

Strong Matrix & Weak Blocks

Evolutionary Inversion of Mélange Rheological Relationships During Subduction and its Implications for Seismogenesis

***Alexander P. Clarke**, Paola Vannucchi,
Audrey Ougier-Simonin, Jason Phipps Morgan*

What's a M^élange?

- Block-in-matrix texture
- Significant mixing

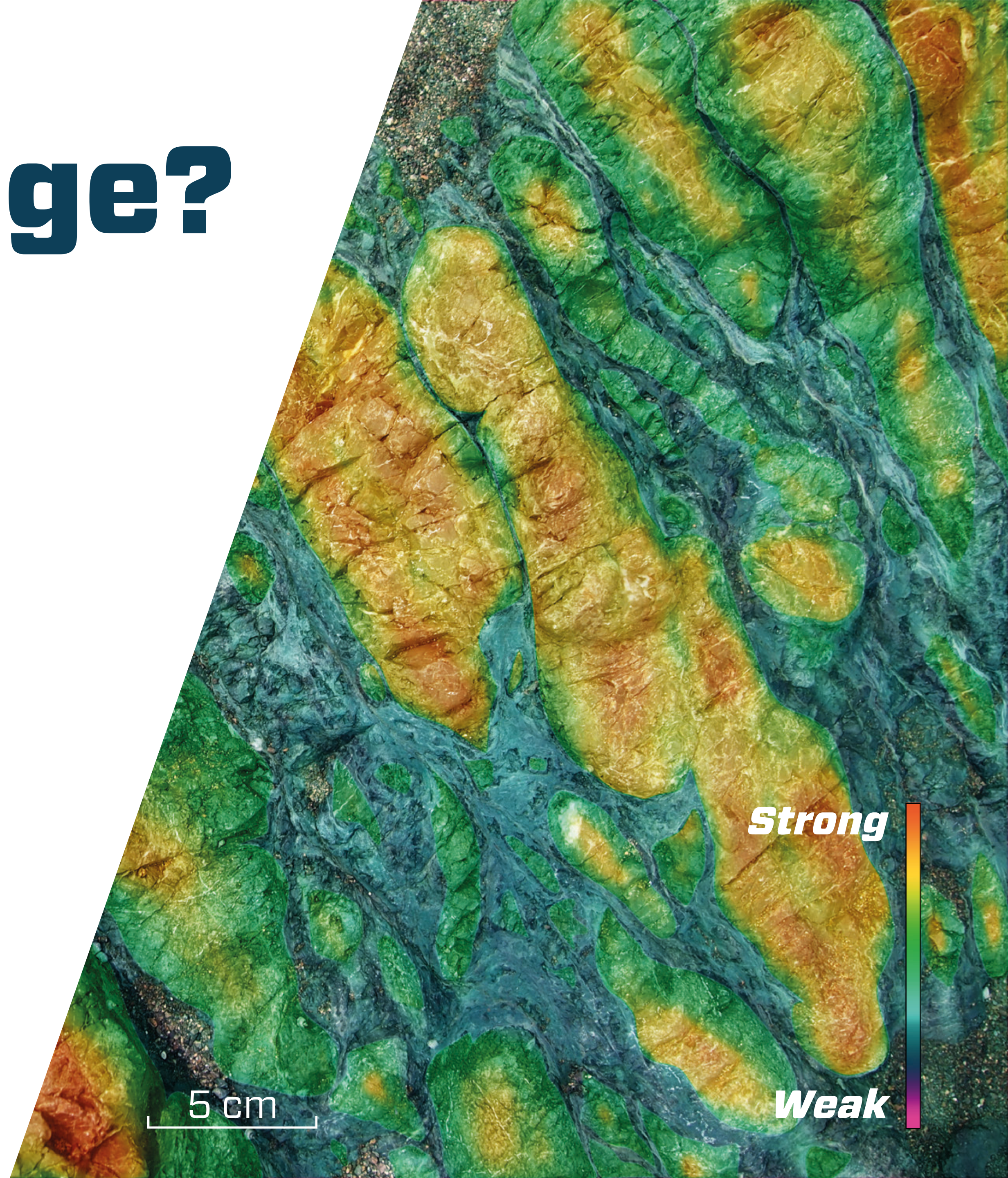
Commonly found in subduction settings. Exhumed mélanges are often used as analogues for heterogenous fault zones.



What's a Mélange?

- Block-in-matrix texture
- Significant mixing

Typically conceived of as strong blocks within a weak matrix. We found weak blocks within a strong matrix.

