THE CONTROL OF TARGET STRUCTURE ON THE CRATER MORPHOLOGY ON THE MOON, MARS, AND VENUS – EVIDENCE AND IMPLICATIONS. T. Öhman[1,2], M. Aittola[2], V.-P. Kostama[2], J. Korteniemi[2], and J. Raitala[2]. [1]Division of Geology, Department of Geosciences, P.O. Box 3000, FI-90014 University of Oulu, Finland (teemu.ohman@oulu.fi), [2]Division of Astronomy, Department of Physical Sciences, P.O. Box 3000, FI-90014 University of Oulu, Finland.

Introduction: The target topography and especially layering within the target are widely known to cause deviations from the generalized crater-formation mechanisms [1 and references therein]. As a result, the crater morphology changes accordingly. Another, fairly unrecognized source of crater shape variation is the presence of faults, fractures or other similar planes of weakness in the target [e.g. 2, 3]. The resulting polygonal impact crater (PIC) shape can be used as an additional tool in deciphering the tectonic history of a cratered surface [e.g. 4].

Some observations of PICs, both from earlier studies and our on-going research [e.g. 5–7], are not fully explained with the current ideas. Thus, new tentative hypotheses regarding the formation of PICs, as well as the effects of impact basin -induced modification on the surrounding crust are proposed.

A third PIC-formation mechanism? Eppler et al. [3] summarized the two mechanisms known to give rise to a polygonal impact crater. These are the Meteor Crater –type enhanced excavation parallel to target fractures (Model 1, simple craters; straight rim segments at an angle with the fractures), and slumping along the fracture planes (Model 2, complex craters; straight segments parallel to fractures) [3].

When simple and complex PIC rim orientations in the same area (and thus in the same geotectonic environment) are studied, the orientation distributions should differ if simple PICs would form by Model 1 and complex PICs by Model 2. However, at least in the Argyre region, Mars, this is not the case [7]. We were not able to see a statistically significant difference between the simple and complex PIC rim orientations. Thus, perhaps these models are not enough to fully explain the formation of PICs?

Model 2 appears to have a stronger observational and theoretical foundation [7], and Model 1 has only been fully described in one location (Meteor Crater). This leads to the idea that perhaps Model 1 may not be the dominating way to make simple PICs.

Crater rims are formed by the structural uplift of the target material, the injection of breccia dikes, and the ejecta [e.g. 1]. Detailed structural studies of simple and small complex crater rims indicate that thrusts are the dominant structural features there. This provides the rationale for our new hypothesis. We suggest that simple polygonal craters and small, not significantly slumped complex polygonal craters can be formed by thrusting along some pre-existing planes of weakness (Model 3). Such mechanism may be in action with larger complex craters too, but the more substantial collapse of larger craters probably is more dominating factor in the polygonal plan view of large craters.

A "preferred" PIC-formation size? We studied the lunar crater shapes in the near-side of the Moon, mainly in the highlands west and southwest of the Nectaris basin (10°W–40°E, 10°N–50°S). The dataset used was the oblique-illumination photographs of the digital version of the Consolidated Lunar Atlas [9]. We identified 160 named (+7 unnamed) PICs >10 km in diameter. When their size distribution (diameter data taken from the USGS-approved list by McDowell [10]) is compared to that of the 656 non-polygonal named craters in the study area, a clear discrepancy is observed. PICs are relatively fewer in the smallest size range (10–20 km), but from 20 km to 50 km in diameter much more common than could be anticipated from the size distribution of the non-polygonal craters.

Pohn and Offield [8] studied lunar crater morphology as a function of crater diameter. They classified craters in the size range of 16–48 km (which they rounded to 20–45 km) as "polygonal", implying that in the size range of 16–48 km polygonal craters are at least fairly common. Thus, our results match perfectly with the classification by Pohn and Offield [8].

Similar discrepancies in the size distributions of polygonal and non-polygonal craters can be seen on Mars [7] and Venus [6] too. When the crater sizes are normalized by dividing the diameter with the average simple-to-complex transition diameter (D_{tr}, highly variable especially on Mars) on each of the planetary bodies studied, an interesting regularity appears (Fig. 1). It seems that PIC formation is most common in the size range of about 1–5 times the transition diameter, although there is some variation between the different planets. Thus, it appears that the formation of PICs is somehow "preferred" in small to mid-sized complex craters.

