中国地质大学 CHINA UNIVERSITY OF GEOSCIENCES 武汉 · WUHAN

UNIVERSITÀ DEGLI STUDI FIRENZE

Consiglio Nazionale delle Ricerche

EGU General Assembly 2023

TS8.2-Analogue and numerical modelling of tectonic processes

EGU23-691

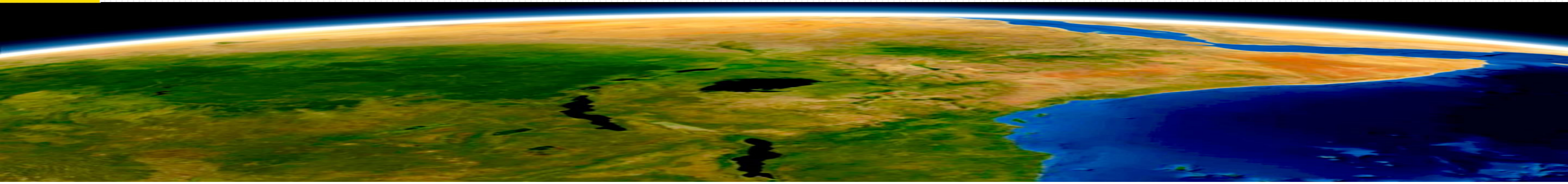
Enhanced-gravity Analog Modelling of the Influence of Pre-existing Brittle Fabrics on Continental Rifting

Yaoyao Zou[1]; Giacomo Corti[2]; Daniele Maestrelli[3]; Chiara Del Ventisette[3]; Liang Wang [1,4]; Chuanbo Shen[1]

(1) Key Laboratory of Tectonics and Petroleum Resources of the Ministry of Education, China University of Geosciences, Wuhan, China; (2) Consiglio Nazionale delle Ricerche, Istituto di Geoscienze e Georisorse, Florence, Italy (3) Dipartimento di Scienze della Terra, Università degli Studi di Firenze, Florence, Italy; (4) Geophysical Exploration Center, China Earthquake Administration, Zhengzhou, China

April 26, 2023

EGU23-691

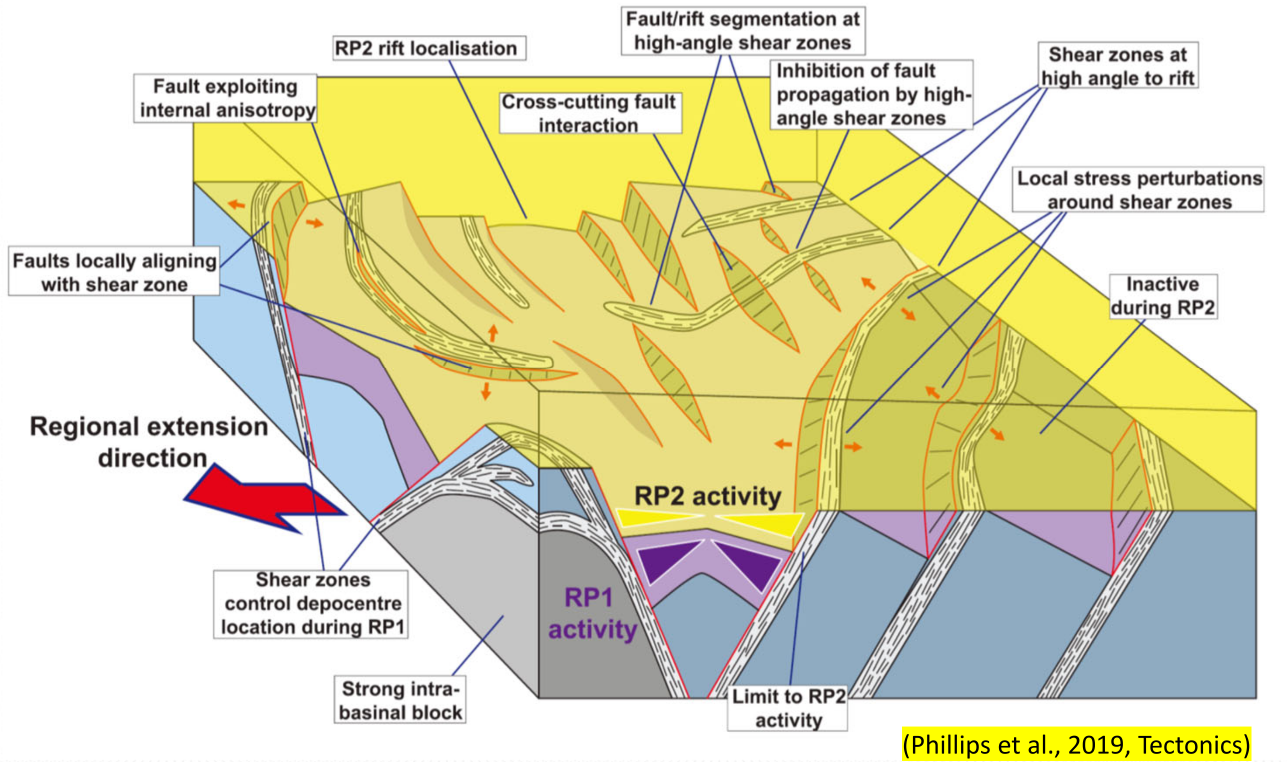


1 Background

EGU General Assembly 2023

1.1 Pre-existing fabrics in rift

- The presence of pre-existing fabrics or weak zones in the crust have been considered an important parameter in controlling the distribution and characteristics of rift-related deformation.
- Many studies have provided insights on how these pre-existing fabrics or discontinuities affect the pattern and evolution of rift-related deformation.
- The example show orthogonal rifting (the simplest kinematical boundary conditions), inherited fabrics may result in complex rift-related structures.