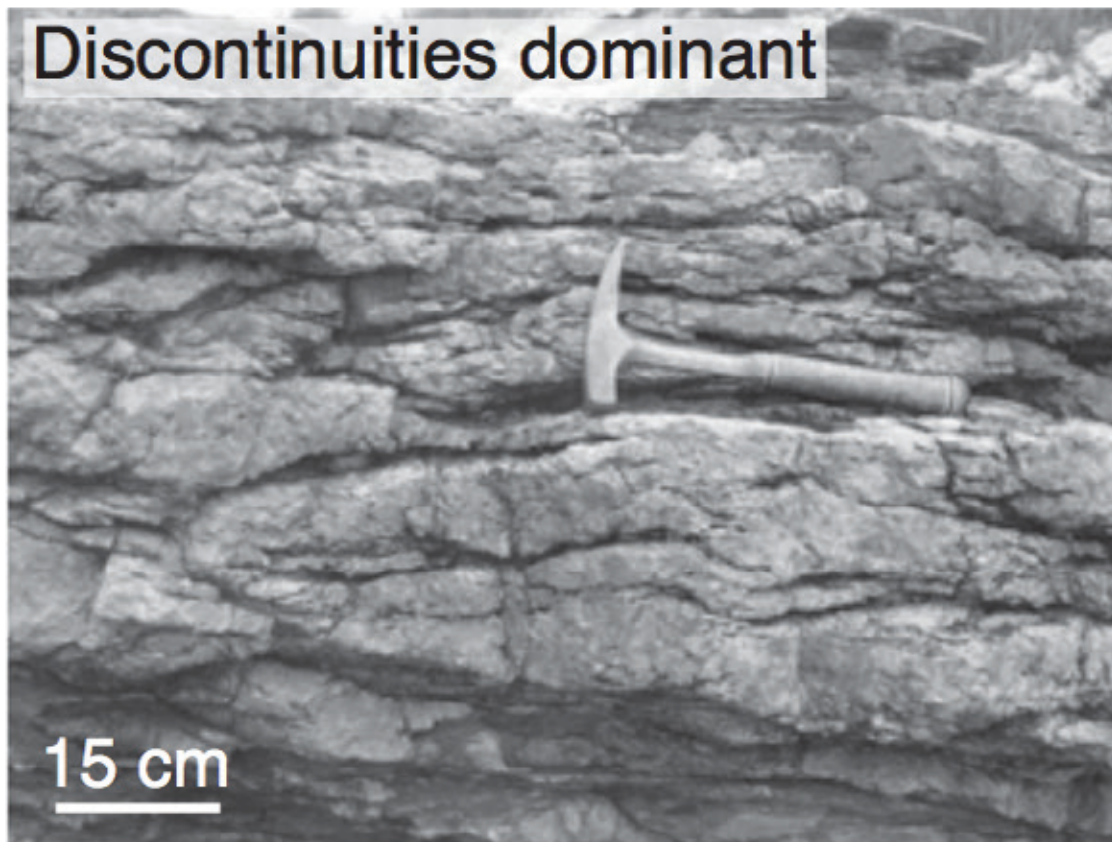


WH

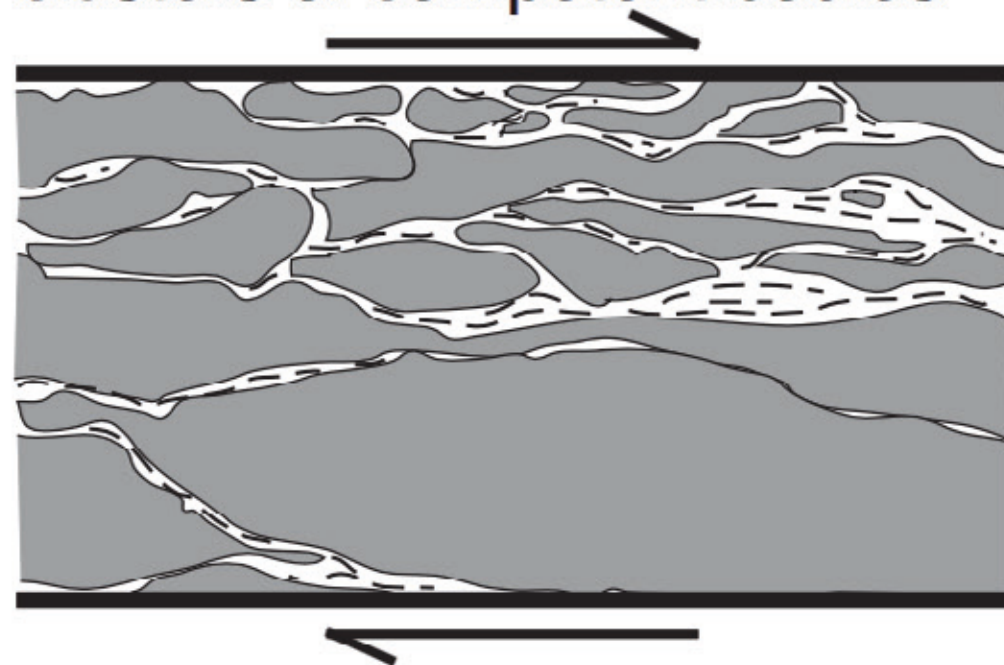
- Blo
- Sig

Typical
blocks
found
strong

Increasing ratio of incompetent/competent material →

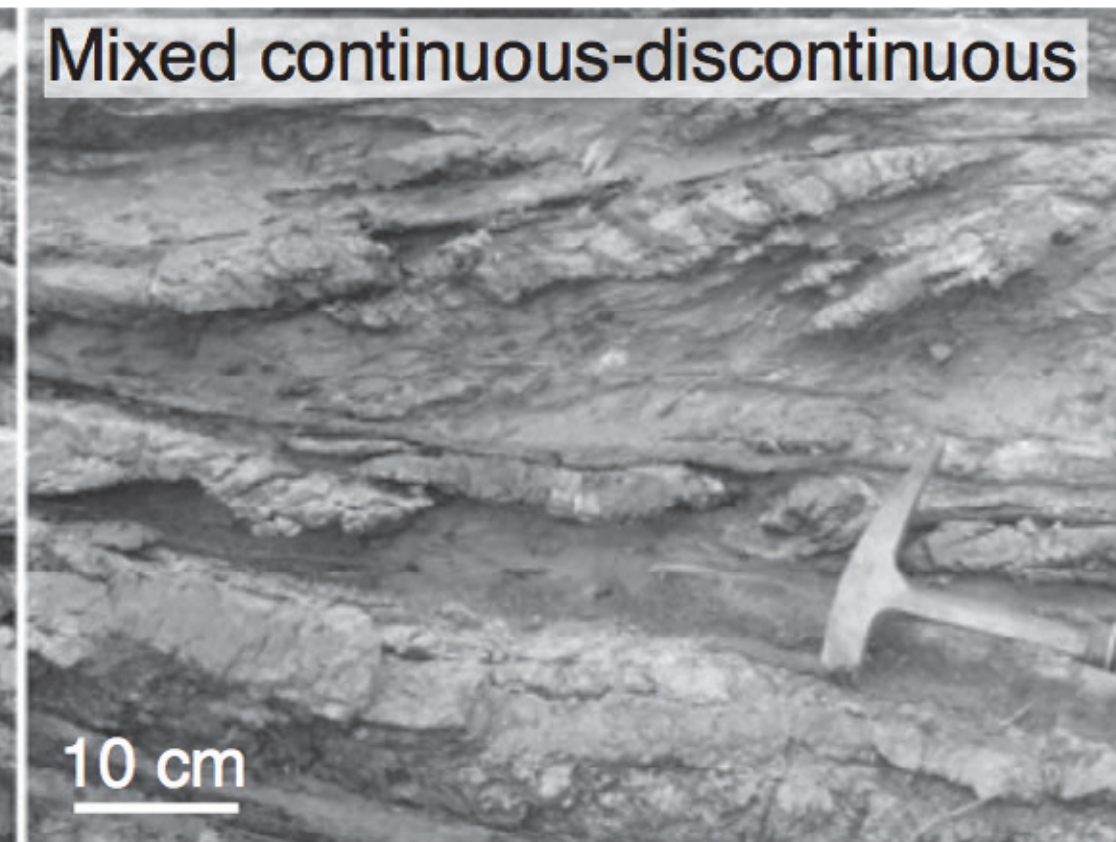


Seismic slip at kilometer-scale possible in interacting clusters of competent bodies

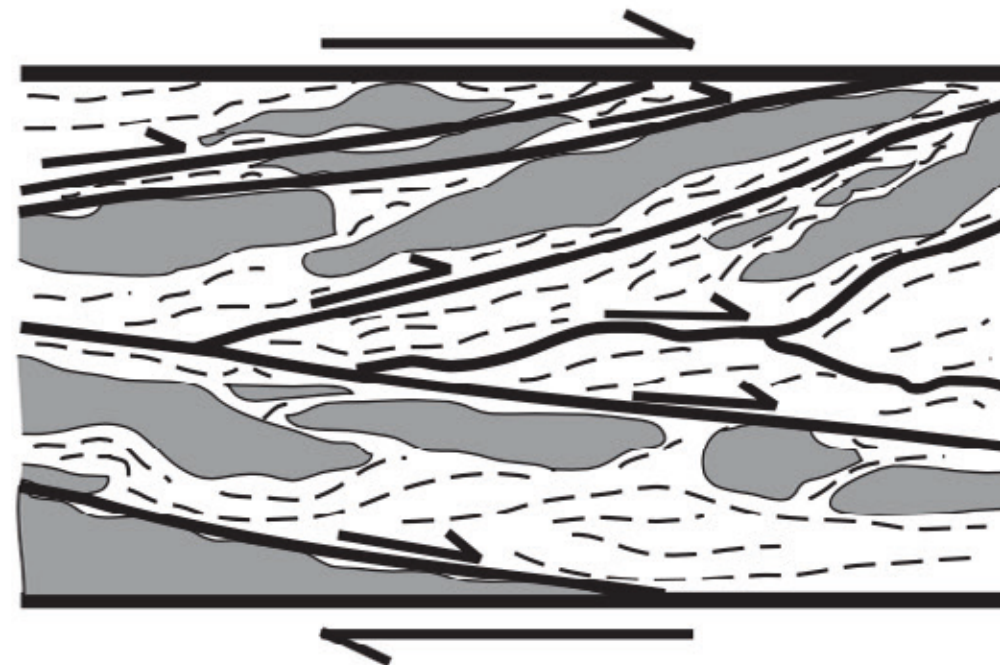


High interaction through stress bridges

Localized peaks in shear strain rate

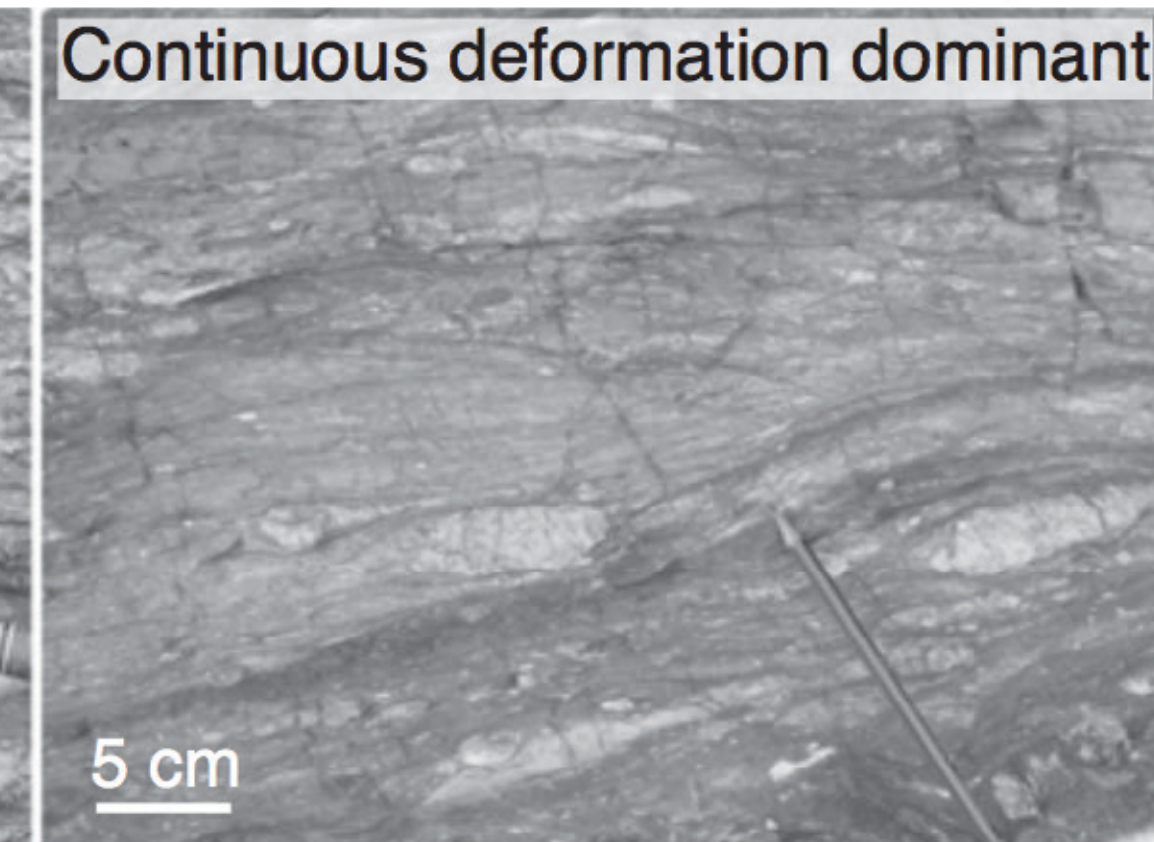


< meter scale seismic slip possible

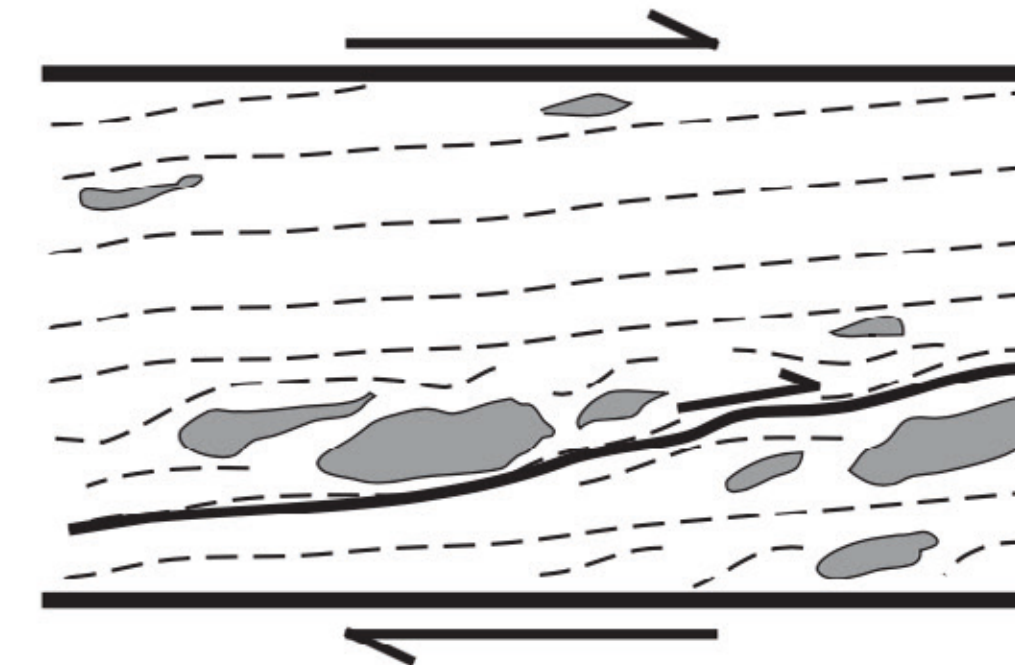


Moderate interaction between competent bodies

Fluctuating shear strain rates



Microseismically active, flowing zone, large ruptures do not nucleate but may propagate through



Low interaction between competent bodies

Fairly uniform shear strain rates

Fagereng & Sibson (2010)

Strong

Weak

Upfront Conclusions

- ***Weak blocks & strong matrix***

Blocks may evolve to be mechanically weaker than the surrounding matrix.

