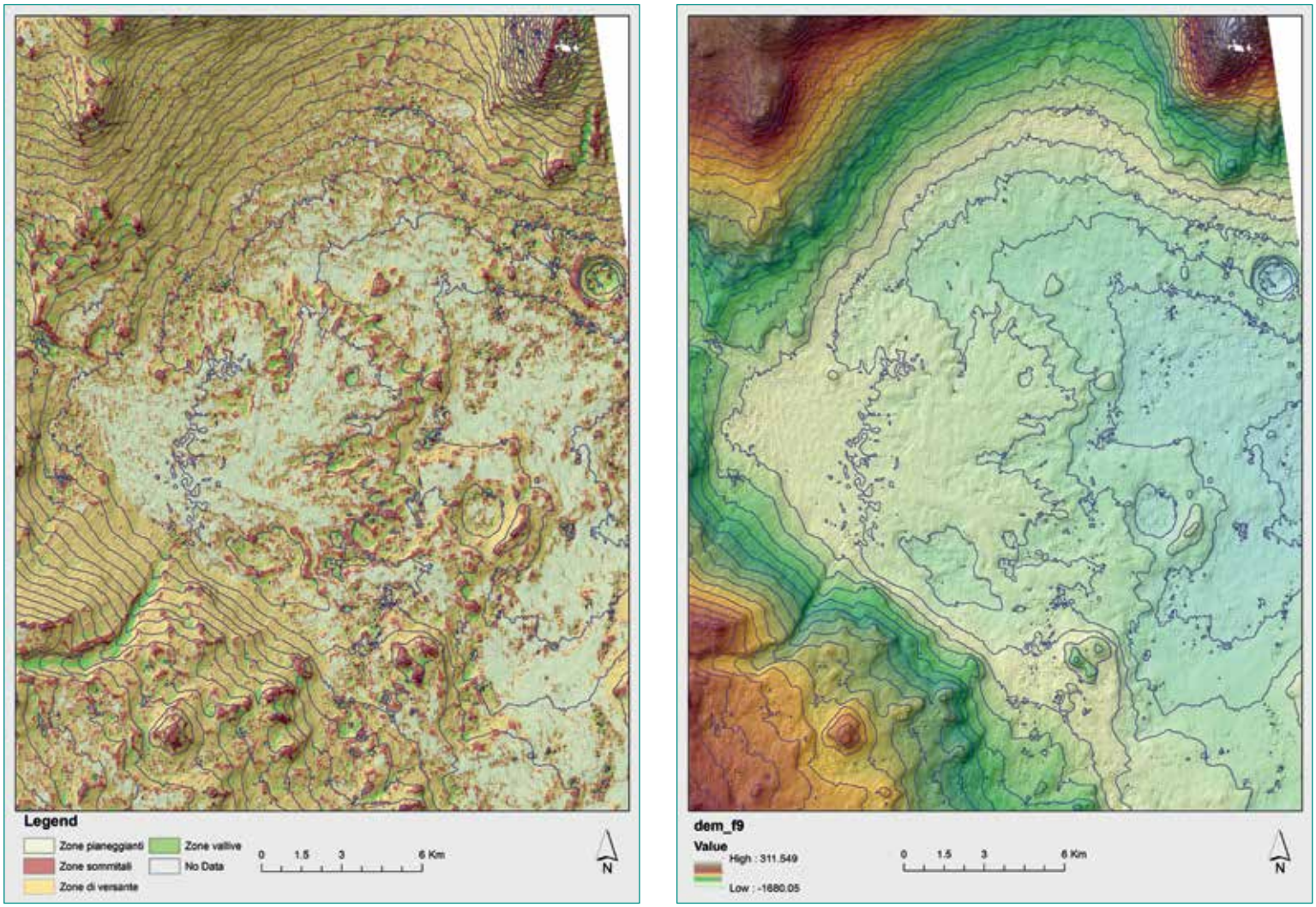

Fig. 2-3 - Thematic maps of the selected test area with slopes, exposure and landforms units

the Moon and eventually Mars accentuate this need. While USGS has been the reference for geological mapping and cartography of the surfaces of other planets, a network of European scientific institutes involved in the pilot project H2020-PLANMAP is aimed to define new rules for updating these products.

In a first experimental phase, the prototype area of the Eberswalde crater on Mars (Fig. 1) was chosen due to its great variability of forms of erosion and demolition and the conspicuous reference literature. It was possible to verify that some forms, morphostructures and depositional facies present in this area of the red planet are, in some ways, similar to those observed on Earth.

In planetary science, as well as in earth science, the geological map represents the most objective synthetic product; in it, the different rock units are distinguished based on observable physical parameters: texture, colour, sedimentary structures and geographical distribution. The stratigraphic relationships between the units are evaluated by applying the classic principles of stratigraphy used in the terrestrial environment, even if, sometimes, these principles do not seem to fully respect the extra-terrestrial geological dynamics. Moreover, the geological and geomorphological analysis carried out in the Martian area shows that geological units could be interpreted in terms of depositional environments, even if any change in genetic interpretation would not result in a change in representation in the geological map.

