

Weak Blocks in a Strong Matrix:

Exploring parameter-spaces for the biggest controls on subduction interface mechanics

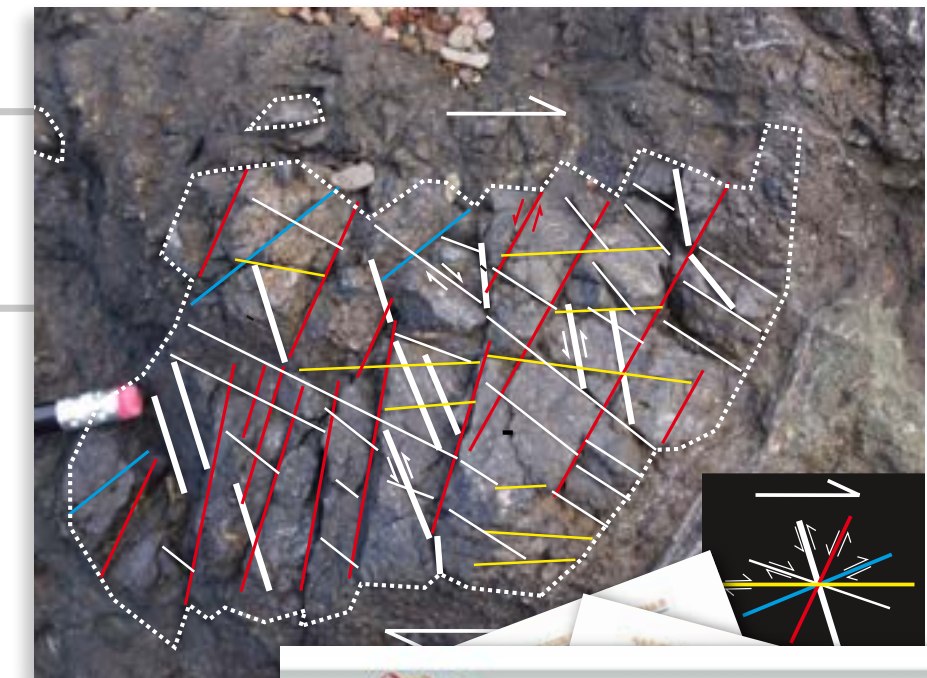
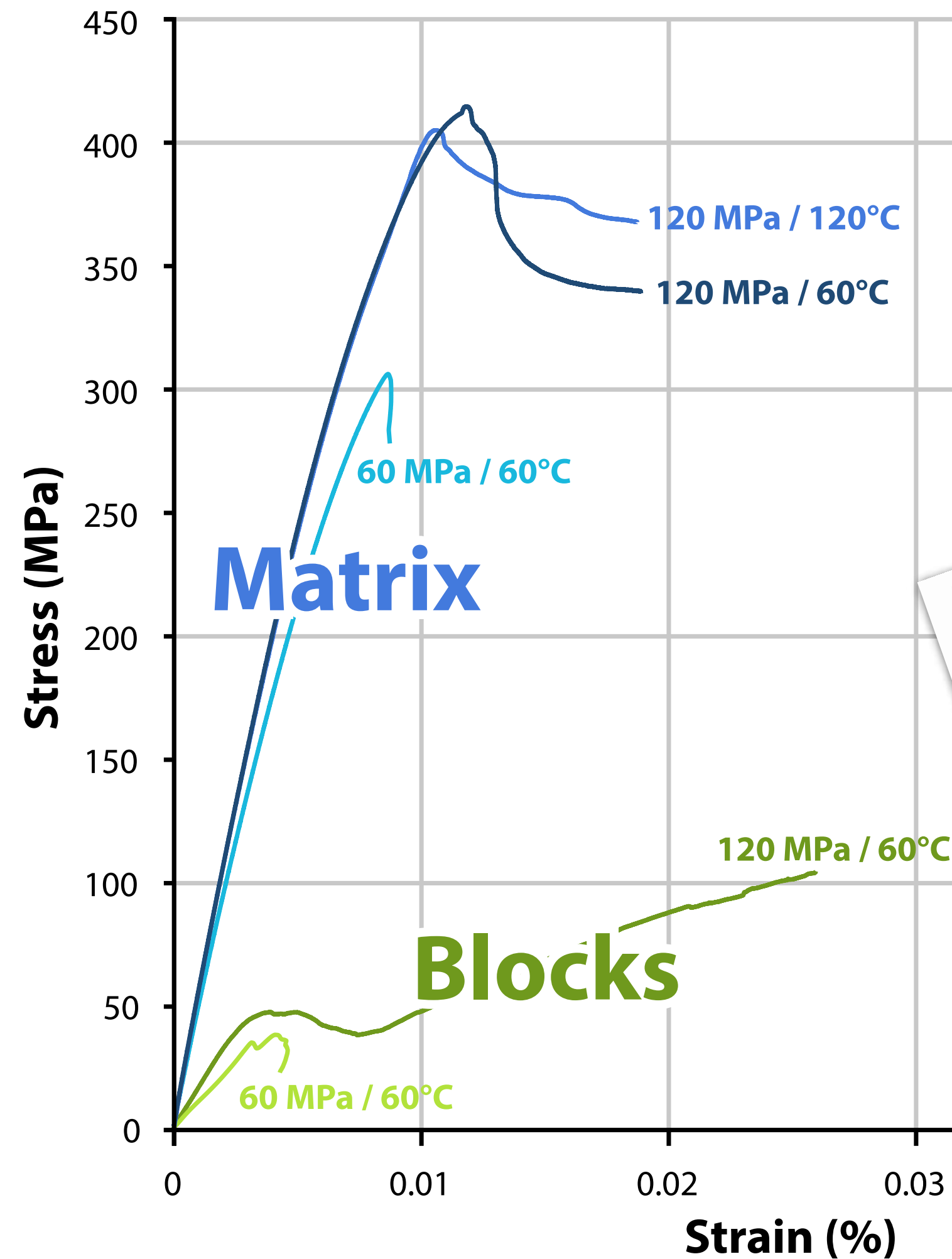
