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Floor-Fractured Craters on Mars – Observations and Origin

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ABSTRACT

Floor-Fractured Craters (FFCs) represent an impact crater type, where the infilling is separated by cracks into knobs of different sizes and shapes. This work focuses on the possible processes which form FFCs to understand the relationship between location and geological environment. We generated a global distribution map using new High Resolution Stereo Camera and Context Camera images. Four hundred and twenty-one potential FFCs have been identified on Mars. A strong link exists among floor fracturing, chaotic terrain, outflow channels and the dichotomy boundary. However, FFCs are also found in the Martian highlands. Additionally, two very diverse craters are used as a case study and we compared them regarding appearance of the surface units, chronology and geological processes. Five potential models of floor fracturing are presented and discussed here. The analyses suggest an origin due to volcanic activity, groundwater migration or tensile stresses. Also subsurface ice reservoirs and tectonic activity are taken into account. Furthermore, the origin of fracturing differs according to the location on Mars.

1. Introduction

Floor-Fractured Craters (FFCs) are characterized by the distinct appearance of their floors, which exhibit fractures, mesas and knobs. They represent a certain type of crater and are found on different planetary bodies.

FFCs were first observed on the Moon in the 1970s. Schultz (1976) investigated the distribution of FFCs on the Moon and classified these structures into different types according to their appearance. Lunar FFCs usually occur near basaltic maria and therefore, have a potential volcanic origin.

A research about the global distribution of FFCs on Mars has been performed by using Viking and Mola data (Korteniemi, 2003; Korteniemi et al., 2006). The presence of ice and water in the subsurface and on the surface of Mars might have played a major role in the formation of fractures in certain regions on Mars (Sharp, 1973; Manker and Johnson, 1982; Clifford, 1993; Carr, 1996; Burr et al., 2002; Rodriguez et al., 2005; Andrews-Hanna and Phillips, 2007; Leask et al., 2007; Russell and Head, 2007; Sato et al., 2010; Zegers et al., 2010; Pedersen and Head, 2011; Schumacher and Zegers, 2011). The origin of fracturing is explained in various models, which include glacial (Morris and Underwood, 1978; Pechmann, 1980; Hiesinger and Head, 2000), fluvial (Sato et al., 2010; Zegers et al., 2010), volcanic (Brennan, 1975; Schultz, 1976; Wichman and Schultz, 1996; Jozwiak et al., 2012) and tectonic activity (Smrekar et al., 2004; Hanna and Phillips, 2006).

However, various geologic processes are able to form these specific surface features. The processes involved in the fracturing of crater floors are still under debate. Research that combines the different origin models for FFCs and the global distribution of FFCs on Mars has not been done. Due to new high resolution satellite images, further insights into the distribution of FFC on Mars might be obtained.

Is there a relationship between the location of the impact crater and the processes which lead to the fracturing? Are all FFCs developed and modified by water and ice activity or do we find FFCs which are influenced by volcanical and tectonical processes?

To answer those questions we use new High Resolution Stereo Camera and Context Camera imaginery to find potential FFCs on Mars. We establish a new global distribution map of FFCs on Mars. They indicate a particularly high spatial density along the dichotomy boundary between the southern highlands and the northern lowlands. Furthermore, we primarily observe them in Arabia Terra, Xanthe Terra, Margaritifer Terra, Sirenum Terra and close to the volcanic regions Hesperia Planum and Syrtis Major. In the southern highlands, only a few individual FFCs are identified (Fig. 1).

In order to investigate similarities and differences in FFCs according to their location on Mars, we focus on two very different craters as a case study. One is located close to the dichotomy boundary within the Arabia Terra region. It is a typical example for

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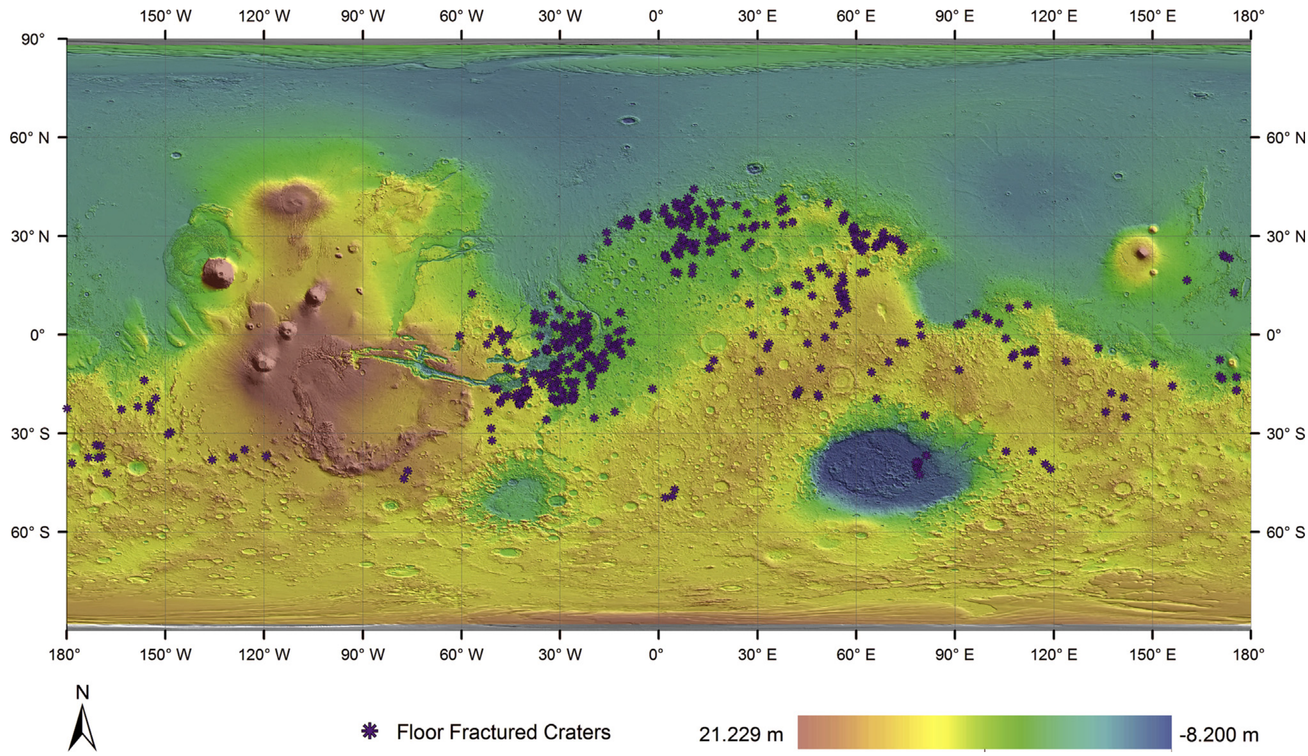