- ***Strength inversion occurs early***

Strength inversion occurs at shallow depths within Subduction Zone.



 *You are here*

 **Costa Rica**



Middle America Trench

*Convergence
Vector*

*Osa
Peninsula*

Cocos Ridge

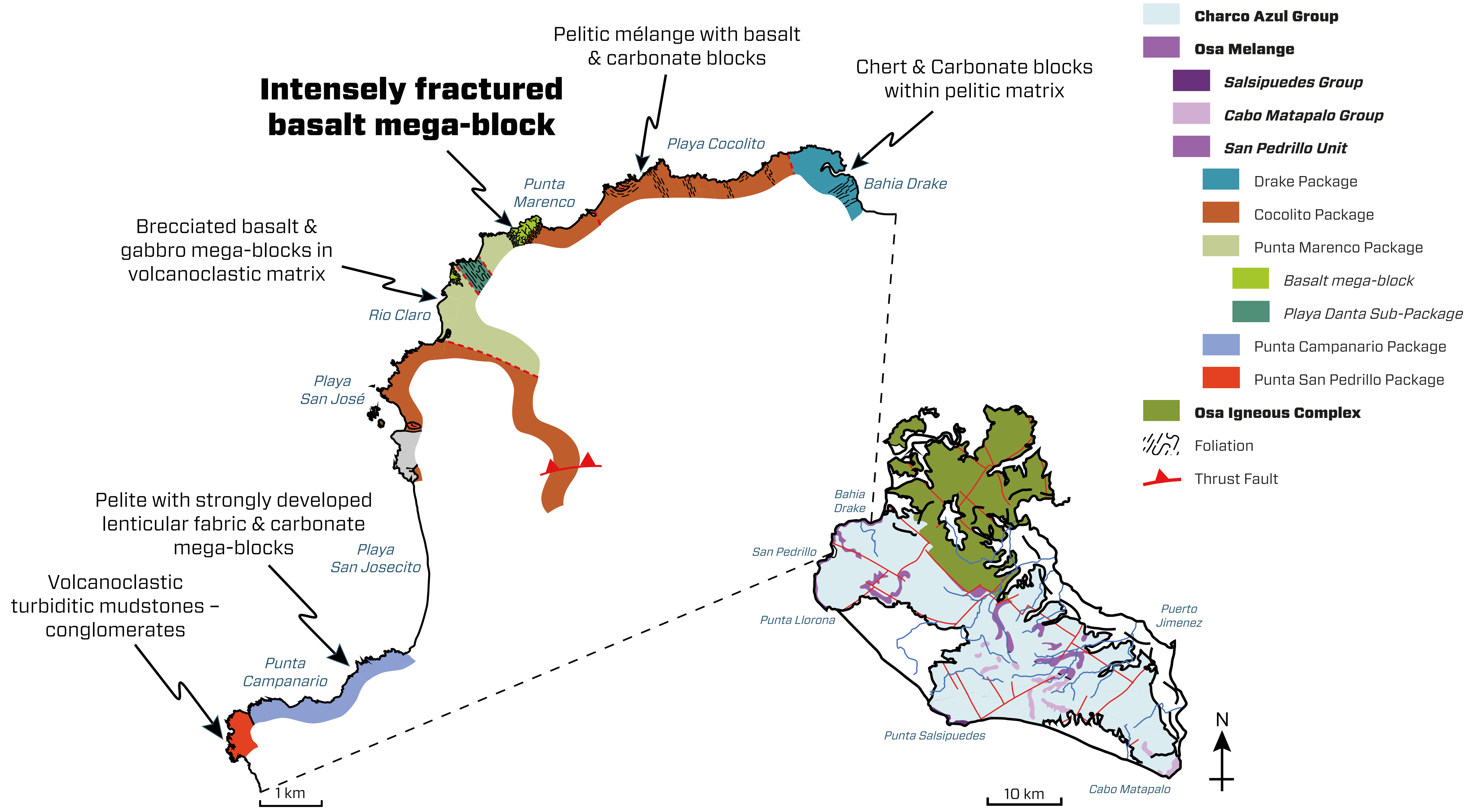


Cocos Ridge

Osa Mélange

OIC

Costa Rica



**Intensely fractured
basalt mega-block**

Pelitic mélange with basalt
& carbonate blocks

Chert & Carbonate blocks
within pelitic matrix

Brecciated basalt &
gabbro mega-blocks in
volcanoclastic matrix

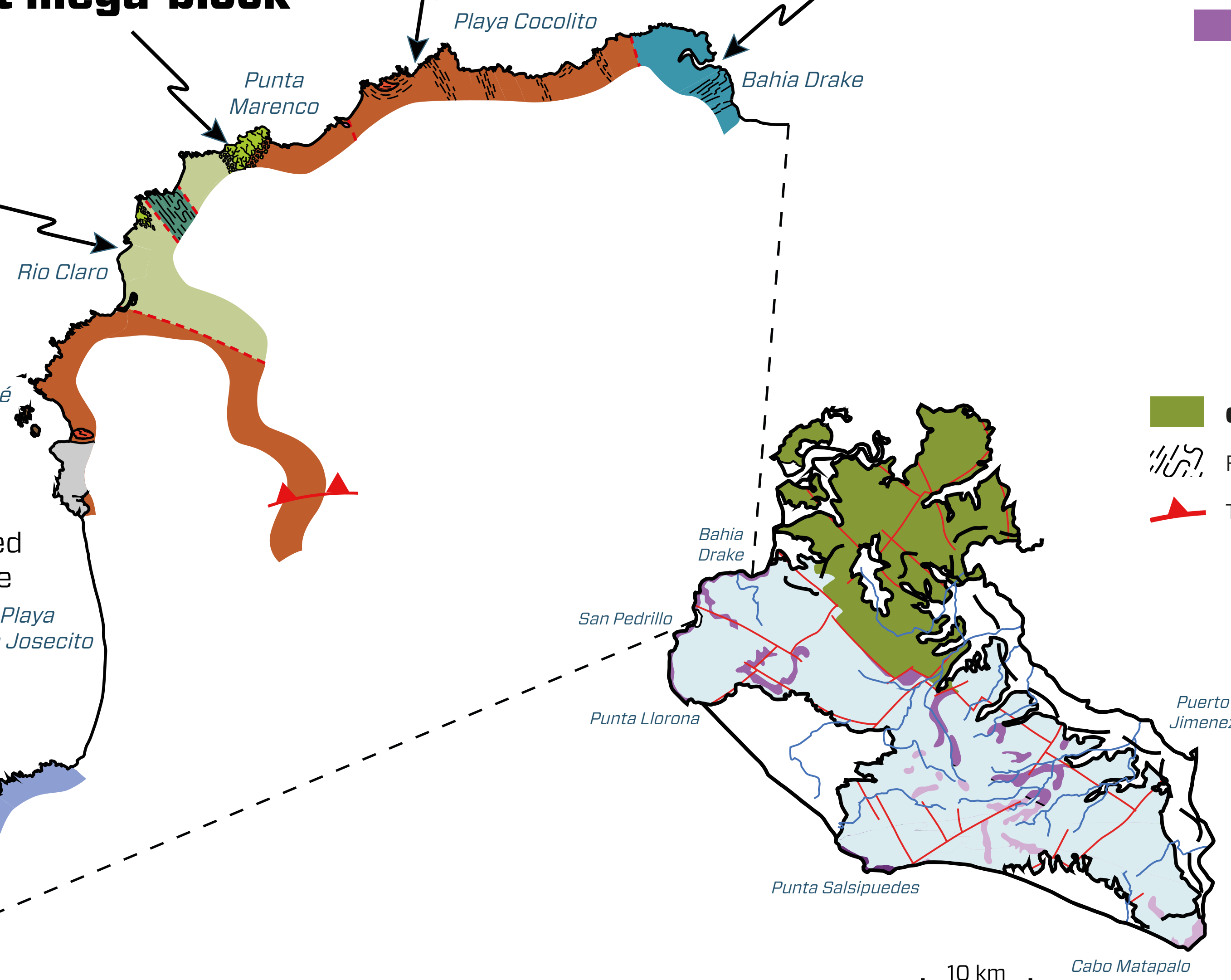
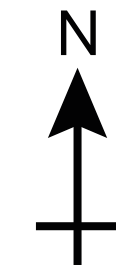
Pelite with strongly developed
lenticular fabric & carbonate
mega-blocks

