Imposed strain localization in the mantle section of an oceanic transform zone revealed by microstructural and stress variations

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Stress variations in space and time within the mantle section of an oceanic transform zone: Evidence for the seismic cycle

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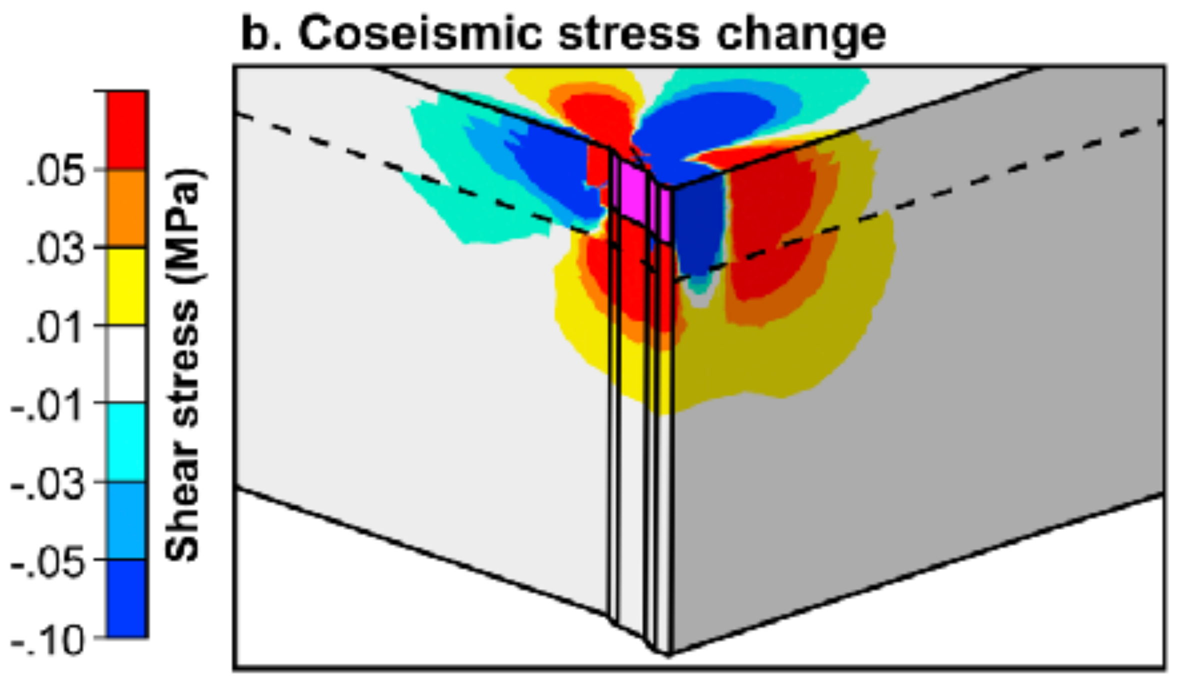
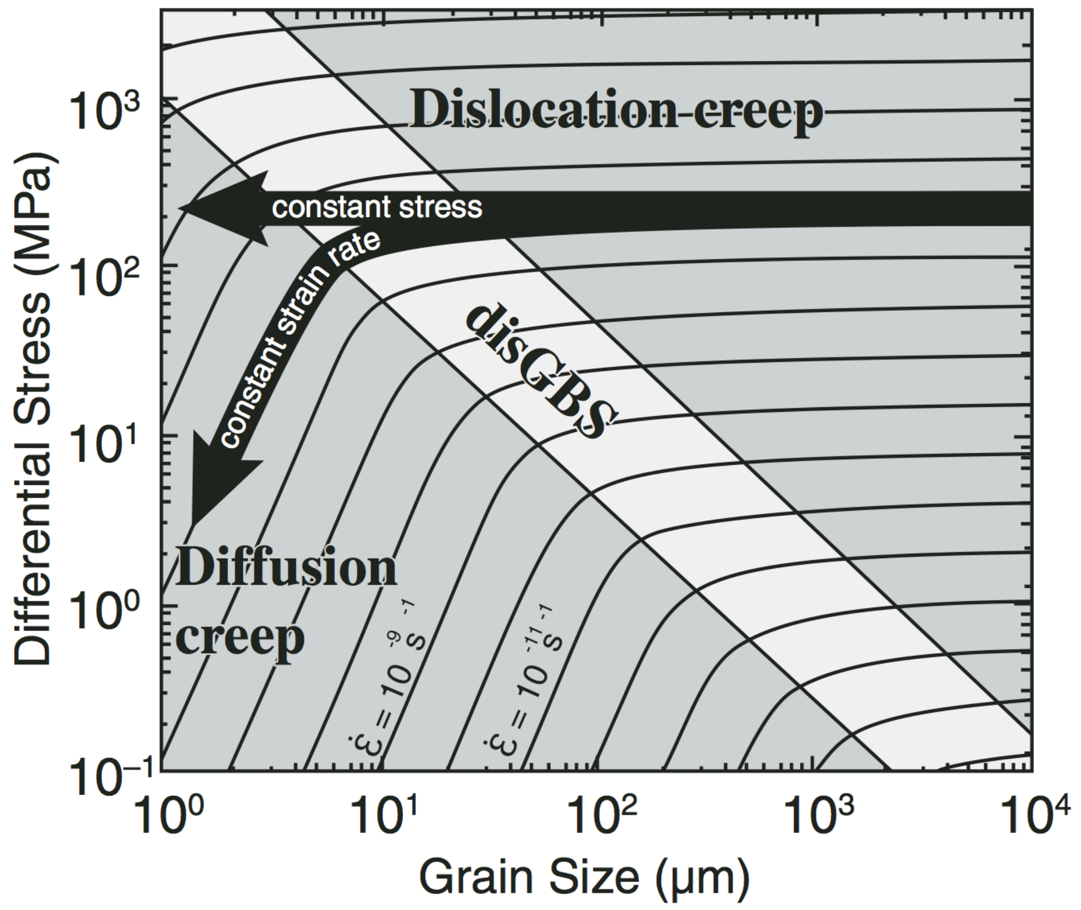
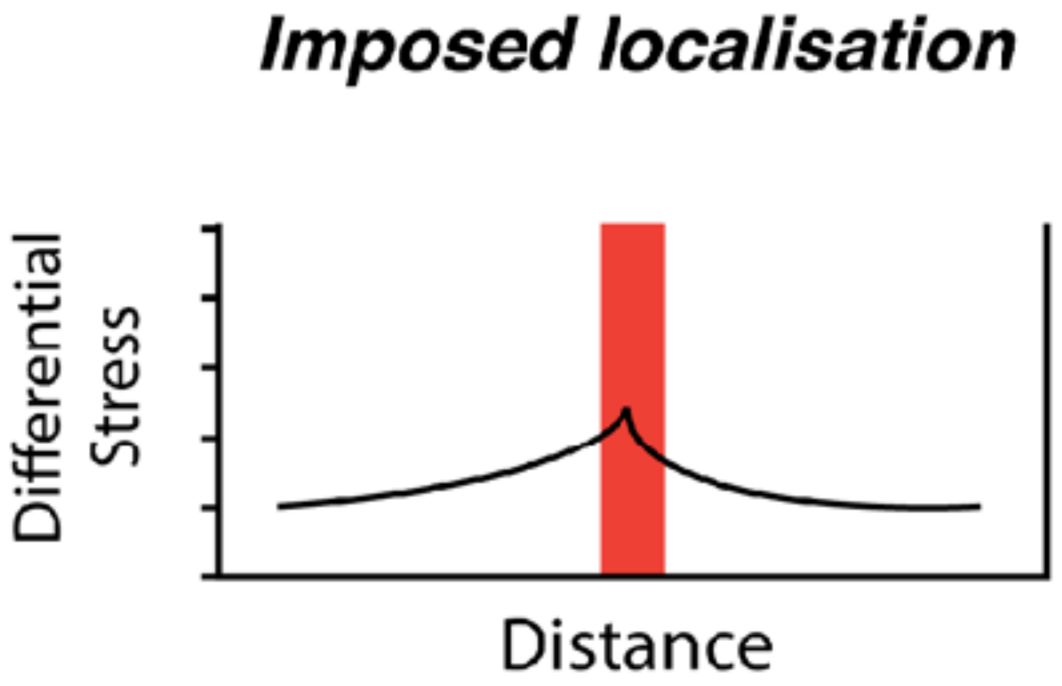
Strain localisation in the mantle section of a transform fault