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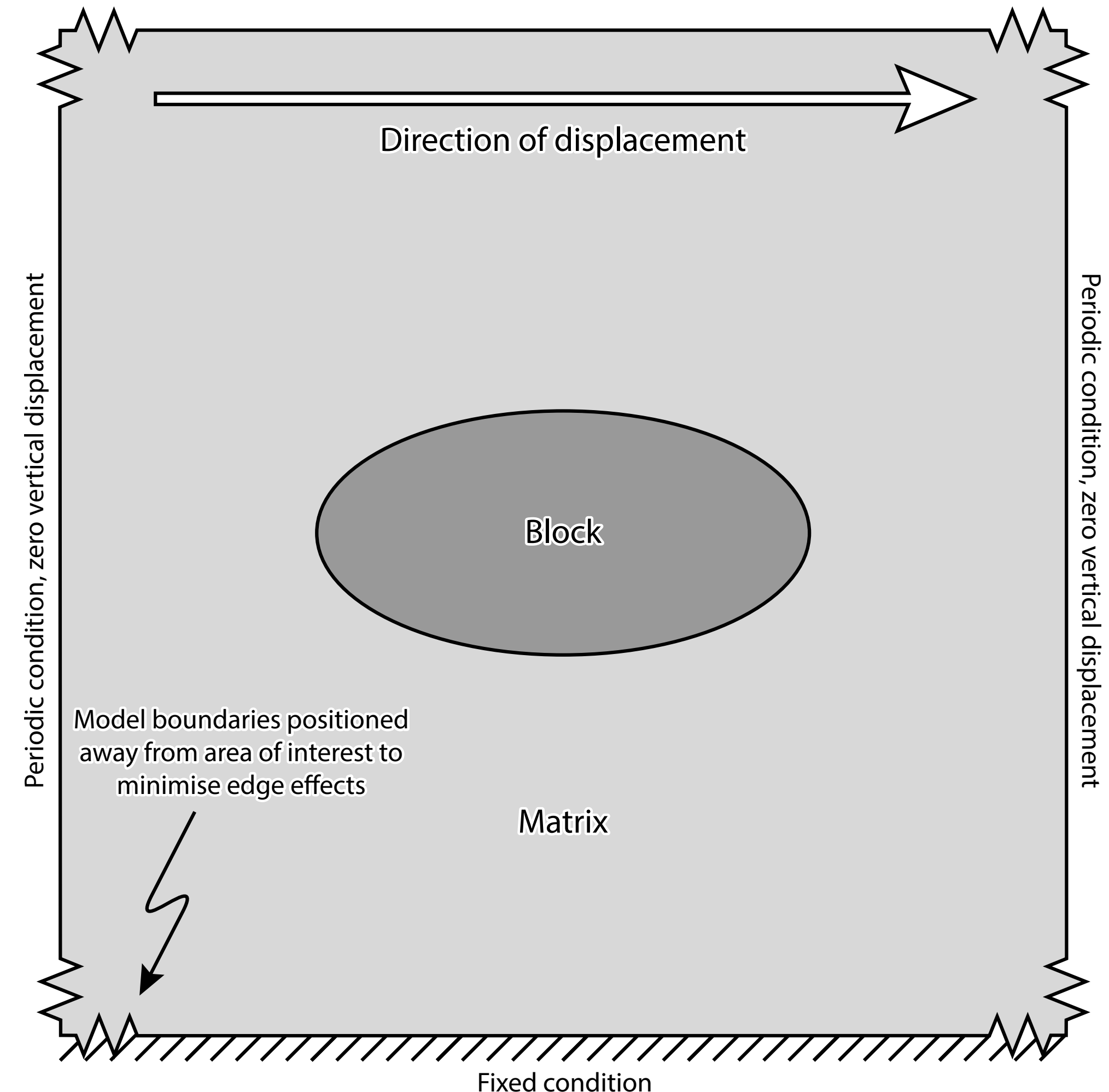
Inspiration for this Study

