SYSTEMATIC FRACTURE PATTERN ON VESTA REVEALED BY POLYGONAL IMPACT CRATERS.

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Introduction: Polygonal impact craters (PICs) are important landforms on planetary bodies. Impact craters commonly exhibit straight rim segments creating polygonal geometries, where pre-existing fractures exist in the target rock [1,2]. Previous studies have shown that PICs abound on various planetary bodies [1–3], including asteroid 4 Vesta. Vesta is a heavily cratered as well as tectonically modified body. The majority of craters on Vesta are PICs [3]. It is therefore important to explore if the planform shape of impact craters is able to detect systematic patterns of fracture sets on the local, regional, or global scales in the asteroid. Previous efforts mapped straight rims of impact craters based mainly on visual assessment, but no systematic approach has yet been implemented to identify geospatial variations of straight crater rims on Vesta, and potential tectonic patterns revealed by crater geometries have never been explored. For that, developing a systematic method to identify straight portions of impact crater rims is essential for consistency across all craters on Vesta and for future comparisons to other planetary objects.

Methodology: We primarily make use of Dawn Vesta FC image mosaics with a resolution of 60m/px [4] and the digital elevation model with a resolution of 93m/px [5]. We utilize global crater catalogues of Vesta [6] for crater identification. A crater rim is defined as the uppermost, topographically raised edge that surrounds the depression caused by the impact. Craters in this mapping effort include all impact structures with diameters ≥ 10 km (but excluding Rheasilvia and Veneneia) for a total of 412 craters. Mapping of craters includes those that are incompletely preserved because some, if not all, straight rim portions may still be present (Fig. 1a), and the information is valuable to assessing the fracture patterns. All mapping is carried out using ESRI ArcGIS software with a fixed mapping scale of 1:200,000. The projection is set to stereographic projection and centered at every crater. All rims are mapped as polylines with regularly spaced vertices set to 1 km by using the streaming function of the ArcMap Editor to ensure equal sampling (Fig. 1b).

After all crater rims are mapped, the detection of straight portions of crater rims will be carried out using shape analysis. Line simplification was performed to remove redundant vertices. We tested multiple settings and chose a simplification tolerance of 0.5 km, which is half of the vertex spacing. Since a curved polyline will retain more vertices than a straight polyline, the polyline length will reflect the difference between

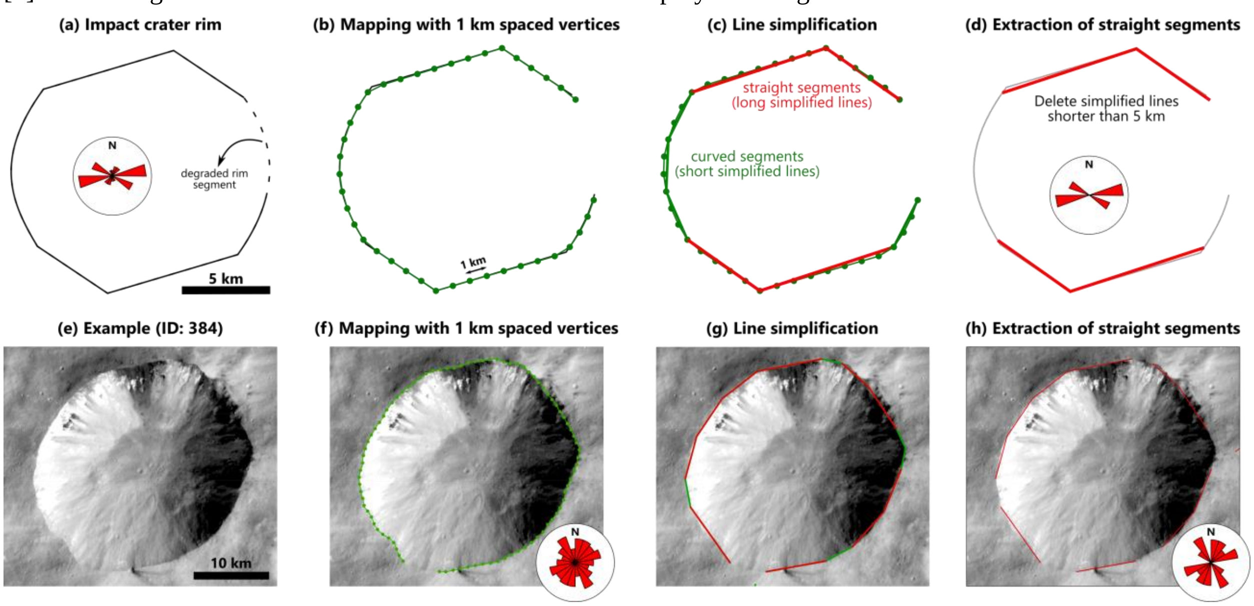

Figure 1. Schematic illustration (top row) and example (bottom row) of the plan view of impact crater geometry, showing mapping and straight segment extraction. (a) Black solid line shows a preserved rim of a crater with the rose diagram showing the orientation of straight segments. (b) The rim is mapped as polyline (green line) with 1 km spaced vertices (green dot). (c) Straight rim segments are simplified to longer sections (red line) between vertices while sections will be shorter along curved rim segments (green line). (d) By deleting short segments, straight rim segments are extracted and rose diagrams can be plotted to visualize their orientations. (e – h) Example on Vesta (centered at -7.394, 37.486) to highlight the steps (a) to (d). Note that the rose diagram in (h) shows three dominant orientations of straight rim segments as compared to (f).