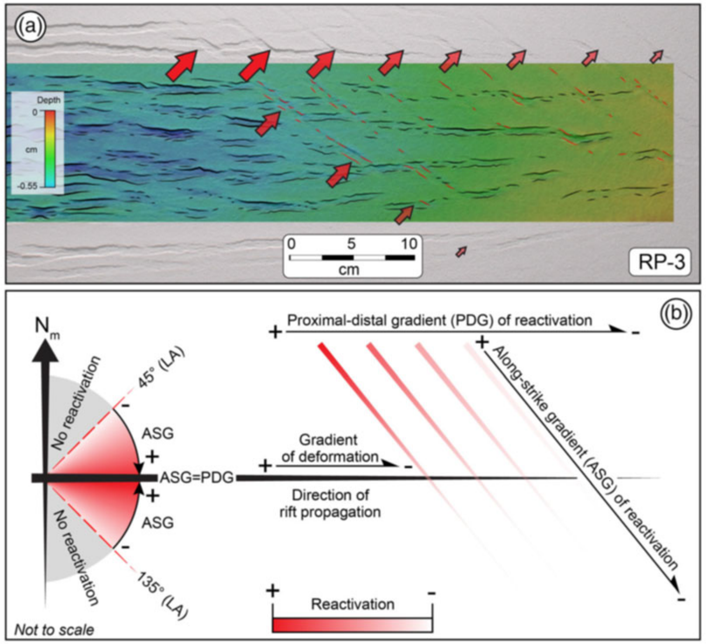
Possible interactions between preexisting basement structures and rift-related faults in North Sea Rift

The orientation of the pre-existing brittle fabrics with respect to the extension direction may be the key factor for the reactivation of preexisting fabrics

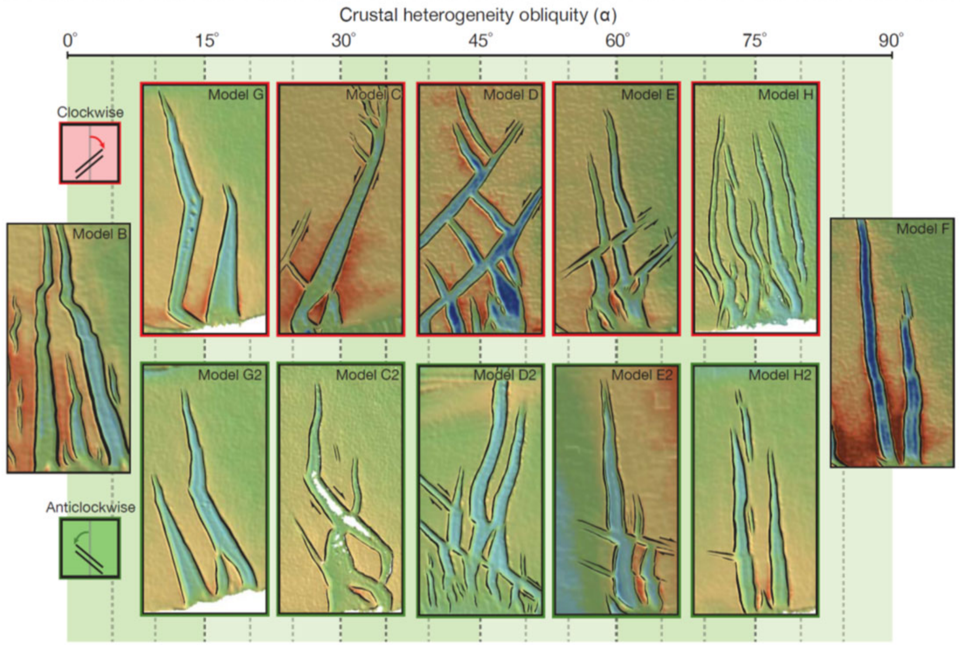
1 Background

1.2 Analog model for reactivation of fabrics

- Analog model has been proven to be a powerful tool to reproduce and analyze rifting and rift-related faulting.
- Previous analog models showed that the orientation of the inherited fabrics with respect to the extension direction has a significant influence on reactivation of inheritance, as well as rift-related fault pattern



(Maestrelli et al., 2020, Tectonics)



(Molnar et al.,2019)

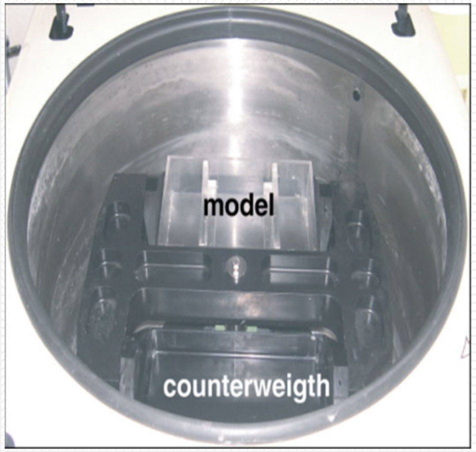
Here, we hope to perform analog model to illustrate the reactivation and influence of inherited fabrics in narrow rifts quantitively

2 Model Setup

- The analog experiment series was performed in an **artificial gravity field** of **18g** using the large capacity centrifuge available at the TOOLab (Tectonic Modelling Laboratory) of CNR-IGG and UNIFI-DST.
- We built a **three-layer** modeling structure， corresponding to the brittle upper crust, ductile lower crust, and mantle. The upper brittle sand layer was cut by a knife to simulate the fabrics in the upper crust. We define a parameter **α** to represent the angle between the rift axis and the trend of cuttings.
- The **geometric scale ratio** of models is ca.10^{-6}, which means that **1mm** in the experiments corresponded to **1km** in nature. The velocity of lateral extension in the models scaled to the natural values of **~7.9 mm yr^{-1}**, which is consistent with the natural examples.

