THE NEED OF A STANDARDIZED GEOLOGICAL AND GEOMORPHOLOGICAL MAPPING ON MARS: CENTRAL ARABIA TERRA CRATERS AS TEST SITES FOR AN OBJECTIVE MAP

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Introduction: The increasing availability and improvement of remotely sensed data and the ingestion in GIS environment, provide an impressive suite of tools to develop ever more detailed planetary geological maps. These datasets allow the realization of thematic maps that somewhat akin to the relatively 'objective' geological mapping approach well-known on Earth.

On Mars, the data coverage has a high-resolution and is extremely widespread, especially in small areas (e.g., basins), making the mapping process even more significant. In these conditions, deposits can be distinguished based on their objectively defined characteristics (i.e., tone, texture, absence/presence of sedimentary structure, compositional hints) apart from the genetic interpretation provided by the morphology. A clear distinction between descriptive (objective) and interpretative (subjective) units is specifically useful when geomorphological interpretation is particularly controversial. Unlike on Earth, Martian deposits are well-preserved down to the deep stratigraphic succession, making stratigraphy a pivotal concept that needs to be included within map information and a prerequisite to a well constrained interpretation of the Martian geological environments.

We firmly believe that the geological map is the first and most important step to reconstruct the evolution of a region of interest, especially when it is still not possible to investigate it with human in-situ exploration. Simultaneously, future crewed missions would require scientists and engineers to overcome not only a range of technological and safety obstacles, but also to have a deep knowledge of geological and atmospheric conditions before human travelers must face them at the landing sites. This level of acquaintance may be pursuit through the detailed analysis of orbiter data, i.e., the reconstruction of geological history and, hence, maps that gather all the information available for a specific region of interest.

Within the Europlanet H2024-GMAP (Geologic MApping of Planetary bodies) infrastructure, we have attempted to apply all these different, but complementary, concepts and information in a single cartographic product of three craters in central Arabia Terra, Mars. For such an aim we have borrowed, where possible, the Earth symbols designed for the Geological Map of Italy [1,2] aiming to make the 'language' of geological maps of Mars and Earth as uniform as possible.

Case study: Sedimentary deposits and associated morphologies are among the most interesting geological records on Mars surface, because of their implication in understanding climatic conditions and their variability through Mars' geological history. In the last decades, past water-related environments have been the most appealing places to be investigated and scientists are still willing to unravel the presence of life on Mars. Considering future missions will still aim to pursuit this goal, it is likely they will be sent in localities that show evidence of past water activity. For these reasons, our work was focused on central Arabia Terra (Figure 1) where several impact craters show internal layered sequences [3]. The study area is represented by the set of three craters shown in Figure 2.

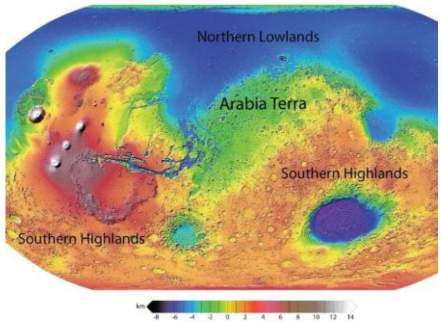

Figure 1 - Arabia Terra location.

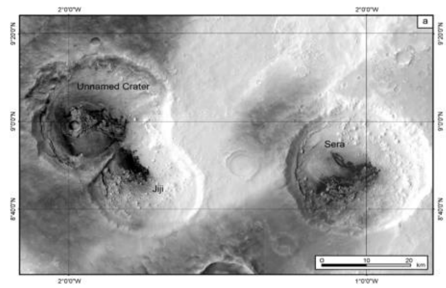

Figure 2 – Sera, Jiji and an unnamed crater as case studies in Arabia Terra, Mars.

Mapping approach: We propose to use a hierarchical path of thought to identify the units (i.e., mapping). This approach uses a combination of some criteria, scrolling through several levels of knowledge with different hierarchy as shown in Fig. 3.

First, scale and illumination conditions (incidence angle and azimuth) are required as a priori information before to start the mapping. The scale gives the idea of the entity of the geological process, and it is tied to the resolution of the images (or data) we intend to use. The knowledge of the scale prevents any morphological convergence issues that might exist between different orders of scales since very similar morphologies may result from different geological processes. Whilst, the knowledge of illumination conditions avoids being tricked by the concavity/convexity appearance, and, hence, relief inversion misinterpretations.

