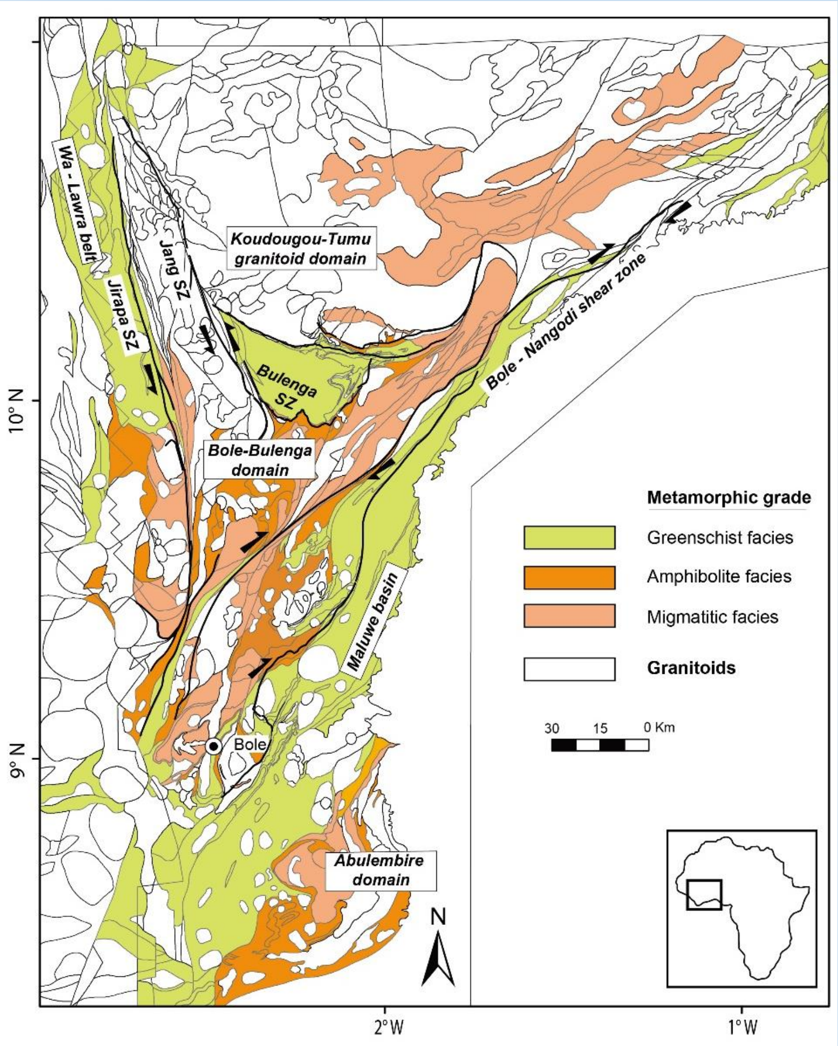
3-D numerical modelling of the influence of pre-existing faults and boundary conditions on the distribution of deformation: example of North-Western Ghana

By X.Feng, M.Gerbault, R.Martin, J.Ganne, M.W.Jessell

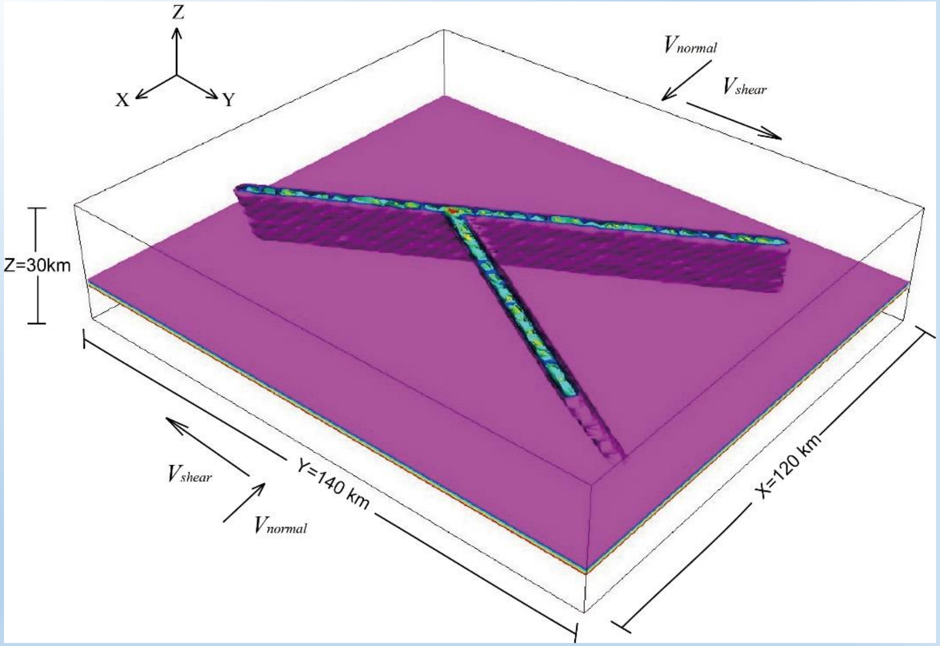
QUESTION ?

? How pre-existing fault orientations influence the distribution of high-strain zones?

? Tensile Vs. Compressional areas?

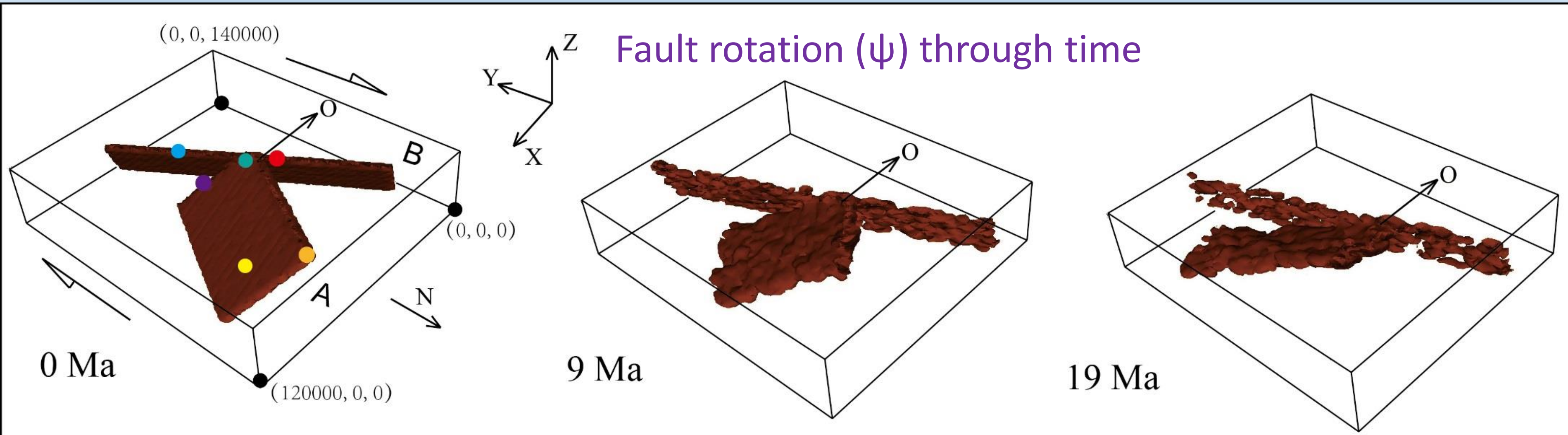


Geological setting NW Ghana

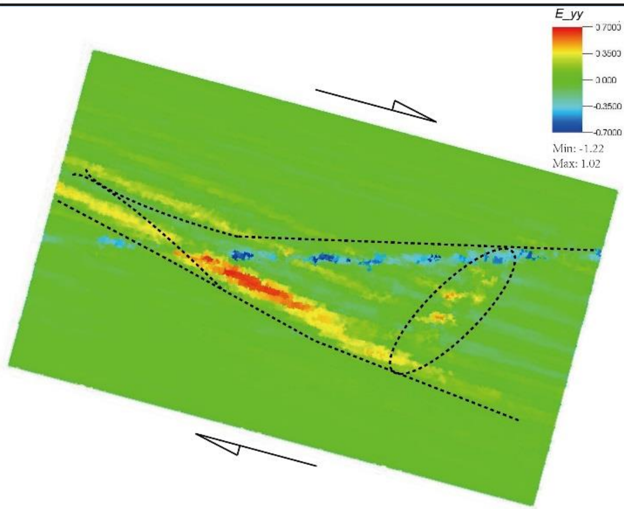


Numerical Model (with Underworld)