(A) 3D diagram showing the general model setup and partial operations. The box in the lower right corner shows the rheological profiles of the model. (B) the schematic diagram shows the plane structure of the modeling lower crust layer and fabrics cut in the upper brittle sand layer. (C) 3D photographic schematic.

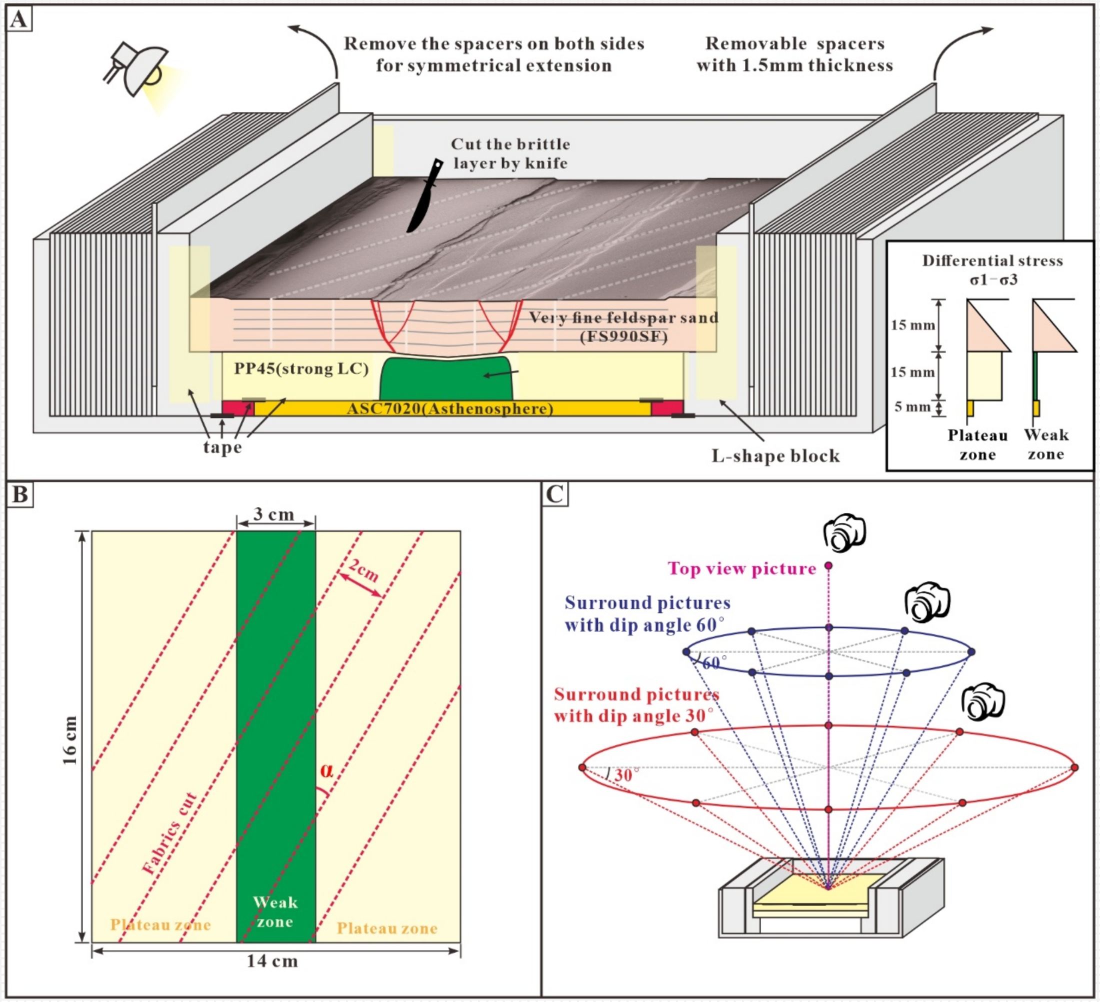
Large Capacity Centrifuge, Tectonic Modelling Lab, CNR – IGG, Firenze



2 Model Setup

EGU General Assembly 2023

- The analog experiment series was performed in an **artificial gravity field** of **18g** using the large capacity centrifuge available at the TOOLab (Tectonic Modelling Laboratory) of CNR-IGG and UNIFI-DST.
- We built a **three-layer** modeling structure , corresponding to the brittle upper crust, ductile lower crust, and mantle. The upper brittle sand layer was cut by a knife to simulate the fabrics in the upper crust. We define a parameter **α** to represent the angle between the rift axis and the trend of cuttings.
- The **geometric scale ratio** of models is ca.10^{-6}, which means that **1mm** in the experiments corresponded to **1km** in nature. The velocity of lateral extension in the models scaled to the natural values of **~7.9 mm yr^{-1}**, which is consistent with the natural examples.



(A) 3D diagram showing the general model setup and partial operations. The box in the lower right corner shows the rheological profiles of the model. (B) the schematic diagram shows the plane structure of the modeling lower crust layer and fabrics cut in the upper brittle sand layer. (C) 3D photographic schematic.

