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Polygonal impact craters on mercury

G.T. Weihs [a,*], J.J. Leitner [a,b], M.G. Firneis [a,b]

[a] Institute of Astrophysics, University of Vienna, Türkenschanzstrasse 17, A-1180 Vienna, Austria
[b] Research Platform – ExoLife, University of Vienna, Austria

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ABSTRACT

The existence of polygonal impact craters (PICs) on Mercury is confirmed by this study, which was performed by analyzing 291 named impact craters greater than 12 km in diameter, photographed by the spacecraft Mariner 10 and MESSENGER. All 15 quadrangles of Mercury were scanned for polygonal impact craters with at least two straight rim segments. A resulting total number of 33 PICs out of the 291 named impact craters is in accordance with the expectation of 10–15% out of all impact craters. Calculations were performed on the number of PICs per quadrangle, on the distribution of polygonal impact craters on the surface, on the distribution of diameters, on the mean values of diameters, and the values of the angles between straight rims and the results plotted. The distribution of PICs per quadrangle does not follow any pattern, but is roughly proportional to the number of impact craters. The diameter range of the PICs lies between 65 and 240 km, on average the value is about 120 km. Some topics need further studies – the lack of small PICs, the interrelations of PICs and geological environments, and the irregular distribution of PICs on the surface showing large empty areas.

1. Introduction

1.1. Mercury's surface

The surface of Mercury is comparable to that of the Moon. The planet has a diameter of 4878 km (Moon 3474 km) and shows no pole flattening, and a hypsometry of about ±2 km (Whitten et al., 2012). MESSENGER's (stands for MErcury Surface, Space ENvironment, GEochemistry and Ranging) and Mariner-10's observations of Mercury enabled a global view at the planet, and indicated the heterogenous composition of Mercury's crust (see Fig. 1). The major features of Mercury are craters, basins, plains, scarps, ridges, fossae, montes, and valles, as well as crater chains consisting of secondary impact craters. Intercrater plains cover about 40% and smooth plains about 20% of the surface, and give evidence for a volcanic origin of the plains (Kiefer and Murray, 1987).

1.2. Definition of polygonal impact craters

A polygonal impact crater (PIC) is a crater whose shape in plan view is more or less angular instead of being circular or ellipsoidal, and the rims are composed of at least two straight segments (Öhman et al., 2005b), as an example see Fig. 2.

Polygonal impact craters are known to be common on the Moon, on Mars, Venus, and on several asteroids and icy moons e.g. Europa and Iapetus (Porco et al., 2005; Denk et al., 2005; Prockter et al., 2002; Öhman et al., 2005a, 2007). PICs have been studied in the sixties and seventies of the last century by Fulmer and Roberts (1963), and (Roddy, 1978), and in the eighties especially by Eppler et al. (1983). A minor renaissance of PIC studies was initiated independently by the papers of Aittola and Öhman, Poelchau and Kenkmann, and Wes Watters in the naughties (Aittola and Öhman, 2006; Aittola et al., 2007, 2008, 2010; Öhman et al., 2003, 2005b, 2006, 2007, 2008; Öhman, 2009; Öhman et al., 2010; Poelchau et al., 2009; Poelchau, 2010; Watters, 2006; Watters et al., 2011).Nevertheless, up to now only in a few studies Mercurian polygonal impact craters were discussed (Wood et al., 1977; Melosh and Dzurisin, 1978; Dzurisin, 1978; Melosh and McKinnon, 1988). Still in studies of Mercurian cratering, polygonal impact craters are conspicuously missing (Herrick et al., 2011a). Only (Wood et al., 1977), remarked that about 16% of the Mercurian craters with complete rims are 'quasipolygonal' (13%) or strongly 'polygonal' (3%) and the authors recognized that wall failure occurs along zones of pre-existing weakness.

1.3. Motivation for the study

On Mars, Venus, and the Moon PICs make up about 10–15% of the impact crater (IC) population, on Mercury a similar result (c.f. Öhman, 2009) could be expected. It is known, for example by

* Principal corresponding author.
E-mail address: a6425059@unet.univie.ac.at (G.T. Weihs).
URL: http://www.univie.ac.at/EPH/exolife/ (G.T. Weihs).

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Wood et al. (1977) and Dzurisin (1978), that polygonal impact craters are at least present on the Mercurian surface. However, there are no detailed studies of them despite the rather high-quality image data of Mariner 10 and especially MESSENGER. Therefore, the main goal of the study was to carry out the first study of the properties of polygonal impact craters on Mercury. In addition, we wanted to investigate if the results of studies of other terrestrial planets that show the formation of straight segments of PIC rims to be controlled by pre-existing tectonic structures of the crust are applicable to Mercury as well (Aittola et al., 2008).

2. Formation of polygonal impact craters (PICs)

The shape of a polygonal impact crater is established during the crater formation and that the subsequent crater degradation does not have a significant effect on it (Pohn and Offield, 1970; Öhman et al., 2006). There exist three models of formation, two first formulated by Eppler et al. (1983) and a third one by Öhman et al. (2008).