NUMERICAL ANSWER



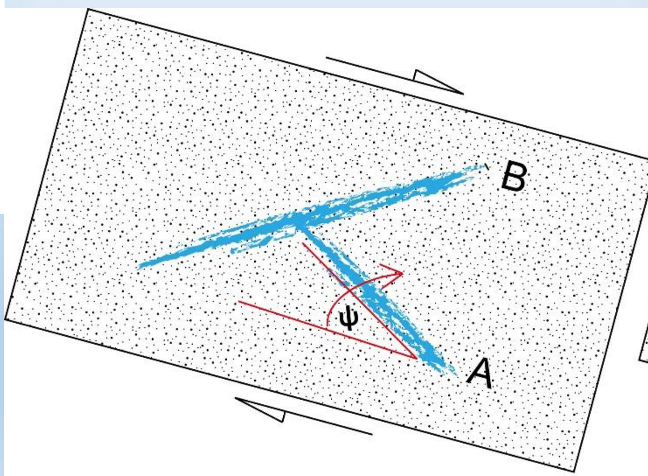
Fault rotation (ψ) through time

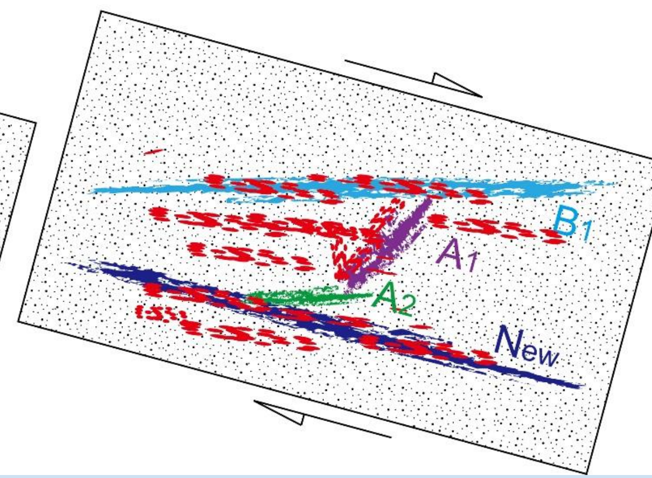


Sketch showing the evolution of faults geometries

Tensile: A1 + A2 + New

Shear: New + B1





Finite strain zones

Tensile in Red (A1 + A2 + New)

Compressional in Blue

Université de Toulouse

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Géosciences Environnement Toulouse (GET) UMR 5563

IRD Institut de recherche pour le développement

WAXI - West African Exploration Initiative

IXOA - L'Initiative d'Exploration Ouest Africaine

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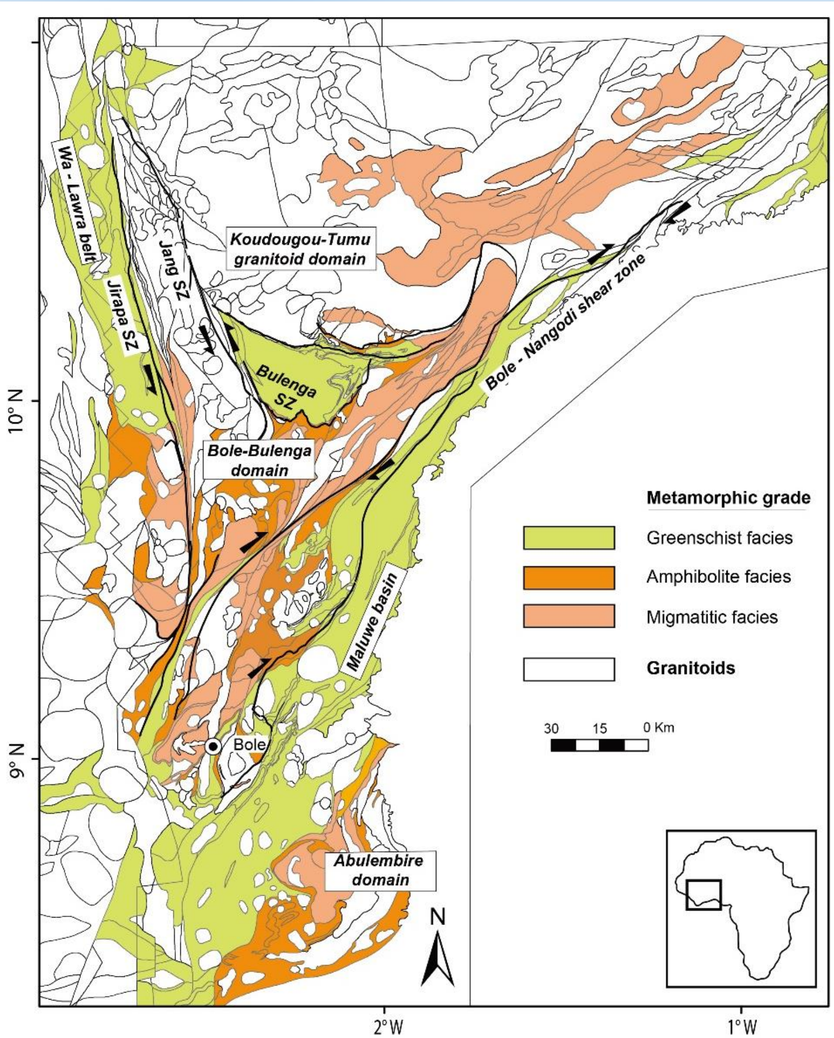
GÉOSCIENCES ENVIRONNEMENT TOULOUSE

By X.Feng, M.Gerbault, R.Martin, J.Ganne, M.W.Jessell

1. Geological setting NW Ghana



- The study area formed during the Eburnean orogeny (2.15–2.00 Ga)
- High-strain zones (Y shape fault system) bound and separate the high-grade terranes from low-grade greenstone belts
- High-grade assemblages are mainly observed between the Jirapa and Bole-Nangodi shear zones and partly around the town Bole.
- Bounded by granitoid domains, two main pulses of intrusions, ranging between 2213 Ma and 2080 Ma.

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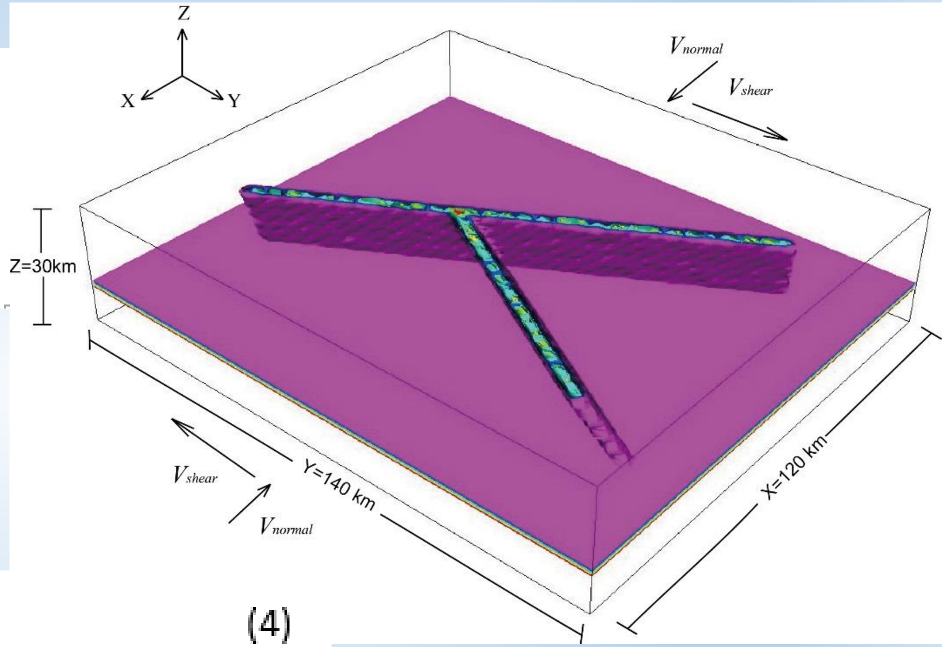
2. Numerical modelling with Underworld

The governing equations of momentum (1), mass (2) and energy (3) conservation are expressed as follows:

$$\frac{\partial \sigma_{ij}}{\partial x_j} = \rho(T) g_i \quad (1)$$

$$\nabla \cdot u = 0 \quad (2)$$

$$\rho C p \frac{DT}{Dt} + (u \cdot \nabla) T = \frac{\partial}{\partial x_i} \frac{(k_i \partial T)}{\partial x_i} + \rho H \quad (3)$$



The depth dependent Drucker - Prager yield criterion (4) and a temperature-dependent non - Newtonian power law (5) viscosity were used:

$$\tau_{yield} = P \cdot tan\varphi + \sigma_p \quad (4)$$

$$\eta_m = 0.25 \cdot (0.75A)^{(-1/n)} \cdot \dot{\varepsilon}^{((1/n)-1)} \cdot exp^{(Q/nRT)} \quad (5)$$

Table. 1. Rheological properties of crustal layers. The non-Newtonian power law is used for the upper and lower crusts, whereas we employ a constant viscosity for fault zones.