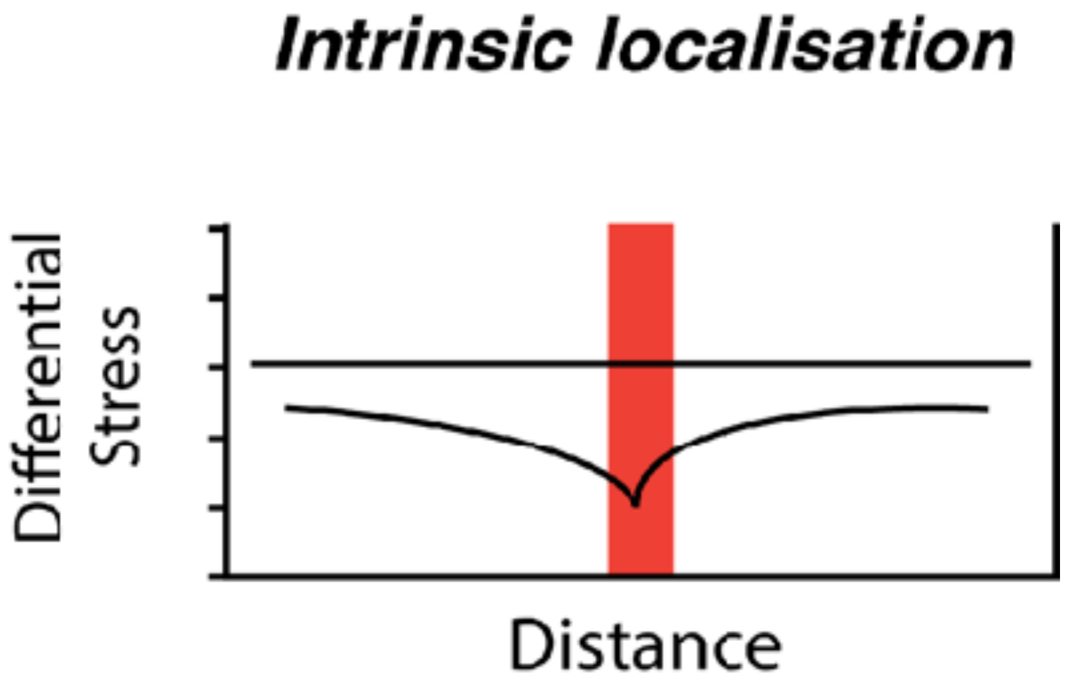


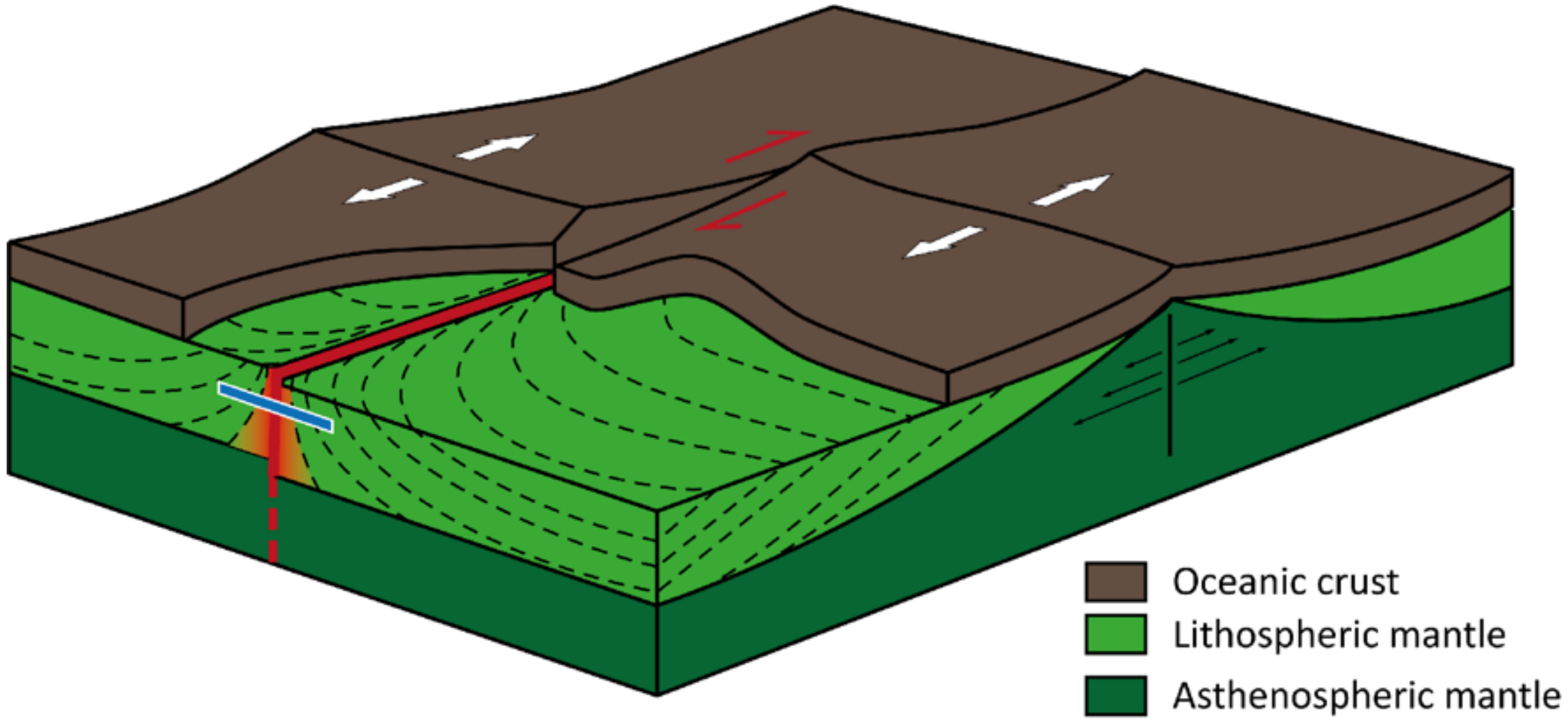
Freed et al. (2012), J. Geophys. Res.



Tikoff et al. (2013),
GSA-SP following Schmid (1983)