3 Results

EGU General Assembly 2023

- The result of 9 models are presented out of 39 models performed for testing the similarity with nature and reproducibility. The DEMs (Digital Elevation Models) of model surface topography were generated with the **Agisoft PhotoScan** by 3D perspective photos. The DEM and the fault interpretation of each model after 10mm of extension are shown, in order to demonstrate the influence of brittle fabrics on the initial rifting basins (Fig.2).

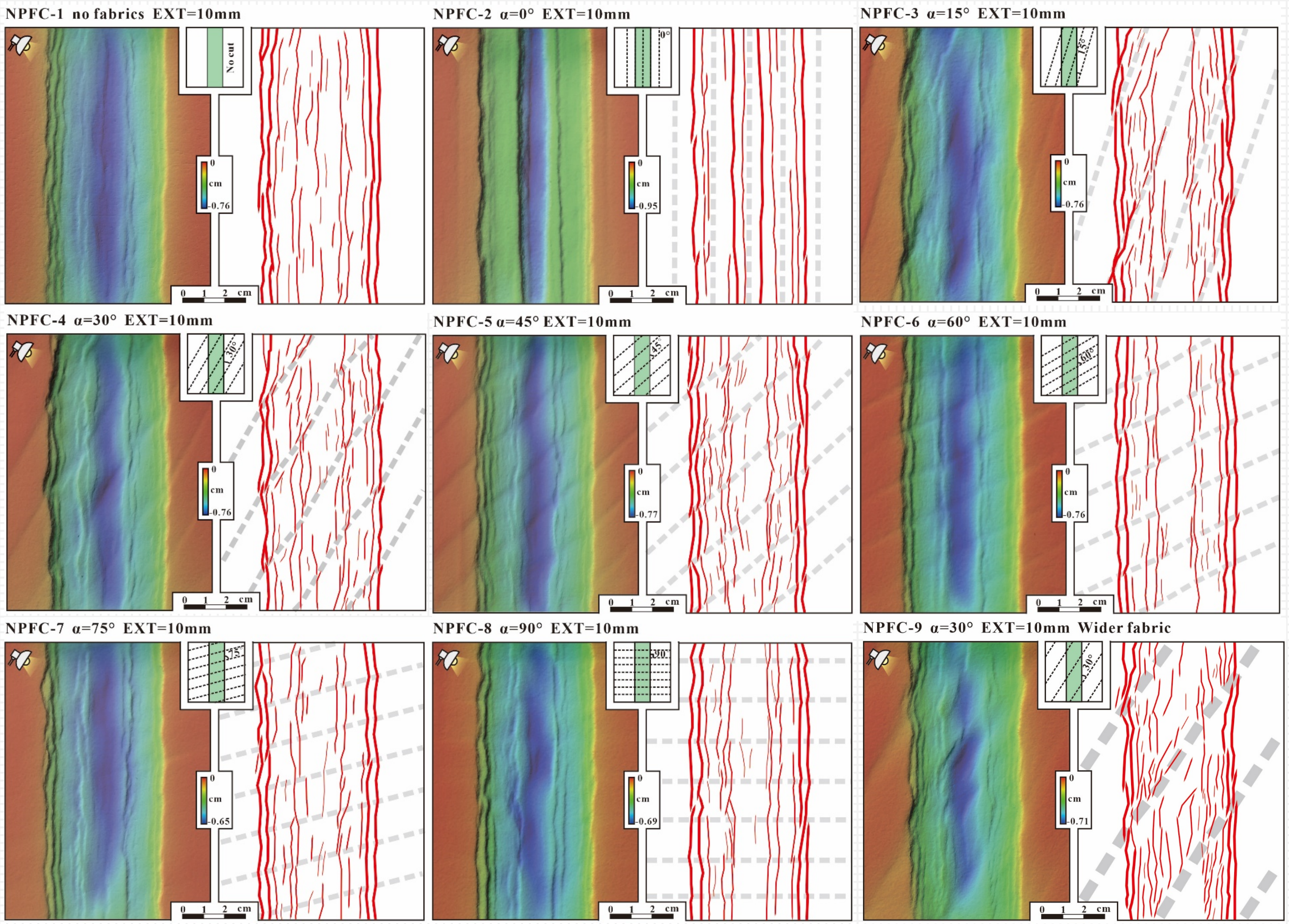


Fig 2. The DEM and the fault interpretation of models

3 Results

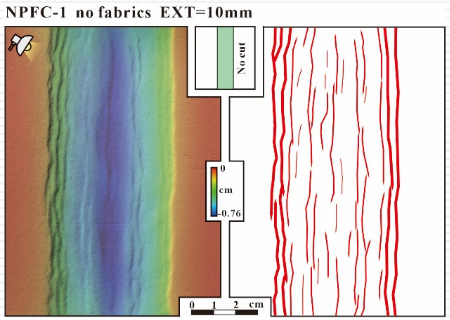
◆ **Low to moderate obliquity (α<= 45°)**

The inherited cut has a **significant influence** on the geometry of the rift-related faults.

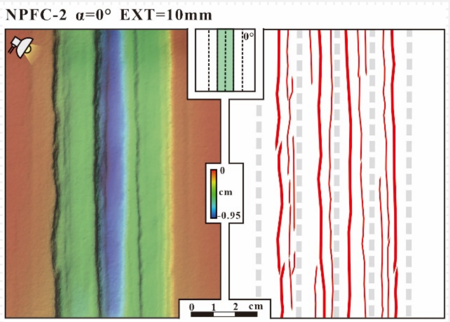
When **α=0°**, displacements are concentrated on a few extremely straight faults.

When **0°<α<=45°,** the **J-shape, S-shape** faults, and **relay ramps** occurred widely.