Layer	A MPa^{-n}/s	n	Q KJ/mol
Upper crust	2.0×10^{-4}	3.4	260
Lower crust	1.3×10^{-3}	2.4	219
Fault	1×10^{20} Pas		

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2. Numerical modelling with Underworld

*Table. 2. Model parameters common to all experiments. *ρ_{fault}, *$\triangle T$ and *φ indicate the values that change according to different models.*

Parameter	Symbol	Value-units
Thickness	Hupper	20 km
	Hlower	10 km
	*ρ_{upper}	2800 kg/m^3
Density	ρ_{lower}	3000 kg/m^3
	*ρ_{fault}	2600 kg/m^3
Dislocation creep power law pre-exponential factor	A	MPa^{-n}/s
Dislocation creep power law exponent	n	-
Power law creep activation energy	Q	KJ/mol
Temperature gradient	*$\triangle T$	°C/Km
Gas constant	R	8.314 $J\ mol^{-1}\ K^{-1}$
Heat capacity	C_p	1000 J/kg·K
Thermal diffusivity	γ	m^2/s
Thermal expansion	λ	K^{-1}
Gravitational acceleration	g	9.81 m/s^2
Friction angle	*ϕ	2.5~36.5 °
Cohesion for Druker-Prager	σ_c	1-20 MPa
Viscosity limit	η	$1e+20<\eta<1e+23$ Pa s

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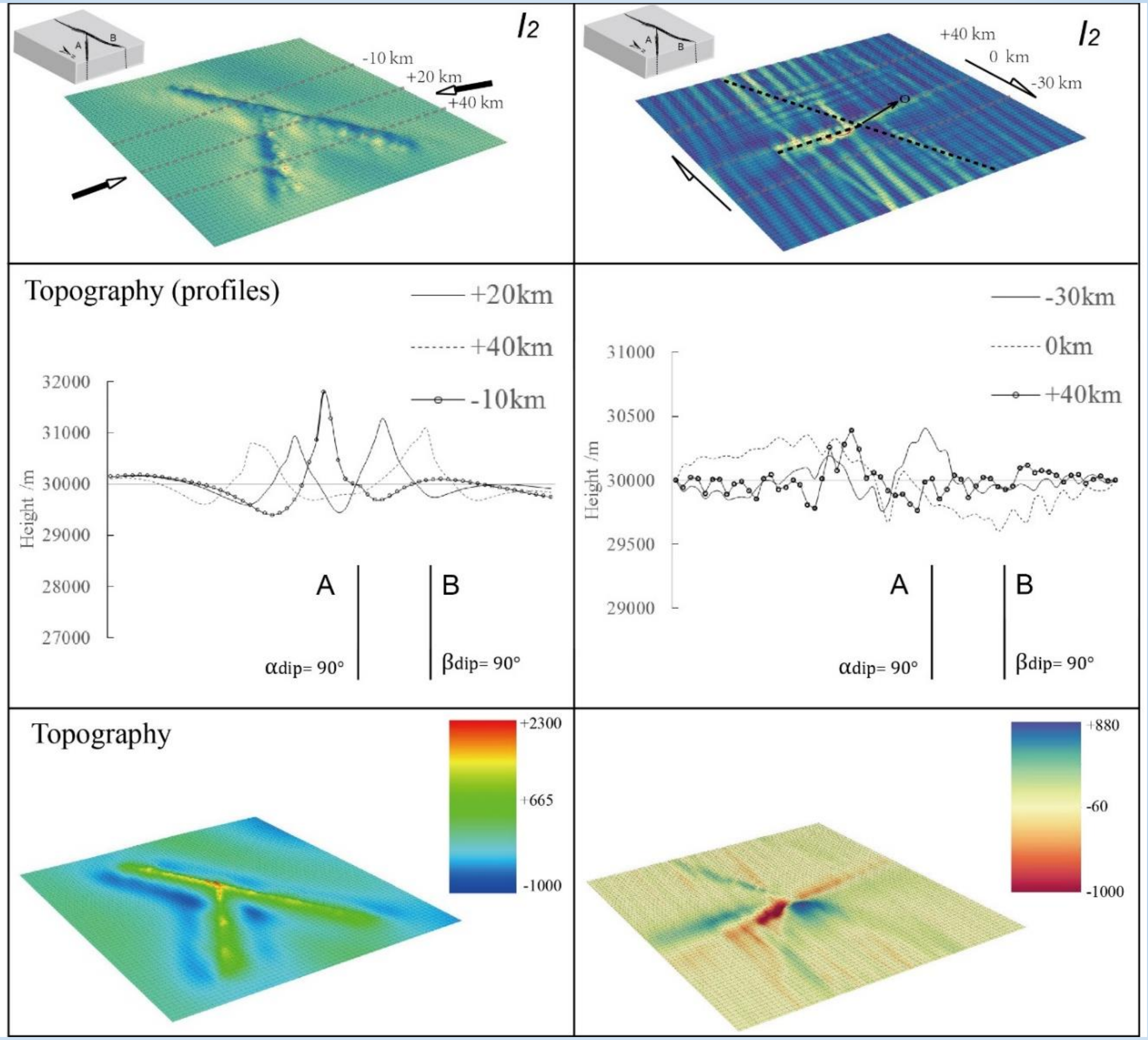
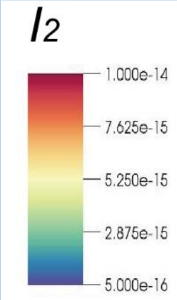
3. Result

Two vertical faults under compressional (left) and simple shear (right) boundary conditions.





