A SEMI-AUTOMATED METHOD FOR DISPLACEMENT-TO-LENGTH SCALING OF FAULTS POPULATIONS. G. Nodjoumi[1], E. Luzzi[1,2], M. Massironi[3], R. Pozzobon[4,3], A. P. Rossi[1], [1]Constructor University Bremen gGmbH (formerly know Jacobs University Bremen gGmbH), Bremen, DE (gnodjoumi@constructor.university), [2]Bay Area Environmental Research Institute, Moffett Field, CA, USA,[3]Dipartimento di Geoscience, Università degli Studi di Padova, Italy, [4]INAG-OAPD, Italy

Introduction: The relationship between displacement and length of a fault can provide insight on the fault growth, on fault interaction and linkage processes, and how fault growth can vary in different geological settings. Main fault growth models comprise the *individual fault growth* [1] where tip rupture and propagation generates single fault lengthening, and the *linkage model* [2] where the interaction of multiple faults within the same population contributes to the faults' growth.

The displacement distribution along the fault length can provide useful information on the interaction with adjacent faults and their evolutionary stage [3].

To assess the type of relation between displacement and length, and to constrain the distribution of a population of faults, the scientific community commonly refers to the power law Equation (1):

$$D_{max} = \gamma L^c \qquad (1)$$

where: D_{max} is the maximum displacement measured on each fault, γ is a constant depending on multiple geological factors, L is the tip-to-tip length of each fault measured along the strike, and c is the scaling exponent, which values determine the relationship type.

Values of c greater than 1 determine a super-linear relationship, while values lower than 1 determine a sublinear relationship [3]. The Dmax/L ratio can also provide information on the possible occurrence of restricted faults: low Dmax/L ratios could in fact suggest that the displacement did not grow linearly with the length, and this can be attributed to mechanical discontinuities related to stratigraphic contacts, which could prevent the fault from growing vertically [4].

In this work, we present a semi-automated method for performing this suite of analyses ingesting only a shapefile of the faults and the corresponding Digital Elevation Model (DEM) as input files.

Method: the method we developed is based on the creation of equally spaced transects for each fault, with a transects' length dynamically computed to reach approximately the maximum depth along each transect.

To perform this analysis consistently with high reproducibility, we developed two Jupyter notebooks and a dedicated conda environment [5].

The processing notebook starts from the user input, which comprises the faults shapefile and the DEM, performing the following tasks:

1) Generation of faults copies with equally spaced nodes using the DEM spatial resolution;
2) Computation of max, min, and mean Width (W) between each graben's fault pairs;
3) Generation of 1st iteration transects at each faults' node, using fault max width as transects length.
4) Generation of 2nd iteration transects by cutting the 1st transects at their intersection with the paired faults. For instance, *fault_1* transects are cut at the intersection with *fault_2* and vice-versa.
5) Generation of 3rd iteration transects by computing the elevation profile for each transect using the DEM and cutting the resulting elevation profile at the maximum depth.
6) Computation of faults displacement using the 3D distance.
7) Computation of all the statistics for all the parameters, including max, min, mean, standard deviation and save them in the transects geopackage and as a spreadsheet file.

The plotting notebook, read the geopackage outputs of the processing notebook and generate all the plots.

D/L ratios and Equation 1 parameters are computed concurrently to the D/L plot.

Data: All faults need to be accurately digitised using a GIS software (e.g., QGIS) and saved as shapefile or geopackage. A DEM of the area is also mandatory. The higher the DEM spatial resolution, the more accurate results can be obtained.

We suggest using an ortho-rectified image and a slope image (derived from the DEM) for the fault digitation.

Output data comprises:

- A geopackage containing the mapped faults and their statistics;
- A geopackage containing the produced transects and their statistics;
- An excel file tabulating the transects geopackage's content;
- Distribution plots of the displacement over the fault's length;

- D_{max}/L frequency plots;
- W_{max}/L frequency plots;
- Dmax/L plot with power law fit.

Results: We tested this method on three Lunar Floor.Fractured Craters (FFCs).
An example of the equally spaced transect generated by the processing notebook is reported in Figure 1.

