Target rock mechanisms influence the impact crater morphology.

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Abstract
Polygonal impact craters (PICs) can be used to decipher tectonics of a cratered surface [1-4]. Studies of PICs on Mars and Venus [5-7] have provided information of their importance in revealing ancient structures. Some observations are not fully explained with the current ideas. Thus, new ideas for the PIC formation type and preferred PIC size are proposed.

The two PIC formation models
Two mechanisms [3] are proposed to cause a PIC. In the simple Meteor Crater, an enhanced excavation parallel to target fractures (Model 1) is found and straight rim segments are at an angle with fractures. A slumping along the fracture planes (Model 2) is found in complex craters where straight segments are parallel to fractures. The orientation of the straight rim sections in a certain tectonic environment should differ for simple PICs (= Model 1) and complex PICs (= Model 2). However, at least in the Argyre region on Mars, this is not the case [7]. We did not observe any statistically significant differences in the orientations of straight rim units between the simple and complex PICs. The two models may not fully explain the PIC formation. Model 2 has a strong observational and theoretical foundation [7]. Model 1 has been fully described for the Meteor Crater only.

An additional type of PIC formation
Crater rims are formed by target uplift, breccia dike injection, and ejecta [1]. A dominant structural feature is made by thrust in both simple and small complex crater rims. This allows us to suggest an additional PIC formation style. The formation of both simple polygonal craters and small complex polygonal craters may have involved a substantial thrust along some pre-existing planes of weakness (Model 3). In the larger complex craters the mechanism may exist but has been destroyed by the late substantial collapse that dominates the morphology of the large craters.

A “preferred” PIC size?
We tested the Model 3 hypothesis by studying shapes of the lunar craters using the oblique-illumination photographs of the digital Consolidated Lunar Atlas [8]. We identified 167 PICs >10 km in diameter. Their size distribution (cf. the McDowell list [9]) was compared to that of the 656 non-polygonal craters in the same area. A clear discrepancy was observed. Small PICs (10-20 km) are relatively few in number. PICs are much more common among the larger craters (20 km - 50 km in diameter) than could be anticipated in comparison to non-polygonal craters. An earlier study [10] of lunar craters also indicated that in the size range of 16-48 km polygonal craters are at least fairly common. Similar discrepancies in the size distributions of polygonal and non-polygonal craters can be also seen on Mars [7] and Venus [6]. When the crater sizes are normalized by dividing the diameter with the average simple-to-complex transition diameter (Dc, highly variable especially on Mars) on each of the planetary bodies studied, an interesting regularity appears. 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, the formation of PICs may somehow be “preferred” in small to mid-sized complex craters.

Discussion: Previous studies [11, see 7 for references] have not sufficiently described relations between straight rim segments and target fractures. Our efforts to describe and understand the formation, occurrence, characteristics, and significance of PICs on several planets has led to tentative hypotheses that should be studied in details. The suggested thrust mechanism (Model 3) and other alternatives for PIC formation (Models 1 and 2) could be tested by impact or explosion experiments in target with known fractures. The “preferred” PIC-formation size (small to mid-sized complex craters) hypothesis is harder to test but the roughly similar size distributions on three planetary bodies require an explanation. Further studies on other cratered surfaces are needed to find if they yield similar or differing results. Knowledge of the fracture depth and spacing on various planets would provide interesting data. The 3D modeling is also desirable in understanding the PIC formation.

References