STRUCTURAL SIGNATURES OF OBLIQUE IMPACTS – INSIGHTS FROM FIELD OBSERVATIONS.

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Introduction: It is well known that the majority of craters are formed by oblique impacts [1,2]. While vertical or near vertical impacts tend to show radial symmetry, it is expected that oblique impacts should exhibit deviations from radial symmetry in the form of asymmetric or bilateral patterns. For example, recent studies have shown that subsurface structures of the innermost crater interior do show preferential directions of folding and faulting that implicate a preferred transport direction and indicate the impact vector [3,4]. This is in agreement with 3D modeling of complex craters [5].

Ejecta blankets are even better indicators for impact angle and direction. The ejecta blankets of craters observed on other terrestrial bodies show a "forbidden zone" that develops uprange, and with increasing obliqueness also downrange, eventually resulting in a symmetrical "butterfly pattern".

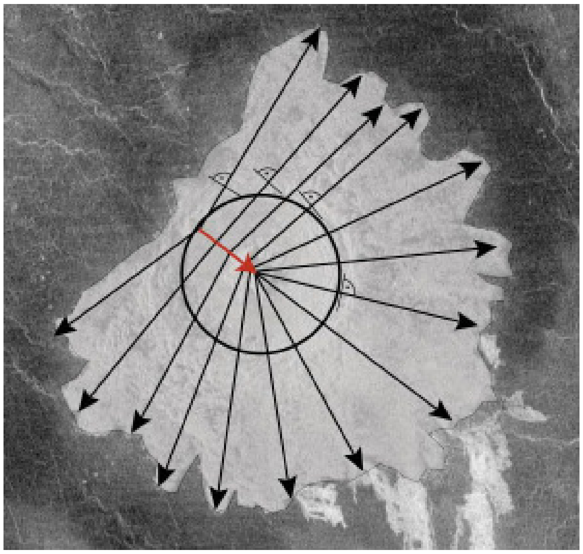

Fig. 1: Theoretical ejecta trajectories displayed in a modified Z-model, line source ejection, with resulting non-radial strike patterns. (Magellan Imaging Radar, Aurelia Crater, Venus.)

Trajectory model: We suggest that the ejecta trajectories that form these blankets deviate from radial symmetry and could probably be traced at the rim and overturned flap of simple craters, which represent the most proximal part of the ejecta. If we use a modified Z-model [6] to describe the mechanism of ejection with a line source that progresses from uprange to downrange during crater development, the resulting flow field should be bilaterally symmetric (Fig. 1). The strike of the folded strata should be orthogonal to the trajectories for originally horizontal bedding. Therefore the folded and uplifted bedding should show deviations from a concentrical alignment to the crater center and display bilateral patterns of strike.

Strike data was collected from Wolfe Creek Crater, Western Australia, a 0.3 Ma old simple crater with an average diameter of 880 m [7, 8]. Field data was compiled with previously published data [9] and translated from a geographic to an azimuthal reference scheme with the point of origin situated in the crater center. The strike of rock layers in the rim was examined for deviations from a hypothetical concentric orientation with regards to the crater center. The deviation is expressed as an angular value for each measurement and is displayed in a polar plot (Fig. 2).

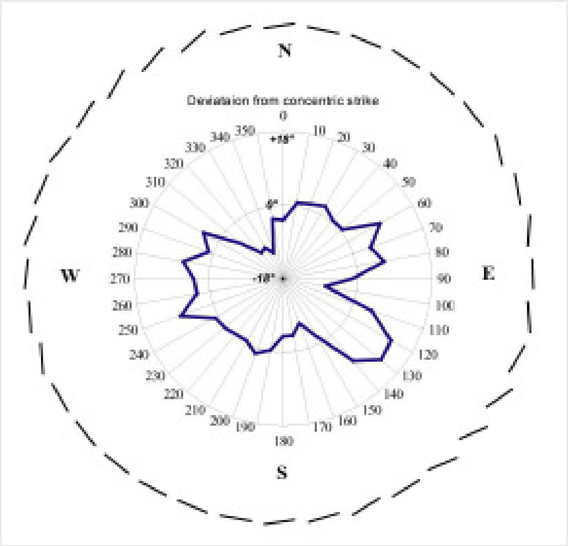

Fig. 2: Polar plot of proximal ejecta strike data displayed relative to crater center. Black lines surrounding the plot indicate average strike.