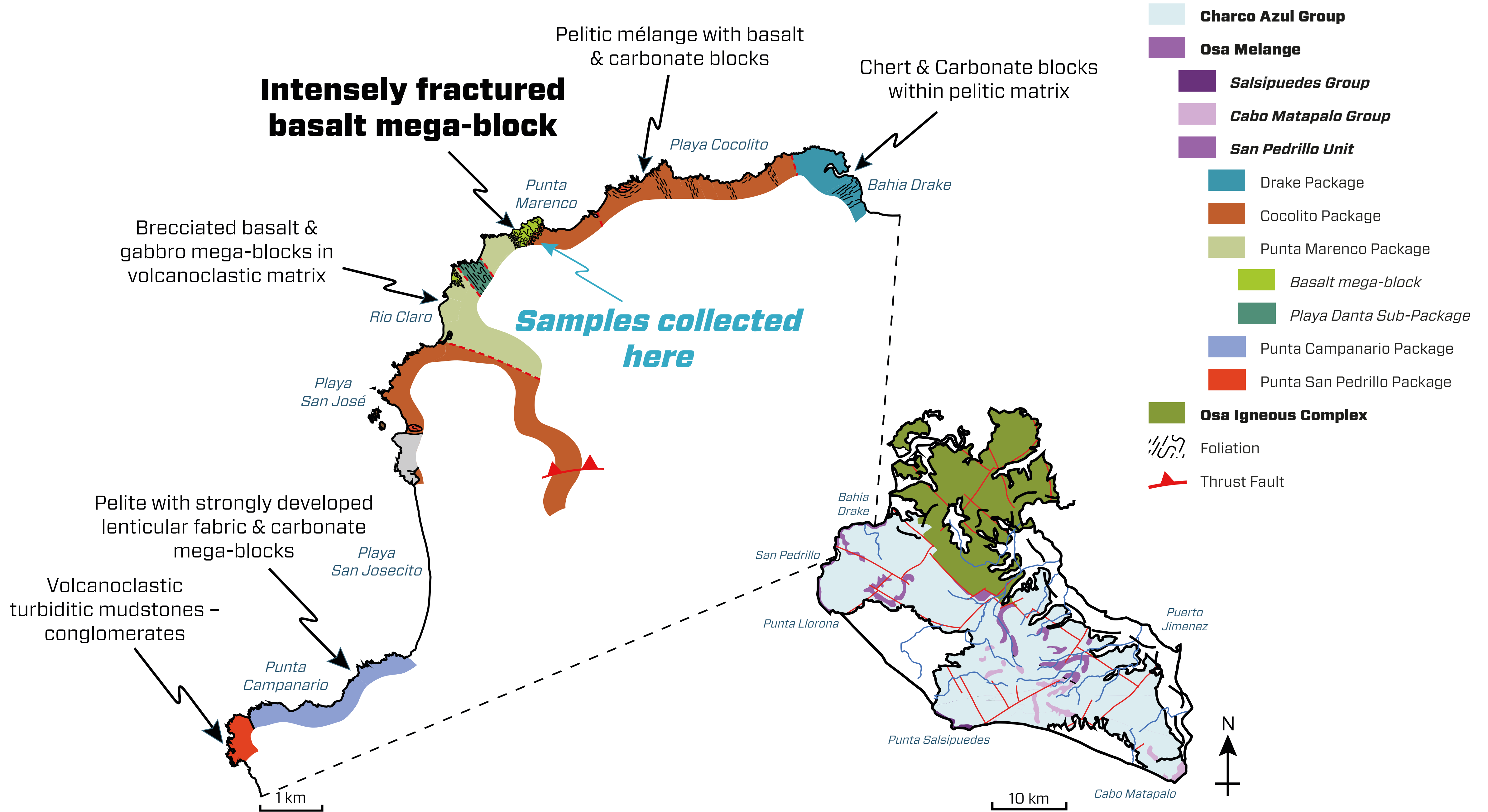
Volcanoclastic
turbiditic mudstones -
conglomerates

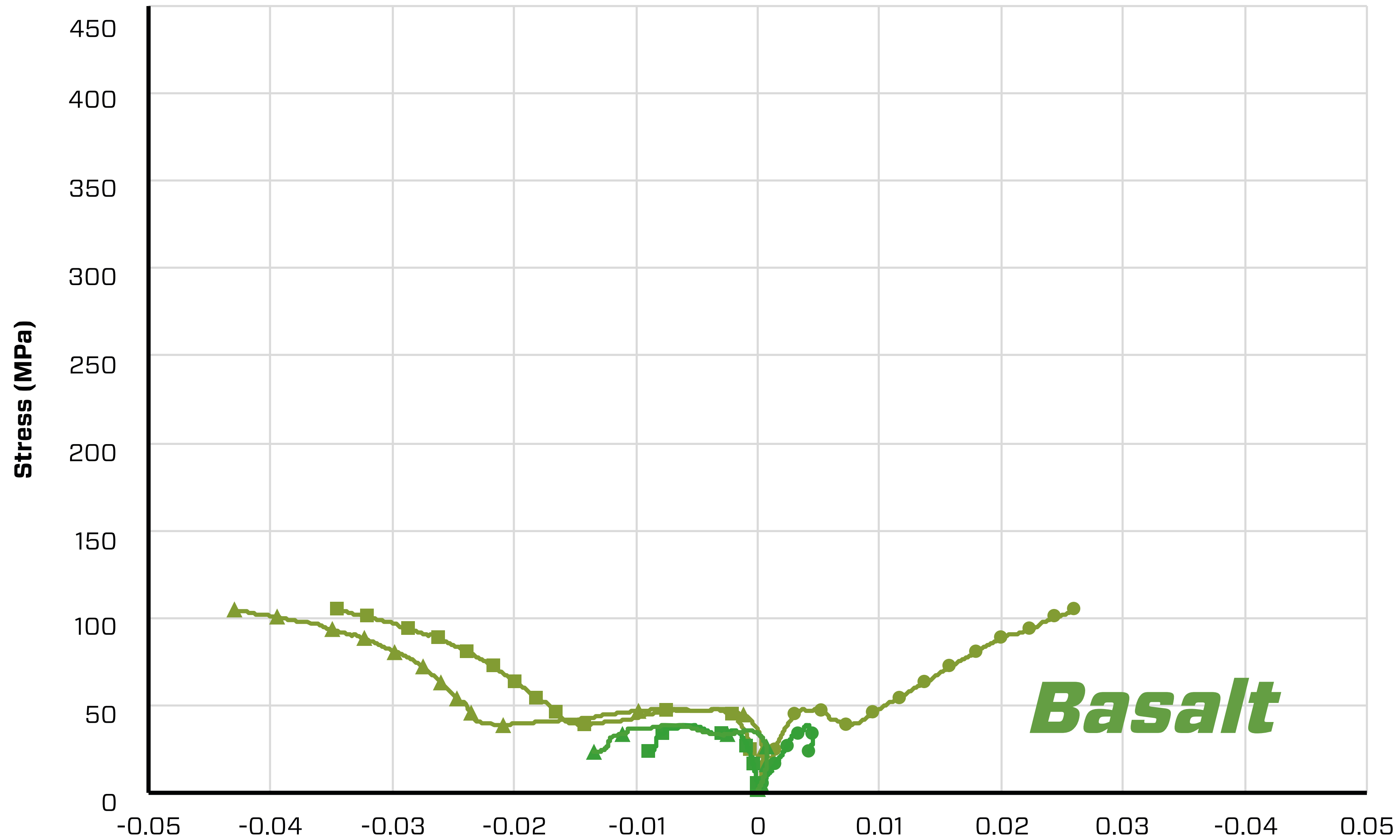
- Charco Azul Group**
- Osa Melange**
- Salsipuedes Group**
- Cabo Matapalo Group**
- San Pedrillo Unit**
- Drake Package
- Cocolito Package
- Punta Marengo Package
- Basalt mega-block
- Playa Danta Sub-Package
- Punta Campanario Package
- Punta San Pedrillo Package
- Osa Igneous Complex**
- Foliation
- Thrust Fault