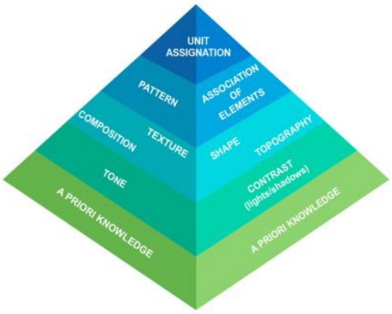

Figure 3 - Unit recognition and assignation process.

Second, to fulfil our goals and to reflect the objectivity of the proposed method, we identified the units using the following combination of criteria, defined both at the CTX and, when possible, at the HiRISE scale, including:

- their main topographic and geological characteristics;
- their surface properties (e.g., rough or smooth textures, albedo, mineralogy, etc.);
- their orbital facies (e.g., bedforms, layering, etc.).

The geological map has three different layers:

- a polygon shapefile representing the units which are described using as objective as possible characteristics (listed above);
- a linear shapefile defining the nature of the stratigraphic boundaries (e.g., disconformity, nonconformity, etc.);
- a linear shapefile marking tectonic features and interpretative geomorphological structures.

Although geology is born as an interpretative science and it is never unconstrained from interpretation, this approach allows to simultaneously, but separately, focus: on the description, the stratigraphic relations (emphasizing the missing time) including different hierarchy, and on the genetic interpretation. The genetic interpretation, in turn, is constrained by the reconstruction of the vertical and lateral relationships among the units that allows to interpret the formation process of a specific landform in the framework of a context of associated landforms (i.e., landscape).

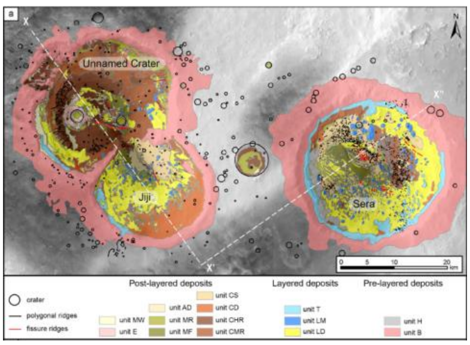

Figure 3 - Geological map of the studied area with the distinction between the three main sequence: pre-layered, layered and post-layered units. Modified from [3].

The purpose of this approach is to introduce a concept that addresses the 'objective' description of the units with all the available dataset that in turn might favor the reproducibility of these observations in different areas/settings. The stratigraphic reconstructions allowed to identify a succession of depositional events separated by unconformities which are expressed by space-space and space-time reconstructions.

Conclusions: This attempt showed how an 'objective' approach is feasible even in planetary science, as long as the available data have a good coverage and high spatial resolution for the selected area. Intracrateric basins in central Arabia Terra lend themselves to be deeply investigated in this sense due to the high-resolution and extremely dense data coverage.
Finally, the problem of different resolution among the visible imagery and the spectral data will be addressed in order to organize a consistent legend. We also plan to identify a set of graphical symbols describing the surface features, locating potential limits in current GIS symbology implementation. The aim is to develop a 'language' as uniform as possible between Earth and planetary geological-geomorphological maps.

Future perspectives: Colonizing Mars is one of the intriguing plans for humanity and it might become feasible in a couple of decades. However, there are several problems science needs to solve first sending humans to Mars. Inevitably, one of the main concerns is represented by the environmental conditions astronauts will have to overcome to establish on Mars, i.e. a desolate, dry and inhospitable rock. Consequently, a high degree of knowledge of the landing sites is required to ensure smarter and safer human missions. What we observe on the surface of Mars today is the result of a complex combination of geological and physical processes through the whole history of the red planet. The basic principle of geology is "the past is the key to the present" and vice versa, it follows that scientists also need to reconstruct the entire geological context (i.e., deep in time) to fully understand current surface conditions. This level of knowledge may be pursuit through maps that gather all the information available for a specific region of interest.
Finally, this research pursuits scientific goals of specific areas of course, but also tries to improve and expand the concept of planetary mapping we are used to, aiming to a sustainable perspective in the planetary field.

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References: [1] ISPRA (2009) *Carta Geologica d'Italia. Guida alla rappresentazione cartografica. Modifiche e integrazioni ai Quaderni 2/1996 e 6/1997*, pp 166. [2] ISPRA (2018) *Carta Geomorfologica d'Italia. Guida alla rappresentazione cartografica. Modifiche e integrazioni al Quaderno 4/1994*, pp 95. [3] Pietro et al. (2023), *JGR*, 128 (3).