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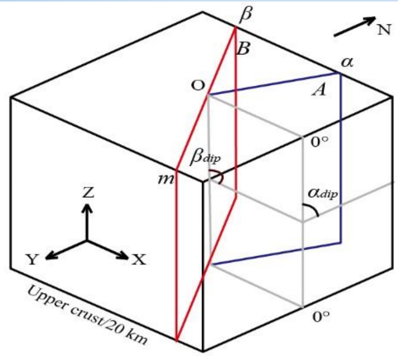
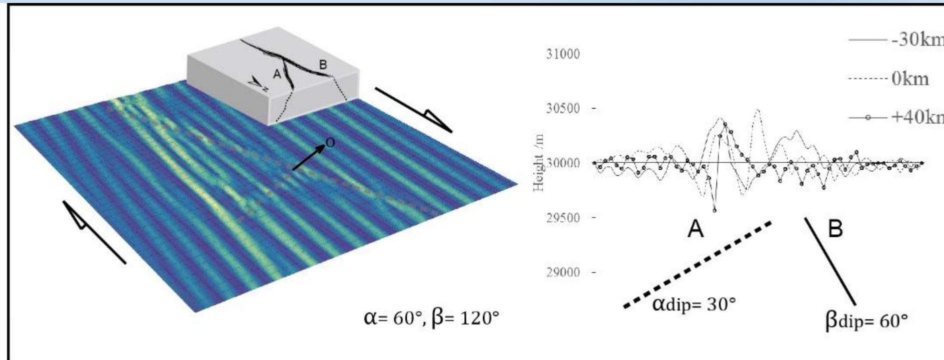
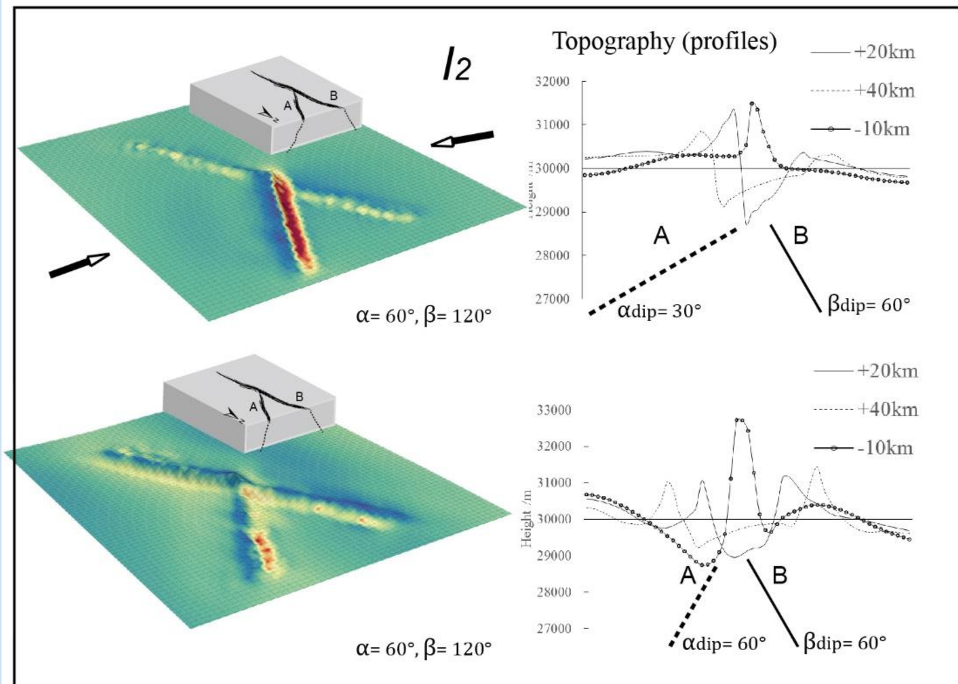
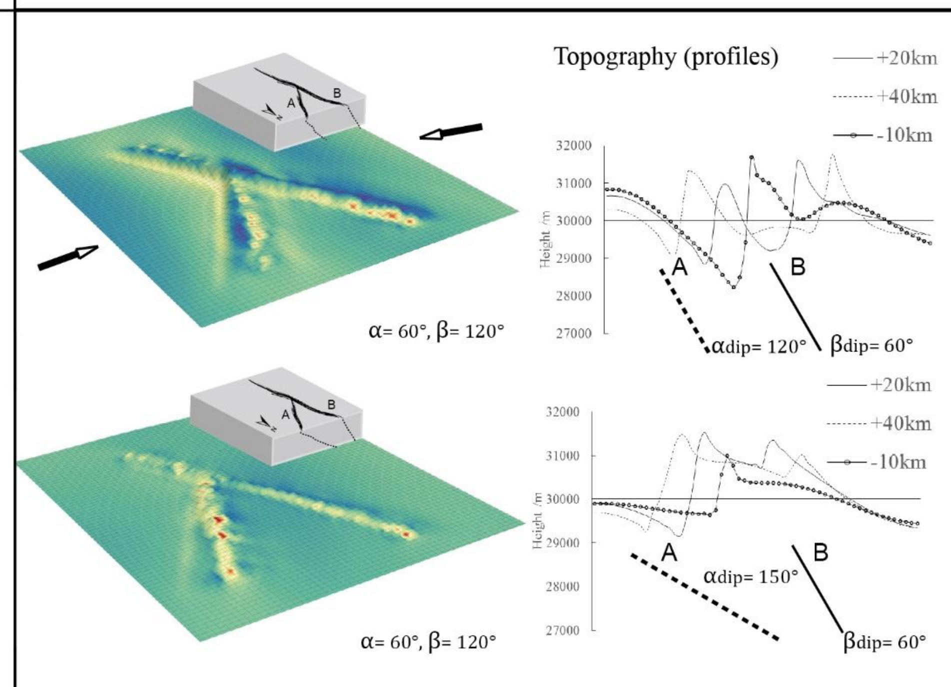
3. Result

Distribution of deformation and Topo Vs. fault orientations









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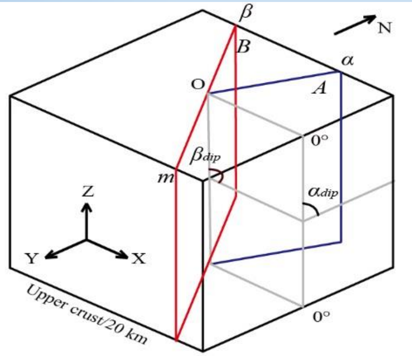

