Observations and Origins of Fractured Craters on Mars

M. Bamberg[1,2], R. Jaumann[2,3], H. Asche[1], T. Kneissl[3], G.G. Michael[3] [1]Geoinformation Research Group, Department of Geography, University of Potsdam, Germany. [2]German Aerospace Center, Institute of Planetary Research, Berlin, Germany. [3] Free University Berlin, Department of Earth Sciences, Institute of Geosciences, Remote Sensing of Earth and Planets, Germany. (Marlene.Bamberg@dlr.de/ Fax: +49 30 670 55 402)

Introduction: Floor-Fractured Craters (FFCs) are characterized by the distinct appearance of their floors, which exhibit fractures, mesas and polygonal features [1]. They appear in different environments and regions on Mars. This work shows the distribution of FFCs on Mars and the processes which form them to understand their relationship with volcanic activity, subsurface water distribution and past climate conditions. Two distinct types of craters have been analyzed and compared. They represent floor fractured craters in a volcanic and a fluvial environment.

Observations: 421 potential FFCs have been identified on Mars by using HRSC- and CTX- images. A strong link appears between floor fracturing, chaotic terrain, outflow channels and the dichotomy boundary (Fig. 1).

HRSC- and CTX- images are used for a detailed analysis of two different floor fractured craters. We used the CraterTools software for ArcGIS for counting and measuring craters, Craterstats2 for analysing the counts and buffered crater counting to date the fracture networks.

A crater in a fluvial environment is located west of the Nili Fossae region, north of Syrtis Major and in the eastern part of Arabia Terra near the dichotomy boundary. Several evidence for glacial, fluvial and tectonic processes are present in this area, a high level of erosion is visible. The crater has a diameter of 90 km, the central peak and the rim are completely eroded. Channels extend from the crater into the northern lowlands and to the surrounding plateaus and adjacent FFCs. Layered deposits, ridges, terrain inversion, polygonal terrain and linear features have been observed in the crater. The observed fractures are 4000 m in average widths and about 700 m deep. However, FFCs are also found in volcanic dominated regions.

The second crater is 47 km in diameter and located south of Syrtis Major with no evidence for fluvial activity in the crater's vicinity. Lava flows border the western rim of the crater. The crater interior is filled by volcanic deposits, volcanic pits, lava flows and wrinkle ridges occure in the crater [2]. A fracturing system with radial branches around the central peak can be observed. The fractures are about 1200 m in widths and up to 200 m deep, they appear with sharp borders. The surface units have a volcanic origin, pits, lava flows and wrinkle ridges occure in the crater.

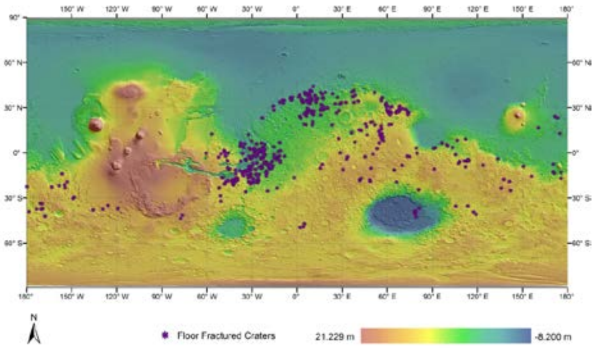

Fig.1: Distribution of floor fractured craters on Mars, based on CTX-images shown on the MOLA elevation map.

Intrusive Volcanism: Impacts lead to a reduction of crustal thickness beneath the crater, furthermore a zone of weakness is developed by pressure and the force of the impact. Magma could easily rise through this zone. Intrusive volcanism is a reasonable origin for FFCs on the Moon [5] and close to volcanic provinces on Mars (Fig. 2A). The presence of volcanic features (lava flows, wrinkle ridges, lava tubes, etc.) close to the crater or even within the impacts are evidence for volcanic activity. Uplifted crater floors support this model [1,3,4,5].

Subsurface Ice: Floor fracturing can occur by melting a subsurface ice- rich layer in the crater, leading to instability and collapse of the deposited surface units [6,7]. Partial melting occurs if the ice layer is too small or the heat flux too low. The crater floor will be stable until a critical mass of meltwater would have been produced (Fig. 2B). Volcanic activity has an influence on the heat flux and increase the temperature. Melting in a thin ice-layer can be produced that way [8].

Groundwater Migration: Ground fissuring and seepage or piping are the two main processes, which can lead to floor fracturing [9]. Ground fissuring can be mainly explained by a rapid drop of the groundwater table [10,11,12]. Seepage and piping occur as soon as the hydraulic gradient in the groundwater reaches a critical value. The flowing water starts to erode and transport soil particles, resulting in the formation of subsurface drainages (Fig. 2C) [13].

Tectonics: Several impact craters can be observed on Mars, which are influenced by tectonic systems. They are located along huge graben systems in the highlands or parallel to the boundary. Those systems run through the crater and surrounding terrains. Smaller fractures extend from the main tectonic system and dissect the crater floor (Fig. 2D). In case of an ice-rich subsurface, outflow can be formed by tectonic pressurization. Fault movements put the subsurface drainage under pressure resulting in outflow events [14].

