Semi-automated fault extraction and quantitative structural analysis from DEM data, a comprehensive tool for fault network analysis

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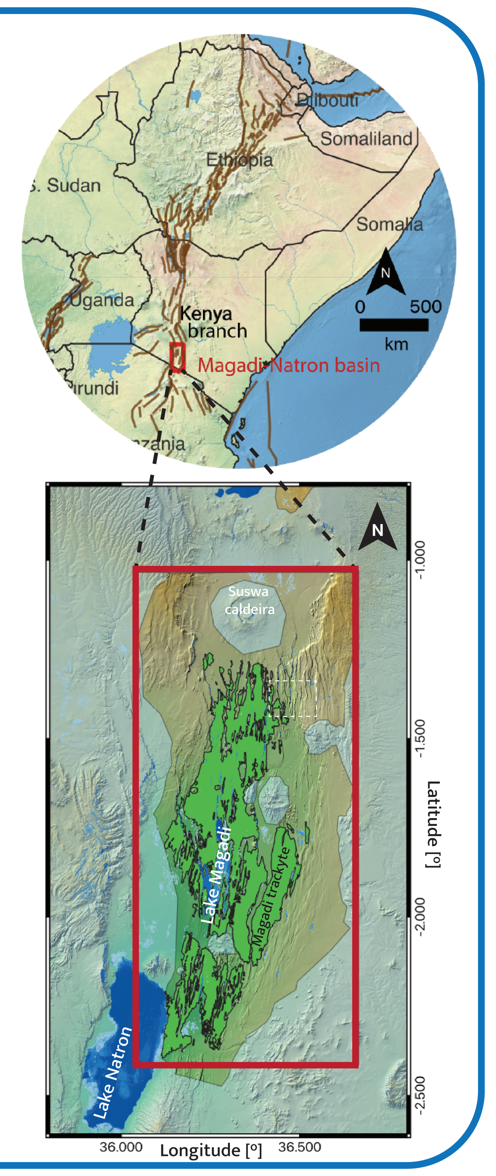
Motivation



- In the last decade : increasing resolution of satellite images, allowing now very detailed Digital Elevation Models (**DEM**).
We used TanDEM-X data, with 12m horizontal and 3m vertical resolution (± 80cm).

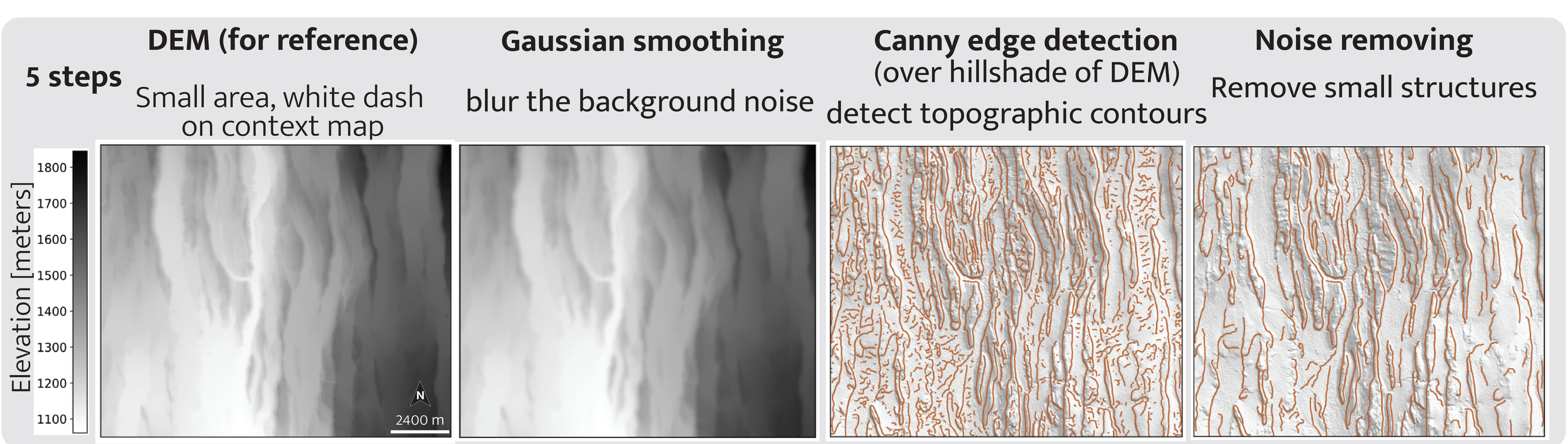
- **Fault network extraction** : characterise deformation patterns in rifts; until now made by hand, extremely time consuming.