Homogeneous model (No fabrics)

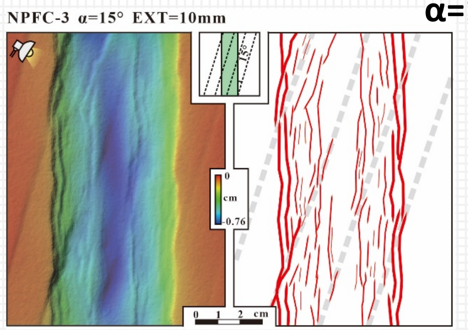


α=0°

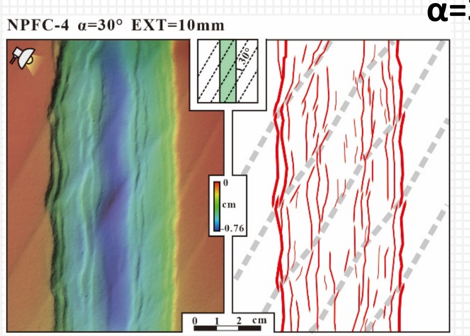


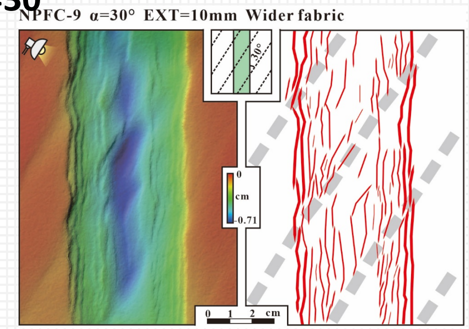
Low to moderate obliquity (0°<α<=45°)

α=15°

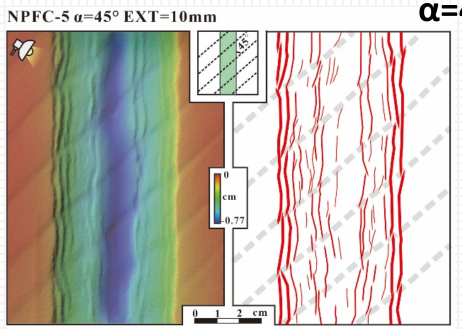


α=30°





α=45°



Normal fabrics

Wider fabrics

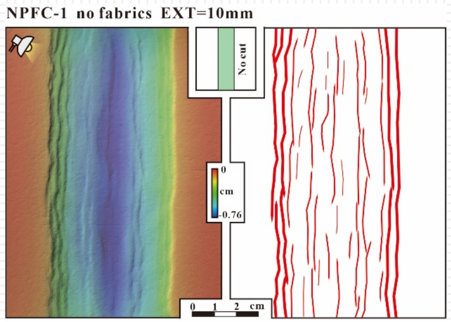
3 Results

EGU General Assembly 2023

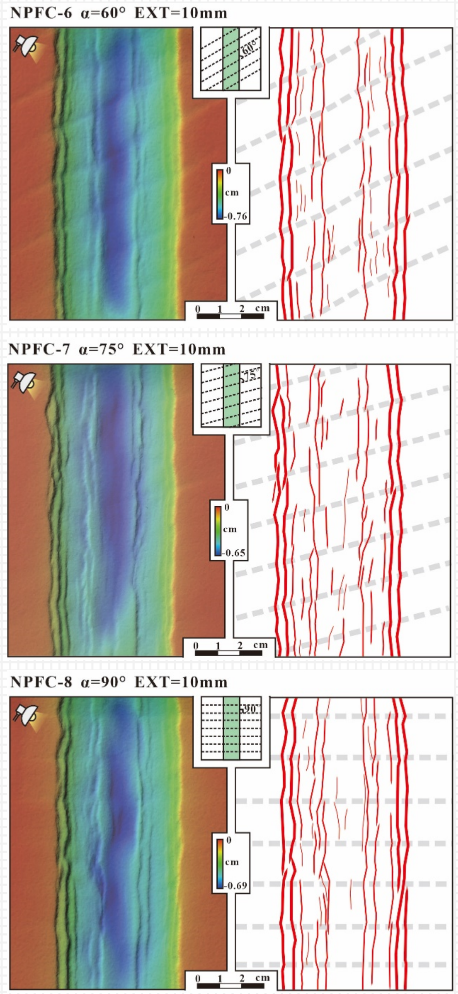
- **High obliquity (α >= 60°)**

The geometry of rift-related faults is closer to the NPFC-1, the no-fabrics model, indicating that the influence of the inherited fabrics is weakening.

Homogeneous model (No fabrics)



High obliquity (α>=60°)



