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Structural Deformations in the Central Pit of a Martian Crater as an Indicator for Impact Direction

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Introduction

The majority of impacts on planetary bodies occur at an oblique impact angle to the target surface because the incidence angle follows a Gaussian probability distribution with a mean value of 45° [1]. The ejecta blanket is the most distinctive indicator for the impact direction in oblique impacts, showing the formation of "forbidden" zones and "butterfly" patterns [2,3]. The position of the central uplift relative to the crater center was proposed as another diagnostic feature [4], but its statistical relevance could not be verified thus far [5] as the position might be caused by heterogeneous target structures [6]. Another promising indicator for obliquity is provided by the internal structure of central uplifts. Some terrestrial craters show a preferred stacking of layered bedrock in the central uplift [7,8] with bedding striking perpendicularily to the long axis of the crater ellipse [8]. The interpretation that this imbrication is caused by remnant horizontal momentum transferred from the impacting projectile to the target during an oblique impact [8] is supported by three-dimensional numerical simulations [9]. Further analysis of Martian craters [10,11] provide evidence that preferred strike orientation in the central uplift could be indicative for an impact direction. Here we present new results of the mapping of an unnamed Martian crater extending and confirming these results for a central pit structure of an oblique impact crater.

Methods

The Mars Global GIS DVD from the NASA Planetary Data System (PDS) was downloaded and implemented into ArcGIS to find potentially interesting oblique impact craters on Mars which have a typical ejecta blanket, well-exposed layered bedrock in a central uplift, and good coverage of high-resolution remote sensing data (HiRISE). An unnamed central pit crater south of Valles Marineris (15.8° S 63.7° W, 54.5 km crater rim diameter, 13 km pit diameter) was mapped with emphasis on structural trends of the exposed layered units in the central pit. CTX and HiRISE data were processed by using USGS's Integrated System for Imagers and Spectrometers (ISIS) to obtain base data for subsequent mapping in ArcGIS. A GIS-based map was created with emphasis on structural deformation of the layered units including strike orientation as indicator for impact direction. We used high-resolution image data (CTX, HiRISE) to determine the apparent strike values and additionally used an available HiRISE DTM of the western part of the central pit to obtain true strike and dip values using the Layertools extension for ArcGIS [12].

Results

The central pit crater can be characterized as an oblique impact crater using THEMIS infrared images showing an uprange "forbidden" zone and a downrange expanded ejecta blanket which indicates an impact direction from ~290-300° (see figure 1).

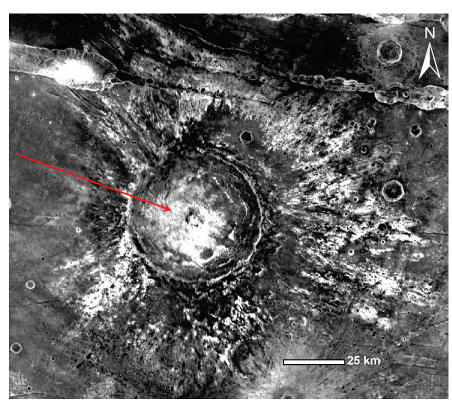

Figure 1: THEMIS nighttime IR showing the ejecta blanket of an oblique impact from WNW.

Apparent strike values show a preferred strike trend of ~30-40° over the majority of the central pit (see figure 2). The data density decrease in the most eastern part of the central pit because of the absence of exposed layered bedrock.

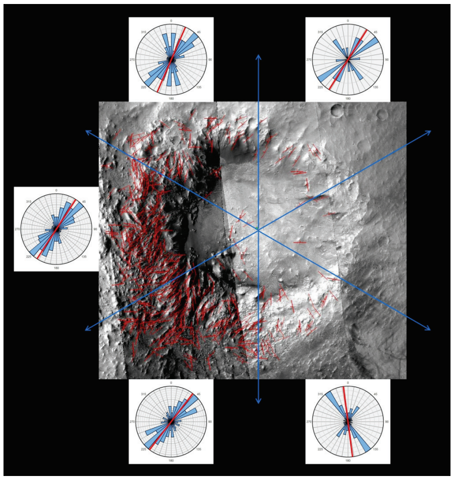

Figure 2: Map of the apparent strike orientations (n=523) on a HiRISE/CTX mosaic and rose diagrams [13] showing a preferred strike trend of ~30-40° .

True strike orientations confirm the preferred trend of ~30-40° of the apparent strike values over the majority of western part of the central pit. The strata predominantly dip WNW with shallow dip angles (see figure 3).

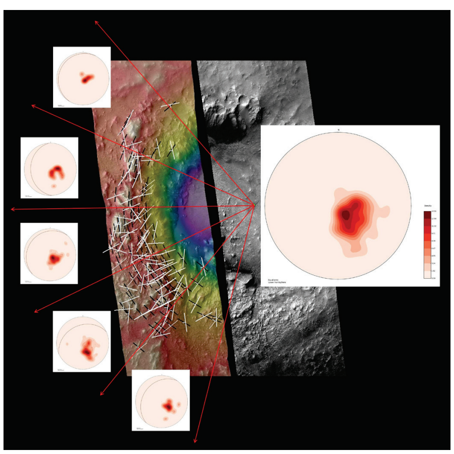

Figure 3: Stereonets (equal area, lower hemisphere, density distribution [14]) of the true strike/dip-angles (n=101) based upon the HiRISE DTM.

Discussion

An oblique impact and the impact direction from 290-300° could clearly be determined based upon the ejecta pattern. The consistent 30-40° strike and westward dip of the analyzed stack of layers surrounding the central pit indicate material motion and shortening along 300-310° and a shear component top-to-the-SSE. This direction shows only a small deviation from the impact direction inferred from the pattern of the ejecta blanket. Shortening and stacking in the central crater floor is explained by the remnant horizontal momentum transferred from the impacting projectile to the target during the oblique impact [8]. The yet unsolved processes of central pit formation will also be considered and current models of pit formation will be cross-checked with the constraints given by the structural data gathered in this work.

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