- Here, we propose a **Python** workflow to address this challenge.
- Semi-automated mapping
- Automatic high resolution structural analysis.

- Focus on the **Magadi-Natron basin** (Kenya branch, East African Rift System).
Promising area because:
  - very dry, sparse rivers, low amount of human constructions
  - sparse vegetation -> DEM represent the ground surface.
  - intra rift topography characterised by normal faults, volcanic units well dated.

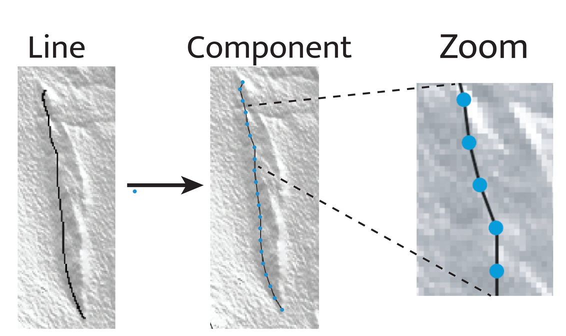
Fault extraction

- **Preprocessing**: masking of volcanoes and lakes, GIS software.
- Mapping **semi automatic** because **settings** specific for the processing area.
- Mapping : **compromise** between map as much faults as possible (big data), of all sizes, and reduce noise (from detection of other topographic features)



+ **skeletonization** (reduce line width to 1 pixel) + **Connection detection.**

- **Network creation**

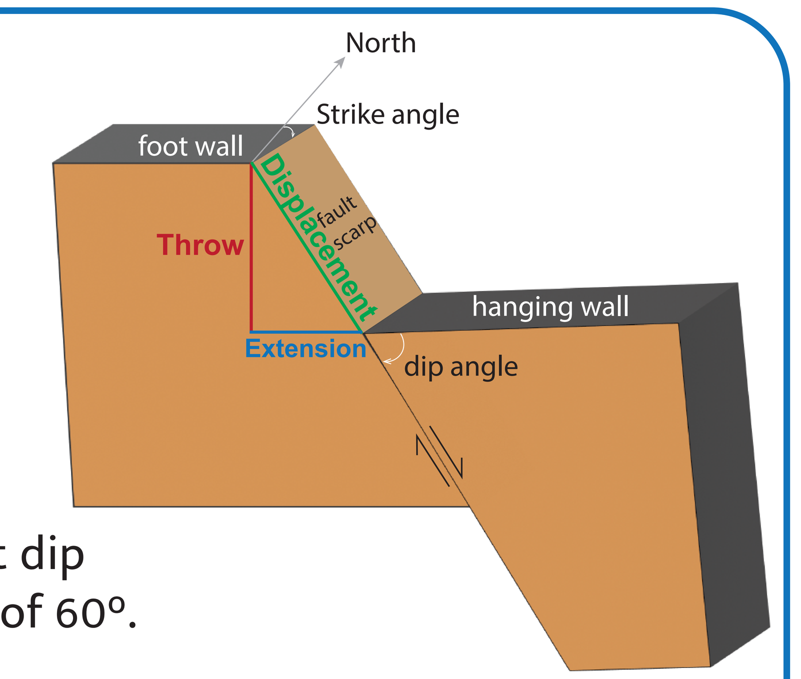


From array to network
For each **component** (=independent structure):
  - set on **nodes** (defined by position (x,y))
  - linked by **edges** (defined by nodes that they link).