Fig. 1. Distribution of FFCs on Mars, based on CTX-images. Four hundred and twenty-one FFCs were found along the boundary and in the Martian highlands.

FFCs in a fluvial and a glacial environment. The second crater is located close to the Syrtis Major volcano in the Martian highlands and is representative of FFCs in a volcanic region. We analyze those two craters in detail by observing the surface structure, units and ages, to obtain the morphology and stratigraphy. For the two observed craters, five potential models of fracturing are discussed by weighing pros against cons.

This will help us gain a better understanding of the spacial distribution of FFCs on Mars and the involved processes in the FFC formation and evolution. Furthermore, it will improve our knowledge of geologic processes within the Martian history. Since water can be involved in the origin of particular FFCs, those craters could also be important as potentially habitable sites correlated with volcanic, fluvial, and hydrothermal activity (McKay and Marinova, 2001; Lammer et al., 2009).

2. Methods

We used data from the Mars Express (MEX) High Resolution Stereo Camera (HRSC), the Mars Reconnaissance Orbiter (MRO) Context Camera (CTX), the Mars Odyssey (MO) Thermal Emission Imaging System (THEMIS), and the Mars Global Surveyor (MGS) Mars Orbiter Laser Altimeter (MOLA).

HRSC provides nearly complete coverage of the eastern Arabia Terra region within the area from 25° to 39°N and from 54.5° to 76°E. This camera has a resolution of 12.5 m/pix for nadir observations, 75 m/pix lateral and 11 m/pix vertical for digital elevation models (Neukum and Jaumann, 2004; Scholten et al., 2005; Jaumann et al., 2007; Gwinner et al., 2010). Digital Terrain Models (DTMs) and nadir images are used to analyze the surface morphologies of both craters. These data are also used to generate geologic cross sections, as well as slope maps of both craters. CTX images, with a resolution of 6 m/pix (Malin et al., 2007), are available within the investigation area. Nighttime images from THEMIS with a resolution of 100 m/pix are used to analyze the thermal inertia of surface materials (Christensen et al., 2004).

The software ArcGIS 10.0 from ESRI is used for the geologic mapping. The geoscientific analysis includes slope, elevation, object size, crater diameter, and crater depth measurements, as well as interpretation of lengths and orientation of linear features. Based on these data topographic cross-sections of the craters are developed and provide important stratigraphic information. Rose diagrams have been produced using the Generic Mapping Tool, psrose (Wessel and Smith, 2013) for further analysis of linear features. The orientation patterns of those features are indicators for certain geologic processes (e.g. tectonics). Detailed observations are needed to analyze the processes involved in the formation and to classify the craters according to their origins. To constrain the age of different surface units crater size frequency distribution (CSFD) measurements have been performed (Hartmann et al., 1981; Neukum, 1983; Neukum and Ivanov, 1994; Hartmann and Neukum, 2001; Ivanov, 2001). In this work we use the CraterTools software extending ArcGIS for counting and measuring craters (Kneissl et al., 2011), and Craterstats2 for analyzing the CSFD data (Michael and Neukum, 2010).

To constrain the formation periods of the fracture networks we conducted buffered crater counts (BCC) using a method similar to that described in Fassett and Head (2008). The formation time of the fractures is dated by considering craters that formed in the vicinity, superposing the fracture wall either directly or with their ejecta. This is necessary because the surface area of the fracture floors is small, and they are likely to have been resurfaced by mass-wasting from the fracture escarpments. The effective counting area is increased by a buffer zone that represents the area where impacts superpose fractures. The width of the buffer zone depends on the size of the crater and the expected extent of that crater's continuous ejecta deposit. The extent of the ejecta is estimated as a multiple of the crater radius, based on the local observations (Kneissl and Michael, 2013).

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