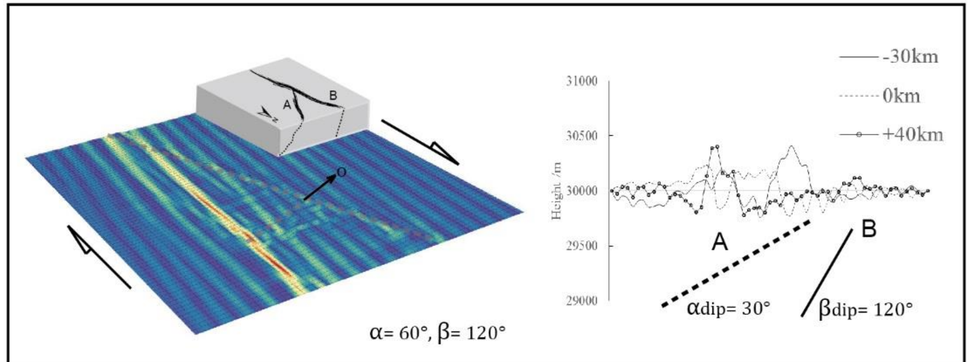

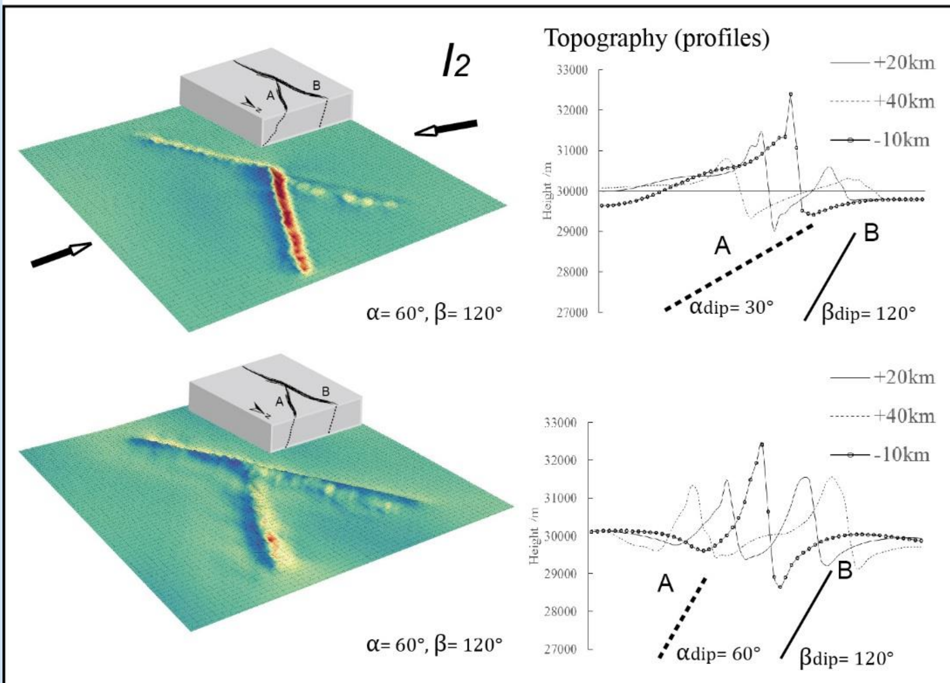

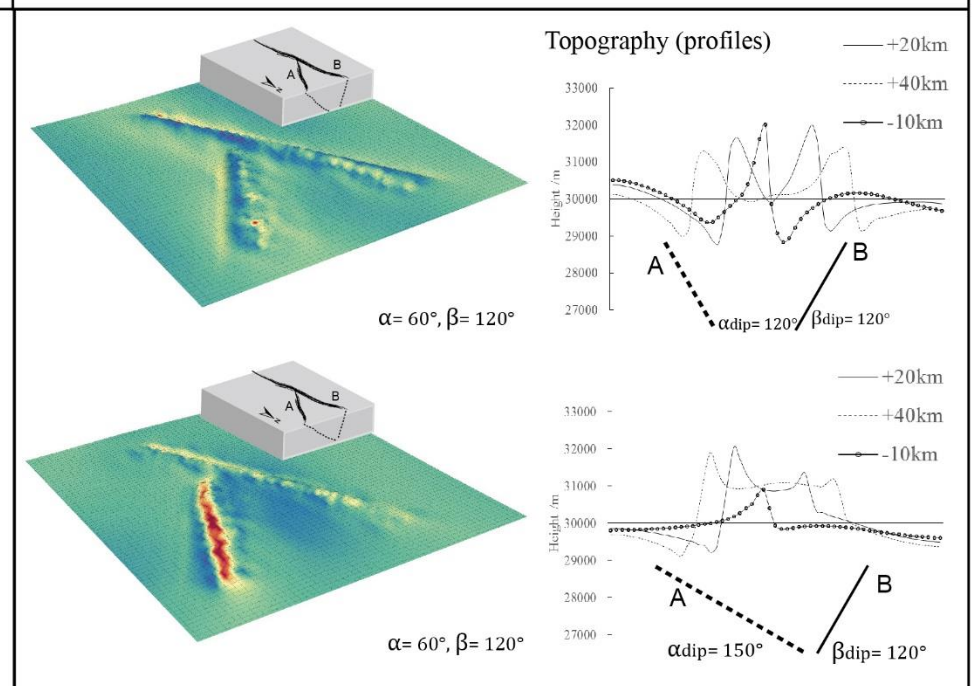

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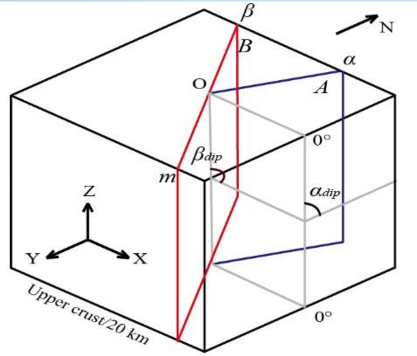
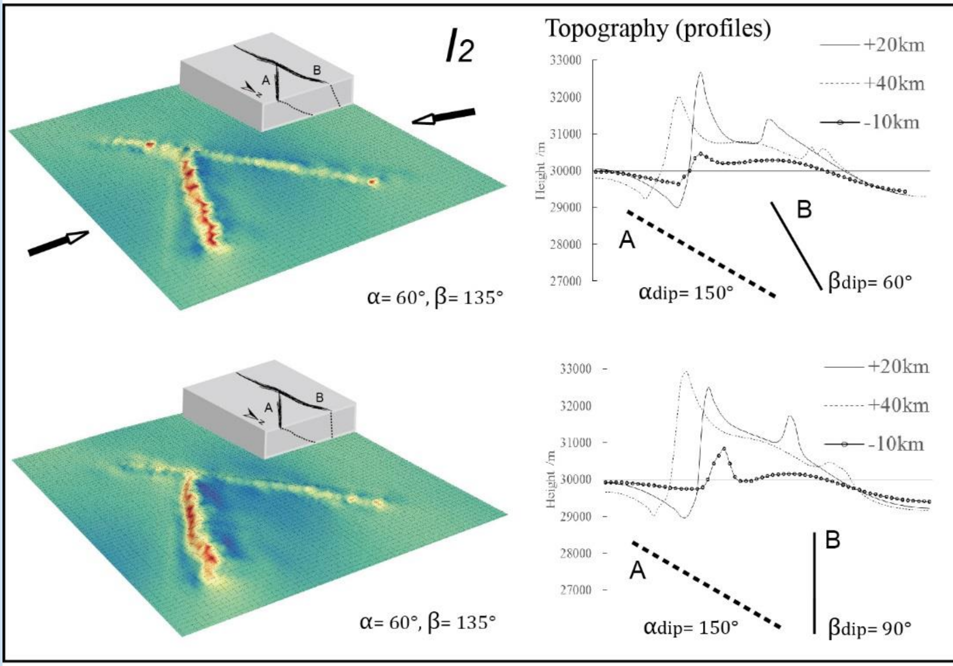
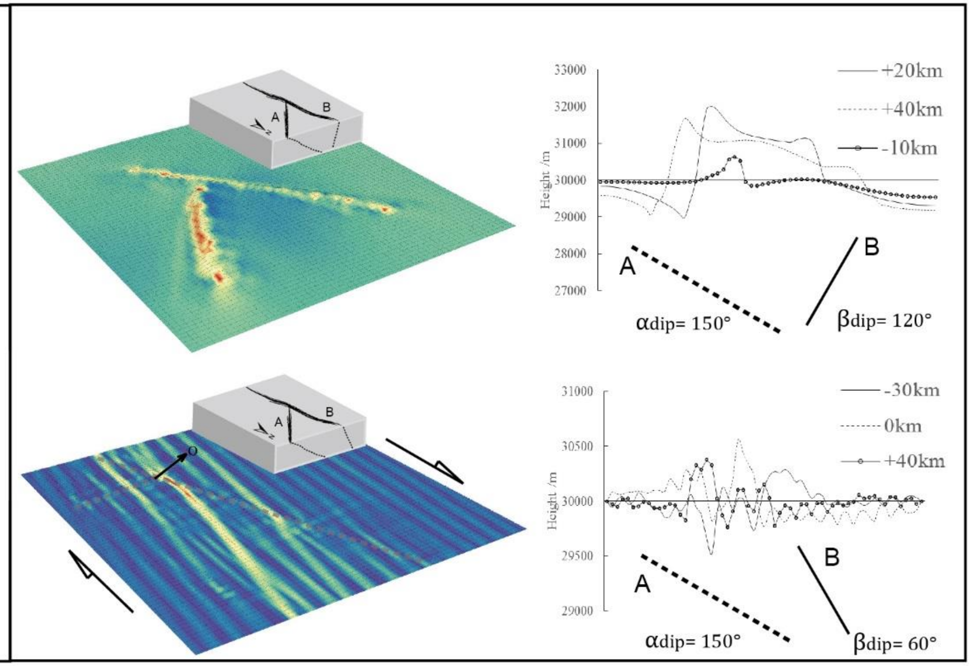
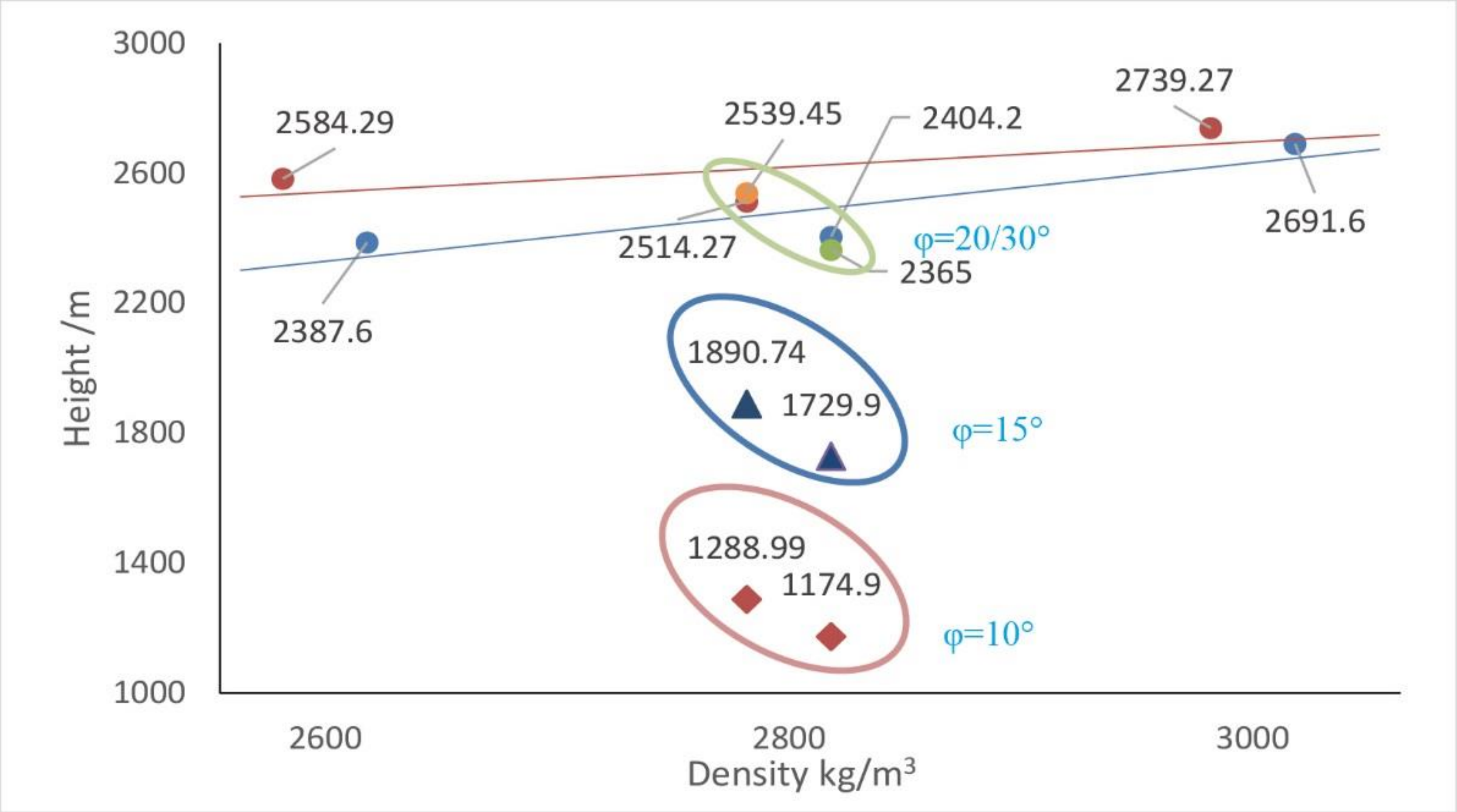