- Fast result: settings of code 5h; running ~5h full workflow on whole basin (=72*million pixels)

Benchmark yourself ! Compare your mapping with the code. See **game** next to the poster.

Structural analysis



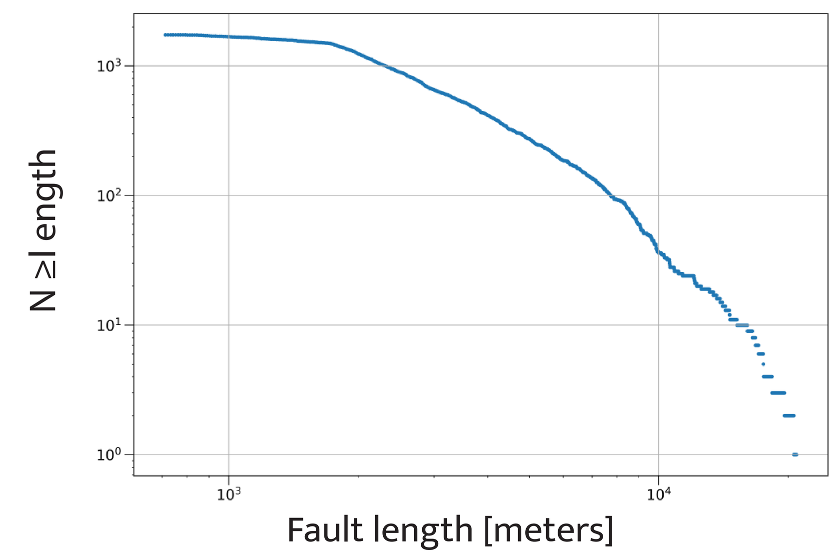
- For **each edge**, extraction of :
  - **throw, extension, displacement**
  - **dip angle, strike angle**
  - **length.**

- Escarpment slope not representative of fault dip
-> we assume representative normal fault dip of 60°.

Results and discussion

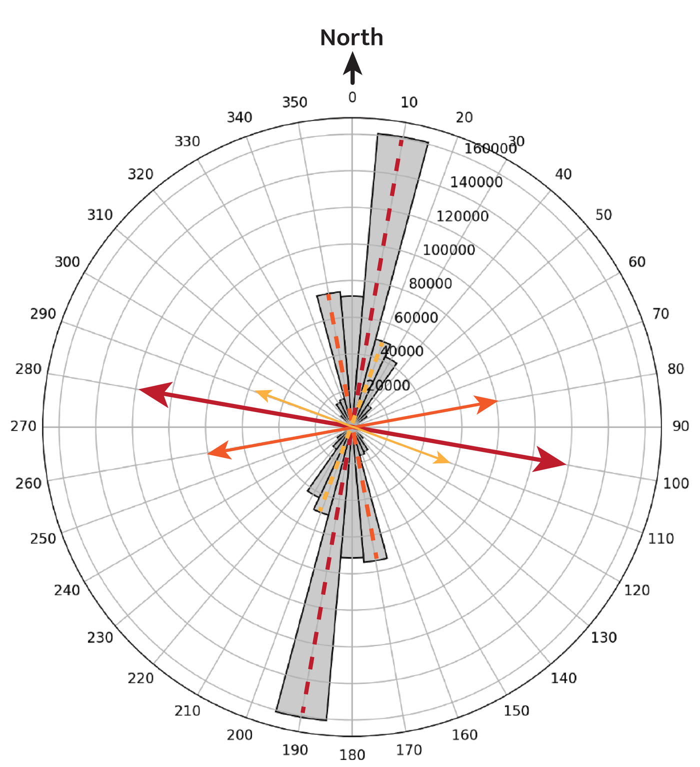
(A) Map whole basin

1736 individual intra-rift **faults** extracted
(~300 more than hand mapped by Muirhead et al. 2016)