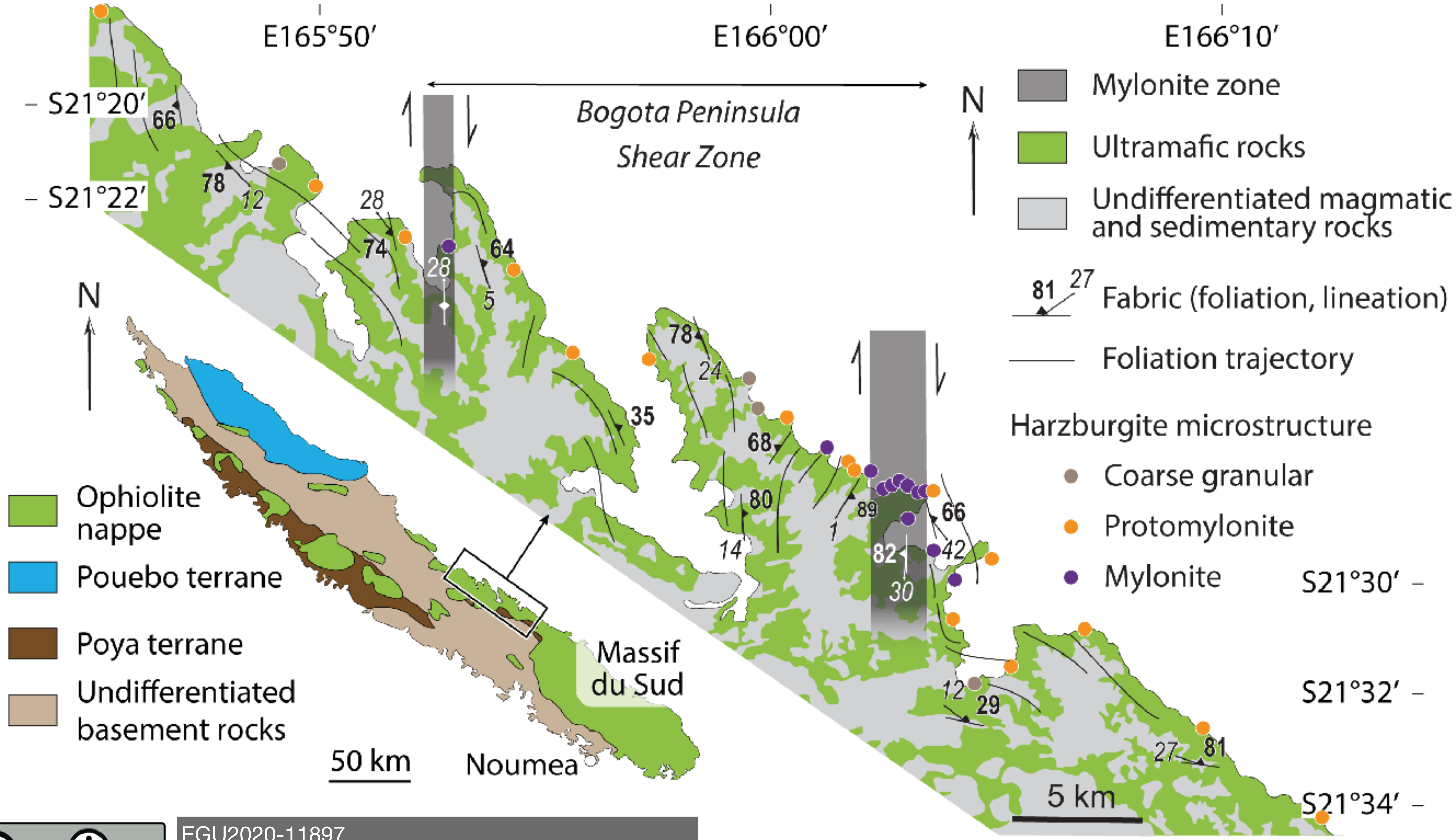






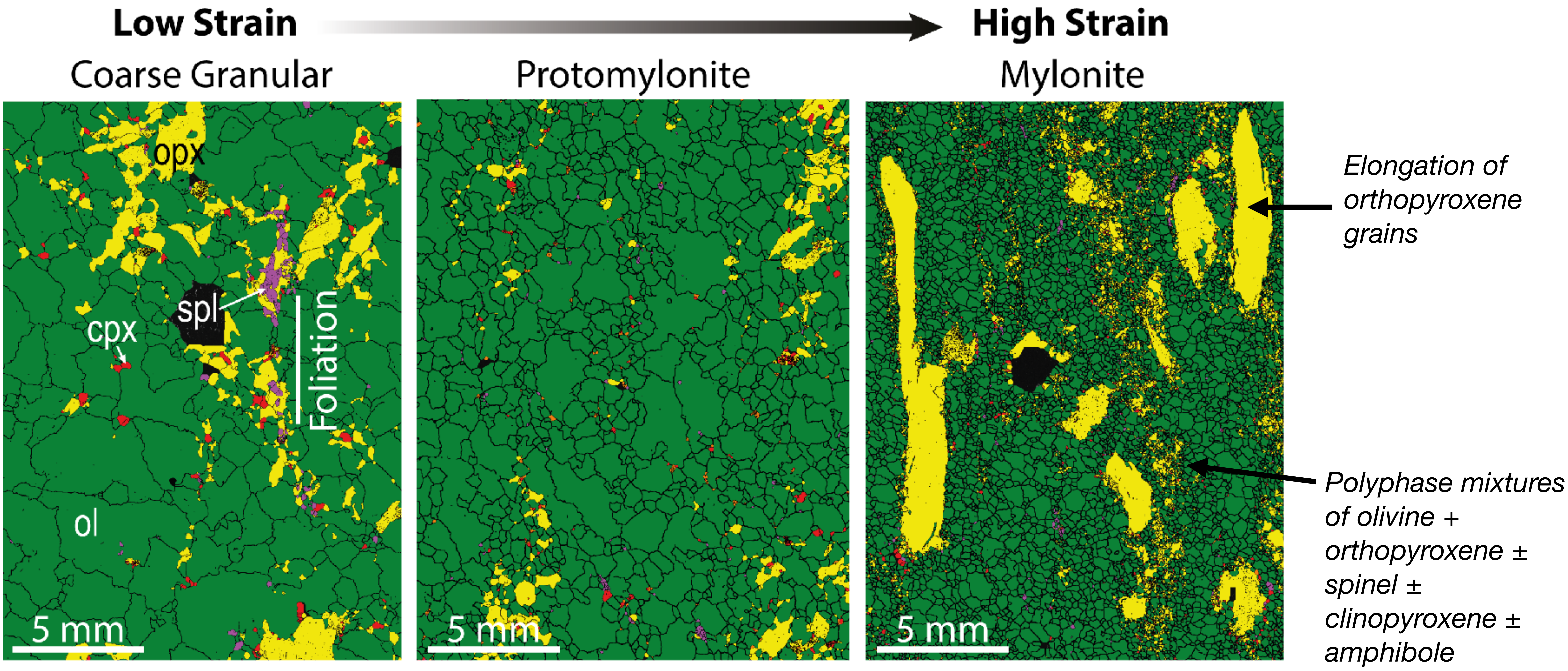
Bogota Peninsula shear zone, New Caledonia -

The exhumed mantle section of an ancient oceanic transform fault



- The BPSZ is a 25-km-wide shear zone that includes heterogeneously deformed spinel harzburgites and dunites.
- Strain is localised in two, 1–2 km wide mylonite zones (Prinzhofer and Nicolas, 1980; Titus et al. 2011).
- We analysed 43 peridotite samples from 32 stations along a 50-km-long transect.