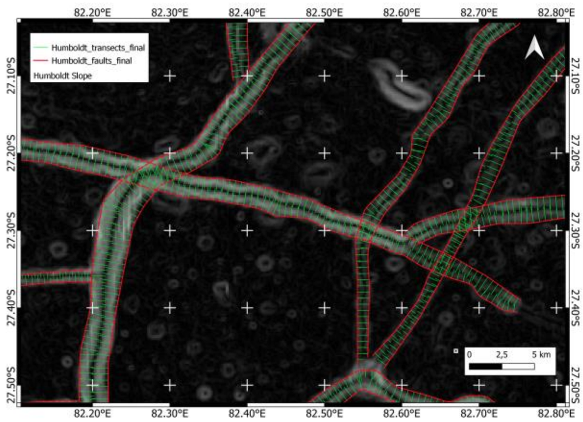

Figure 1. Example of equally spaced transects (green) overlayed to slope map derived from the LRO LOLA - SELENE Kaguya TC DEM Red lines represent the faults shapefile.

We implemented also an automated classification based on the Coefficient of Variation (CV) method using the Convex Hull (Figure 2), which is one of the first attempts to provide an objective and quantitative classification for the displacement distribution plots [5].

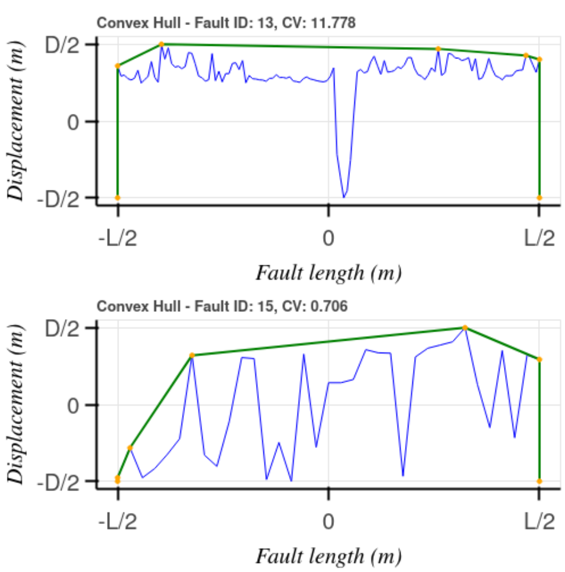

Figure 2. Example of Displacement over Length profiles for 2 faults and the respective CV. Green line represent the Upper Convex Hull. Blue line represents the displacement distribution.

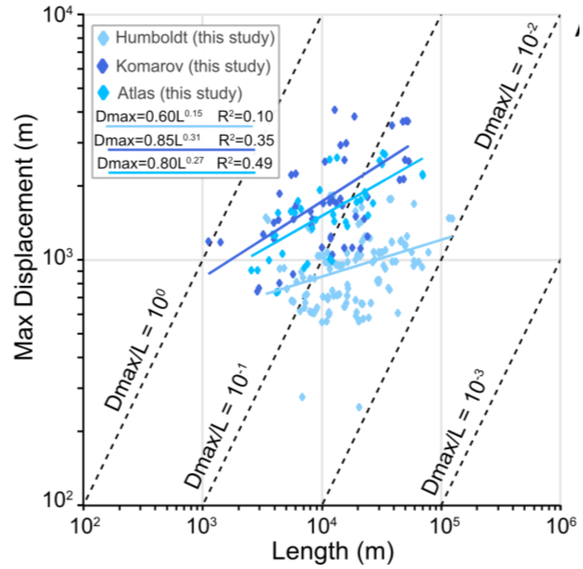

Figure 3. Example of D/L scaling loglog plot for relative to the Lunar FFC of this study. Solid lines represents the power-law best fit for the 3 craters.

The final D/L scaling plot includes the original data, the power-law best-fit lines and the lines representing specific coefficient limits (Figure 3).

Conclusions: Thanks to the method presented here, we were able to perform the displacement-to-length scaling of three Lunar FFCs with a minimal user input, reduced only to the initial input files. This approach could lead to improve the knowledge of fault growth by performing large-semi-automated scale analysis previously manually performed.

The presented workflow is agnostic and customizable, and it could be applied to generic topographic datasets on Mars, the Earth, and other planetary bodies.

Open Research: The code is available on Zenodo [6]

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References:

[1] Cladouhos, et al., (1996), *Journal of Structural Geology, 18(2-3), 281*-293. [2] Childs, C. et al., (1995), *Journal of the Geological Society, 535-549, 152, 3.* [3] Callihan, M. B. et al., (2019), *Lithosphere 2019; 11 (2): 294–305*. [4] Wilkins S.J. and Gross M.R. (2002b), *Journal of Structural Geology, 24(9)*: 1413-1429. [5] Martin&Watters, (2022), *Icarus, Volume 388, 2022,115215, ISSN 0019-1035*, [6] Nodjoumi G. et al., (2022), *Zenodo:* 10.5281/zenodo.7477125