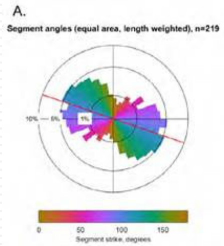
α=60°

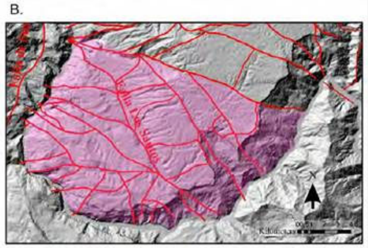
α=70°

α=90°

4 Discussions

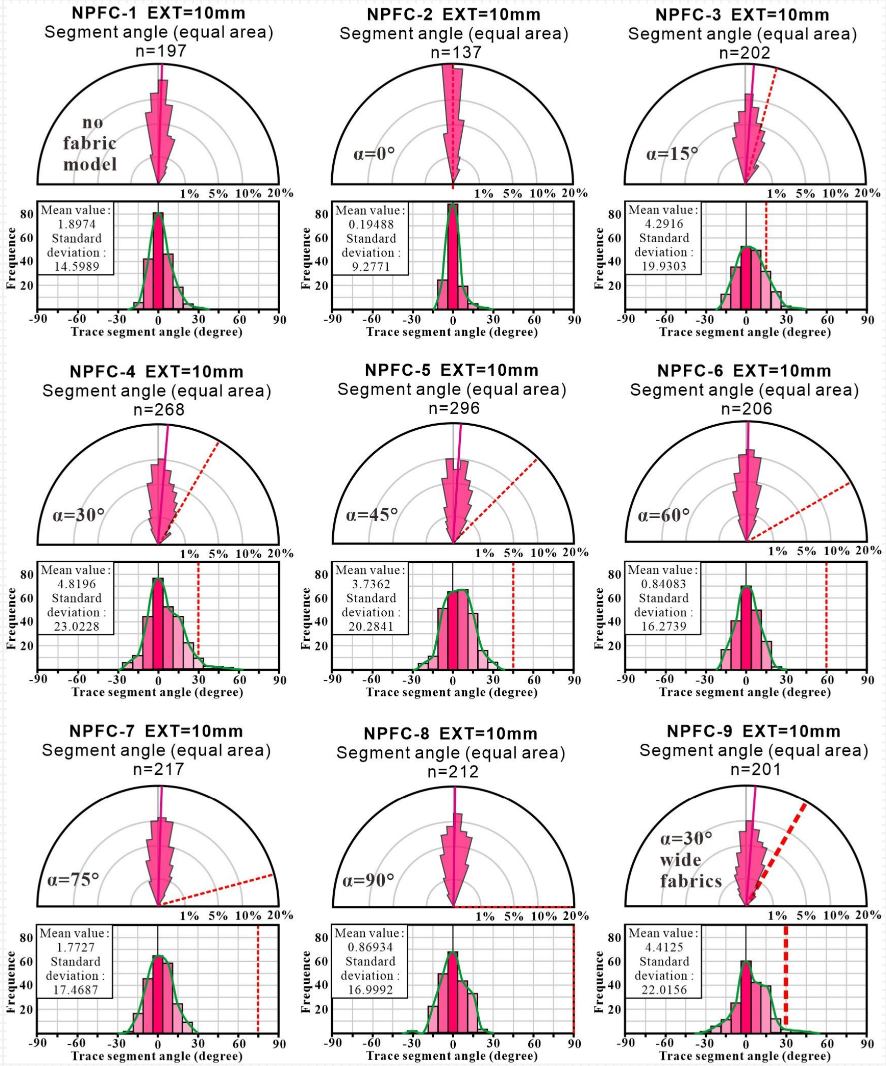
Statistical analysis of models was performed with the free software FracPaQ (Healy et al., 2017) for MATLAB™,





The re-orientation of fault segments

- When **α=0°,** the trends of fault segments focus more on S-N direction, indicating the concentration of orthogonal extension stress.
- When **0°<α<=45**°, the trend of fault segments rotate visibly, indicating the strong impact of the fabrics;
- When **α>= 60°,** the trends of faults segments seem familiar with the no fabrics model



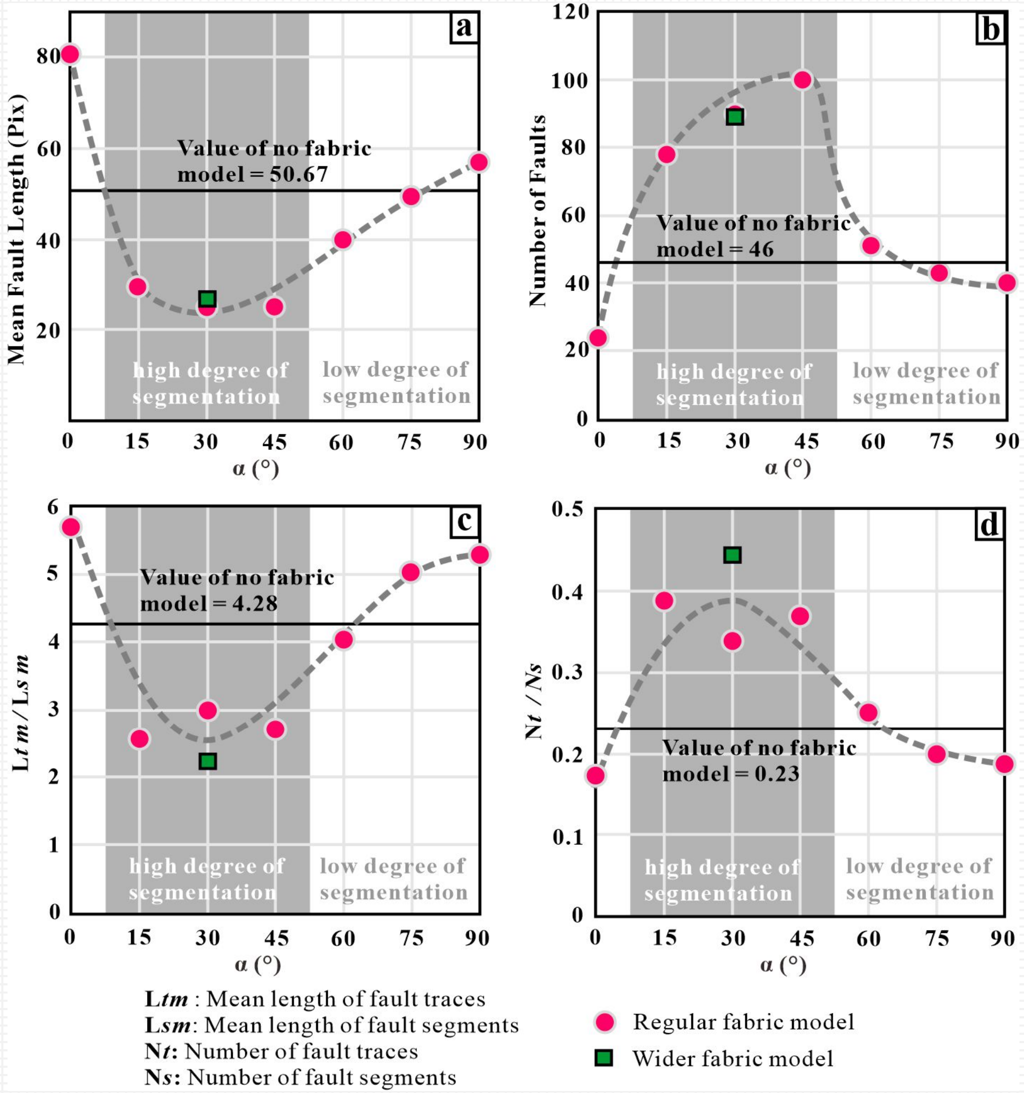
The rose diagrams and histograms of the fault segment angles according to the fault interpretation of each model.