Microstructural transitions along the strain gradients

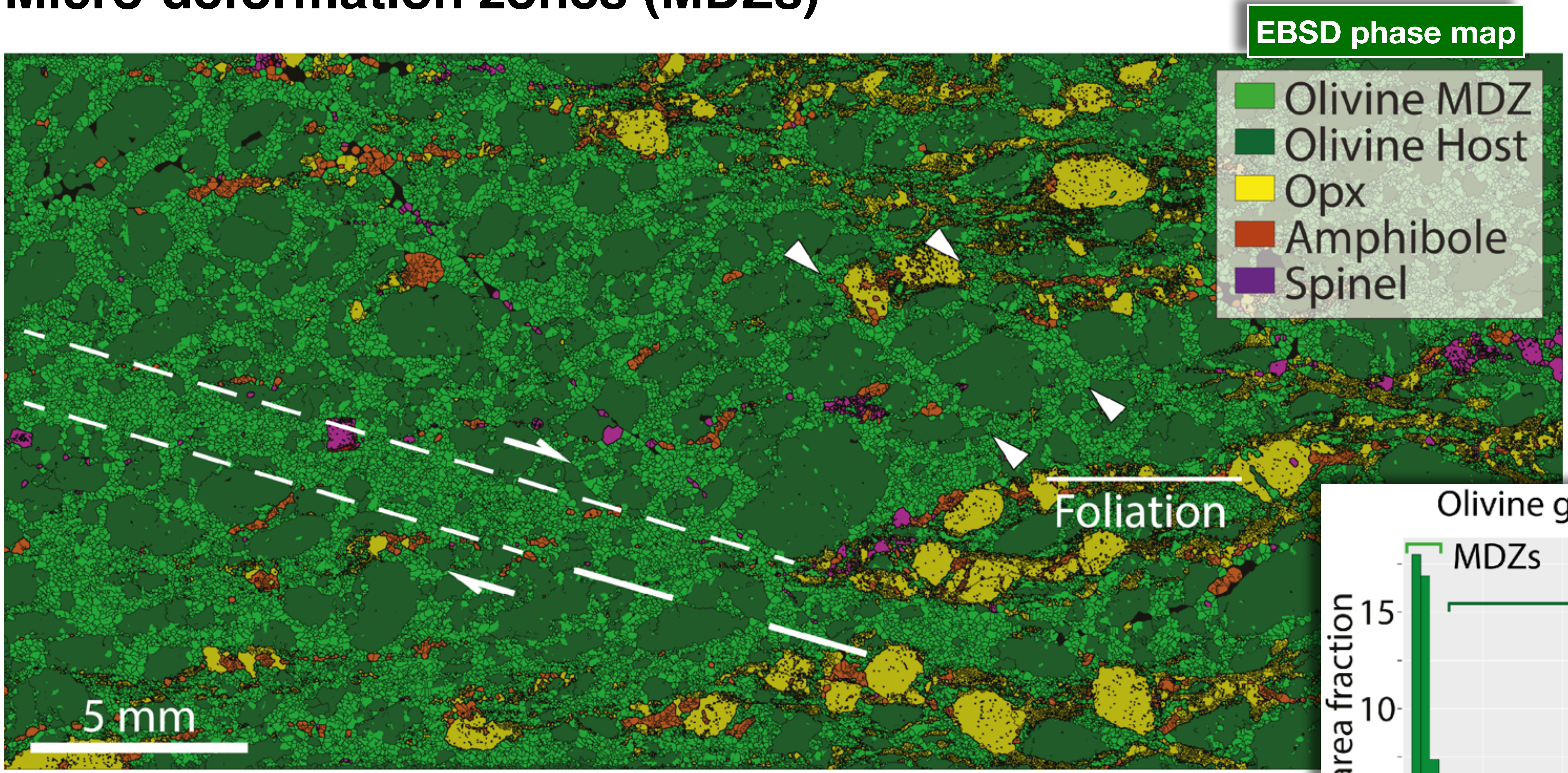


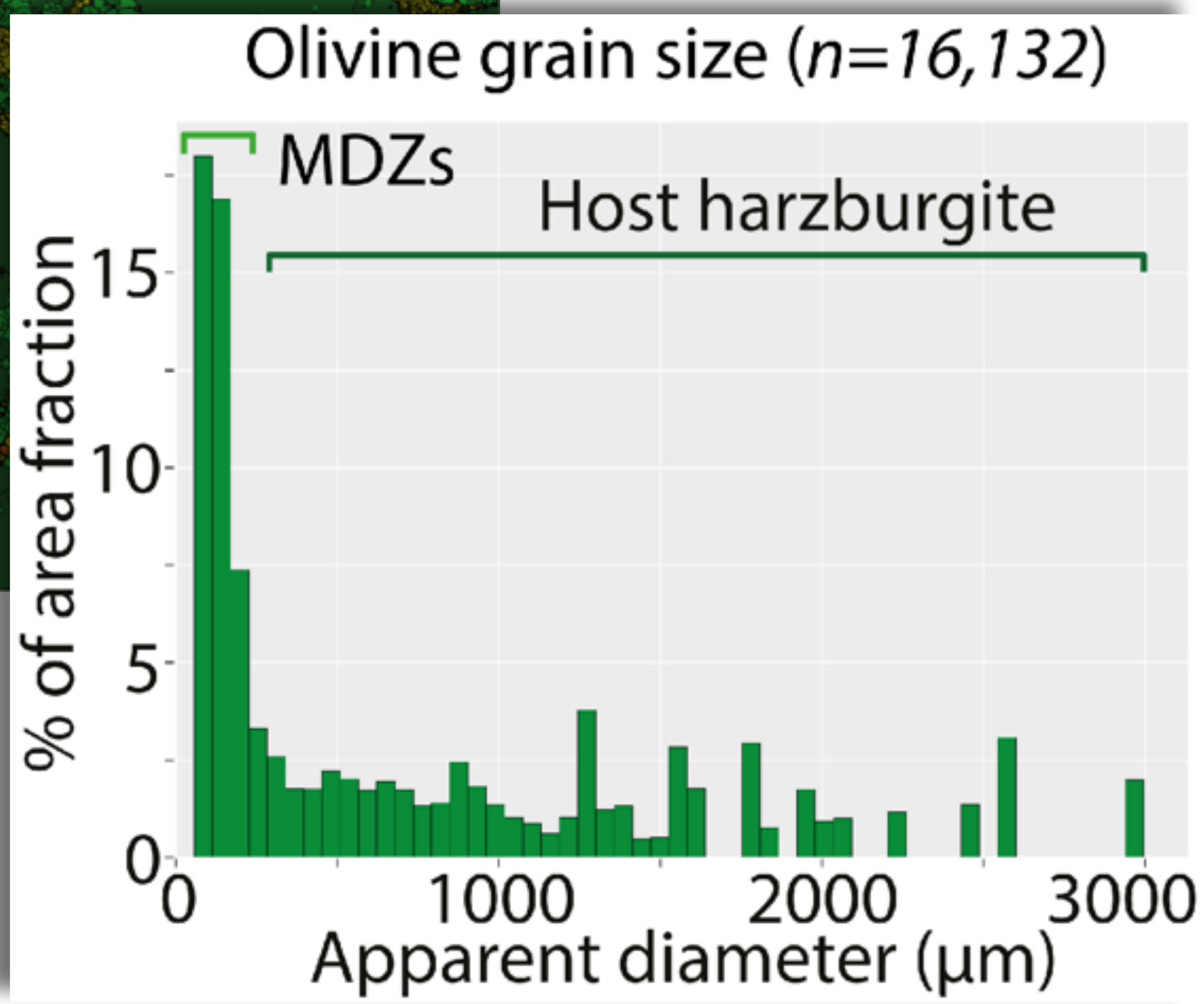
Olivine grain size: 1 - 5 mm

Images are EBSD phase maps

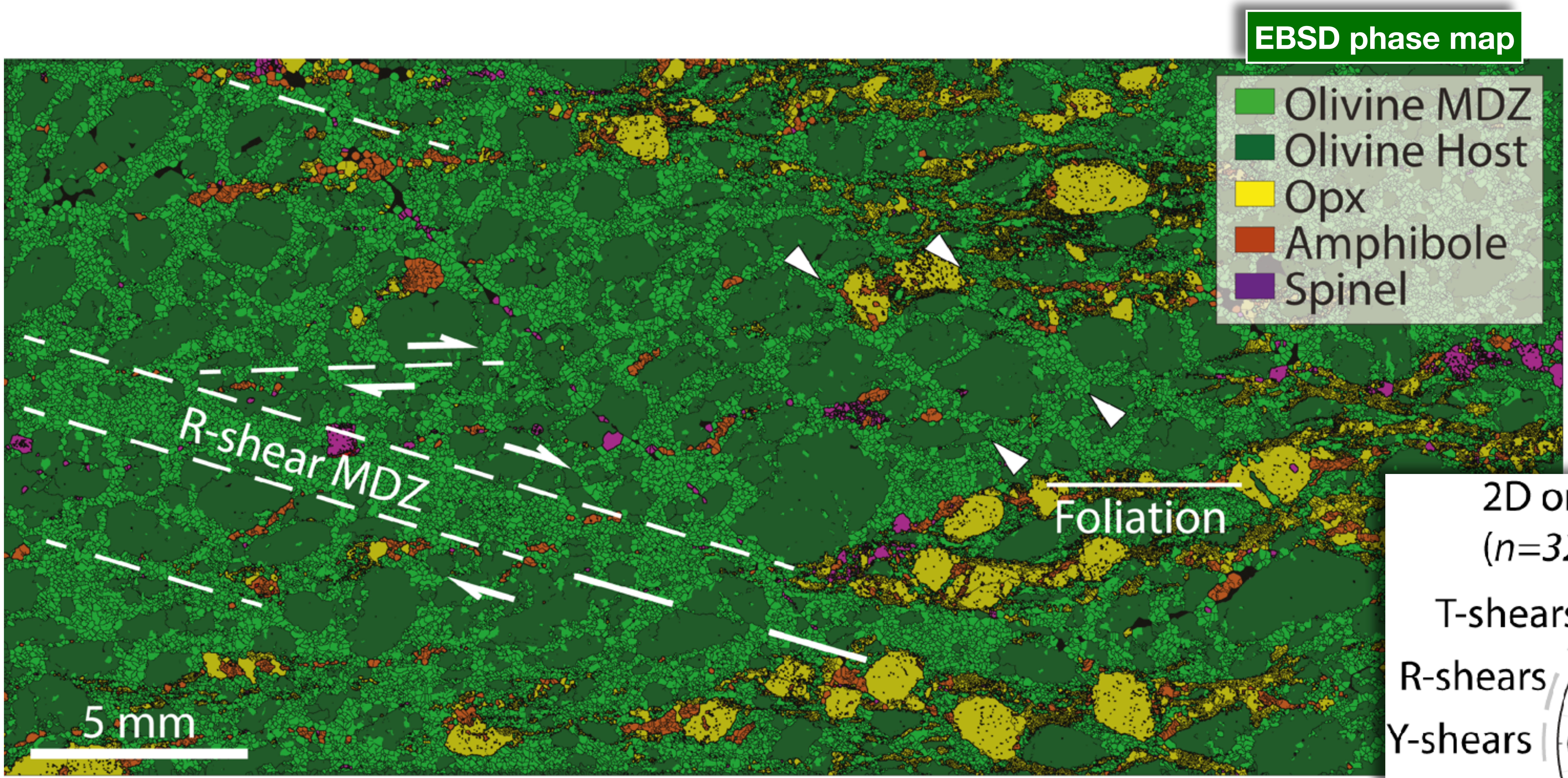
Olivine grain size: 0.2 - 1.5 mm

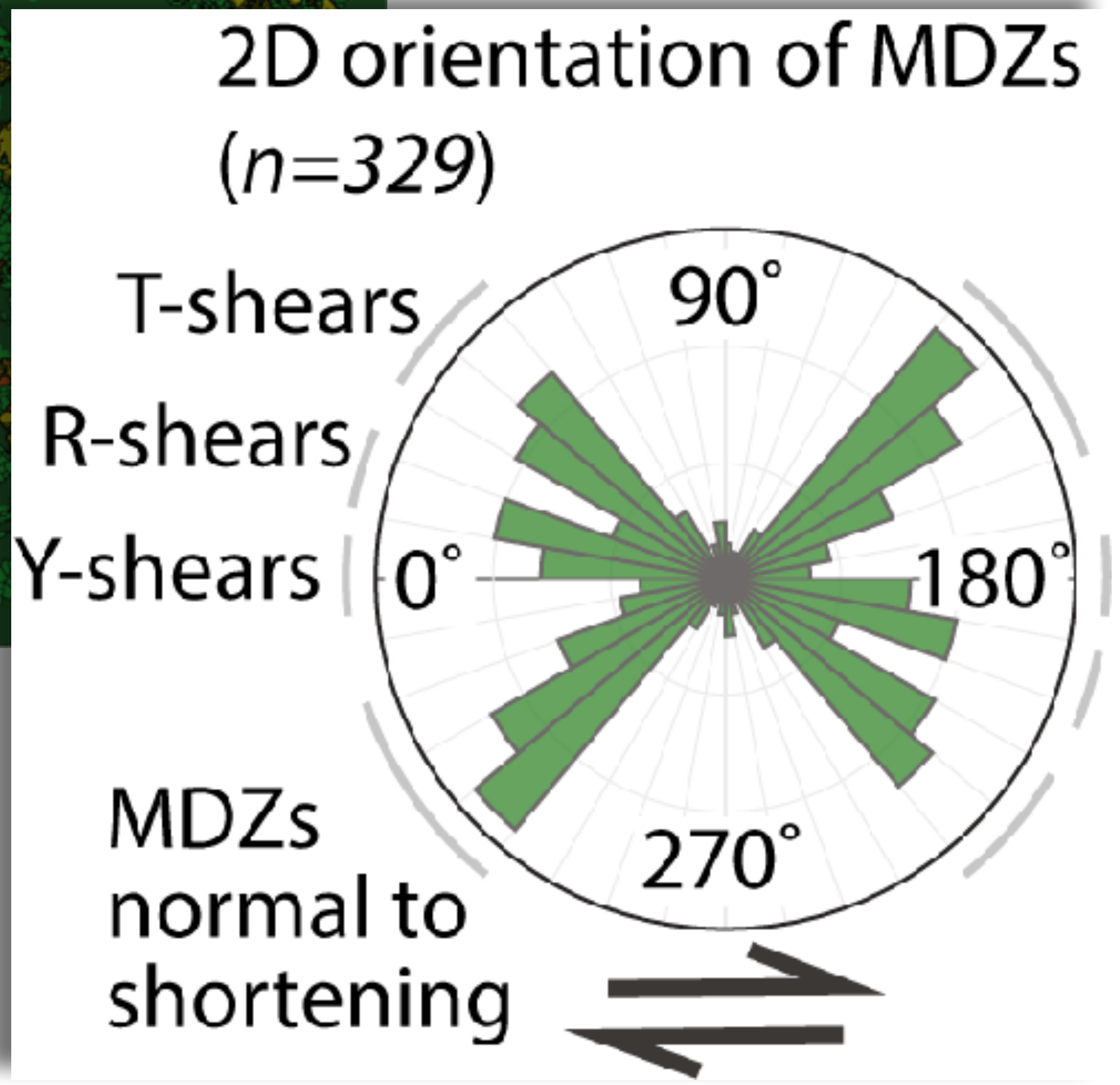
Micro-deformation zones (MDZs)





- Monophase domains filled with recrystallized olivine or orthopyroxene grains.