- Observations show that mélangé blocks can be weaker & more compliant than the matrix.
- Swarms of ruptures in weak blocks may produce tremor.
- Exploration of rheological & geometric properties possibility-space found that rheology (esp. Young's modulus) is the greatest control on shear zone stresses.



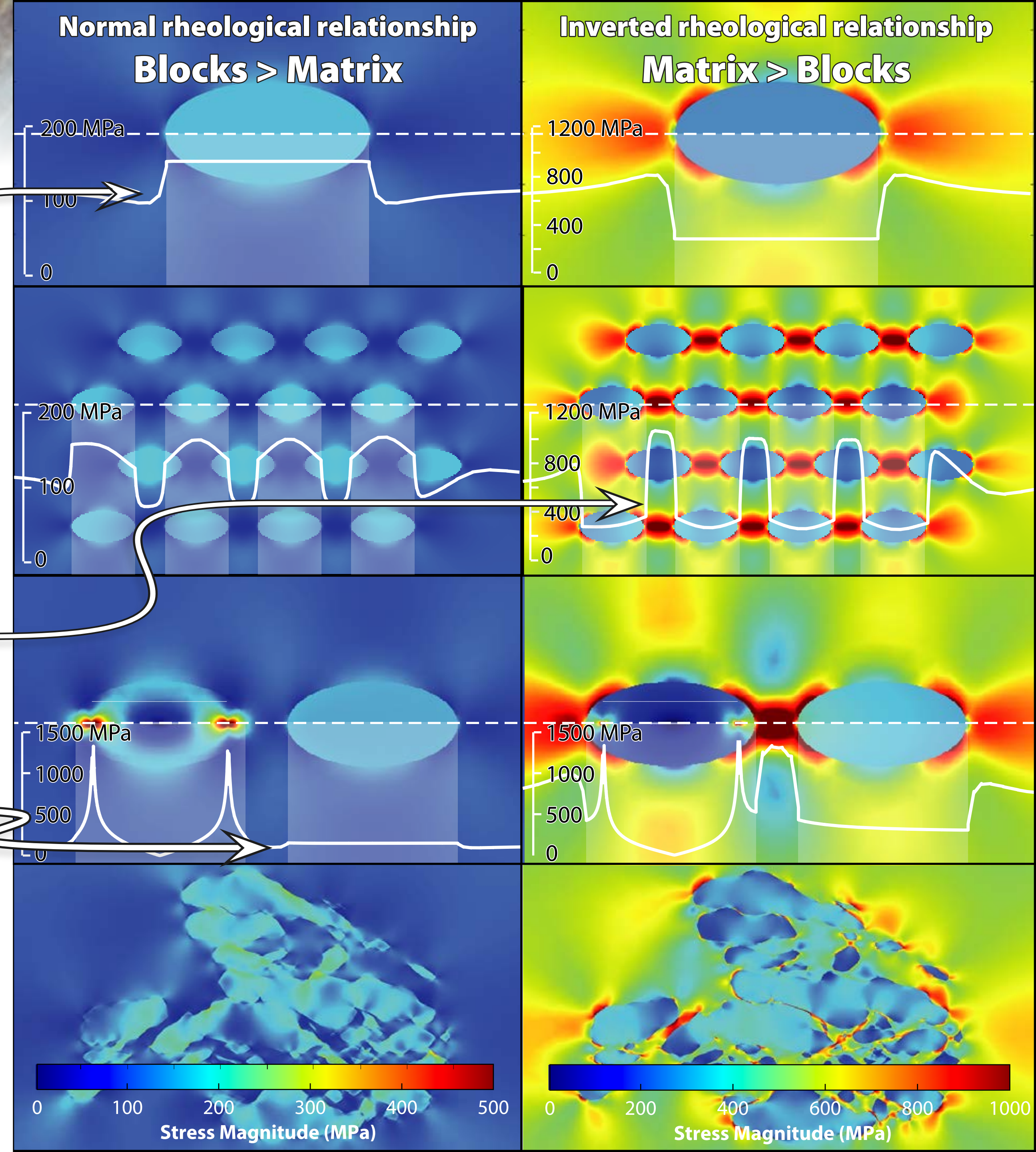
Numerical Modelling Setup

- FEM using Comsol Multiphysics®.
- 2D simple shear of Eshelby-style inclusions.
- Models show magnitude and location of Von Mises stress accumulations.
- **Geometric variables:**
 - Block proportion
 - Aspect ratio
 - Angularity
 - Orientation
- **Rheological variables:**
 - Young's modulus
 - Poisson's ratio



Stress Fields Around blocks

- Stresses in matrix approach those in blocks.
- Stress shadows around blocks interact when block spacing is sufficiently small.
- Compliant matrix insulates blocks from elevated stresses in neighbours.
- Patterns of stress fields controlled by geometry.