Results: Crater size-frequency distribution measurements indicate that both craters occurred at the Noachian- Hesperian boundary. The fracturing could have been active during a long period of time- starting shortly after the impact event itself. A volcanic origin is plausible for the fracturing in the martian highlands and close to the volcanic provinces on Mars, equal to the observed FFCs on the Moon. Tectonic structures can also be the reason for fracturing in some craters in the highlands and along the boundary. Water migration in the subsurface can produce fissures and sapping channels close to the crater. An ice-rich layer in the subsurface can melt due to a high heat flux or a volcanic heat source, this will also cause fracturing. Polygonal terrains can be used as indicators for a water- or ice-rich crater infilling and glacial environment. Lots of processes have been involved by the modification of impact craters.

There are several origins for fracturing depending on the environment and location on Mars. Researching FFCs will help to investigate the climatic conditions, fluvial and volcanic activity, which are needed for the formation of fractures in certain regions on Mars at the Noachian- Hesperian boundary.

References: [1] Schultz, P.H. (1976) The Moon 15, 241-273. [2] Jaumann, R. et al. (2010) EPS 294, 272-290. [3] Brennan, W.J. (1975) The Moon 12, 449-461. [4] Wichman, R.W. & Schultz, P.H. (1996) Icarus 122, 193-199. [5] Jozwiak, L.M. et al. (2012) JGR 117, ID E11005. [6] Manker, J.P. & Johnson, A.P. (1982) Icarus 51, 121-132. [7] Zegers, T.E et al. (2010) EPS 297, 496-504. [8] Schumacher, S. & Zegers, T.E. (2011) Icarus 211, 305-315. [9] Sato, H. et al. (2010) Icarus 207, 248-264. [10] Holzer, T.L. & Pampeyan, E.H. (1981) Water Resources Research 17, 223-227. [11] Sheng, D. et al. (2003) Journal for Numerical and Analytical Methods in Geomechanics 27, 745-561. [12] Budhu, M. (2008) Environmental & Engineering Geoscience 14, 281-295. [13] Watson, I. & Burnett, A. (1993) CRC Press. [14] Hanna, J.C. & Phillips, R.J. (2006) Geophysical Research 111, ID E03003.

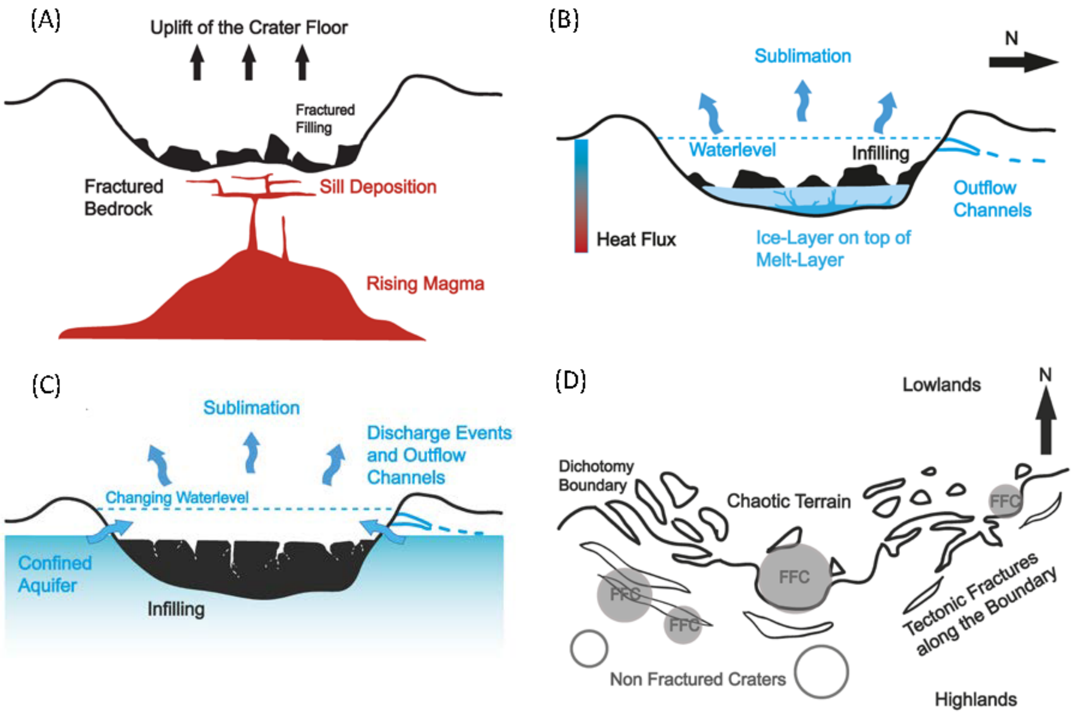

Fig.2:(A) Szenario of intrusive volcanism and sill deposition close to volcanic provinces on Mars. (B) Model for fracturing in a fluvial or glacial environment in the Arabia Terra region. (C) Model of fracturing due to seepage and piping in a fluvial environment close to the boundary. (D) Tectonic systems along the boundary and in the martian highlands.