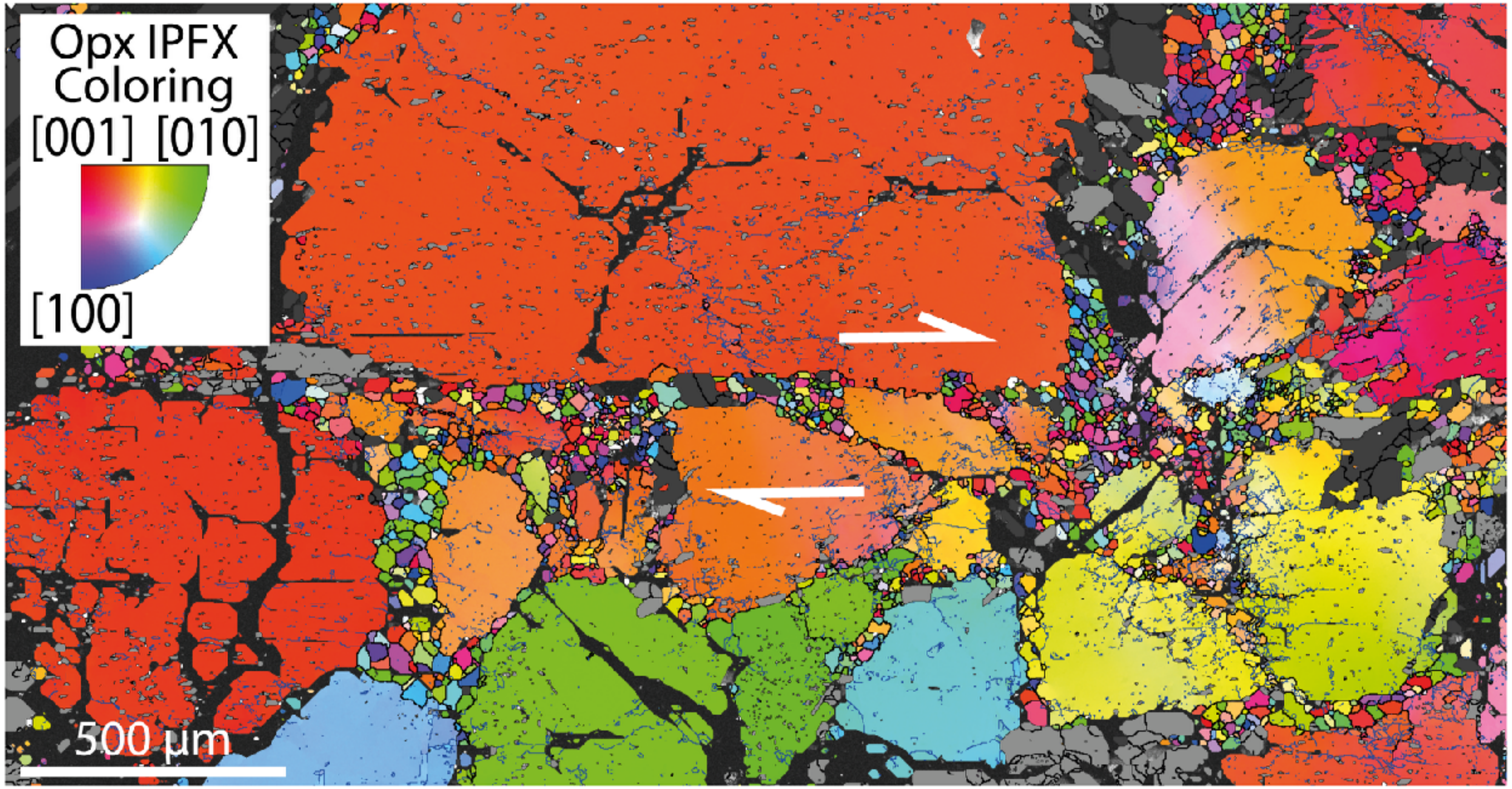




- With respect to the kinematic framework of the sheared harzburgites, the MDZs occur in distinct orientations similar to the orientations of Riedel shears in brittle fault zones.

Micro-deformation zones have brittle precursors

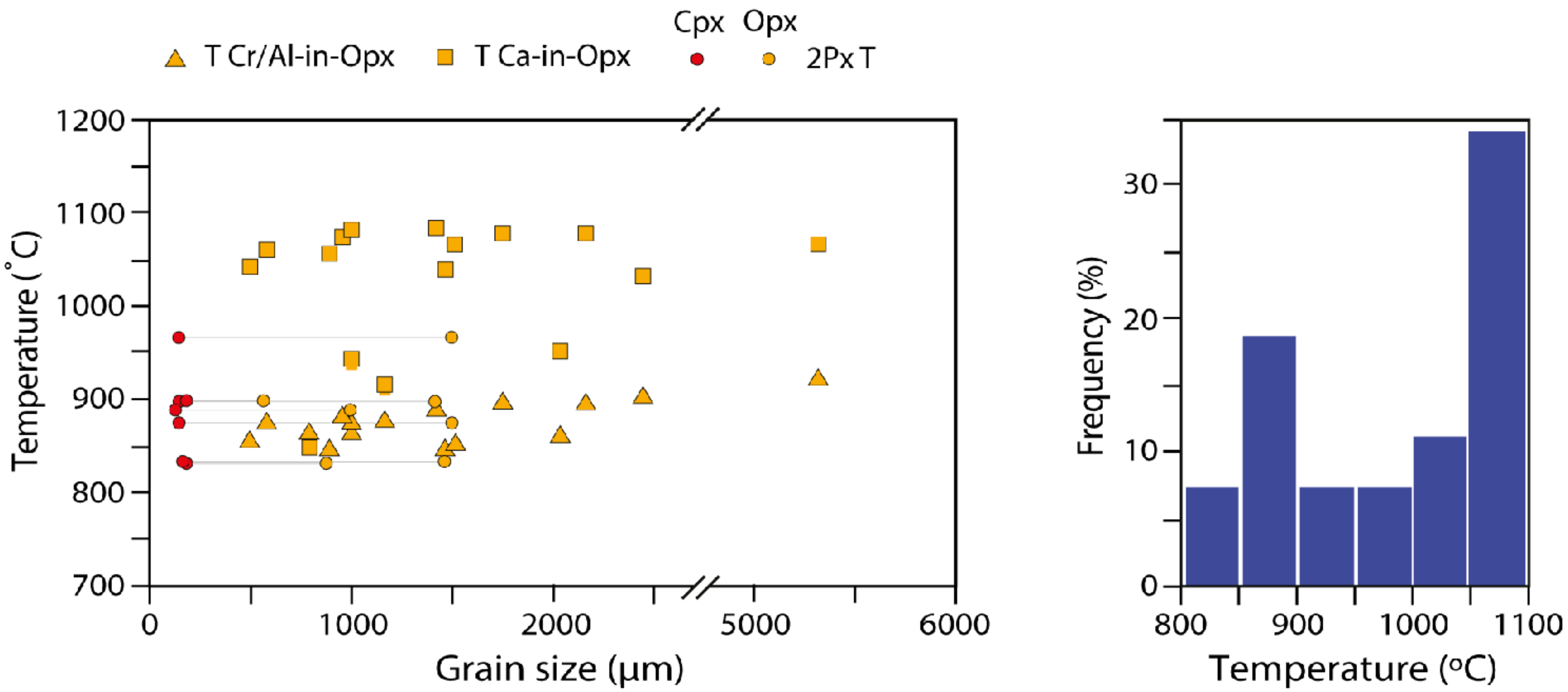
EBSD crystal orientation map



- The MDZs typically develop as transgranular structures truncating and offseting originally continuous relict olivine and orthopyroxene grains. Some MDZs only cut through a single grain of olivine or pyroxene.