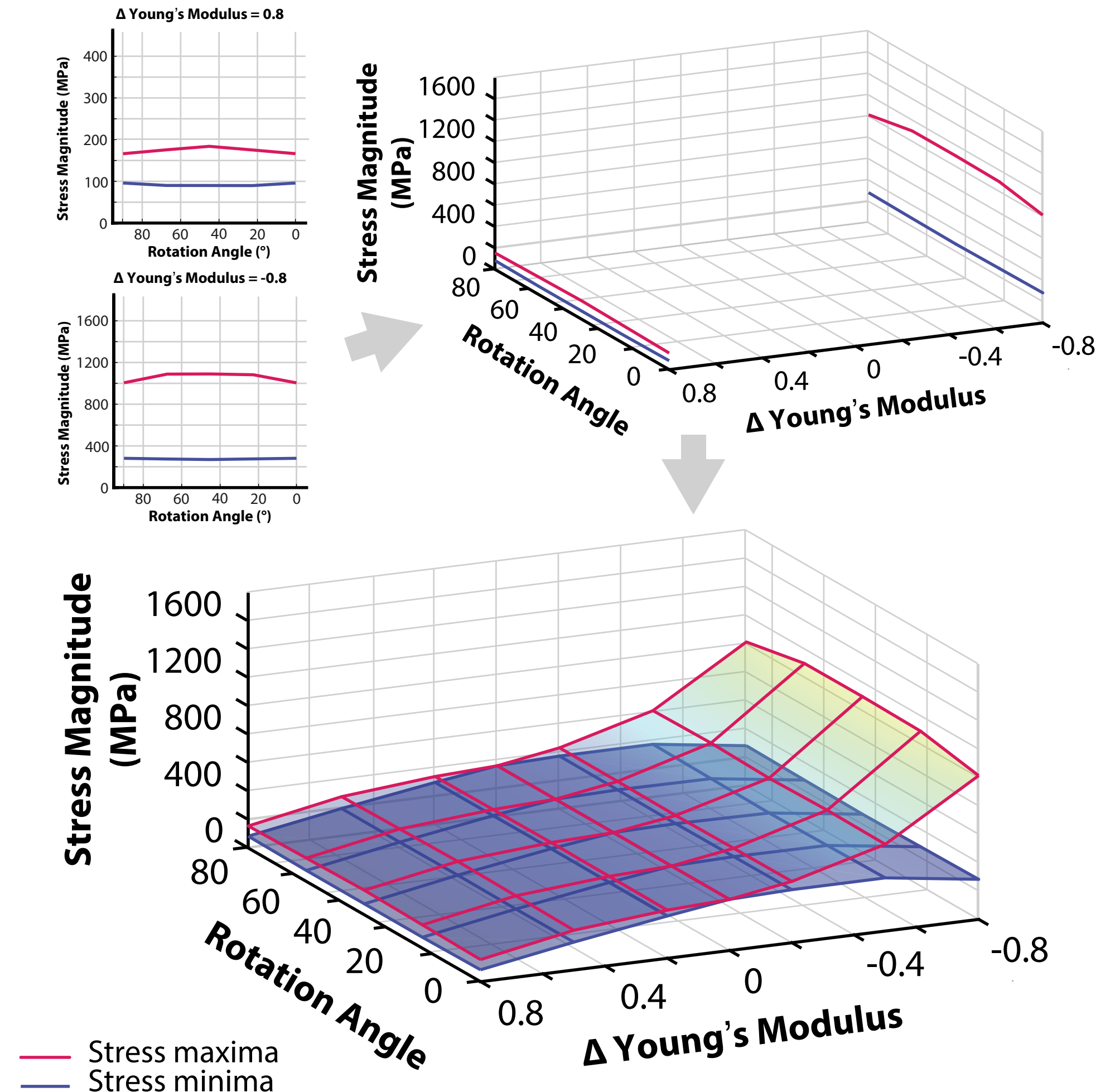
Defining Parameter-Spaces

- Parameters were varied systematically between models runs.
- Rheological properties varied in tandem to ensure consistent average rheologies.