2.1. Model 1: simple PICs forming at the crater excavation stage

In this model the polygonal shape of the crater originates already from the excavation stage. Eppler et al. (1983), formulated in this theory, based on the previous investigations of Shoemaker (1963), Roddy (1978), and Schultz (1976), that the excavation of the transient crater proceeds preferentially along directions of weak zones in the crust and, therefore the transient cavity will enlarge in directions parallel to trends of the crustal structure. That means, the structure of the target material is dominant at the end of the excavation stage and forms the shape of the PIC.

Poelchau et al. (2009) described the details how a square-shaped morphology actually forms, and illustrated it for the example of the Meteor Crater, Arizona (see Fig. 3). Two pre-impact fracture sets in the target are dominating the formation of the square-shaped crater. In an early phase of the excavation stage the structure of the target is not important for crater formation, because the stresses exceed the strength of the target material, but in the end the structure becomes dominant.

Watters et al. (2011) examined another simple polygonal impact crater – Endurance Crater at Meridiani Planum, Mars.

2.2. Model 2: complex pics forming at the crater modification stage

The second model presented by Eppler et al. (1983) explains the formation of polygonal craters of the size range and morphology of complex craters. In this model the shape of the PIC is formed at the modification stage and results in straight crater rim segments being parallel to the pre-existing planes of weakness. An

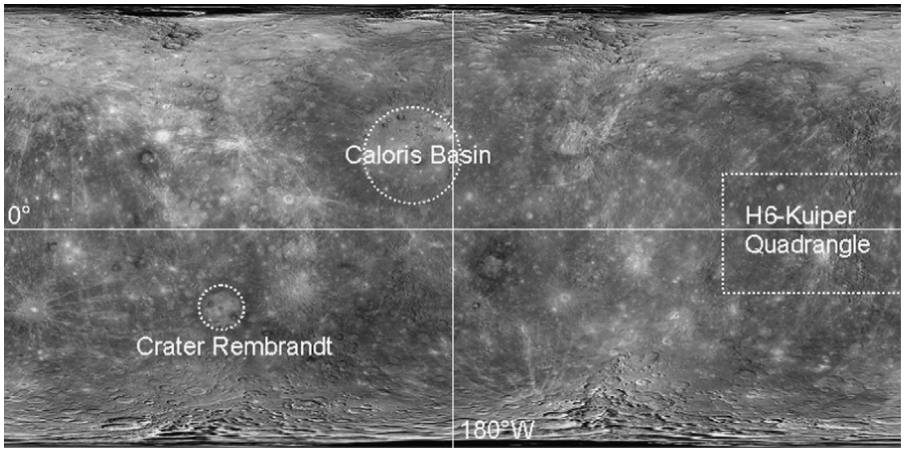

Fig. 1. Global Mercury Map (MESSENGER MDIS, center latitude: 0°), center longitude: 180°W, Map Projection: Simple cylindrical projection, Resolution: 3.74 km/pixel. The features Caloris Basin (1550 km), Crater Rembrandt (716 km) and the H6-Kuiper Quadrangle (between latitude −22 and 22°, and longitude 0–72 W°) are roughly marked.

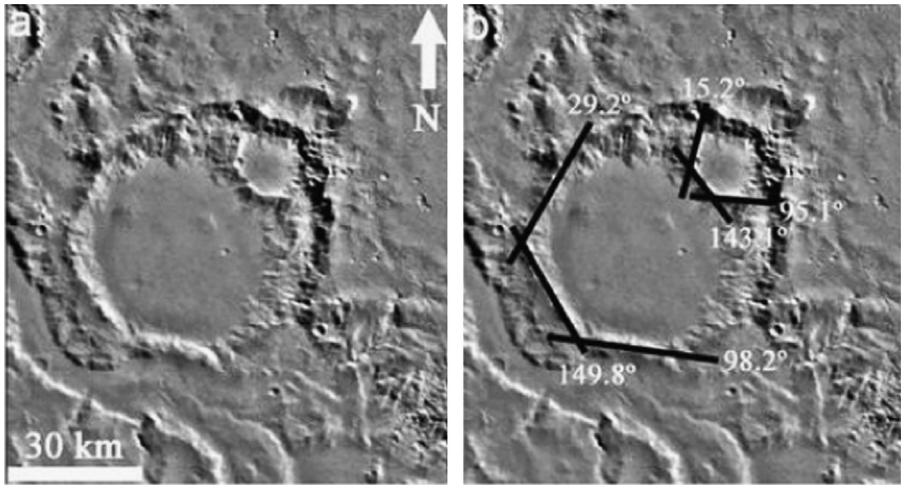

Fig. 2. (a) Example of polygonal impact craters (PICs) north of the Argyre basin on Mars (36.3°W, 30.5°S), (b) with interpretation and measurement of straight rim segments (Öhman et al., 2006).