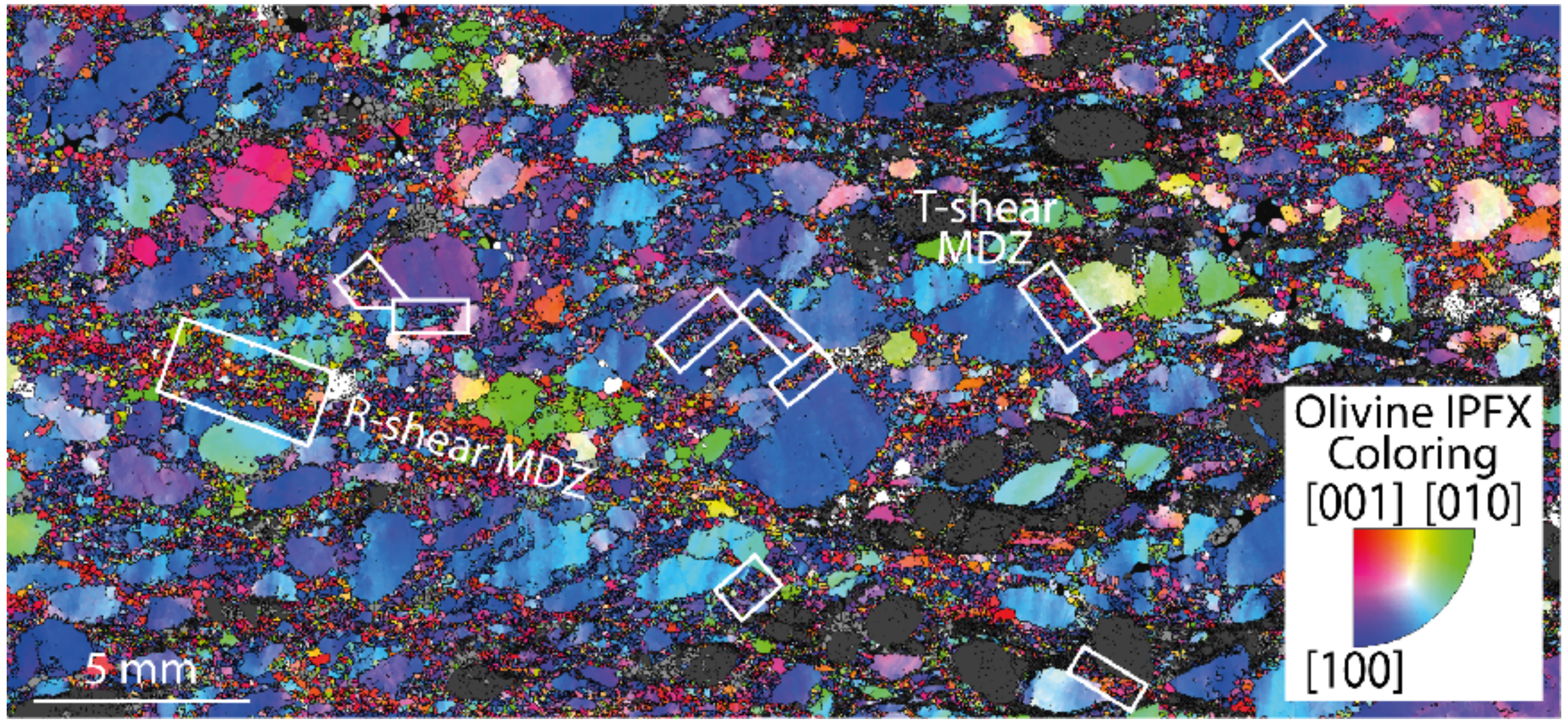
Deformation temperatures range between 818°C and 1070°C -

The MDZs formed at temperatures higher than 600°C, which is inferred to be the temperature of brittle-ductile transition in the oceanic lithosphere.



Ca-in-Opx geothermometer (Brey and Köhler, 1990), Al/Cr-in-Opx geothermometer (Witt-Eickschen and Seck, 1991), Two-pyroxene geothermometer (Taylor, 1998).

Olivine in the MDZs formed primarily by dynamic recrystallisation



- **Host harzburgite:** Slip on (001)[100], common in the BPSZ (Prinzhofer and Nicolas, 1980).
- **T-shear MDZ:** Host control rather than activation of slip systems related to the shear zone kinematics.

subgrain rotation recrystallization

Stipp et al. (2002)

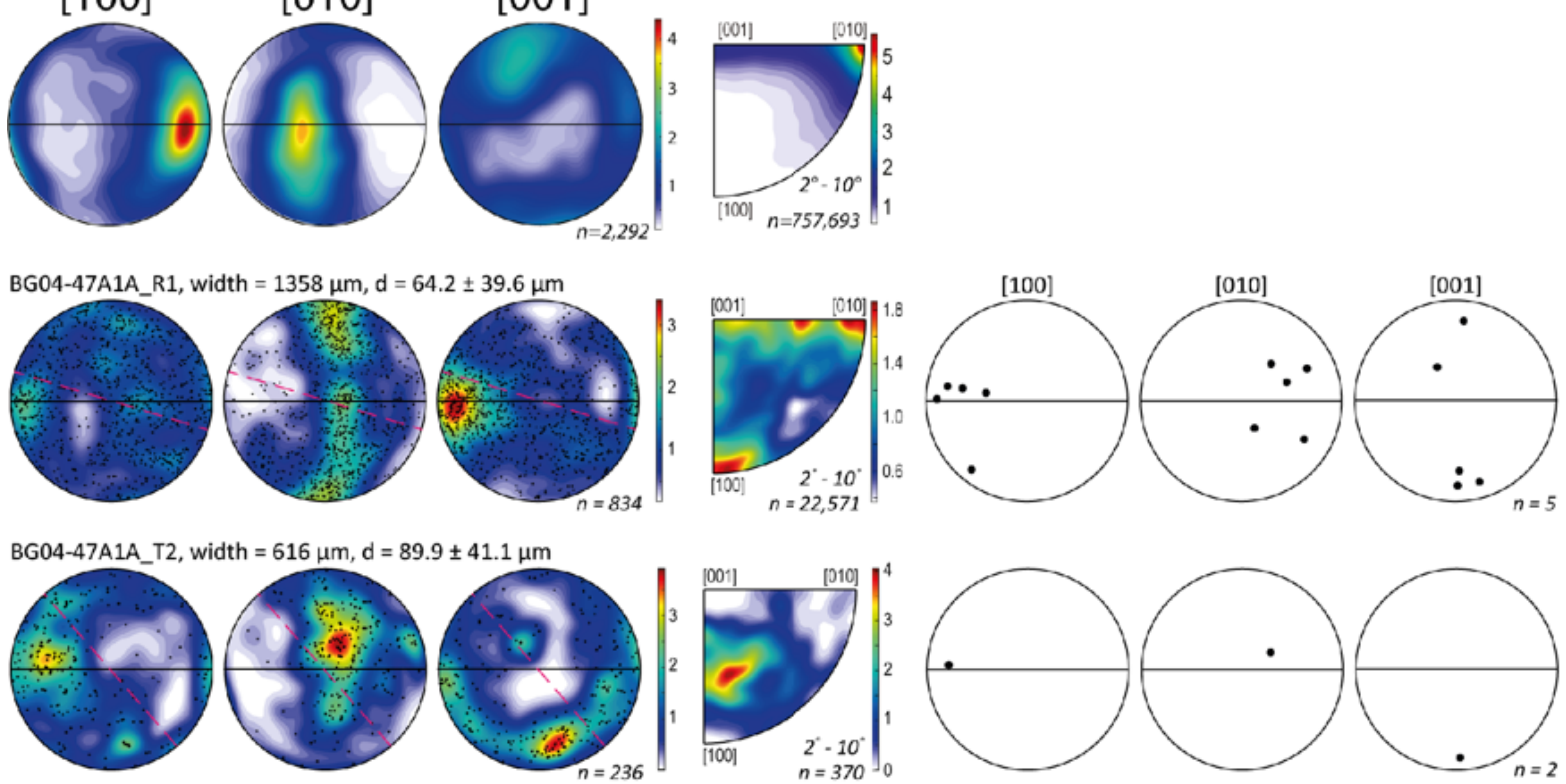
- **R-shear MDZ:** [001] and [100] slip indicates high stresses on the order of few hundreds MPa (Demouchy et al., 2013).

MDZ **Adjacent host grains**

Host harzburgite

R-shear MDZ

T-shear MDZ



Spatial and temporal variations in differential stress

Micro-deformation zones

Stress ranges from 22 to 81 MPa, which is 2–6 times higher than the stress of the corresponding host harzburgites.

Host Harzburgites

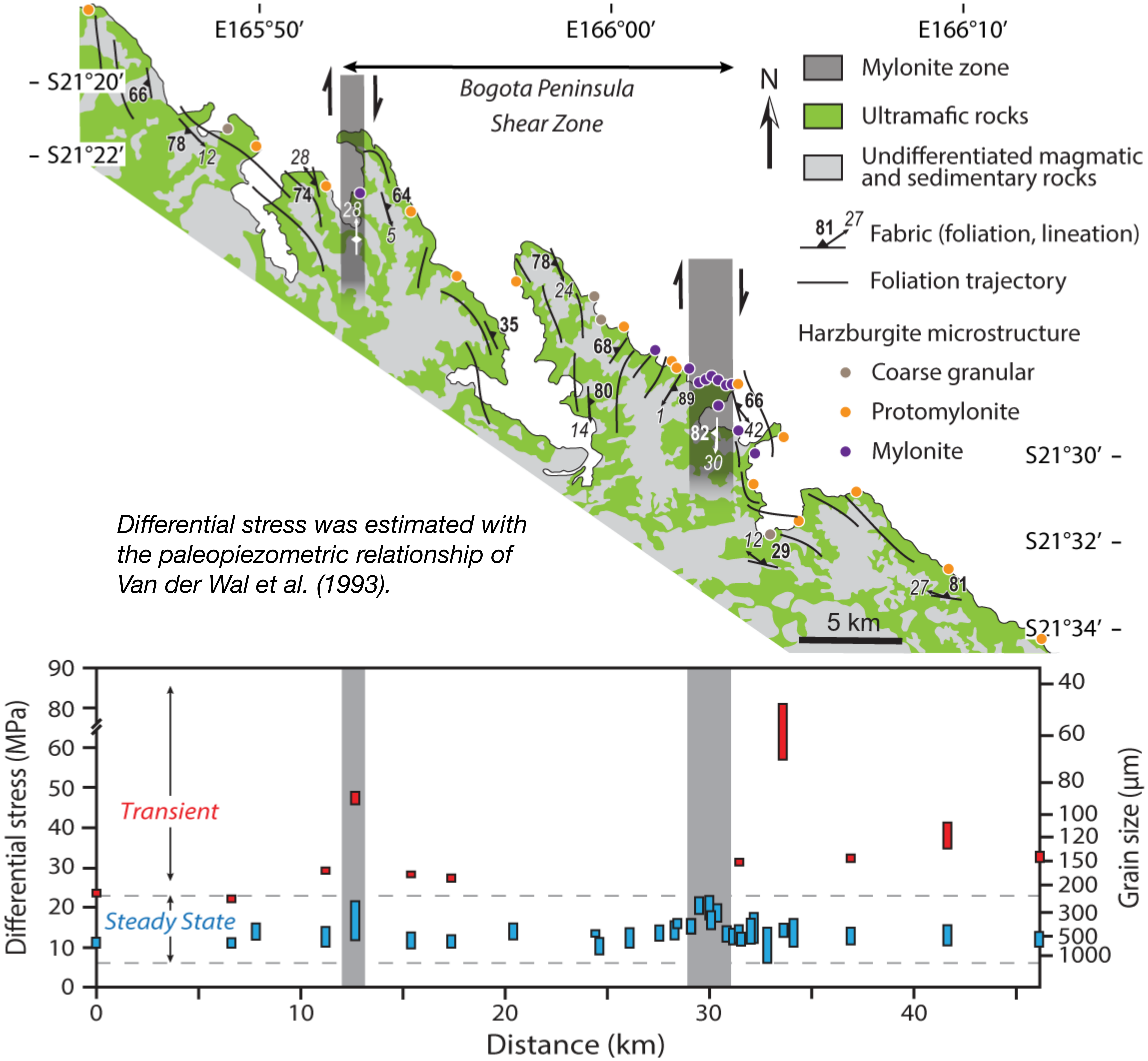
Stress increases with strain toward the two mylonite zones.