3. Result

Density variations Vs. friction angle in building Topo



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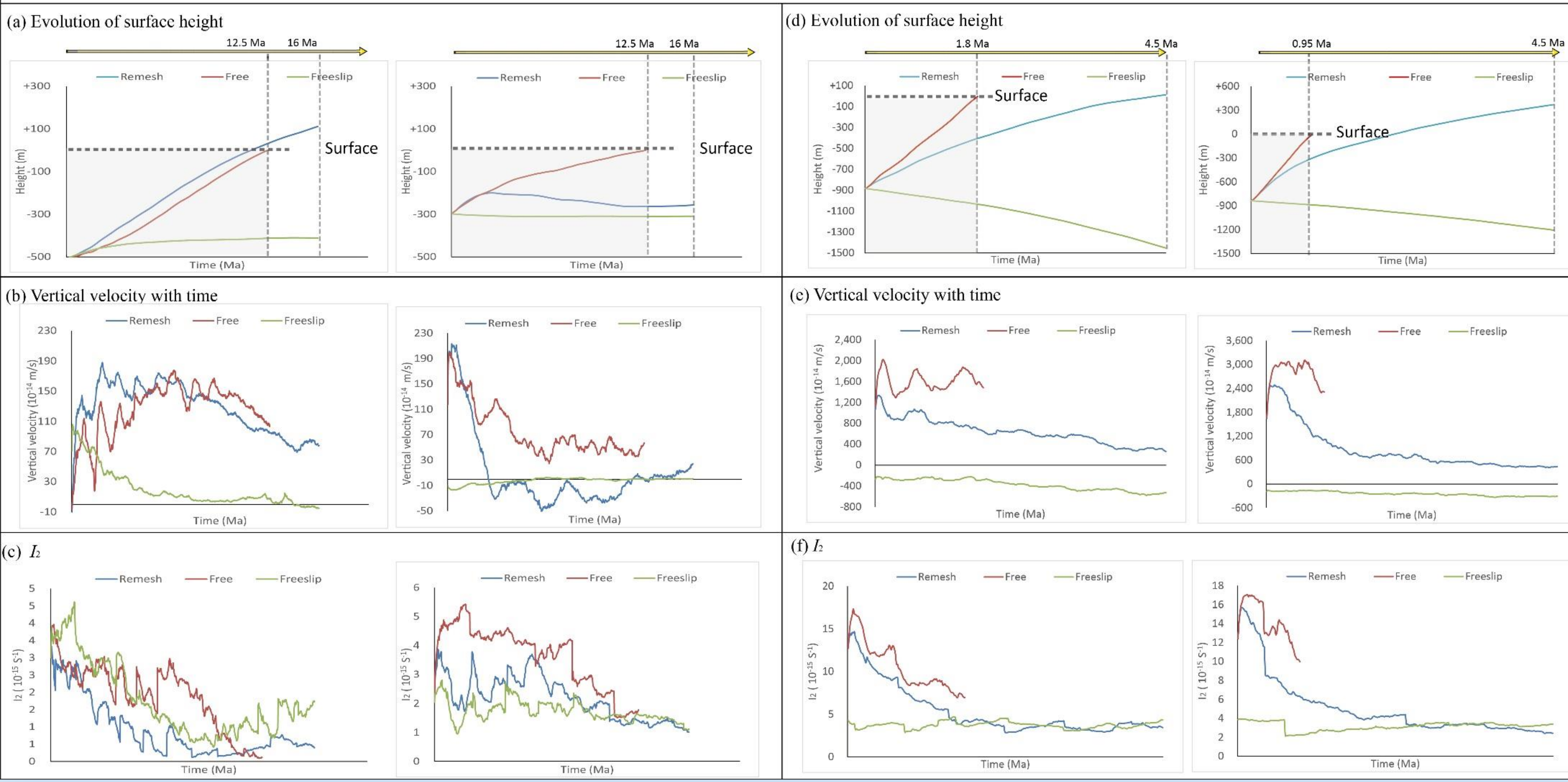
3. Result

Effect of the top surface boundary conditions

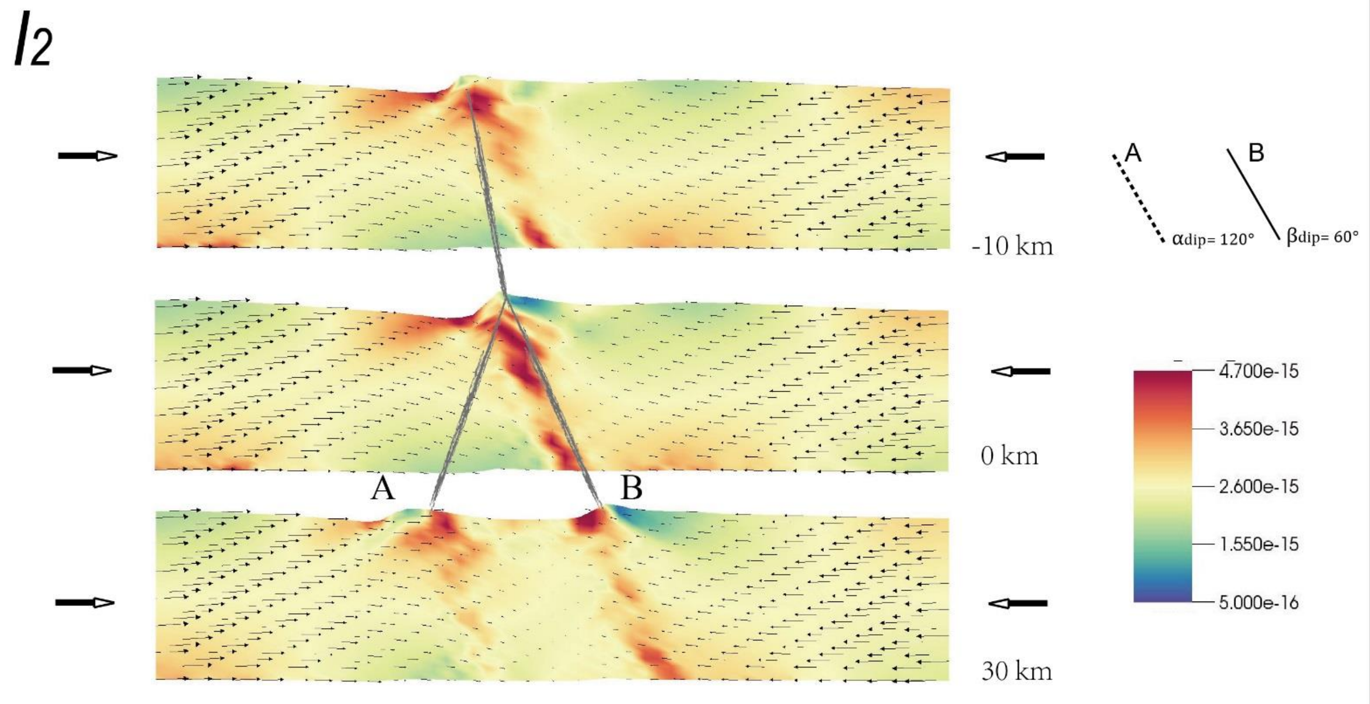
1. Freeslip, 2. Free, 3. Remesh

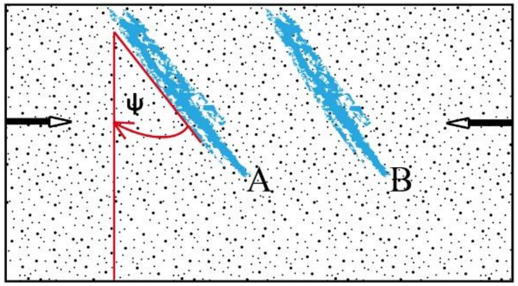
In simple shear (particle 1 and particle 2) | In compression (particle 3 and particle 4)

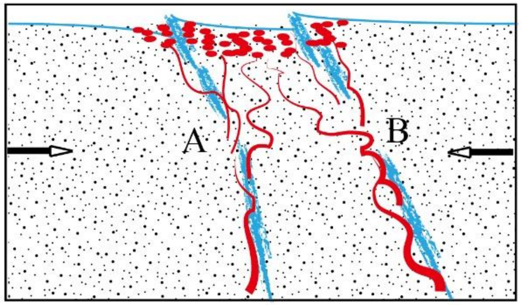


3. Result

Faults rotation under compressional boundary conditions.