4 Discussions

EGU General Assembly 2023

Segmentation and linkage of faults

- Faults statistics plots were used to show the relationship between **α** and **faults segmentation degree**. All of the 4 plots show a common and obvious tendency.
- When **α=0°**, The faults of models have minimal degree segmentation;
- When **15°<α<=45°** , the segmentation reach the highest degree;
- When **α>60°,** the segmentation degree return to normal

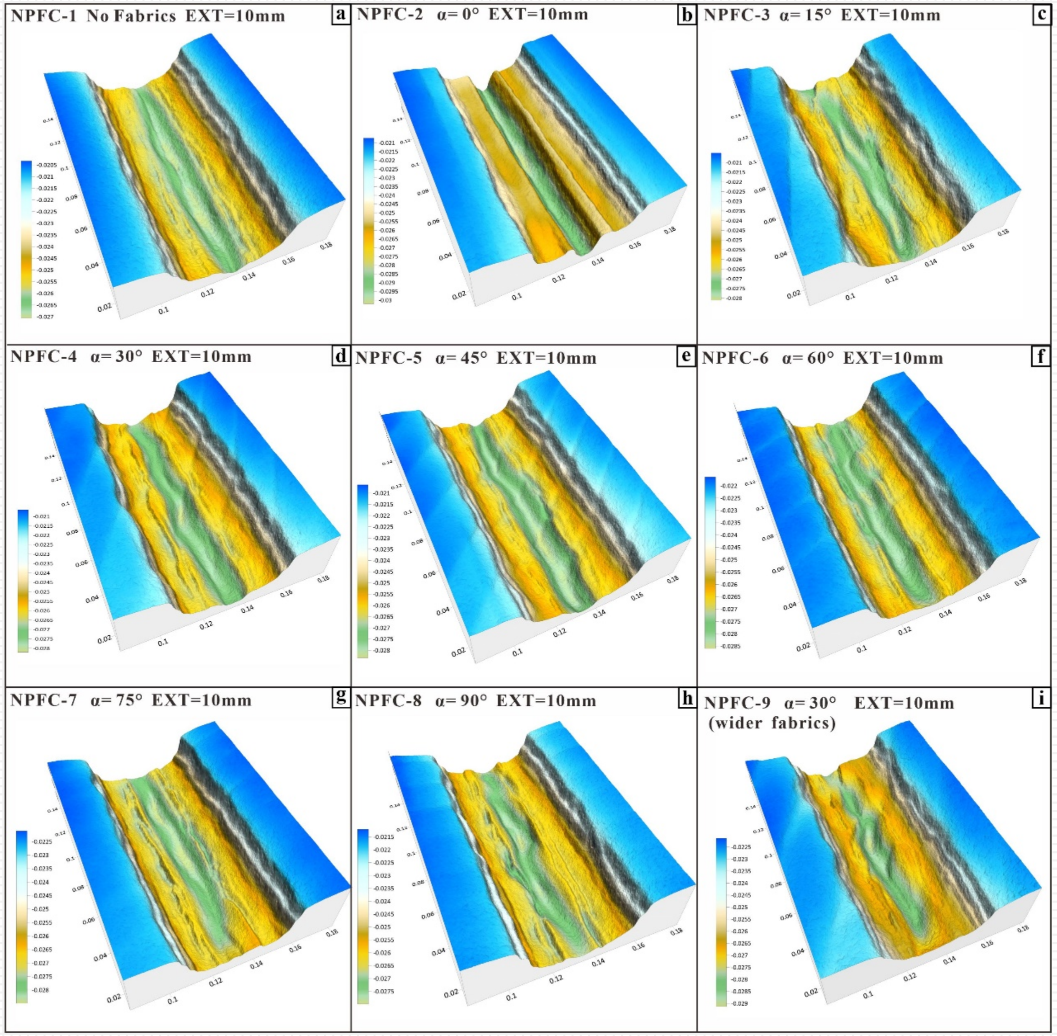


The fault statistics parameters of each model plotted against the α, which are (a) the average length of fault traces, (b) the number of fault traces, (c) the ratio of the average length of fault traces to fault segments, and (d) the ratio of the number of fault traces to fault segments.