Coarse granular tectonites: 6–14 MPa

Protomylonites: 10–16 MPa

Mylonites: 11–22 MPa

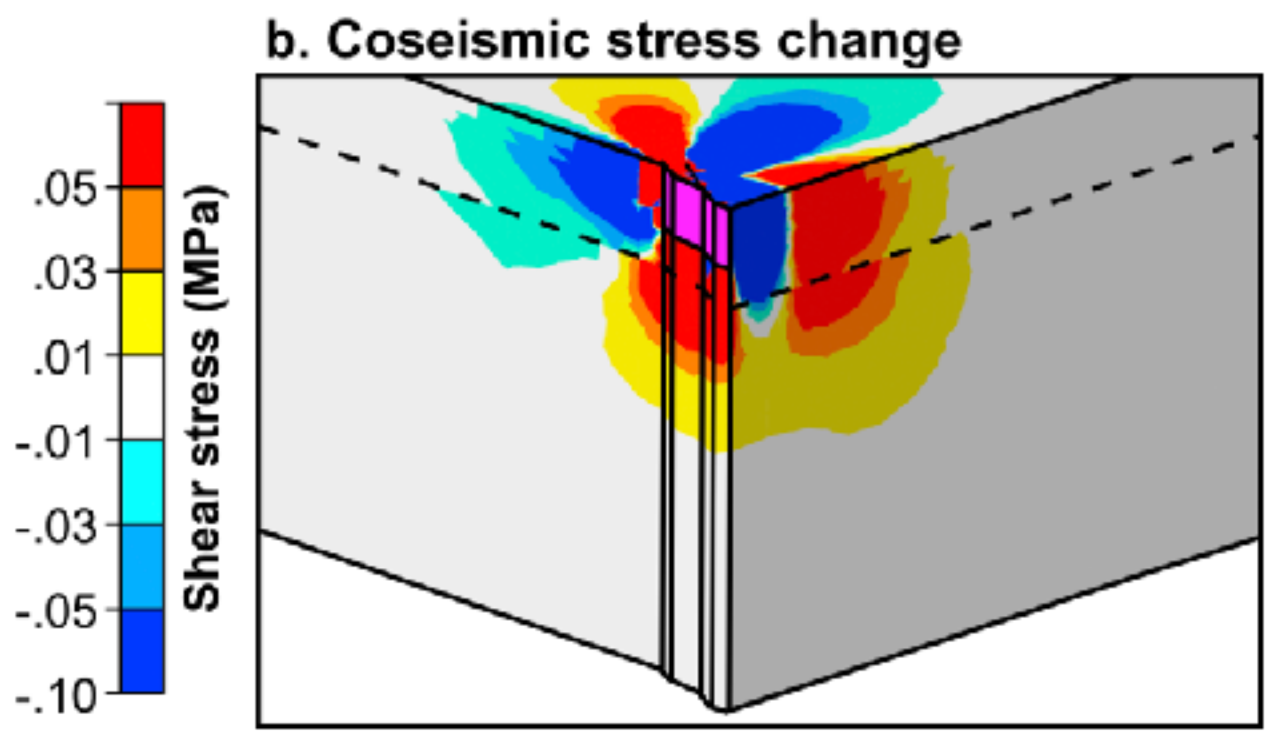
Chatzaras et al. (2020), Geology



Differential stress was estimated with the paleopiezometric relationship of Van der Wal et al. (1993).

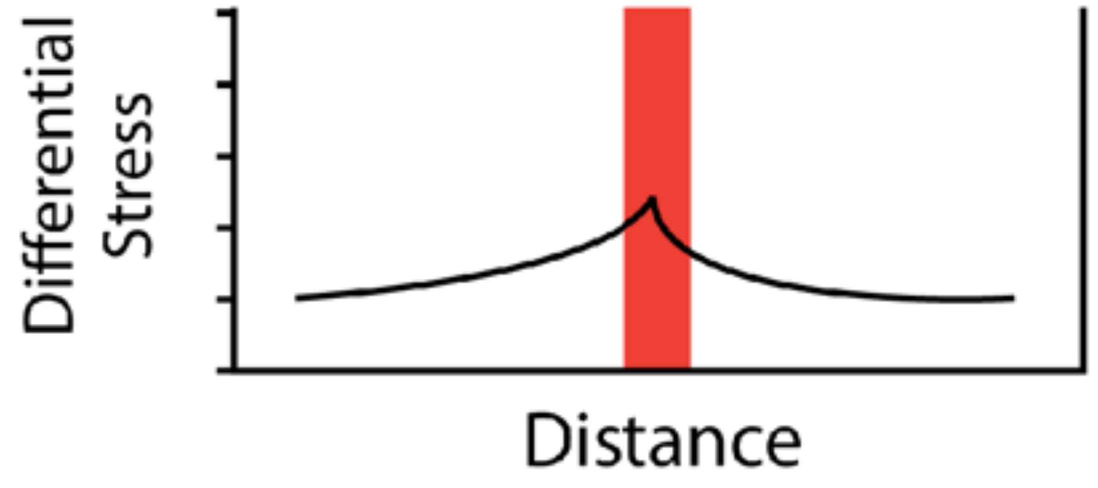
Interpretation of spatial variations in steady state stress

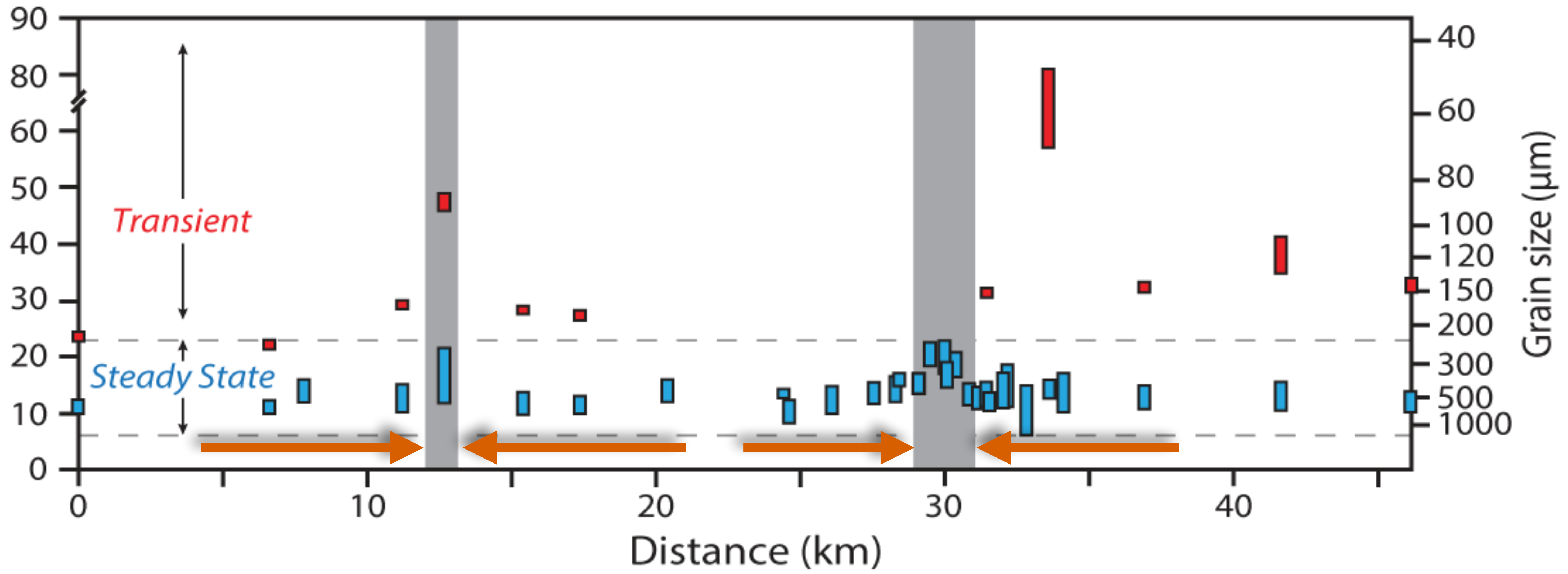
- The host harzburgites record the steady state stress within the Bogota Peninsula shear zone.
- Stress and strain rate increase in the mylonite zones.
- The mylonites do not represent weak zones.
- We interpret strain localisation in the mantle shear zone to be imposed by downward propagation of earthquake rupture, which increases stress (and strain rate) in the underlying upper mantle.