1 km

10 km







Basalt

60 MPa / 60°C

120 MPa / 60°C

Basalt

Porosity **5.7 %**

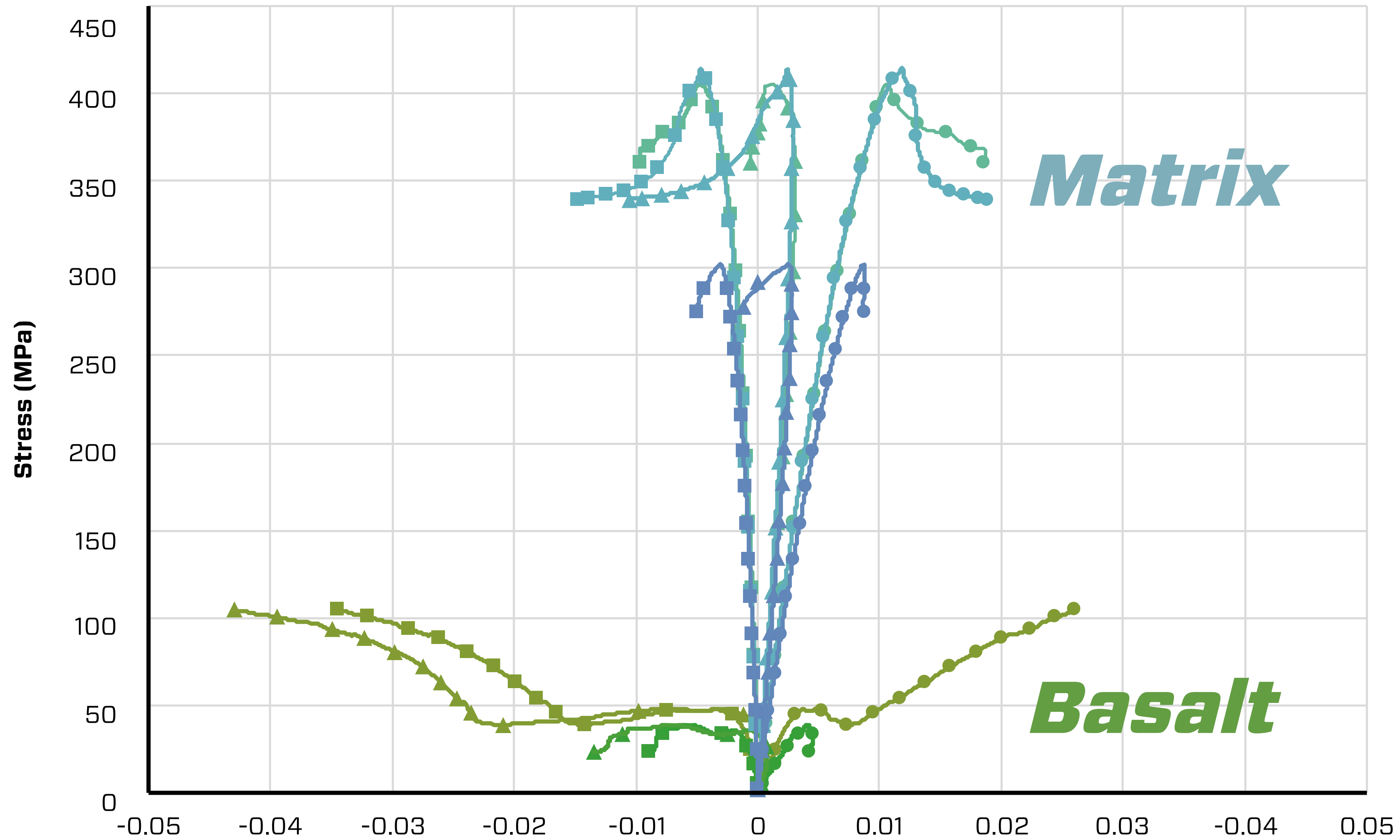
Density **2.9 Mg/m³**

Basalt

● Axial Strain

■ Circumferential Strain

▲ Volumetric Strain



Basalt

60 MPa / 60°C

120 MPa / 60°C

Matrix

60 MPa / 60°C

120 MPa / 60°C

120 MPa / 120°C

Basalt

Porosity **5.7 %**

Density **2.9 Mg/m³**

Matrix

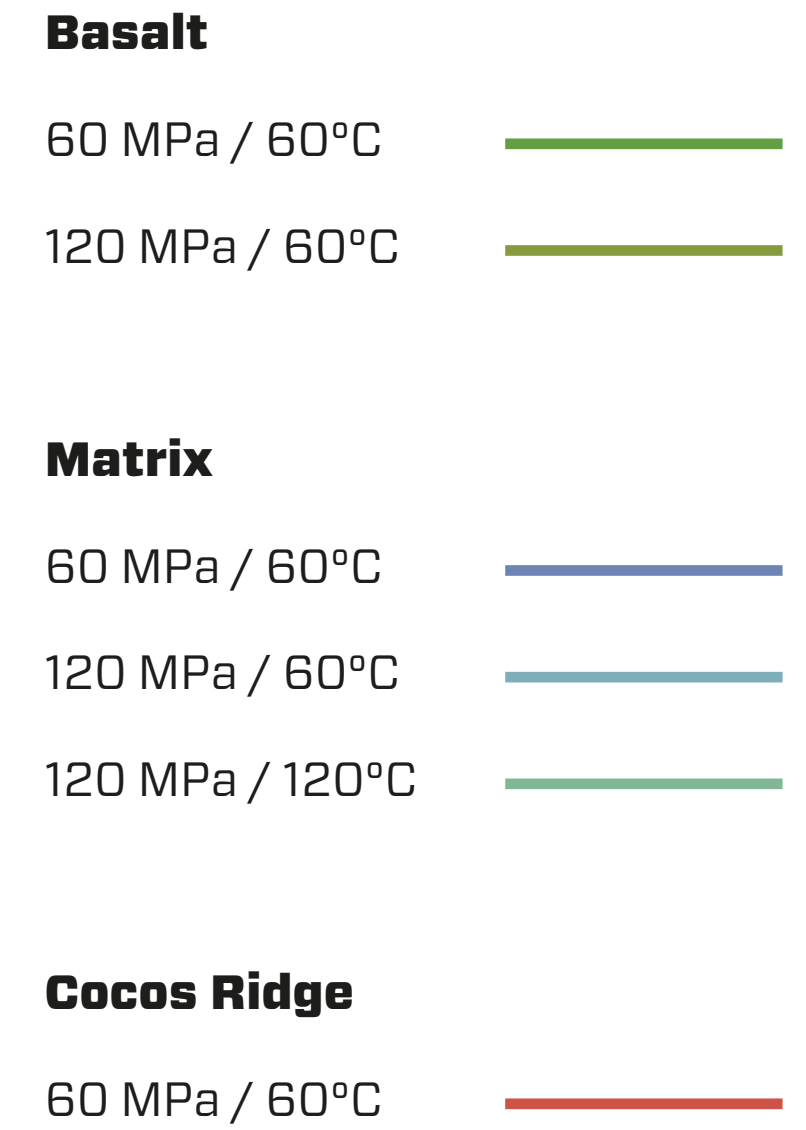
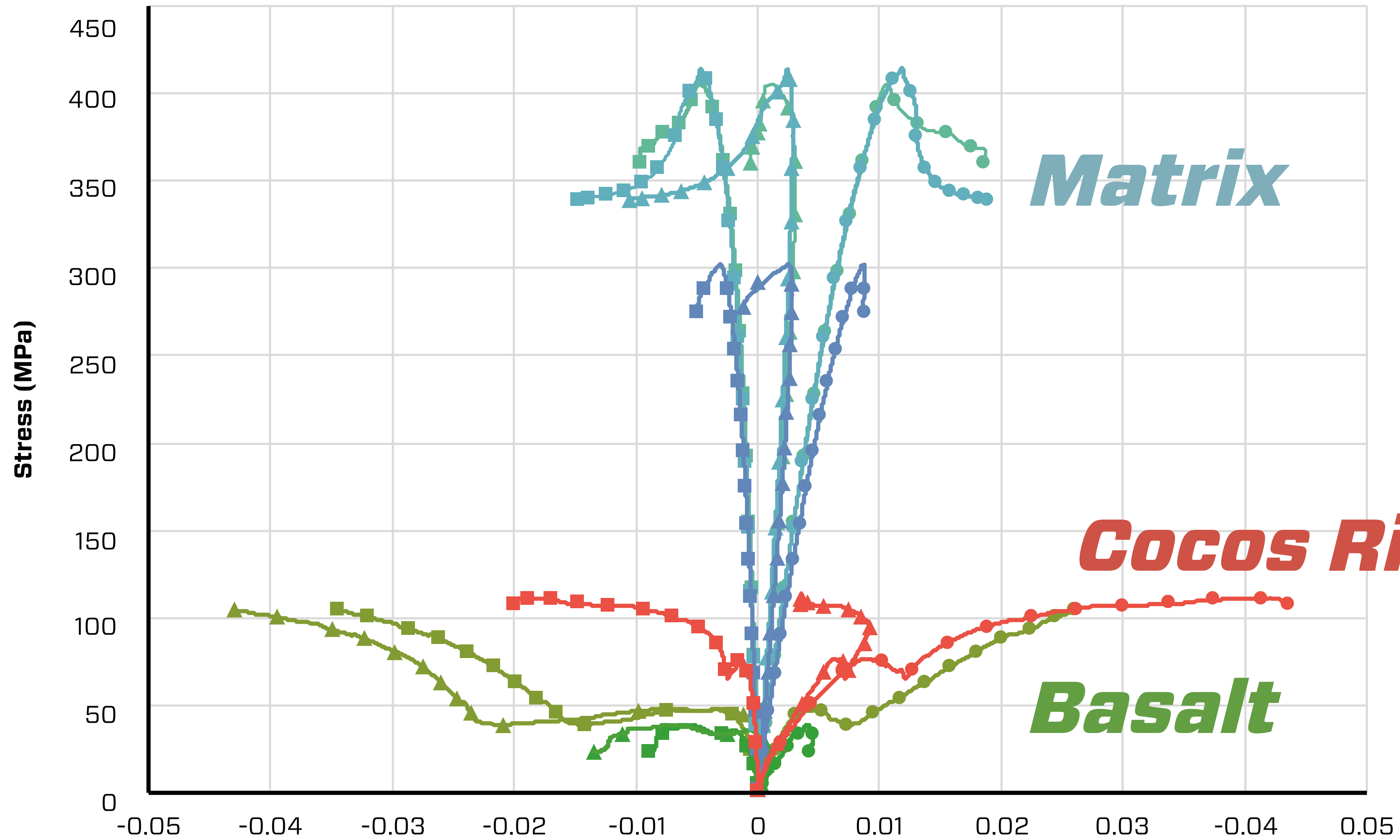
Porosity **1.2 %**