Basin-induced conjugate shear fracturing? Impact basins are surrounded by radial and concentric fracture systems. Theoretically post-impact modification of the basins should induce conjugate shear fractures (strike-slip faulting) too [e.g. 11]. These, however, have not been observed, and in the case of the lunar basins it seems that the stress field is not strong enough for actual shear fracturing to take place in significant extent [11]. However, our observations of the PIC rim orientations around Martian basins [7] suggest that perhaps conjugate shear fractures are present there. These inferred possible conjugate sets of fractures surrounding the Argyre and Hellas basins are not readily explained by other tectonism affecting the area and the PICs in it, and their geometry fits the theoretical basin-induced shear fractures. However, more detailed tectonic studies in the vicinity of the Martian (as well as e.g. Mercurian, in the light of the forthcoming Messenger data) impact basins are encouraged to test the validity of this hypothesis. Such studies should involve PICs as well, because it seems apparent that they reflect an old tectonic pattern that may not be manifested by other tectonic features like graben or ridges [7 and references therein].

Discussion and conclusions: Our continuing efforts to describe and understand the formation, occurrence, characteristics, and significance of polygonal impact craters in the Solar System has led to several tentative hypotheses. These can and should be tested. The suggested thrusting mechanism (Model 3, together with Models 1 and 2), for PIC formation could be best tested with impact or explosion experiments in target with controlled or at least carefully measured fractures. The previous studies [e.g. 12, see 7 for other references] have not described the relations between the straight rim segments and the target fractures.

The "preferred" PIC-formation size (small to mid-sized complex craters) hypothesis would be slightly harder to test. Roughly similar size distributions on three planetary bodies require an explanation, even if further studies on other cratered surfaces would yield differing results. The knowledge of the depth and spacing of fractures on different planets would give interesting reference data. 3D-modeling would obviously be desirable for further understanding of all aspects of PIC formation.

To test the highly hypothetical idea of PICs indicative of basin-induced conjugate shear fracturing would require detailed observations of tectonic features surrounding impact basins. New high-resolution datasets of Mars, as well as the forthcoming Messenger imagery of Mercury provide good opportunities for this.

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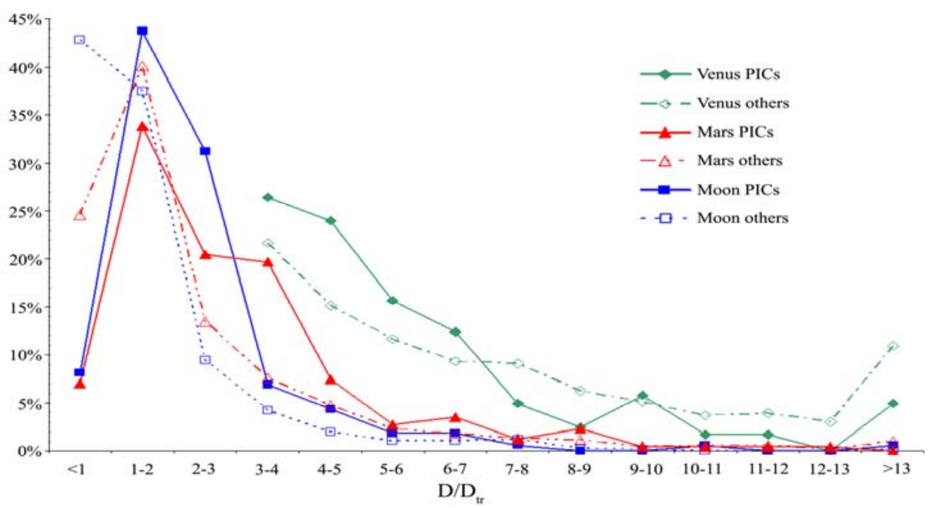

Fig. 1. Size distribution of PICs and non-polygonal ("others") craters on Venus (>12 km) [6], Argyre region of Mars (>5 km) [7], and the Moon (10°W–40°E, 10°N–50°S, >10 km named craters). D_{tr}'s were 4 km, 7 km and 15 km for Venus, Mars and the Moon, respectively. The rapid drop of the number of the smallest Martian PICs and non-polygonal craters is merely an effect of the size selection.