HYPOTHETICAL PHREATOMAGMATIC ORIGIN OF TWO DEPRESSIONS NEAR GALAXIAS FOSSAE, MARS – BASED ON HIRISE DTM ANALYSIS. M. Hencz, Eötvös Loránd University of Science, Dep. of Physical Geography, Hungary, H-1117, Budapest, Pázmány Péter stny. 1/C, hencz.matyi92@gmail.com

Introduction: Previous studies confirmed the presence of ground ice on Mars [1]. Due to the ground ice and the co-existing volcanic activity, magma-ice interactions were widespread during the history of Mars (e.g. in Early Amazonian) [2-3]. We selected two enigmatic depressions situated near Hrad Vallis in Galaxias Fossae (34°80' N, 141°85' E) due to their unusal appearance (*Fig. 1*). The southern structure was investigated in previous studies [4-6], while the other, smaller edifice was not studied. In contrast to these studies (see below), we infer phreatomagmatic origin for both of them.

Description of the structures. Both of the aforementioned unnamed negative-relief landforms are located in a relatively flat lava plain, near Elysium Mons [7]. The southern, larger depression (informally called 'Galaxias depression' [6]) contains several concentric fractures, which Levy et al. (2010) called "crevasse-like" cracks from the glaciological terminology [4]. The depression is narrowing towards the center, where it exhibits a nearly flat terrain containing dunes. The whole structure is surrounded by a higher ridge and radially-oriented blasted sediments. The depth of the ~2500-m-diameter depression is 150 m below of the surrounding area. 500 meters to the north from this landform another unusual, cone-like, 300-m-diameter edifice is located, with a deep crater-like structure. The crater floor is below of the surrounding area as it shown with yellow color in *Fig. 1*. The whole cone-like edifice is located in a bigger (1200 m in diameter) depression.

The main hypotheses set forward in the previous studies regarding to the origin of the larger structure were the followings. 'Galaxias depression' was formed by: a) volcanic processes, when the heat of the magma melted the subsurface ice, and the material deficiency caused the collapse of the structure (glaciovolcanic processes) [4-5], b) impact processes, which melted the subsurface ice, and due to this material deficiency, the uppermost part of the impact crater has collapsed, which create the concentric fractures [6]. In this abstract, an alternative model is given for the formation of this depression (expanded with a nearby cone) preferring volcanic processes model supplemented by phreatomagmatic explosive effect for both structures.

Methods. HiRISE images (PSP_005813_2150 and PSP_005879_2150) and a HiRISE Digital Terrain Model (DTM) were used (DTEEC_005813_2150_005879_2150_A01.IMG). This DTM is shown in *Fig. 1*. In Global Mapper 16® the original DTM was exported into a lower, 20x20 m resolution elevation GRID file. In Surfer 13® 2 maps were generated from this GRID: terrain slope and 3D surface. Cross-sections were made in ArcMap from the original DTM.

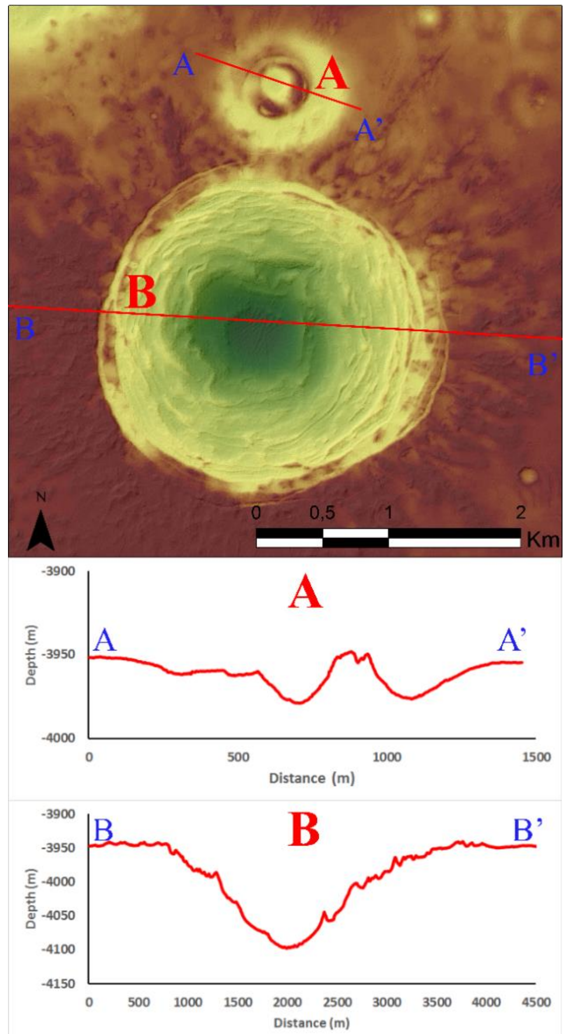

Fig. 1: The depressions near Galaxias Fossae (source: [5]. A and B diagrams show the cross sections generated along the lines.

Hypothetical phreatomagmatic origin. These concentric features (called ice-cauldron) are common on Earth in glaciovolcanic settings [8]. On Mars, volcanic heating also may be able to form depressions through the melting of the subsurface ice [4]. Phreatomagmatic processes are inferred on Mars, too, when hot magma and meltwater interact, and due to the rapid expansion of the steam originated from the meltwater, explosive eruption occurs [9]. In this case, a variable amount of explosive ejecta radially spreads out from the volcanic centre, in some cases a volcanic cone (tuff ring, tuff cone) construct, when the phreatomagmatic explosions are very close to the surface [10]. Hesperian-Amazonian aged phreatomagmatic volcanic centers are described at 500 km to the southeast (Hadriacus Patera) [11]. Building upon these known terrestrial and inferred martian processes, an alternative model is described below for the origin of the two depressions.