Planetary geological mapping is deeply linked to the availability and quality of data (resolution of images and DTMs, availability of spectral and elemental composition data, etc.), which implies great differences in the potential of the analysis between different planets but also between different parts of the same planet. Moreover, the presence of direct surface analyses

Some peculiar landforms of Mars

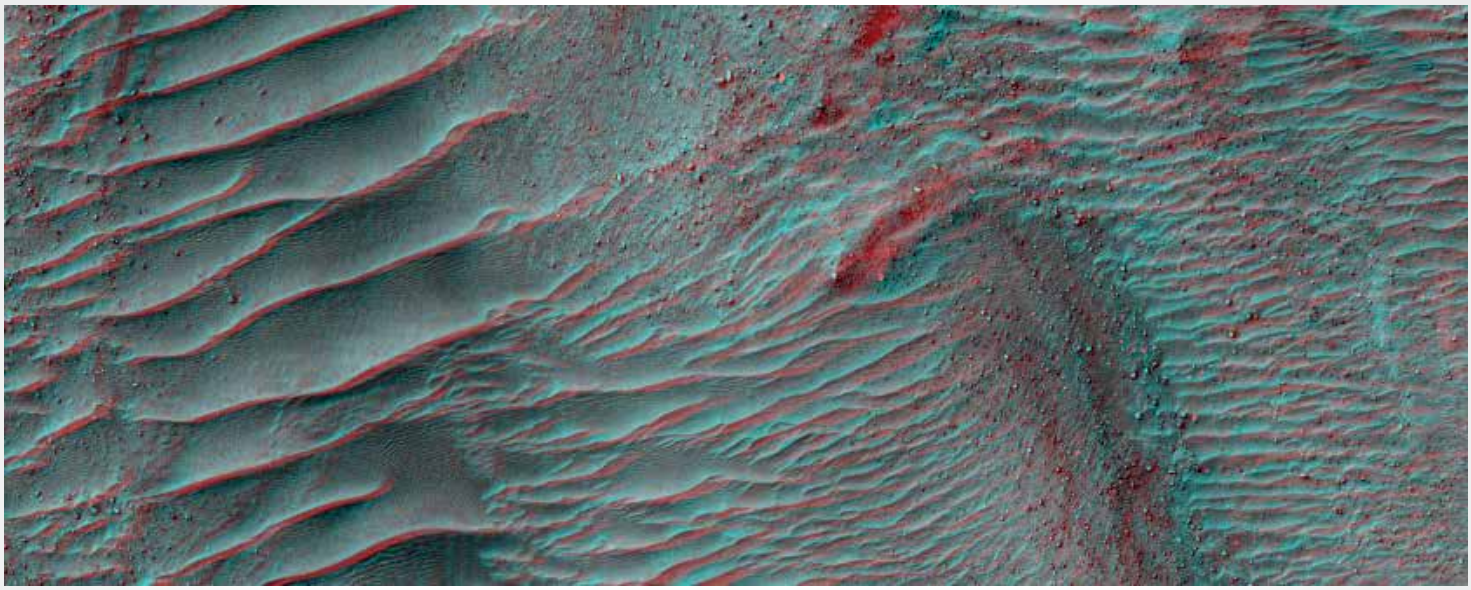

Fig. 4, 5 e 6 - The images show peculiar forms defined in literature as TARs (Transverse Aeolian Ridges). These forms are typical and very common on Mars; TARs are found in the flat bottom of craters, along the base of canyons, on large flat surfaces and at the base of vertical scarps. TARs are characterized by a great variability in their geometry (maximum ridge height, average height, wavelength, slope of the surfaces, etc.). These shapes vary in dimensions but above all very peculiar lateral contacts characterized by sudden transitions between morphotypes dissimilar in size. The direction of alignment of the TARs, on the other hand, is quite constant. Image credits: NASA/JPL/University of Arizona

Fig. 7 - This image shows a series of landforms that seem, at a first sight, similar to casting phenomena due to gravitational morphogenetic processes as on Earth. It is not possible to establish the exact origin of this phenomena (debris flow, mud flow or earth flow) not knowing the granulometry of the deposit and the density of the flow. As for the Earth landforms, also in this case we can identify a detachment zone, a transfer zone and an accumulation area. The flows seem to originate at the edge of the crater. The flows transfer zone follow a straight line, while it seems that the deposit expands in the accumulation area in peculiar lobed forms. Image credits: NASA/JPL/University of Arizona.

is only rarely available, with the exceptionof in situ landing and rovering missions on the Moon and Mars.
Regarding Mars, geological mapping is essential for the identification of landing and trafficability sites as well as to define the exploration areas for landers and rovers.
The geomorphological analysis and the related cartographic representation of the main forms of erosion and accumulation are based, in principle, on the same techniques and methodologies used for the geomorphological representation of landforms in the terrestrial environment.
Exceptions are the surveys on deposits associated with the forms of accumulation that require the collection of a series of specific data (grain size, texture, sedimentary structures, etc.) difficult to detect by remote observation techniques.
The development phases of the project start with the photo-interpretation of the available high-resolution images followed by the creation of DTMs as much detailed as possible and, finally, the production of thematic maps (slopes, exposure, basic topographic units, etc.). The data thus acquired and the morphometric analysis of the forms, carried out through the study of topographic profiles and the evaluation of the geometric relationships of the observed morphotypes, could help in understanding which have been in the past and which are currently the main processes and morphogenetic agents that have shaped the landscape of Mars.

Final remarks

This project involves different professionalities: geologists, geomorphologists, astronomers, physicists, chemists and mathematicians; the contribution of the Geological Survey of Italy is to adapt and update the cartographic protocols guidelines, developed for the cartographic representation of the Italian territory, to make them applicable to the production of geological - geomorphological maps of pilot areas of planet Mars. This contribution aims to expand the geological and cartographic information by including genetic considerations not currently provided by existing USGS

KEYWORDS

PLANETARY MAPPING, GEOLOGICAL MAPPING, MARS, GEOLOGICAL SURVEY

ABSTRACT

Planetary geological-geomorphological mapping has some peculiarities which need to be addressed in order to standardize the technical and scientific approach. The aim of this project is the attempt to apply the cartographic standards rules used in the Italian Geological Mapping Project (CARG Project) for the realization of geological and geomorphological maps at various scales of detail even in the planetary environment.

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