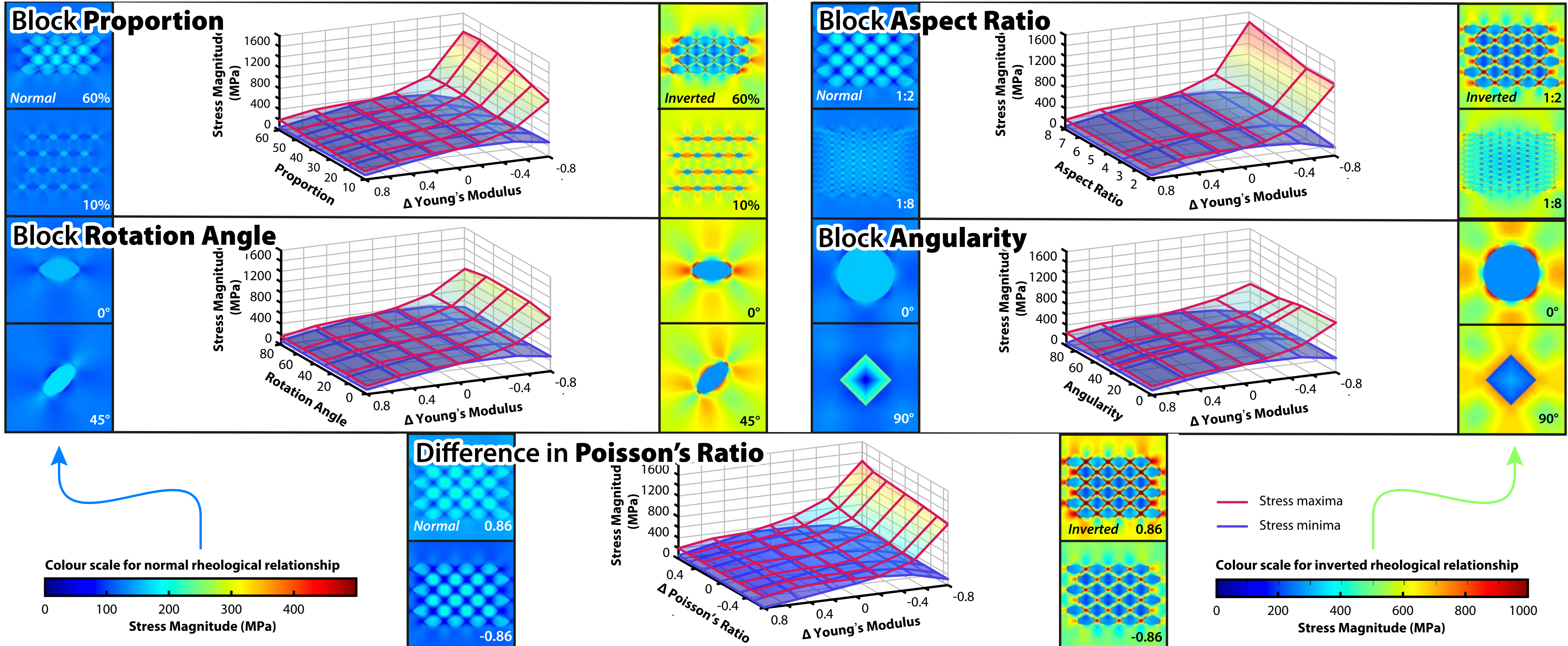
- $$\Delta E = \frac{E_{\text{block}} - E_{\text{matrix}}}{E_{\text{max}}}$$
 +ve: Blocks > Matrix
 -ve: Matrix > Blocks