Density **3 Mg/m³**

● Axial Strain

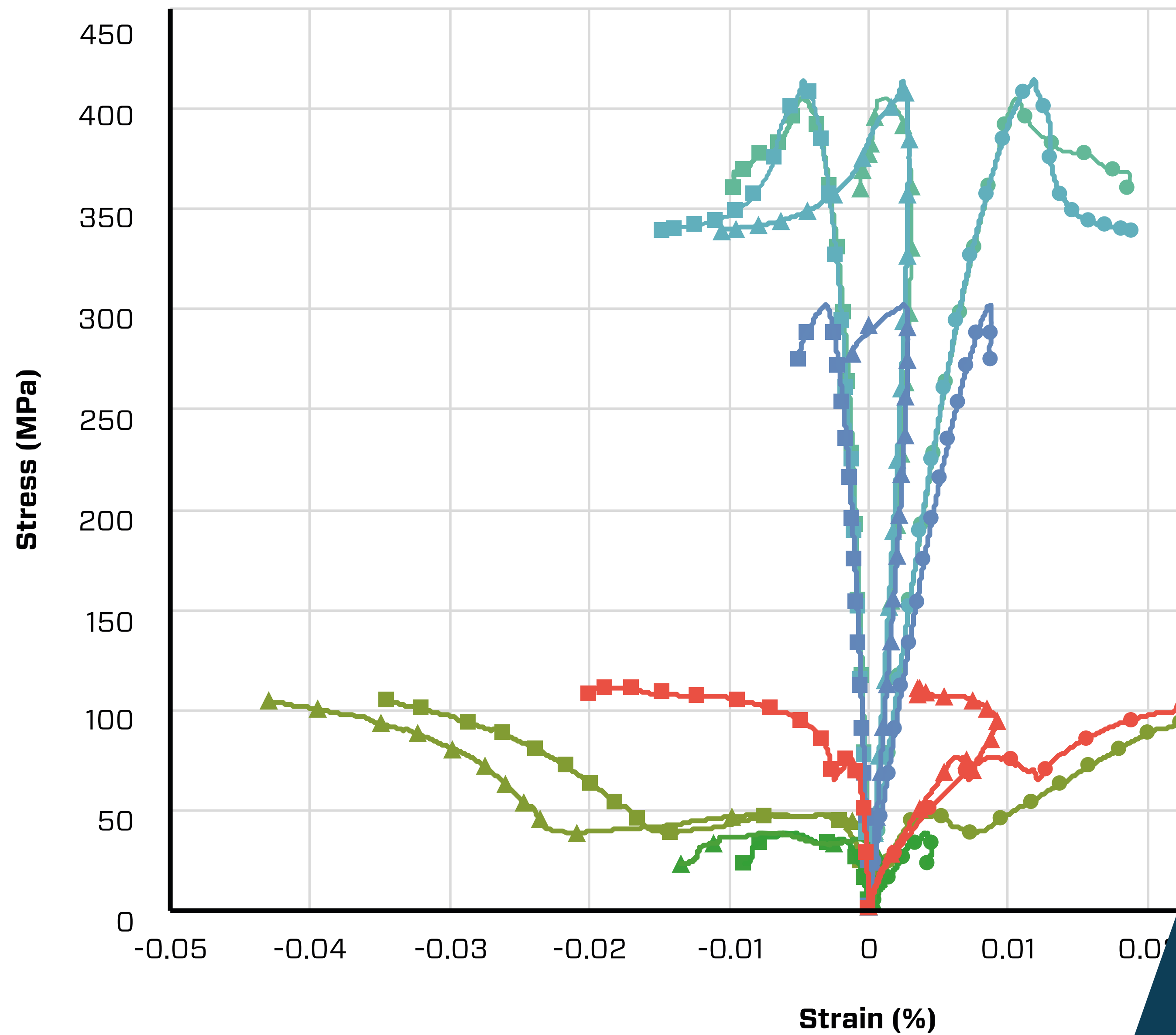
■ Circumferential Strain

▲ Volumetric Strain



Basalt	
Porosity	5.7 %
Density	2.9 Mg/m³
Matrix	
Porosity	1.2 %
Density	3 Mg/m³
Cocos Ridge	
Porosity	4.9 %
Density	2.6 Mg/m³





● Axial Strain

■ Circumferential Strain

▲

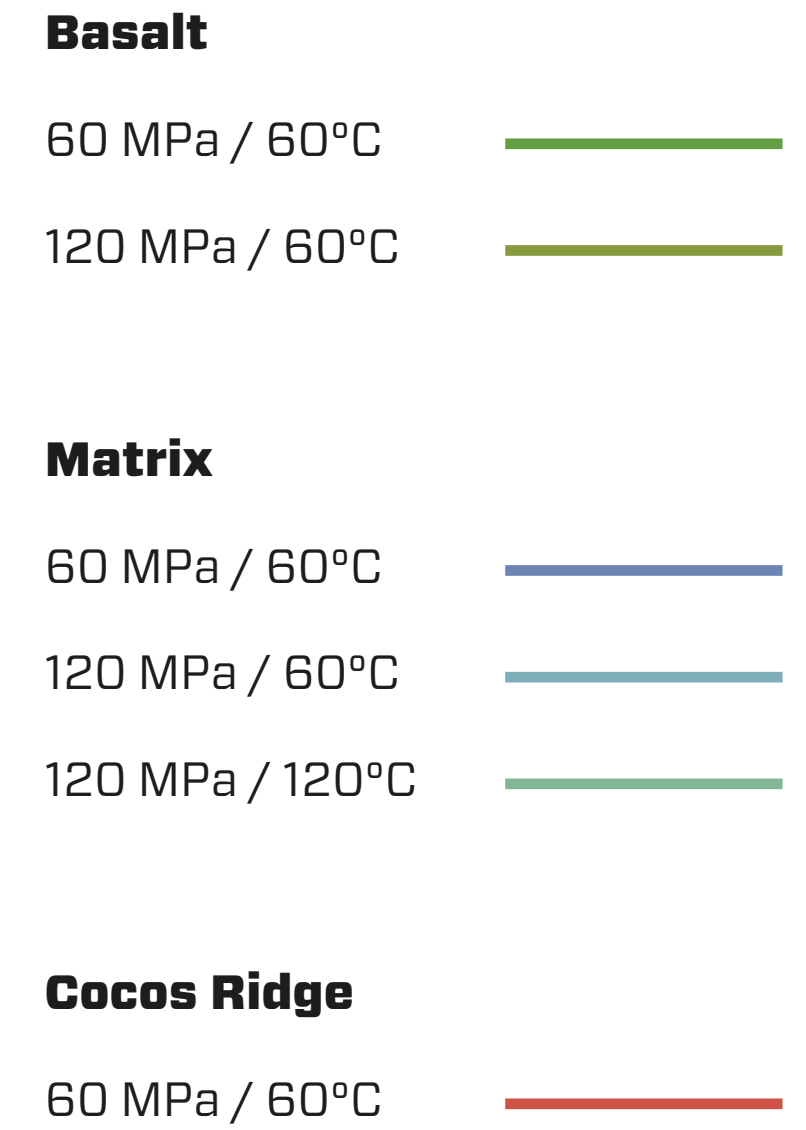
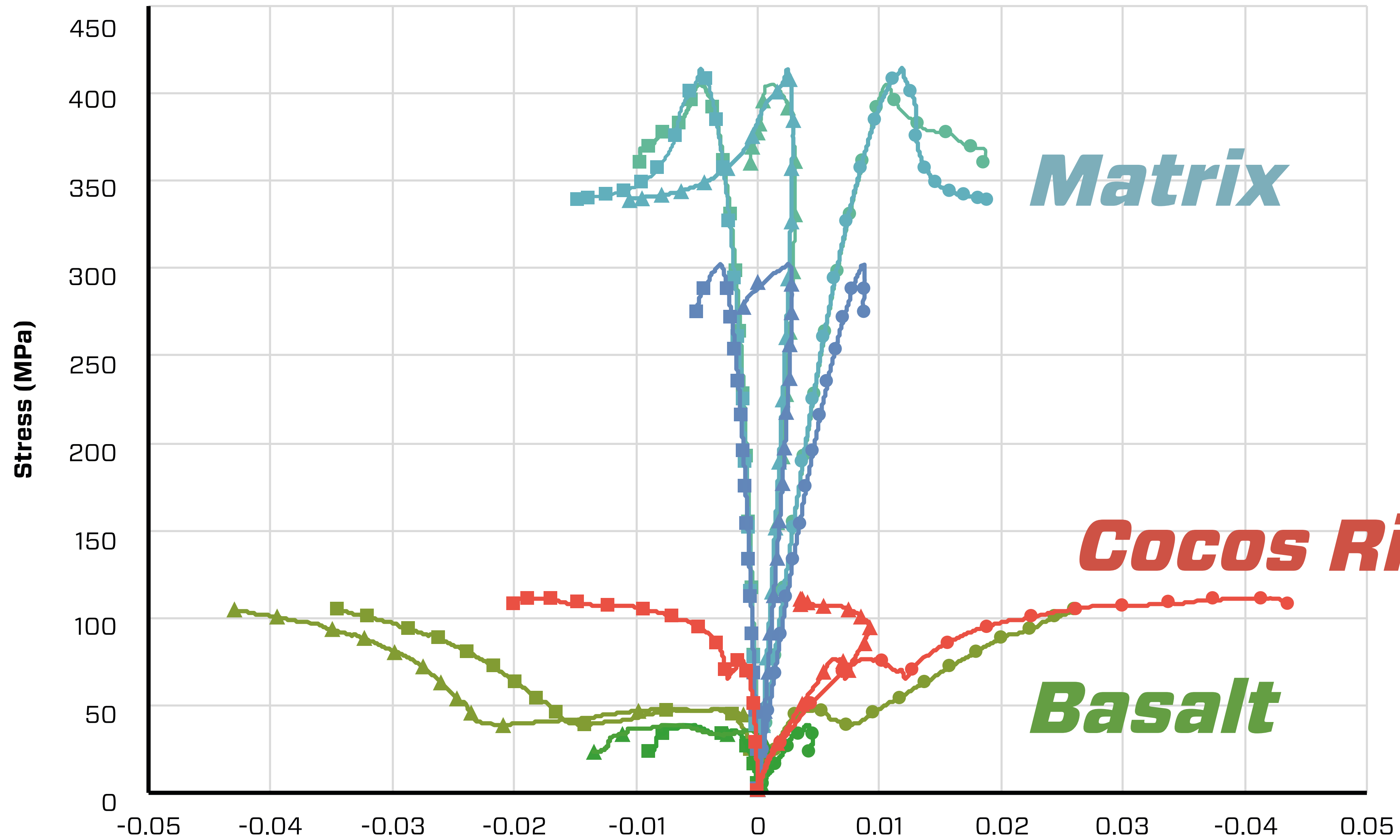
Matrix

Epoxy

Convergence Vector

Cocos Ridge

Galapagos Islands



Matrix

Cocos Ridge

Basalt

Basalt	
Porosity	5.7 %
Density	2.9 Mg/m³
Matrix	
Porosity	1.2 %
Density	3 Mg/m³
Cocos Ridge	
Porosity	4.9 %
Density	2.6 Mg/m³