curved and straight rim segments. Therefore, we split the polylines at the remaining vertices (Fig. 1c). Split simplified polylines with lengths in excess of 5 km were then extracted (Fig. 1d) and interpreted to be the straight rim segments. This cut-off was identified to return the best straight rim data after trying multiple cut-off lengths and surveying if meaningful data was deleted or curved segments were preserved. This automated method provides a quantitative approach to extract the straight rims of the craters, in which the straight segments are defined to show < 0.5 km lateral variation along the simplified line with a length of 5 km or more. Each crater was visually evaluated if the results were geologically meaningful. Craters, in which the simplified polylines mismatch the crater shape, were excluded from the analysis. A crater example is shown in Fig. 1e – h illustrating all the above steps (Fig. 1a – d) on ArcGIS with straight rims extracted, revealing three dominant orientations.

Data of all mapped craters are compiled with the classification of circular craters (with no straight segment extracted) or PICs. Each crater is given a unique identification number for recording (e.g., Fig. 1e). The extracted straight crater rims were also analyzed to detect regional/global patterns. Rose diagrams were plotted to visualize the orientations of straight crater rims across the surface of Vesta and weighted using the extracted rim segment lengths.

Preliminary results: In total, 408 impact craters were mapped, and four craters are found to be too degraded to map any rim segments (Fig. 2). A total of 301 craters (73.8%) are found to have at least one straight rim segment preserved, and therefore they were classified as PICs. Of those, only eight PICs had to be excluded in the analysis due to the mismatch of simplified polylines with the crater outline. Rose diagrams were plotted for the extracted straight crater rims in six 30° latitudinal and twelve 30° longitudinal bins (Fig. 2). The diagrams indicate that, if straight cater rims represent fractures, there is a dominant E-W orientated fracture pattern at both polar regions but no preferred fracture orientations at the equator. There is no obvious longitudinal variation of fractures; the patterns are dominated by the polar E-W oriented fractures. Such a global, systematic tectonic pattern has not yet been described for Vesta. In the future, we aim to explore potential regional variations of orientations of straight crater rims and the origin of this pattern.

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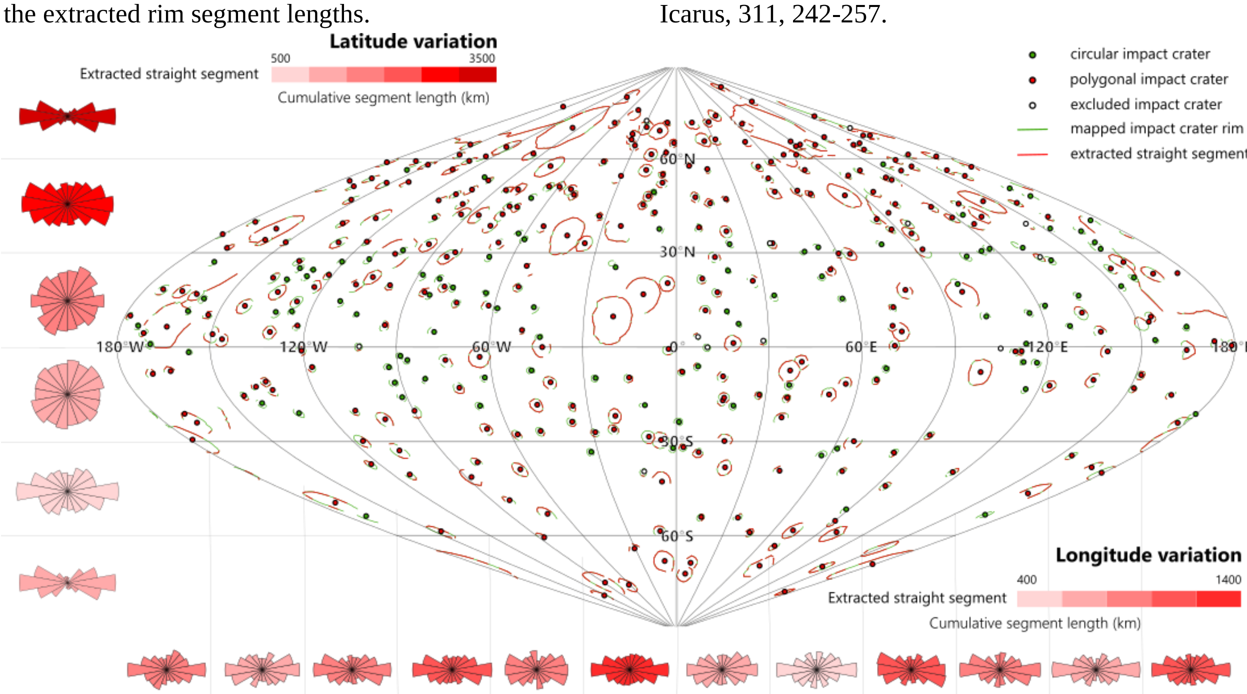

Figure 2. Global map of Vesta in sinusoidal projection, showing the mapped craters and their rims (green) with the orientations of straight segments (red) presented as rose diagrams. The center coordinates for each crater are plotted with a point symbol on the map color-coded by category. Rose diagrams are plotted for only extracted straight segments (red) in 30° latitudinal and longitudinal bins. The color darkness represents the cumulative length of straight rims, with darker reds representing more and/or longer straight rims.