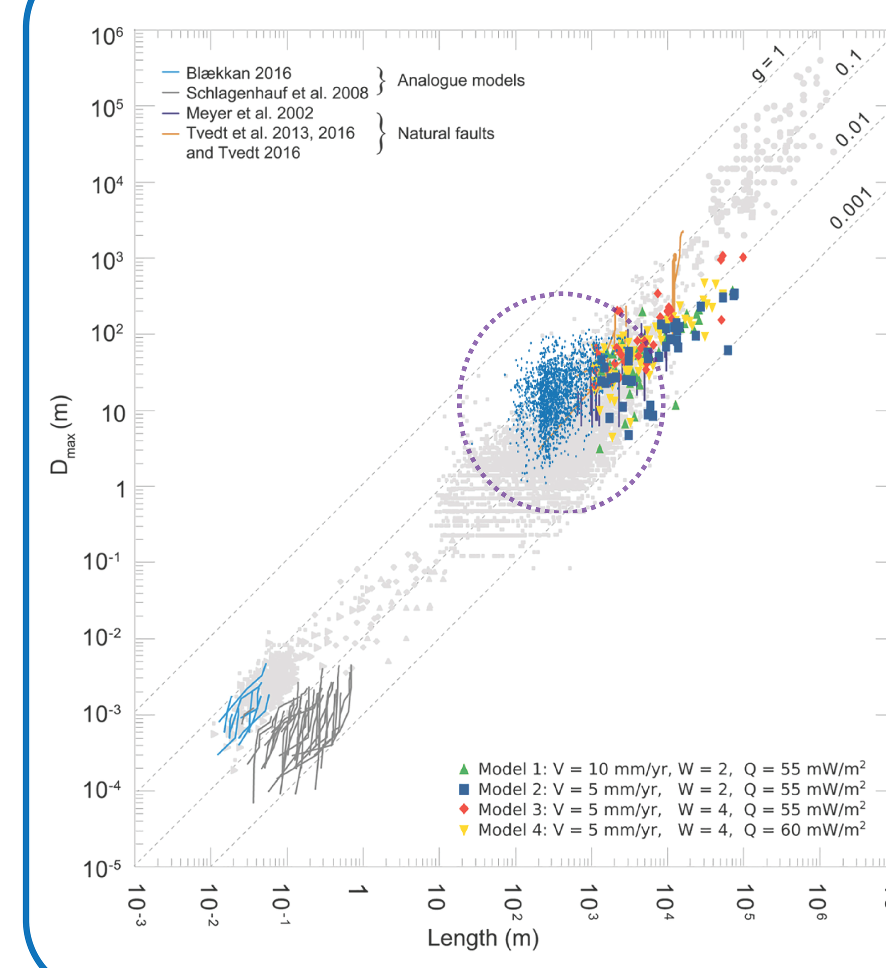
(B) Fault length distribution

Fault length distribution **similar** to intra-rift faults analysed by hand from **field data** by Muirhead et al. 2016.



(C) Length weighted rose histogram of edges strikes

- Extension (plain line) perpendicular to strike.
- **Several fault families** ->
Possibly **time-dependent extension direction**
- Caused by plate kinematic changes (Strecker et al. 1990) or local stress field changes (Muirhead et al. 2016).



(D) Displacement - length diagram

Our data (blue points in ellipse) over figure from Naliboff et al. 2020

- Huge **diversity** of fault characteristics
- Agreement with previous data sets
- Interesting trend: displacement in our study area near maximum range of previous studies.

Take home messages

- Our semi-automated workflow maps accurately the faults, in a way as good as human, with little parametrization.
- This Python program is easy to adopt and fast to run.
- We derive a high-resolution database of 1736 faults that - for the first time - includes the along-strike variation of throw, extension, and displacement of each fault in our study area.

Outlook

- Workflow works on natural DEM but also **analogue models** DEM and numerical models results
- Code made in **2 separable parts** : fault extraction and structural analysis.
-> possible to input a hand mapping + a DEM to get the structural analysis of an area
- Workflow **versatile** : map topographic changes, so could be applied anywhere where tectonic drives the topographic changes -> other rifts, on Earth or other planets, bathymetric data... up to your needs !

References

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