ICE AND FIRE: THE POSSIBLE INTERACTION BETWEEN PERIGLACIAL AND VOLCANIC ACTIVITY IN THE FORMATION OF A FLOOR FRACTURED CRATER, TERRA SIRENUM, MARS.

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Introduction: Floor-Fractured Craters (FFCs) are characterized by their typical floors, which exhibit fractures, mesas and knobs and they are found on different planetary bodies. The origin of fracturing is explained by many models that hypothesize different genesis: the periglacial one [1], the groundwater migration [2], a volcanic origin [3], tectonic pressurization [4] and/or a mix of these phenomena. Diverse FFCs are expected to have different genetic origins. As a result, distinguishing geological features and composition within FFCs is critical for understanding their unique evolution.

In this work, we focused on a FFC (Fig. 1) located in the southern hemisphere of Mars (37 ° S, 190 ° E) in the Noachian terrain of Terra Sirenum. This region has large and isolated basins, a relatively young graben (Sirenum Fossae), and one of the largest runoff channels on Mars, Mad'anim Vallis. Our study crater, placed in the Gorgonium Chaos (a basin extended for about 240 km in diameter [5]) is about 18 km in diameter.

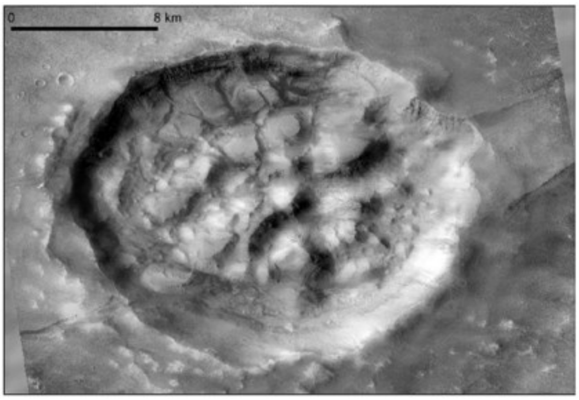

Fig. 1 – The crater analyzed in this study.

It has a smooth and degraded rim, a chaotic floor characterized by a polygonal fault network bounding large and irregular blocks and tilted mesa toward the wall. The central/southern part of the crater appears to be more elevated than the floor margins which could suggest a doming volcanic process, maybe connected with the presence of Sirenum Fossae graben, which cuts the crater. The ejecta presents double-layered morphologies [6] which are typical of impact in a glacial substrate [7]. Both the periglacial and volcanic process could have acted in this crater and contributed to the fracture formation. To evaluate this possibility, we perform a geological, morphometrical, chronological and compositional analysis of the crater. The aims of this work are to i) understand the role of the water/ice in the formation of the fractures, ii) evaluated the presence of volcanic deposits and thus iii) evaluate the possible involvement of periglacial and volcanic processes in the fracturing of the crater floor.

Methods: Through remote sensing we analyzed different images at various spatial resolutions from the High-Resolution Imaging Science Experiment (HiRISE, [8]) and Colour and surface Imaging System (CaSSIS, [9]) camera and of Mars Orbiter Laser Altimeter (MOLA, [10]) altimetric data. The photointerpretation led to the identification of different Photogeological Units, i.e. areas that have the same characteristics of tone, texture, structure and response to erosion. The recognized landforms have been classified according to their presumed morphogenesis.

The crater counting is performed for the ejecta in order to find the absolute model age of the crater. We outlined the ejecta unit in ESRI ArcGIS 10 environment and craters with diameters larger than 50 m were mapped at a scale of 1:15,000 using the CraterTool extension [11]. We modelled the crater size-frequency distribution with the Craterstats2 software [12], using the chronology function of Hartmann and Neukum [13] and the production function of Ivanov [14].

The mineralogical composition of the crater is evaluated using spectral data from the CRISM [15] spectrometer. As a first step, we used the RGB color composites of CRISM (also called browse products, [16]), which enable a rapid, visual and qualitative multiparametric evaluation of the spectral characteristics of the surface.

