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Kinematic analysis of lobate scarps cross-cutting Mercurian craters

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1. Introduction

Craters work as a good marker on planetary surfaces, both for kinematics and strain analysis. Some authors measured their elongation and elongation direction to estimate the strain of intensely faulted areas of Mars and Ganymede [2], [5], [9]. In other cases the craters' deformation was used to infer the nature of the cross-cutting faults [8], [10], [12]. However, the latter studies did not make any assumption on the slip's geometry (i. e. the fault's true dip and the slip's vector), which is fundamental to estimate kinematic parameters, based on the analysis of craters cross-cut by faults. By using faulted craters of Mercury, we propose a new method to obtain quantitative kinematic parameters for the crosscutting faults. This method can be used as a univocal criterion for all types of faults, independently from their nature and hosting rocks' rheology, leading to assess their true slip direction, horizontal and vertical components of their displacement and thus the slip's plunge, fault's true dip and displacement along the fault's plane. Moreover, the latter parameters can be used to estimate fault's rake and then to study the overall kinematics of the analyzed faults with a quantitative and comprehensive approach. We analyzed 14 craters of Mercury found throughout the 30% of the Mercury's surface covered by the Digital Elevation Model (DEM) from [6].

2. Method

Craters can be used as a proxy for measuring fault's dislocation assuming that their rim outline was almost perfectly circular (in planimetric view) prior to deformation. A stereographic projection centered on each analyzed crater is the best compromise both for evaluating the crater's shape and for measuring its geometry. To obtain the horizontal component of the slip, Δx, a circle is built on one side of the faulted crater, and then the same circle is pasted on the opposite side of the crater. The distance between the two circle's centers represents Δx (Fig. 1) and its orientation is also the slip's trend. The vertical component of the slip, Δh, is obtained with the difference between two opposite rim's height measures. The measures are performed along cross-sections built parallel to the slip's direction. Once Δx and Δh are known, along with the slip's trend and fault's strike, the whole slip's geometry can be analyzed with the aid of simple plane trigonometry. Finally, the fault's rake, λ can be estimated through the vector dot product of the slip's unit vector and the strike unit vector.

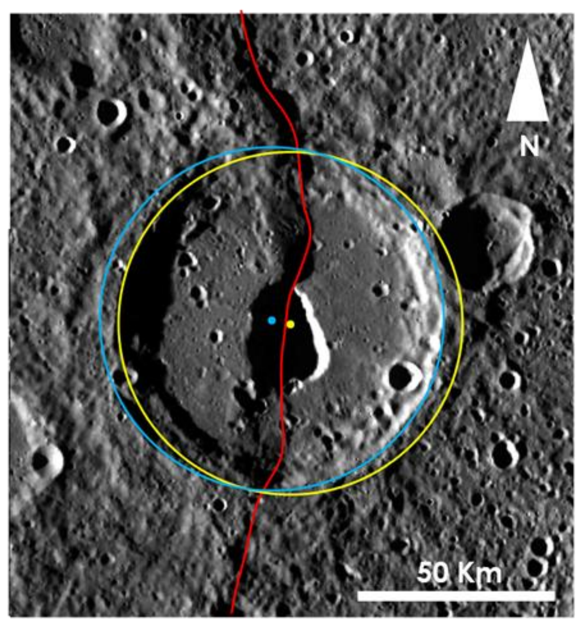

Figure 1: MESSENGER MDIS image of Geddes Crater. The thrust cross-cutting this crater causes a horizontal shortening of about 6279 m.

6. Results

Using MErcury, Surface, Space ENvironment, GEochemistry and Ranging (MESSENGER) images released by the Mercury Dual Imaging System (MDIS) instrument onboard the spacecraft, and the derived global mosaics, together with the DEM derived from an ortho-mosaic of MDIS flyby images [6], 44 craters cross-cut by linear features were found and 14 craters could be studied with this method. The analyzed Mercurian craters show that the resulting faults' true dip angle, δ, is $7° < \delta < 57°$. This range is much wider than the range of $25° < \delta < 35°$ hypothesized by [7] and [13]. The faults' rake, λ results to be dip-slip or near dip-slip for low angle thrusts and NNW-SSE/NNE-SSW trending lobate scarps, while it has a greater strike-slip component (i.e. oblique-slip faults) for faults with steeper angles and different orientations. Moreover, north-facing faults most likely present dextral oblique-slip trends. Finally, faults' displacement, D was calculated on the basis of the slip's plunge obtained from each fault. Doing so, the displacement – length ratio, γ [1] could be calculated resulting to be $3.09 \times 10\text{-}3 < \gamma < 3.59 \times 10\text{-}2$, coherent with the results from [11]. When topographic data will be available for the whole planet's surface, this method can help refining and validating the current hypotheses put forth to explain the tectonic evolution of Mercury [3], [4], [8].

References

[1] Cowie, P.A., & Scholz, C.H.: Displacement-length scaling relationship for faults: data synthesis and discussion, Journal of Structural Geology, Vol. 14, pp. 1149–1156, 1992.

[2] Golombek, M.P., Tanaka, K.L., & Franklin, B.J.: Extension across Tempe Terra, Mars, from measurements of fault scarp widths and deformed craters, Journal of Geophysical Research, Vol. 101, pp. 26119-26130, 1996.

[3] King, S.D.: Pattern of lobate scarps on Mercury's surface reproduced by a model of mantle convection, Nature Geoscience, Vol. 1, pp. 229–232, 2008.

[4] Melosh, H.J. & Dzurisin, D.: Mercurian global tectonics: a consequence of tidal despinning?, Icarus, Vol. 35, pp. 227–236, 1978.

[5] Pappalardo, R.T. & Collins, G.C.: Strained craters on Ganymede, Journal of Structural Geology, Vol. 27, pp. 827–838, 2005.

[6] Preusker, F., Oberst, J., Head, J.W., Watters, T.R., Robinson, M.S., Zuber, M.T., & Solomon, S.C.: Stereo topographic models of Mercury after three MESSENGER flybys, Planetary and Space Science, Vol. 59, pp. 1910–1917, 2011.

[7] Schultz, R.A., & Watters, T.R.: Forward mechanical modeling of the Amenthes Rupes thrust fault on Mars, Geophysical Research Letters, Vol. 28, pp. 4659–4662, 2001.

[8] Strom, R.G., Trask, N.J., & Guest, J.E.: Tectonism and volcanism on Mercury, Journal of Geophysical Research, Vol. 80, pp. 2478–2507, 1975.

[9] Thomas, P.G., & Allemand, P.: Quantitative analysis of the extensional tectonics of Tharsis Bulge, Mars: geodynamic implications, Journal of Geophysical Research, Vol. 98, pp.13097–13108, 1993.

[10] Watters, T.R.: Compressional tectonism on Mars. Journal of Geophysical Research, Vol. 98, pp. 17049–17060, 1993.

[11] Watters, T.R. & Nimmo, F.: The tectonics of Mercury. In: Watters, T.R. & Schultz, R.A. (eds) Planetary Tectonics, Cambridge University Press, pp. 15–80, 2010.

[12] Watters, T.R., Robinson, M.S., & Cook, A.C.: Topography of lobate scarps on Mercury: new constraints on the planet's contraction, Geology, Vol. 26, pp. 991–994, 1998.

[13] Watters, T.R., Schultz, R.A., Robinson, M.S., & Cook, A.C. 2002. The mechanical and thermal structure of Mercury's early lithosphere, Geophysical Research Letters, Vol. 29, p. 1542, 2002.