● Axial Strain

■ Circumferential Strain

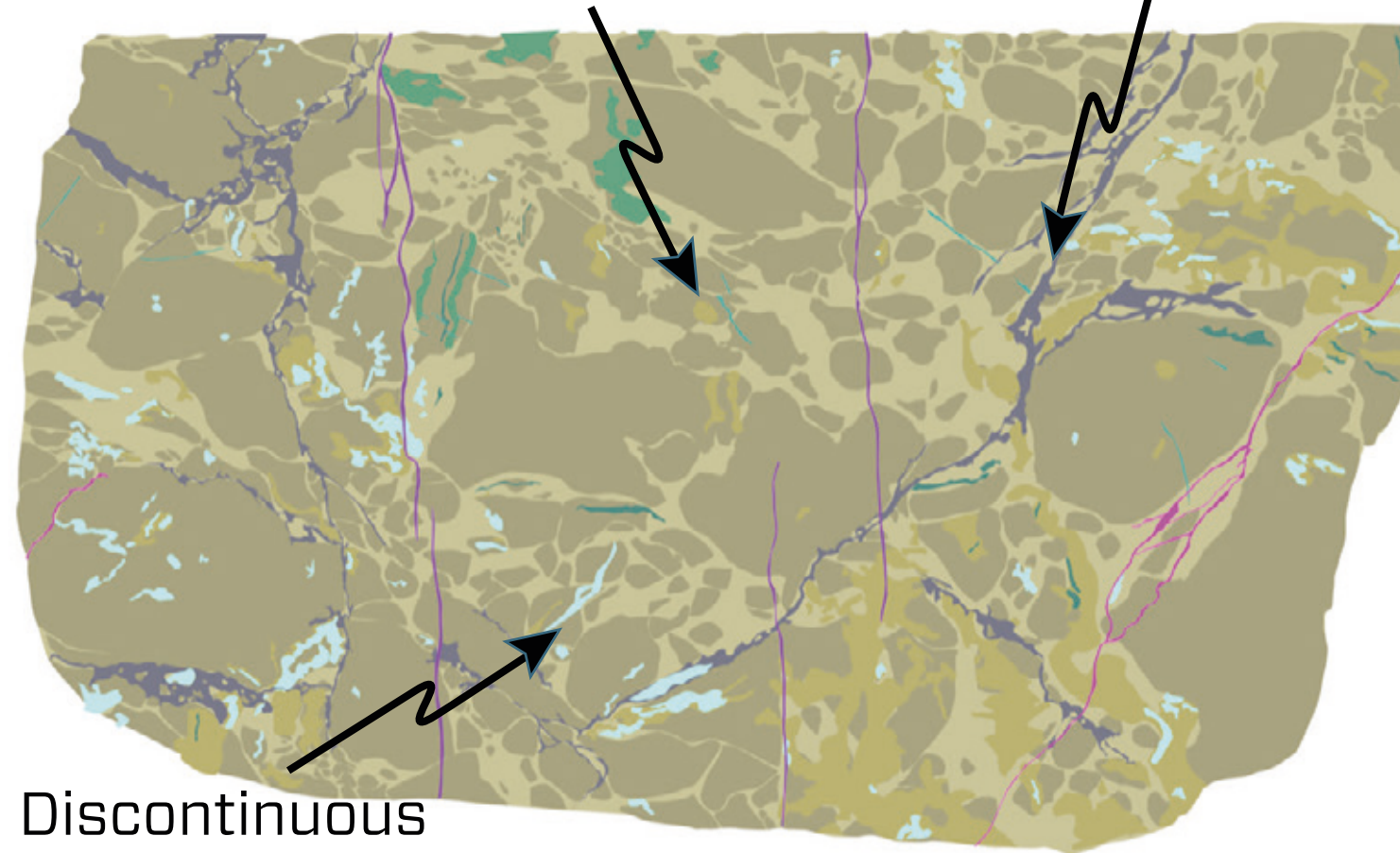
▲ Volumetric Strain

Matrix



Lenticular fabric

Gouge-filled fractures

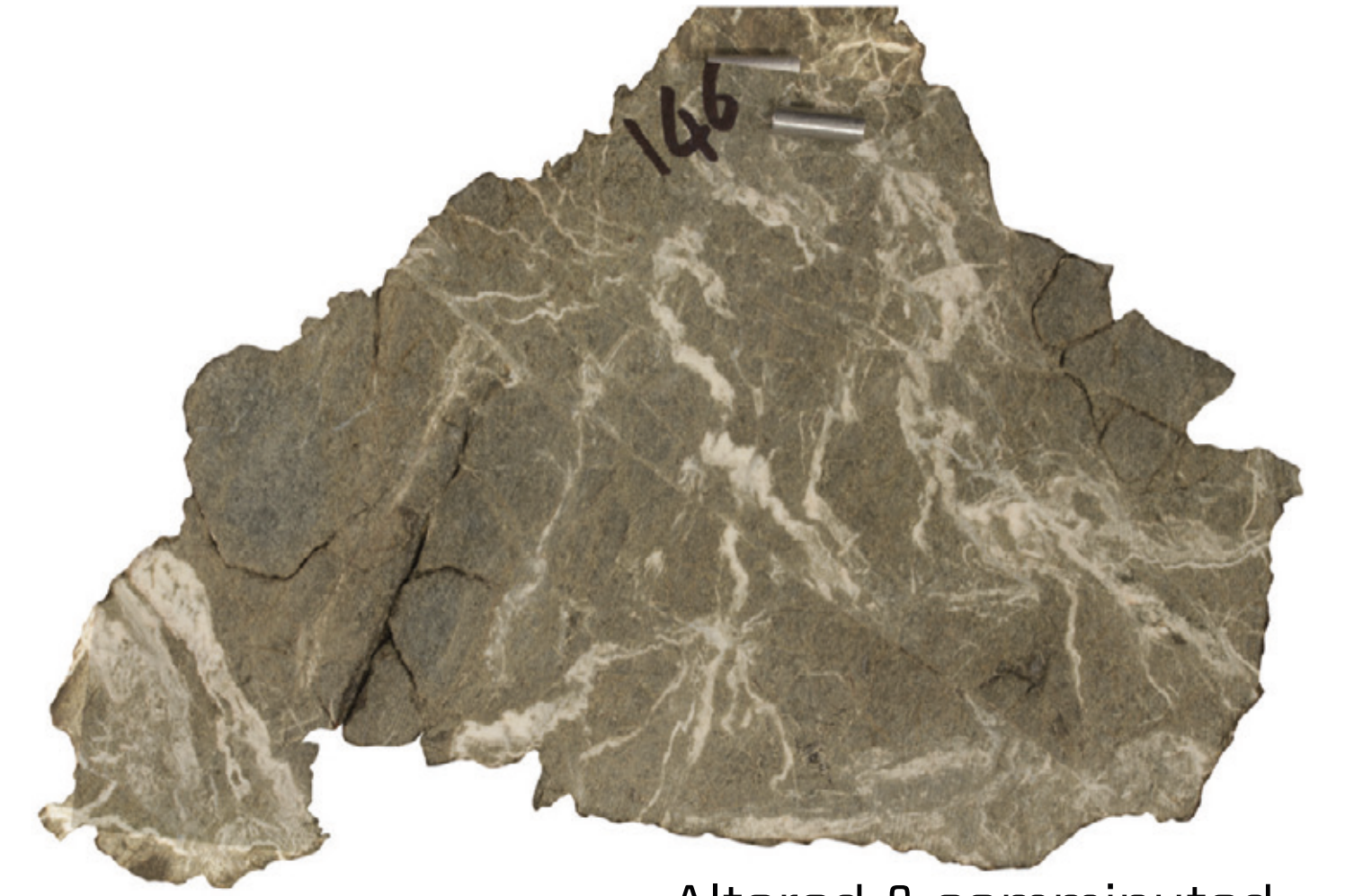


Discontinuous zeolite veins

Basalt Blocks

Less Altered

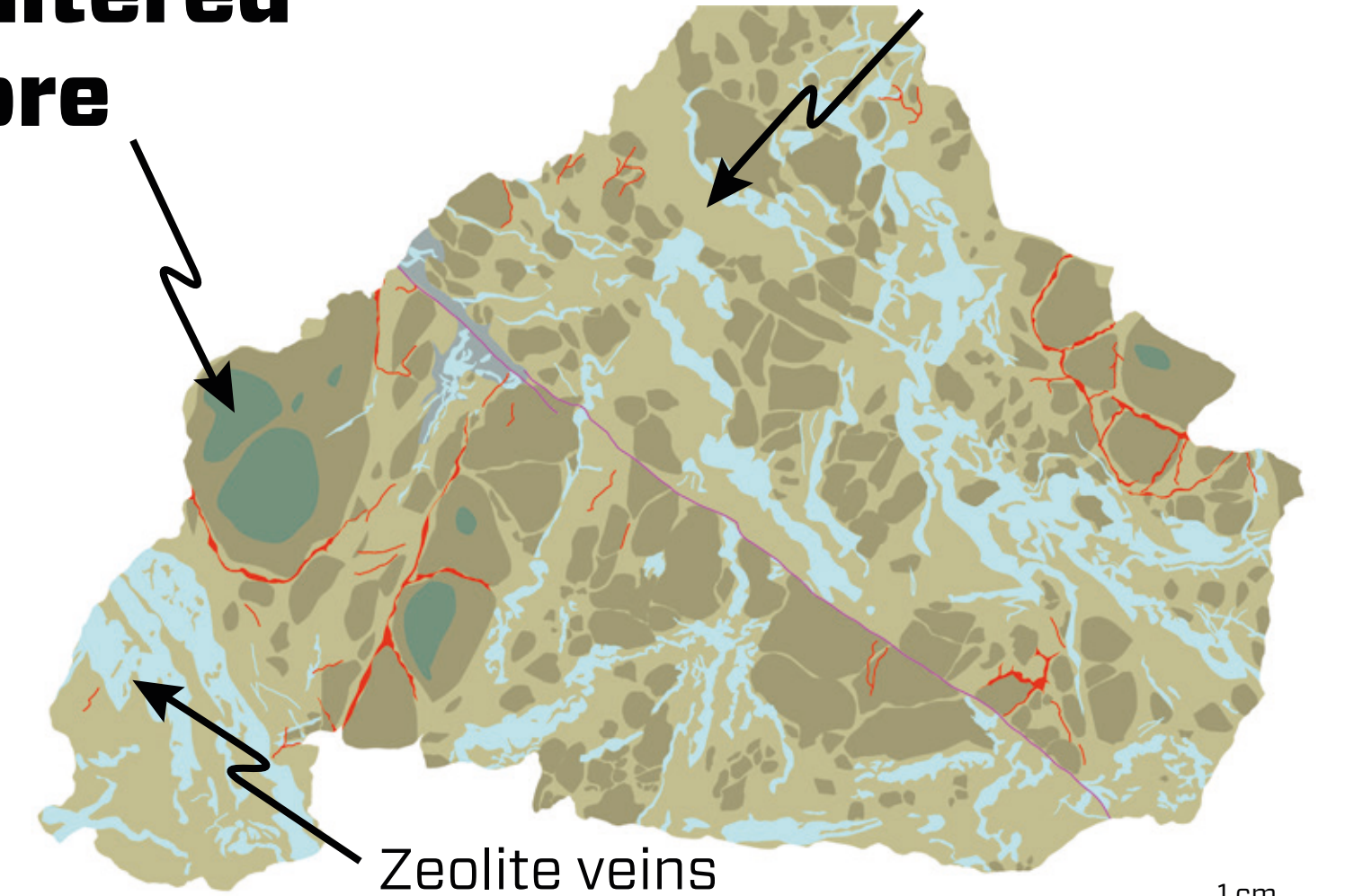
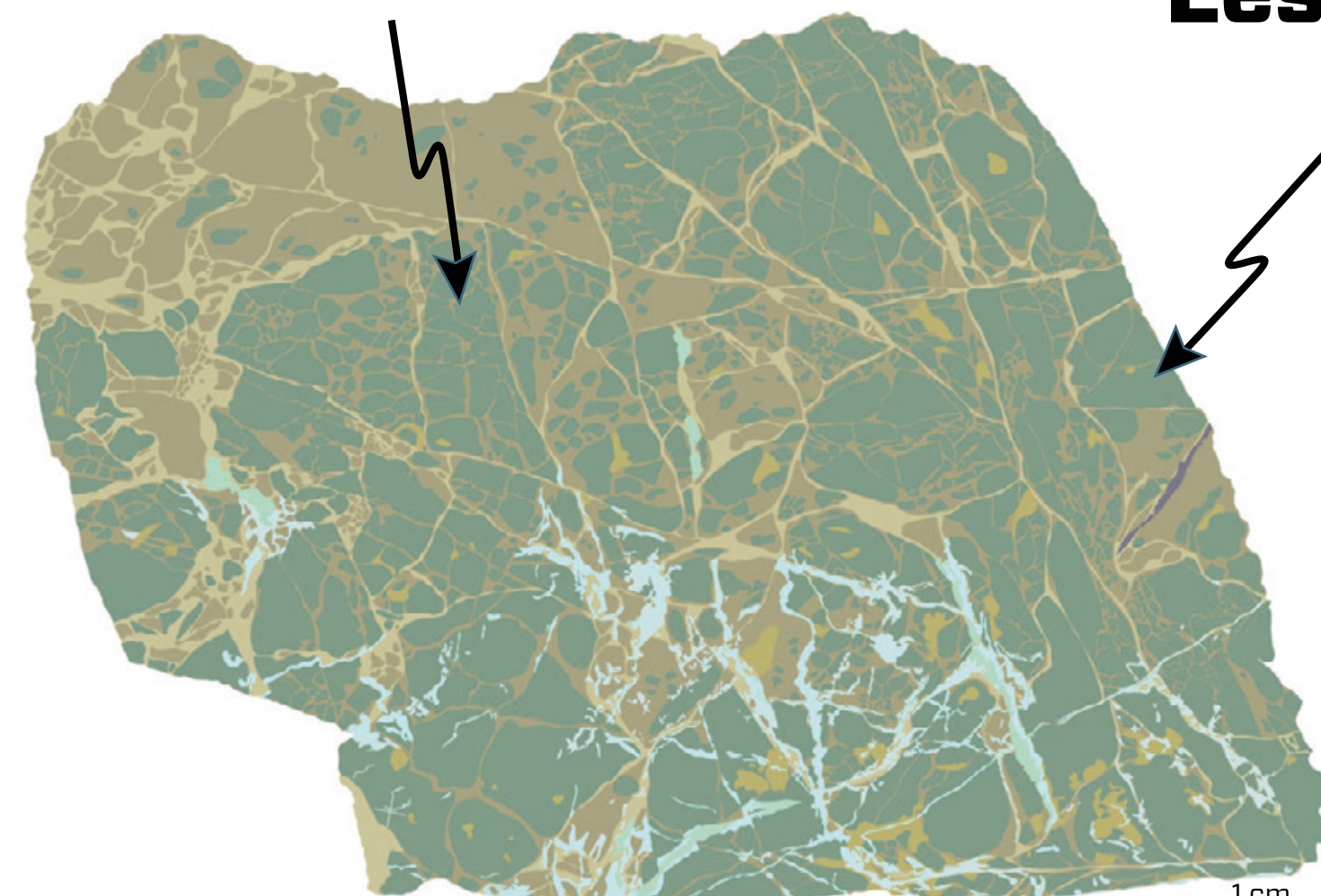
More Altered



Intense brecciation

Less altered core

Altered & comminuted "internal matrix"



Zeolite veins

Basalt Block



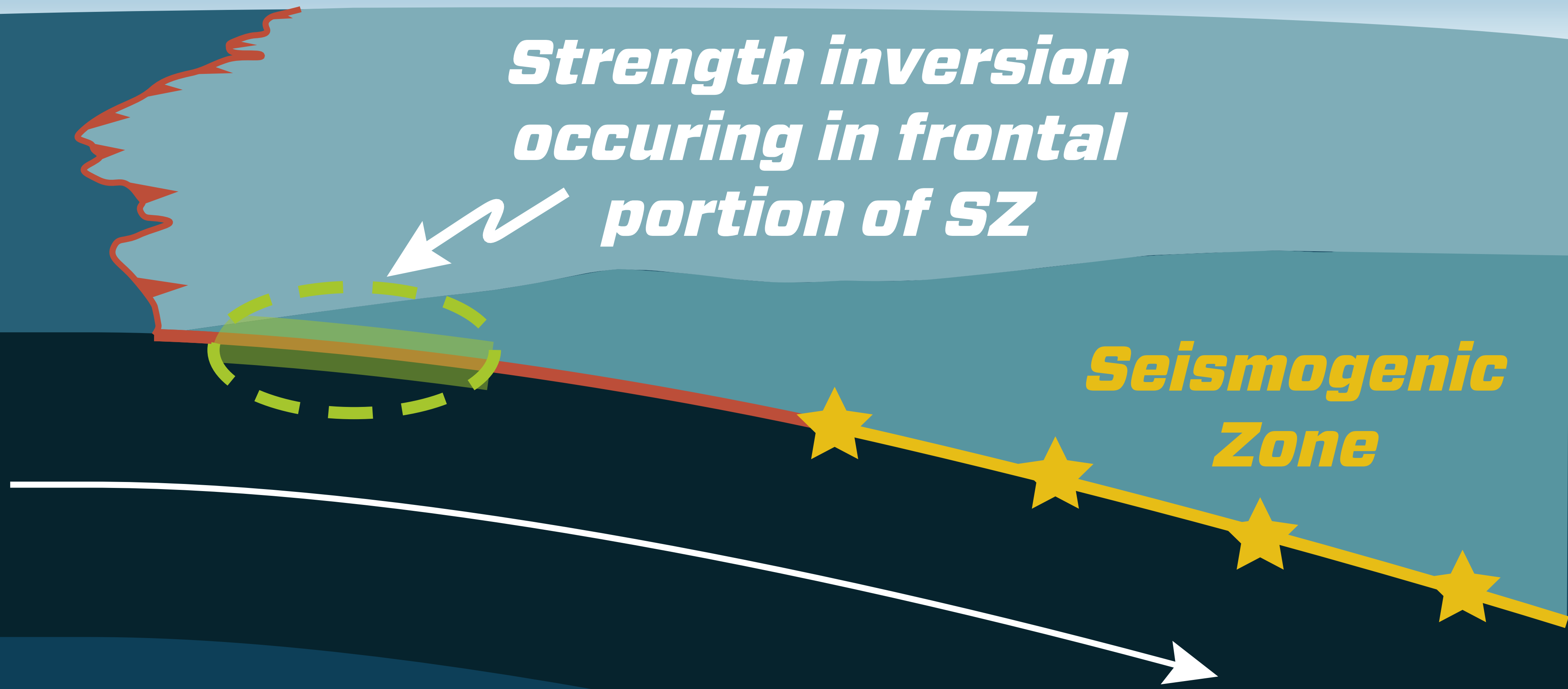
Matrix Injection

Matrix

20 cm

***Strength inversion
occurring in frontal
portion of SZ***

***Seismogenic
Zone***





*Altered material
subducted into
seismogenic zone*

The diagram illustrates a cross-section of a subduction zone. On the left, a red, jagged line represents the leading edge of a tectonic plate being subducted. This material is shown moving downwards and to the right, following a curved path. A dashed green circle highlights the area where the material is being subducted. A white arrow points from the text 'Altered material subducted into seismogenic zone' to this area. Below the subducting plate, a white line represents the mantle boundary. A white arrow points from this boundary towards the right, indicating the direction of mantle flow. The seismogenic zone is highlighted in yellow and contains four yellow stars, representing seismic activity. The background is a gradient of blue and green, representing the ocean and the mantle respectively.

*Seismogenic
Zone*

Full Conclusions

- *Blocks may evolve to be mechanically weaker than the surrounding matrix.*
- *Strength inversion occurs at shallow depths within Subduction Zone.*
- Subducted material may have undergone strength inversion by the time it reaches seismogenic zone.
- Strength inversion can influence earthquake generation
- Field evidence of past rheological relationships are not indicative of present mechanical properties.
- Strength inversion has very general implications for how we think about block-in-matrix rock units.