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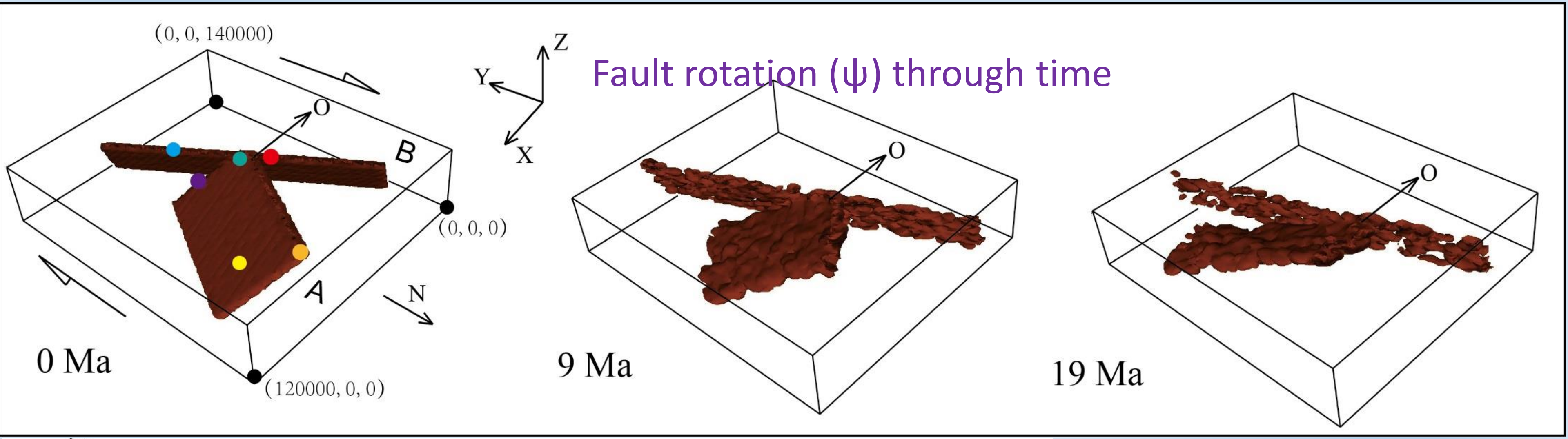
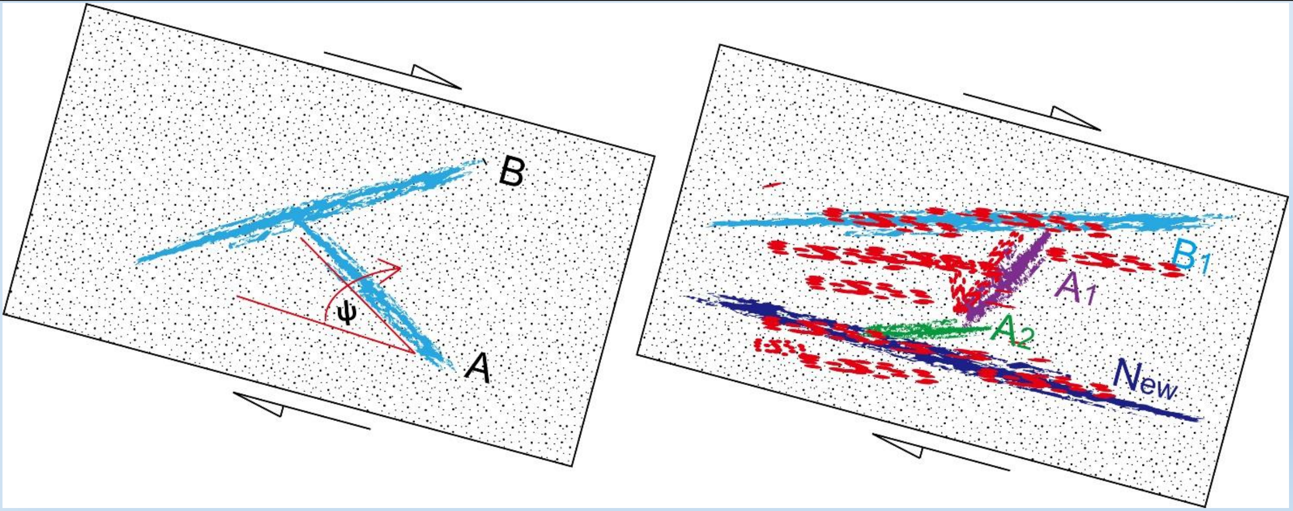
3. Result

Faults rotation under simple shear boundary conditions.





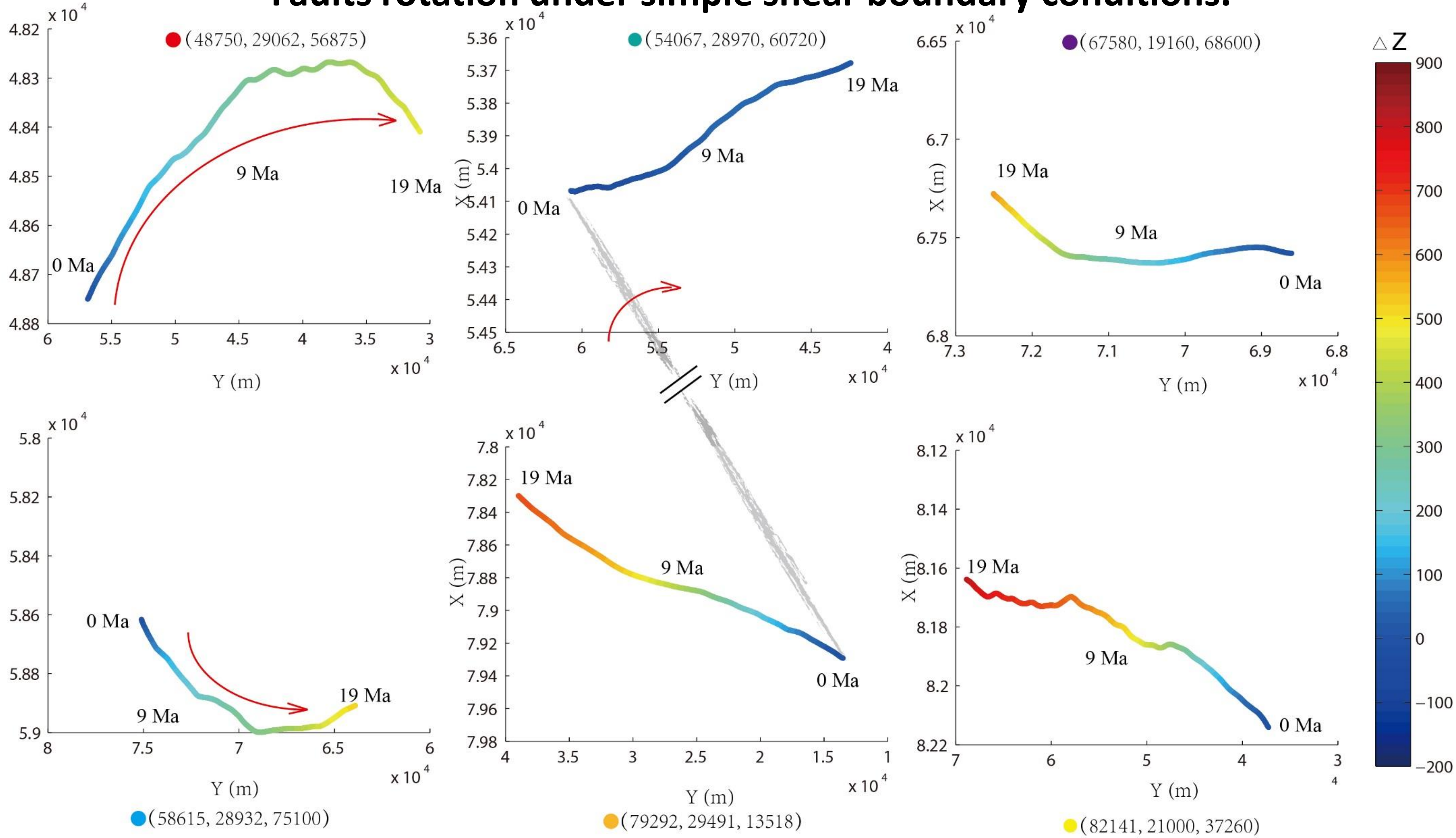
Sketch showing the evolution of faults geometries

Tensile: A1 + A2 + New

Shear: New + B1

3. Result

Faults rotation under simple shear boundary conditions.