Freed et al. (2012), J. Geophys. Res.

Imposed localisation





Interpretation of temporal variations in stress recorded by the MDZs

- The MDZs are superimposed on the steady state microstructure of the host harzburgites.

- Stress during mantle fracture is not constrained from our data.

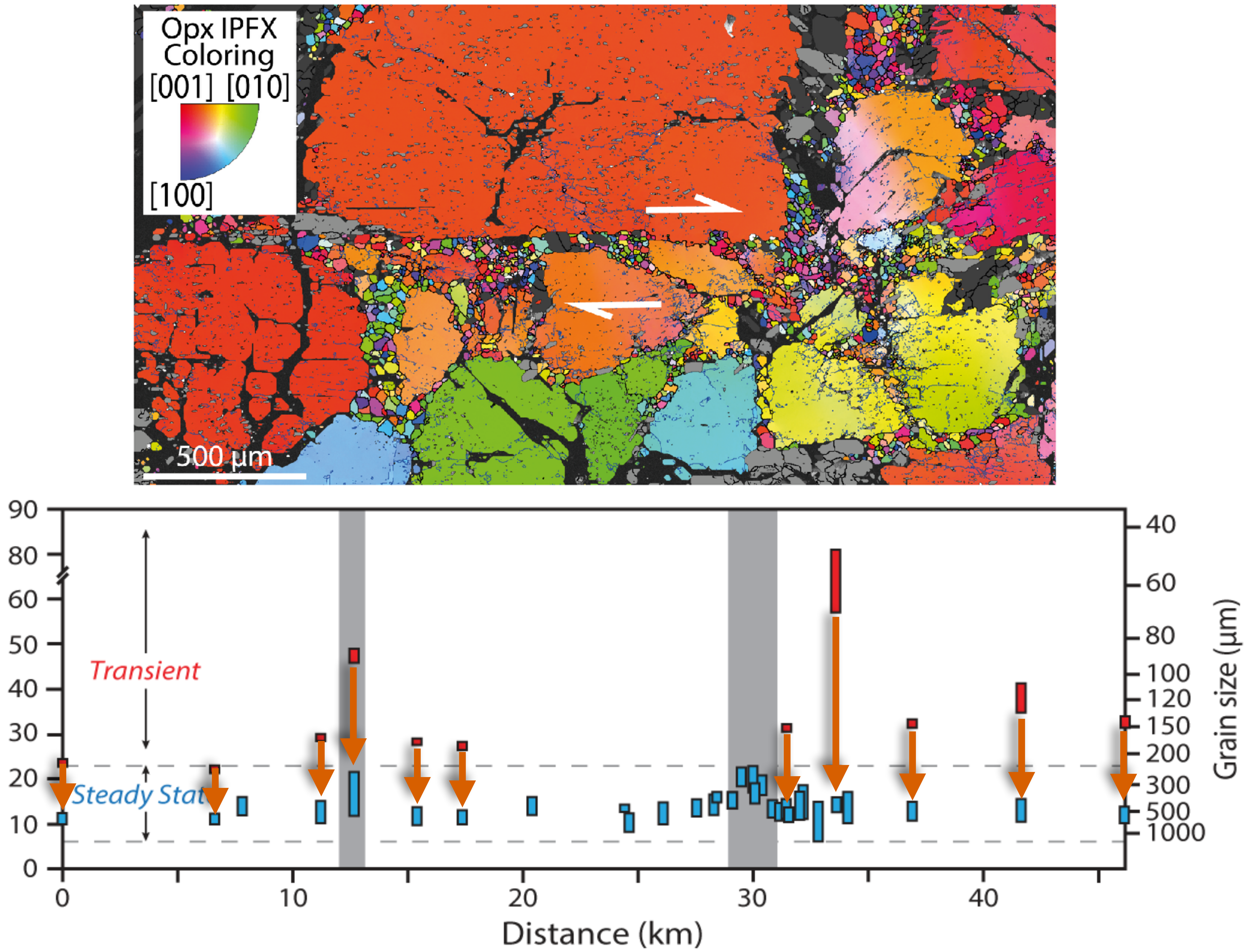
but

- Synchronous activation of olivine [001] and [100] slip in the MDZs, requires high stresses on the order of few hundreds MPa (Demouchy et al., 2013).

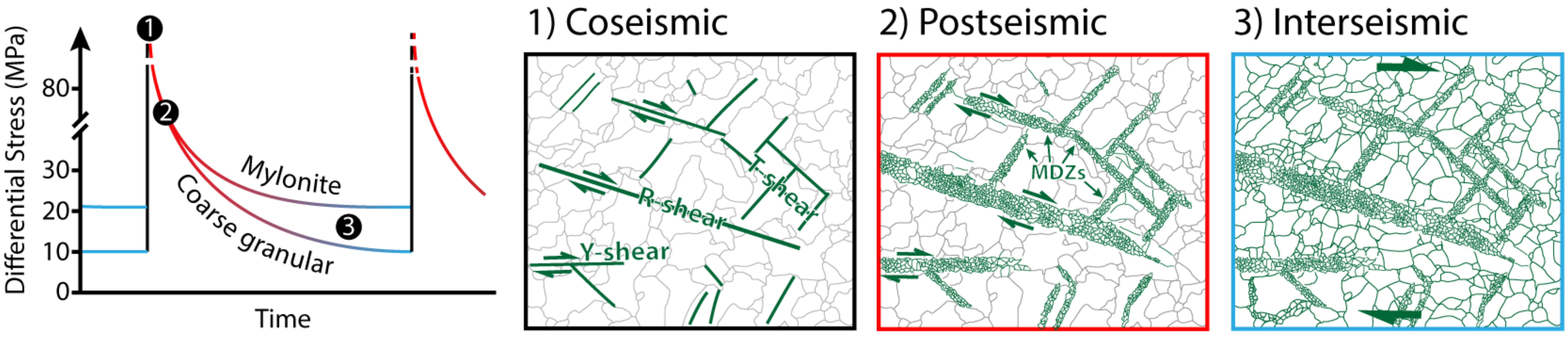
- Stresses in the MDZs reflect some point in the stress relaxation pathway between the high stresses during fracturing and the low stresses during steady state ductile deformation

- Temporal stress variation requires imposed strain localisation.

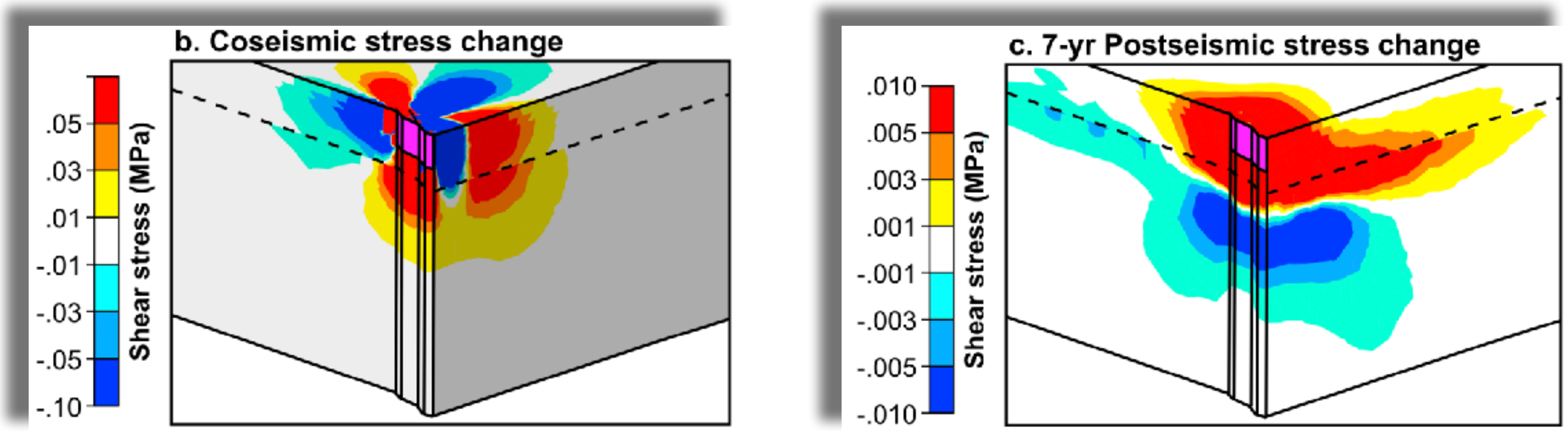
MDZs show brittle-followed-by-ductile deformation.



Links to the seismic cycle



Chatzaras et al. (2020), Geology



Freed et al. (2012), J. Geophys. Res.