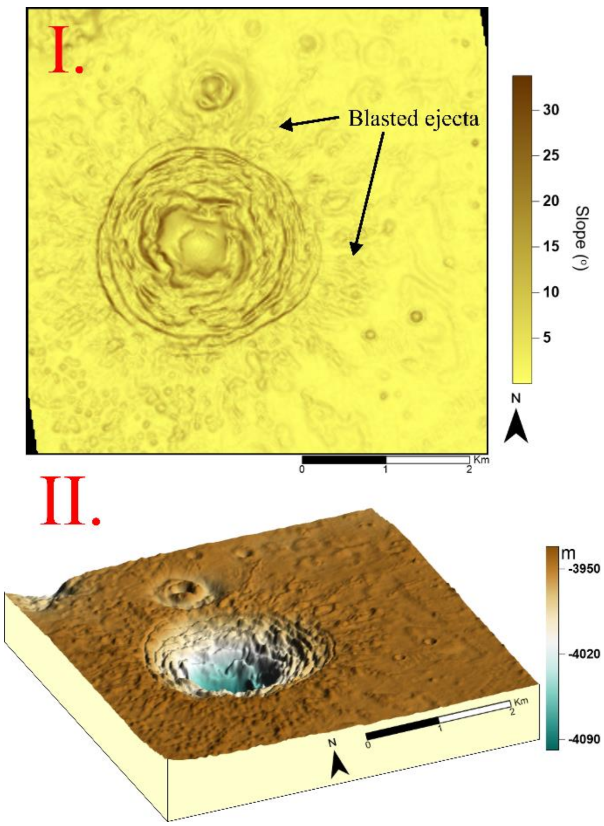

Fig. 2: *I.*: Terrain slope map of the depressions based on HiRISE DTM [5]. *II*: 3D surface map (vertical exaggeration 2,5X)

The proposed formation model. The ascending magma contacted the subsurface ice and melted it. The amount of magma was enough to contact the meltwater, and as the ice got thinner, magma and water could interact explosively relatively deep (cca. 150 m). During this process, gradual concentric collapse could take place due to the loss of the ice. We assume that this volcanic event was not confined to the subsurface, but produced phreatomagmatic explosive volcanic eruption. The blasted ejecta around the structure is clearly visible, especially in terrain slope map (*Fig. 2/I)*.

The smaller depression located to the north of 'Galaxias depression' could also have formed by phreatomagmatism. The shape of the structure is similar to tuff rings or tuff cones located on Earth (e. g. Montaña Amarilla or Montaña Pelada in Tenerife [12]). The diameter of the crater is also similar to tuff cones/tuff rings on Earth [13]. This cone-shape is visible in *Fig. 1*. Based on these terrestrial analogies, a tuff cone/tuff ring could be formed. In addition, near-surface water reservoire is a necessary condition to form a tephra ring that is shaped like this structure. This could be the meltwater regime near the surface. Following the cessation of active volcanism, the long lasting thermal effect of the feeder dyke could melt more ice in a larger area around the volcanic vent resulted subsurface material deficiency. Due the this, the whole volcanic cone sank, and a negative landform was formed. This depression is clearly shown on the cross section A (*Fig. 1/A*) and in 3D surface map, too (*Fig. 2/II*).

If this is a tuff ring, it must be younger, than the 'Galaxias depression', because it stratigraphically overlies the ejecta of the southern depression. Moreover it is possible that these structures were formed at the same volcanic cycle, or from the same magma pocket. Based on terrestrial evidences, the main difference between the formation of the two structure is the depth of the phreatomagmatic explosions.

Conclusions. Two depressions were investigated near Galaxias Fossae, Mars. Previous work inferred impact or glaciovolcanic origin for the 'Galaxias depression' [4-6]. The other structure have not been examined earlier. In this study we prefer a volcanic phreatomagmatic origin for both of these landforms. We propose that these two landforms formed in similar processes, and the main differences are the intensity of magma-water interaction and the depth of the phreatomagmatic explosions. These sites are of high astrobiological significance due to the larger thermal influx and the possible past presence of liquid water [14].

References: [1] Byrne, S., et al. (2009), *Science*, 325, 1674–1676 [2] Allen, C. C. (1979), *JGR*, 84, 8048–8059. [3] Pedersen, G.B.M. et al. (2010), *Earth and Planetary Sci. Letters*, 294, 424-439. [4] Levy, J. S. et al. (2010), *41st LPSC*, 1054. [5] HiRISE Science Team (2007), *hirise.lpl.arizona.edu/PSP_005879_2150.* [6] Levy, J. S. et al. (2016), *Icarus*, 285, 185-194. [7] Tanaka, K. L. et al. (2014), *USGS Scientific Investigations Map* 3292, pamphlet 43 p. [8] Gudmundsson, M. T. et al. (2004), *Bull. Vol.*, 66, 46-65. [9] Sheridan, M. F. & Wohletz, K. H. (1983), *JVGR.*, 17, 1-29. [10] Lorenz, V. (1973), *Bull. Vol.*, 37/2, 183-204. [11] Cassanelli, J. P. – Head, J. W. (2016), *Icarus*, 271, 237-264. [12] Carmona, J. et al. (2011), *J. of African Earth Sci.*, 59, 41-50. [13] Lorenz, V. (1986), *Bull. Vol.*, 48, 265-274. [14] MEPAG SR-SAG (2006), *Astrobio.*, 9, 677-732.