E = Young's Modulus

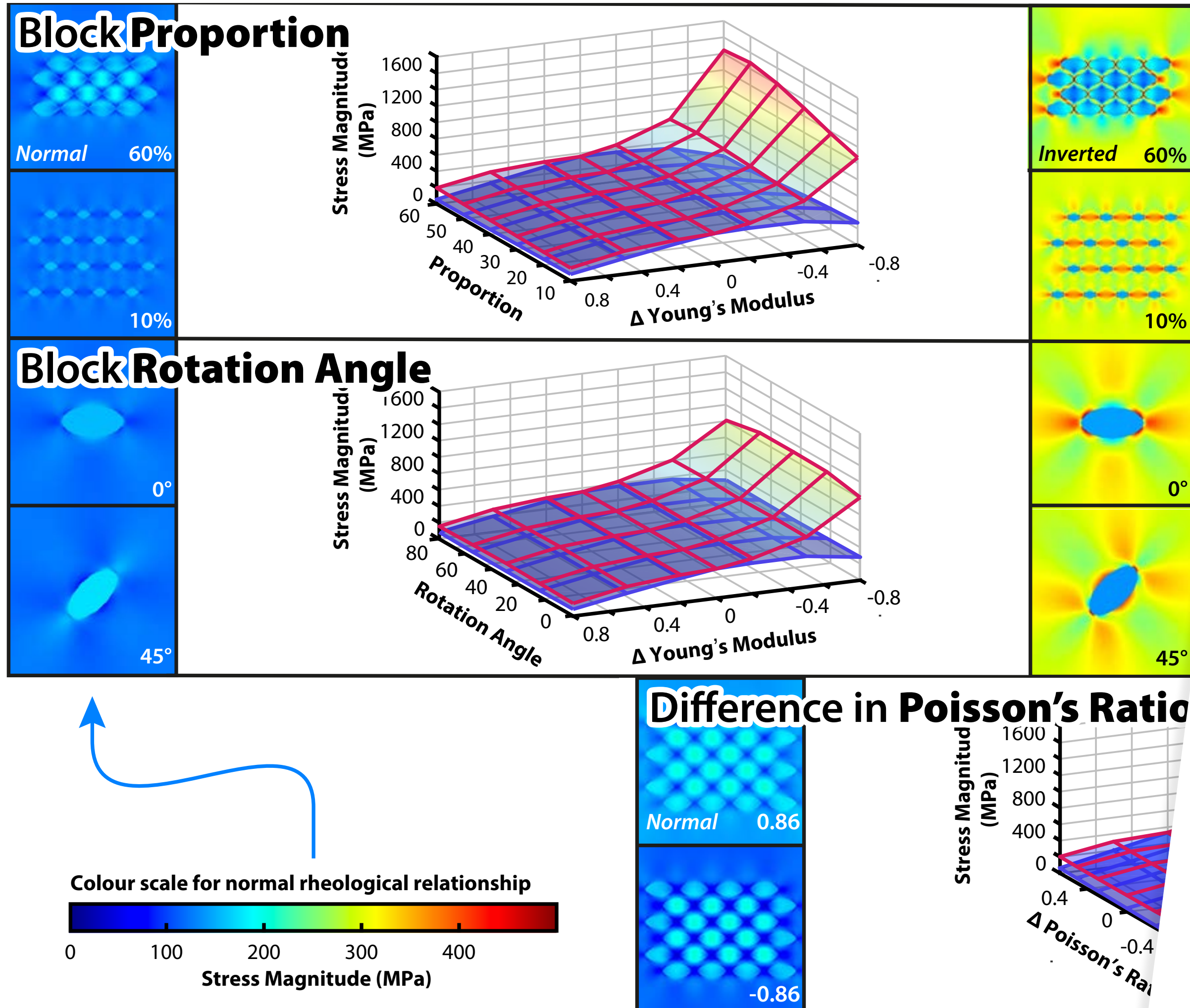
- 3D plots show variance of stress with Δ Young's modulus and other parameters.