4 Discussions

Positioning of deposition center

- when 0°<=α<=45°, the inherited fabrics clearly controlled the location of deposition center;
- When α>= 60°, it seems to have no apparent regularity.



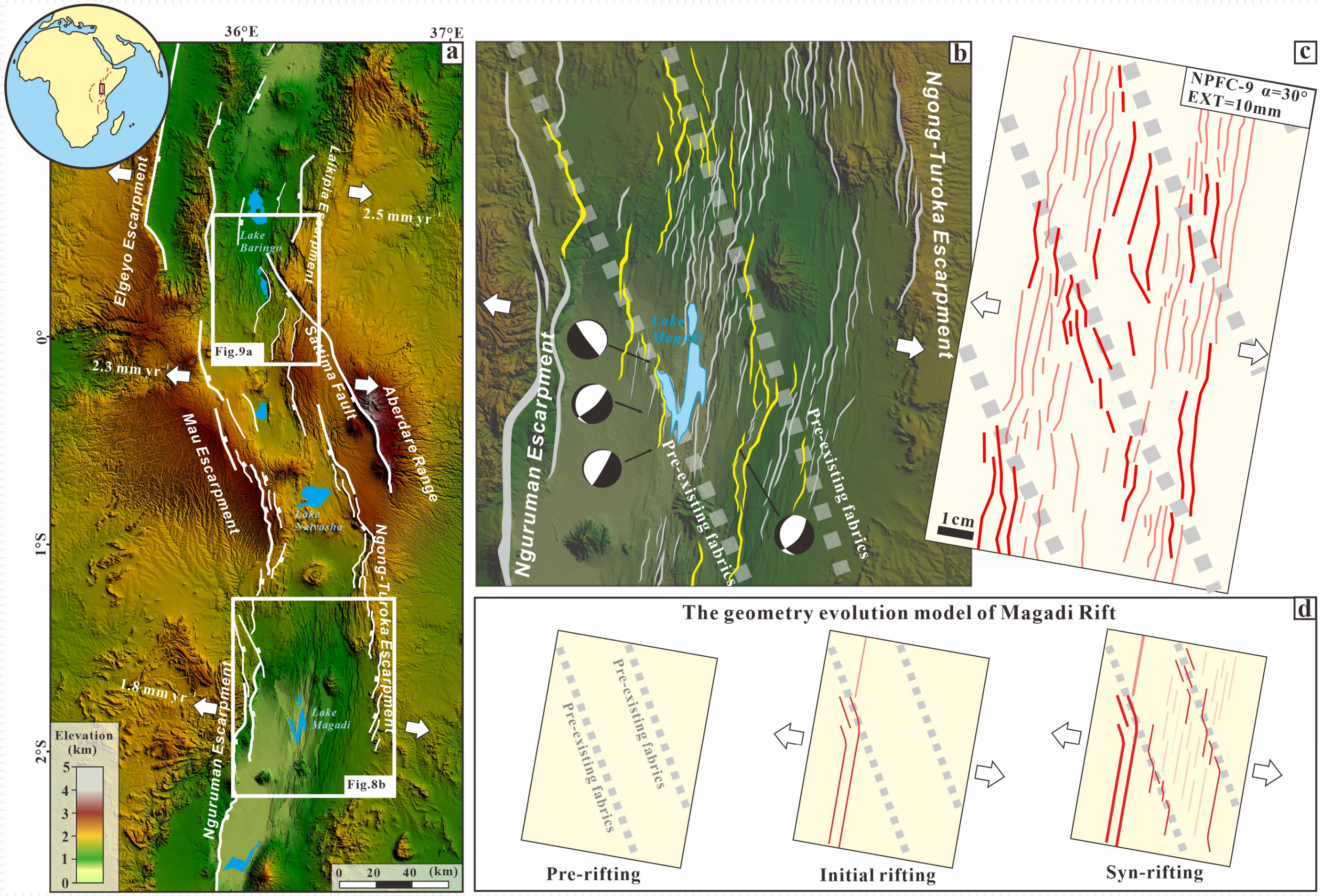
3D relief rendering of analog models.

5 Comparing with Natural Examples

EGU General Assembly 2023

Lake Magadi Basin, EARS (α = 30°)

- Magadi Rift is located at the southern of eastern branch of East African Rift System (EARS), which was thought to be the most typical example to illustrate the influence of brittle fabric on rift system.
- The NPFC-9 demonstrates high similarity with the Magadi Rift, including the obliquity of fabrics (α=~30°) the geometry of faults (J-shape and S-shape fault; en-echelon structures, relay ramps and so on)



Comparison between the Lake Magadi Basin and the model NPFC-9. (a) The DEM map of the Kenya Rift, EARS. The border faults were drawn in white lines modified from Acosta et al. (2015) and Richter et al.(2021).

6 Conclusions

- Inherited brittle fabrics have significant impact on the geometry of rift-related structures. The interaction is particularly obvious when the angle between it and the rift axis is less than or equal to 45° , and become weak when more than 60°。

- Inherited brittle fabrics may results in stress localization(parallel to rift axis) or stress rotation (low to medium oblique)， which caused J-shape，S-shape faults and echelon structure

- Low to medium oblique fabrics may cause remarkable segmentation of both border and faults， as well as the positioning of deposition center.

- The results of experiment series strong support the structure evolution of Magadi Rift, the East African Rift System .

CHINA UNIVERSITY OF GEOSCIENCES

UNIVERSITÀ DEGLI STUDI FIRENZE

Consiglio Nazionale delle Ricerche

EGU General Assembly 2023

Really Appreciate and Question Please

EGU23-691