The fracture directions are important markers in order to evaluate the relationship with the main regional tectonic structures. We have mapped all fractures in QGIS 3.22 as linear features. Using the Field Calculator, we have calculated the azimuth of the fractures and their length in meters. We have finally plotted all the data in a rose diagram using GEOrient V10 program.

Results: Based on the imagery data of HiRISE, CaSSIS and CTX, we created a geological and morphological map of the crater that displays ten photogeological units. The units are distinguished by the

location within the crater in Wall Units, Floor Units and Mesa units. The mesas can be divided into three types based on stratigraphy and morphological appearance. The first type includes the mesa in the north part of floor. This type of mesa presents all the stratigraphic sequence. The second type of mesa includes those in the central part of the crater. They present only the bedrock part, with the slope covered by blocks and loose material. The last type of mesa includes the mesa in southern part, which show elevation lower than those in the central and northern part of the crater. Furthermore, we have noticed that the mesas are tilted toward the crater rim of about 8°.
The crater counting of the ejecta constrains the absolute model age of the crater to around 3.4 ± 0.09 Ga.
The CRISM- FAL (false color), MAF (mafic mineralogy), PHY (phyllosilicates), PFM (Fe/Mg-phyllosilicates), PAL (Al-phyllosilicates) and ICE (carbon dioxide frost or ice) browse products were used to investigate the mineralogical composition of the crater and its infilling. These mineralogical maps indicate that the central/southern mesas are characterized by the presence of Olivine and Pyroxene, while the rim and the inner wall of the crater show signs of Fe/Mg Phyllosilicates.
The analysis of the fracture's strike within the crater results in line with the main orientation of the Sirenum Fossae fractures (NW-SE).

Discussion: We compared many formation models for this type of crater to understand which suits our case. There is no definitive evidence for which process is responsible for the fracturing floor of this crater. Thus, we propose the mutual interaction of at least three processes: firstly, the fluidized morphology of the crater's ejecta and the presence of Phyllosilicates at the marginal part of the floor and wall could be indicative of the presence of water/ice at the moment of the impact and later on in the modification of the crater. Secondly, the tilting of mesas, and the presence of olivine and pyroxene in the central/southern part of the floor (where the doming is more evident) could relate to volcanic processes subsequent to the impact. The agreement of the crater fracturing with the main direction of the Syrenum Fossae system and the presence of olivine in the central/southern mesa may suggest brittle deformation induced by magmatic injections. A possible dynamic model is summarized in Fig. 2. As 1) first step there has been the formation of the impact crater, about 3.4 years ago, with presence of ice in the subsurface which could have been melted leading to the formation of an inland lake and/or glacial deposits. In the following phases there has been the deposition of possible lacustrine material in the crater floor. At some point, 2) there has been the first action associated to the Sirenum Fossae opening, that could be associated to magmatic injection and the formation of a magmatic dome inside the crater, most of all in the central/southern part of the floor (laccolith intrusion). 3) The heat induced by the magmatic material brought to melt of a possible underground permafrost; thus, many parts of the floor went in subsidence and modified its shape. 4) A second action of Sirenum Fossae have started to dissect the magmatic deposit and have brought other magmatic material to the surface (layering deposits,). Finally, the morphological map highlighted that the crater 5) was later modeled and modified by the action of at least three main morphogenetic agents: subsurface ice, gravity, and wind.

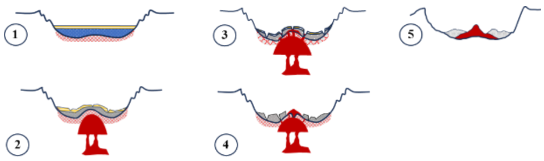

Fig. 2 – The model of the possible sequence of events which interest the crater history.

Conclusions and future steps: In this work we focused on the analysis of the landforms of a Floor-Fractured Crater located in the southern hemisphere of Mars (37 ° S, 190 ° E) in Terra Sirenum. We perform several analyses in order to define the processes driving the fracture formation. Based on data collected to date, we propose a hypothesis for the origin of floor fractured craters, which involved the combination of different processes including periglacial, tectonic, gravitational, and volcanic events. As next steps, we will further analyze the compositional characteristics of the crater trough the quantitative analysis of spectra of both CRISM and CaSSIS data.

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