Exploring Parameter-Spaces



Exploring Parameter-Spaces



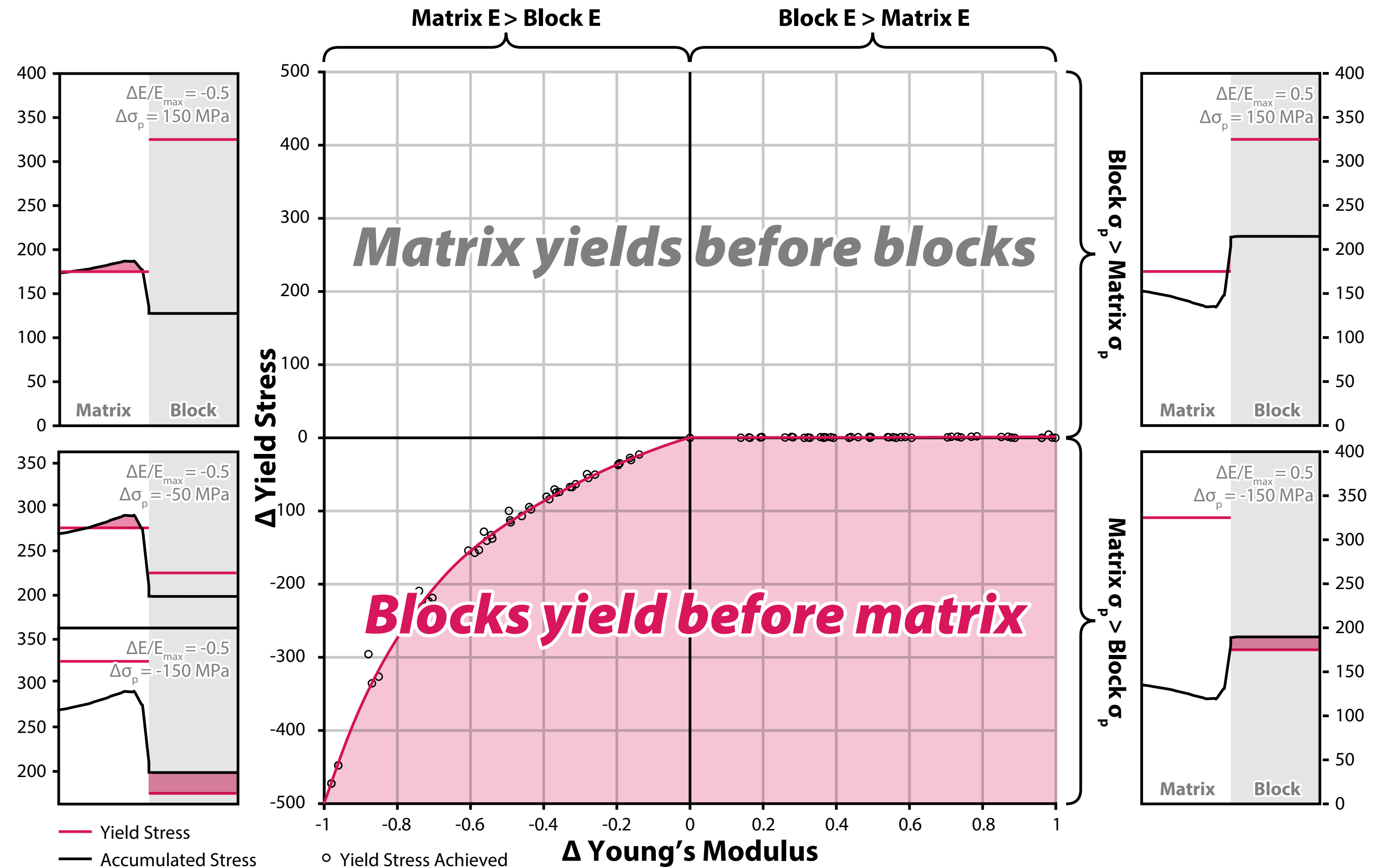
- Overall stresses and stress contrasts are greater in the inverted rheological relationship than the normal rheological relationship.
- Mélanges with an inverted rheological relationship can withstand less strain before permanent deformation.
- Varying other parameters results in changes to stress magnitudes which are an order of magnitude less than varying Young's modulus.

Normal Rheological Relationship Inverted Rheological Relationship

- | | |
|--------------------------------|--------------------------------|
| ↗ Block proportions = ↗ stress | ↗ Block proportions = ↗ stress |
| ↗ Aspect ratio = ↘ stress | ↗ Aspect ratio = ↗ stress |
| ↗ Angularity = ↗ stress | ↗ Angularity = ↘ stress |
| ↘ 45° Rotation = ↗ stress | ↘ 45° Rotation = ↗ stress |

Which Yields First?

- As stresses in compliant matrix approach stresses in blocks, if the matrix has a lower yield stress, it will yield first.
- In inverted rheological relationship, which yields first depends on interplay between $\Delta E/E_{\max}$ and $\Delta\sigma_p$.
- If compliant matrix yields before blocks, matrix flows around blocks and stress accumulations in blocks can slow or stop increasing.
- If matrix is more rigid than blocks, external blocks geometry is dictated by the matrix and stresses in blocks continue to accumulate throughout.



Take-Away Messages

- 1 Rheological controls on stress accumulations have an order of magnitude greater effect than geometric controls.**
- 2 Inverted rheologies facilitate shear failure in blocks without block-to-block contact.**
- 3 Parameter-space visualisations aid understanding of complex interactions between the many factors which influence subduction shear zone behavior.**