Strike data from the inner wall of the crater rim shows a strong connection to the rim morphology, whereas strike data of the proximal ejecta shows certain patterns that could indicate bilateral symmetry and might fit the model proposed above. In order to improve the interpretation of such data, 3D numerical models are needed. Currently, trajectories of tracer particles in oblique impacts are being modeled with a three-dimensional hydrocode [D. Elbeshausen et al., this volume]. We expect the results to greatly improve our understanding of the crater flow field, to show whether the modified Z-model is feasible, and to indicate if deviation from radial symmetry can be expected in the crater rim.

Dip in the crater rim: Dip data from Wolfe Creek was analyzed in a similar manner to the strike data. In an oblique impact more deformation is to be expected downrange due to downrange-directed particle motion [4, 10]. This could also have an effect on the amount of folding and uplift in different sectors of the crater wall and could be recognized in deeper dip values of originally horizontal layers. When converted to an azimuthal reference scheme, Wolfe Creek dip data shows a sector with relatively low dip angles, which could be interpreted as an uprange sector (Fig. 3).

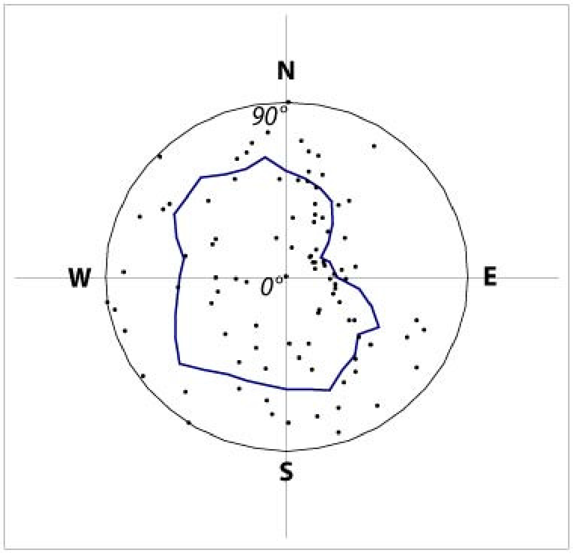

Fig. 3: Polar plot of dip data displayed relative to the crater center. Dip values are shallow in the ENE, which might indicate an impact direction.

Asymmetry in the central uplift: As stated in the introduction, central uplifts show asymmetric behavior and can be used to indicate an impact vector. We will continue research on central uplifts and have planned further fieldwork in Australia, which will focus on structural aspects in these features. One of our goals is to use our field results to enhance 3D numerical models [D. Elbeshausen et al., this volume], while at the same time utilizing these models to gain a better understanding of the formation processes involved in oblique impact cratering.

Conclusions: Through our method of analysis, we were able to display deviations from radial symmetry in field data collected at Wolfe Creek Crater. It is still uncertain to which degree these features are caused by a possible oblique impact. It may also be possible that pre-impact conditions like uneven bedding or joint sets, or post-impact processes like erosion have a strong effect on the symmetry of the final crater, and might even superimpose any structural signatures caused by the obliqueness of an impact. Thus 3D numerical models are of great importance for us. Modeling of particle trajectories could confirm or revise our current conception of the impact cratering flow field and in turn help improve our interpretation of field data, leading to a better estimation of the direction and angle of impact. We also hope to gain similar insights on the formation and structure of central uplifts.

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