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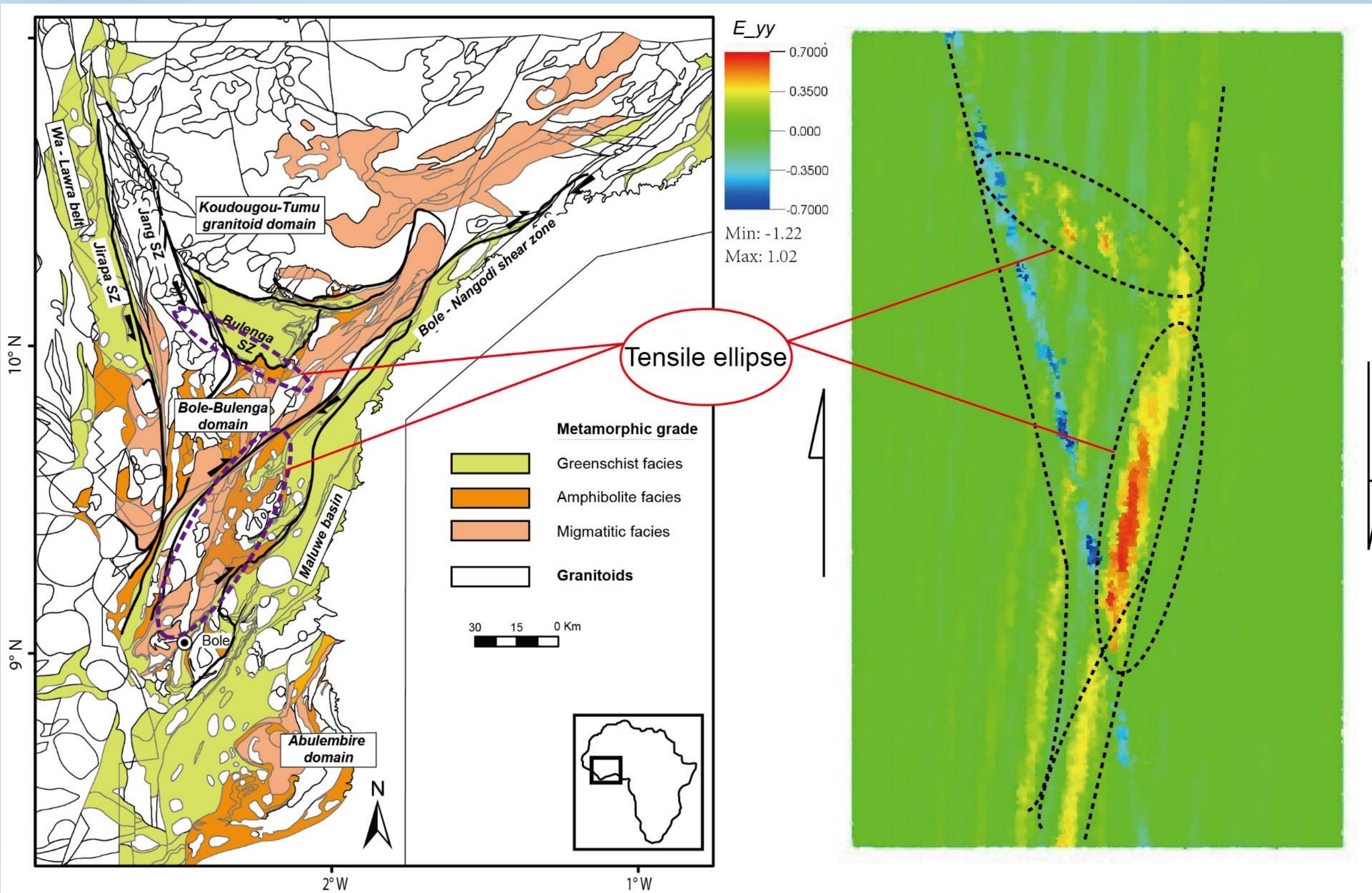
3. Result

Finite strain zones

Tensile in Red, Compressional in Blue



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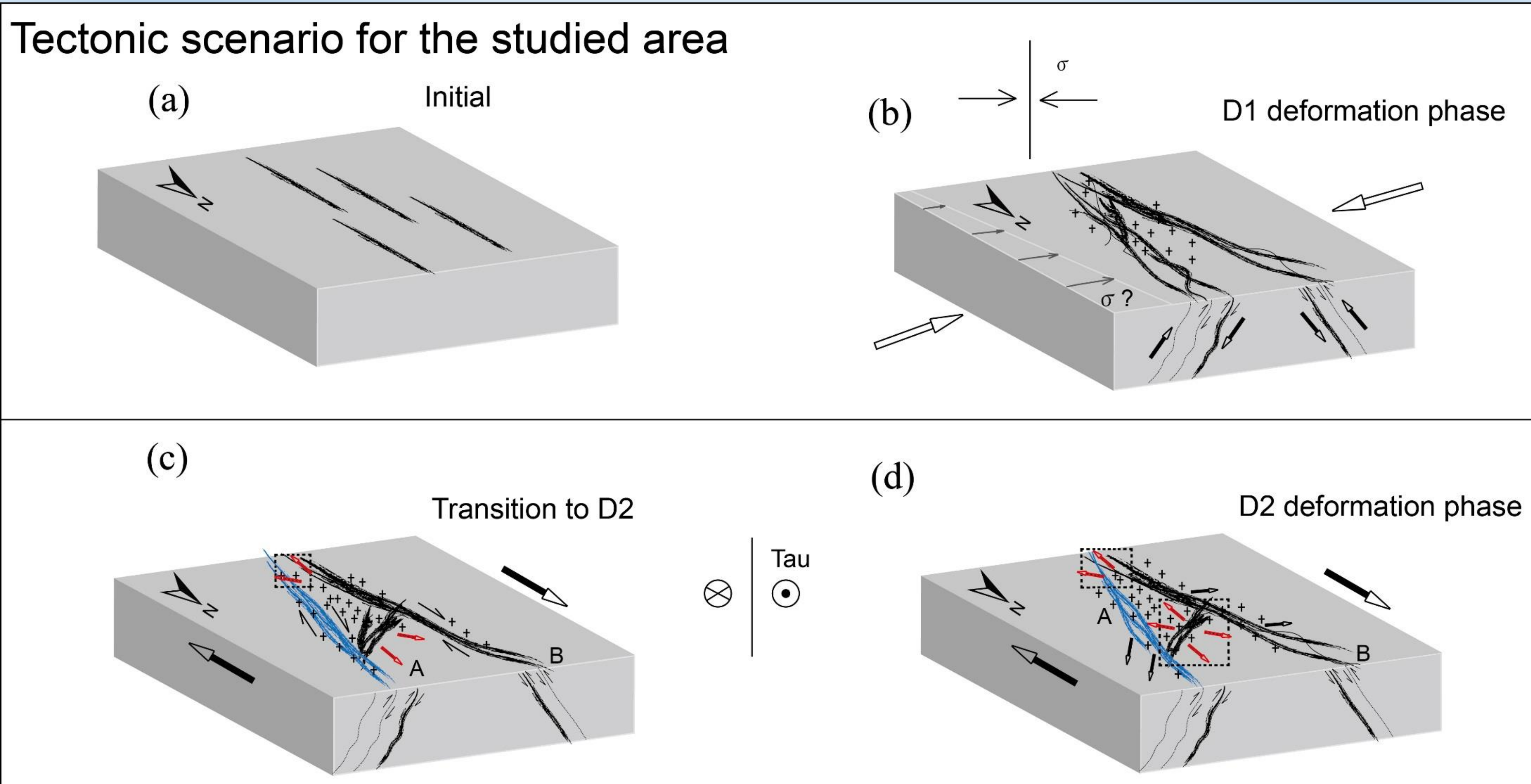
4. Reconstruction

D1 deformation phase: Compression

D2 deformation phase: Local extension



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Thank you!