Strain localization processes at a magma-starved ridge: from micro-scale to macro-scale

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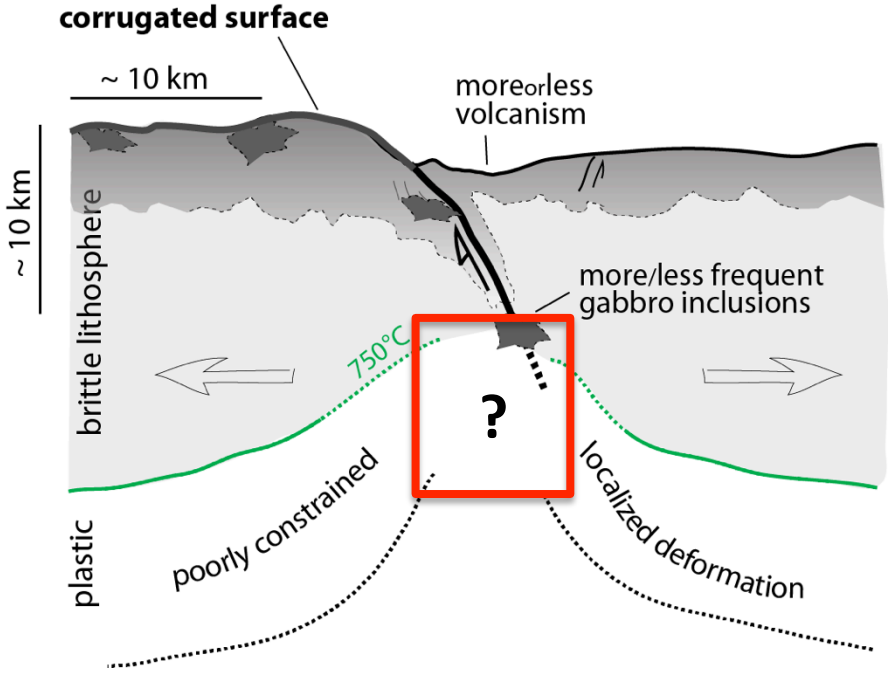
Detachment faults exhume mantle-derived rocks from the base on the brittle lithosphere to the seafloor.

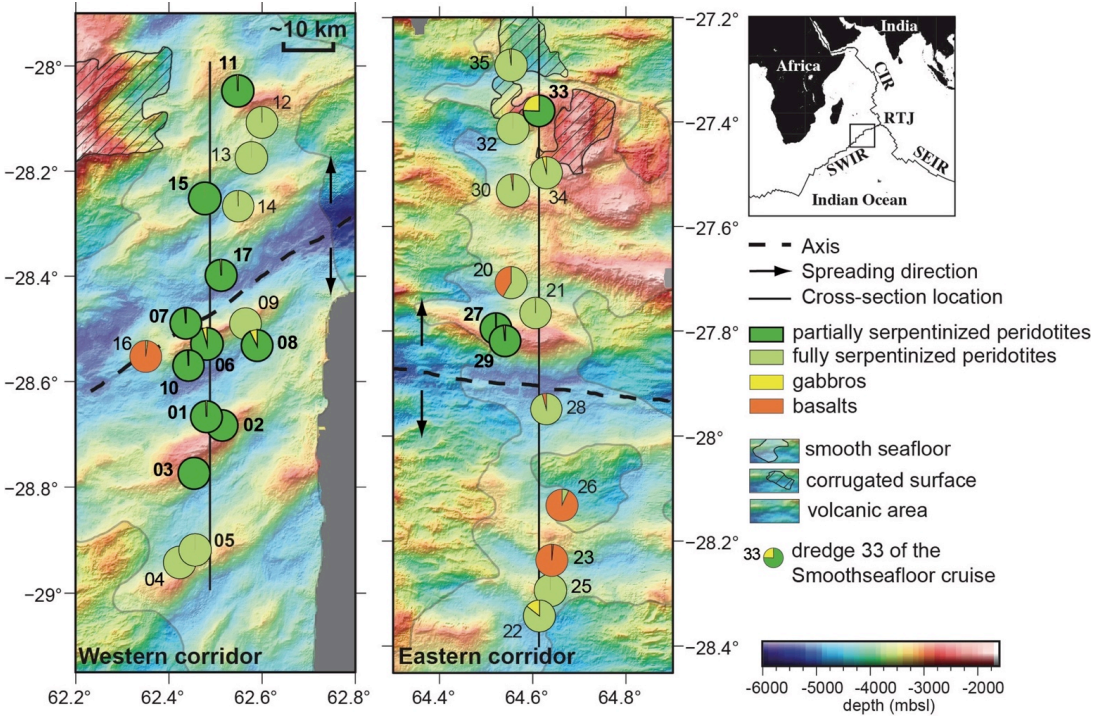
- *What are the strain localization mechanisms in the deep axial lithosphere when there is **no magma** ?*
- *How to make detachments in a **thick** lithosphere (≥ 15 km) ?*



[modified from Cannat et al., 2008]

The Eastern SouthWest Indian Ridge (SWIR)

Dredges realized on and off-axis recovered **variably serpentinized peridotites**, with minor amounts of gabbros (< 4%) and basalt (16%).



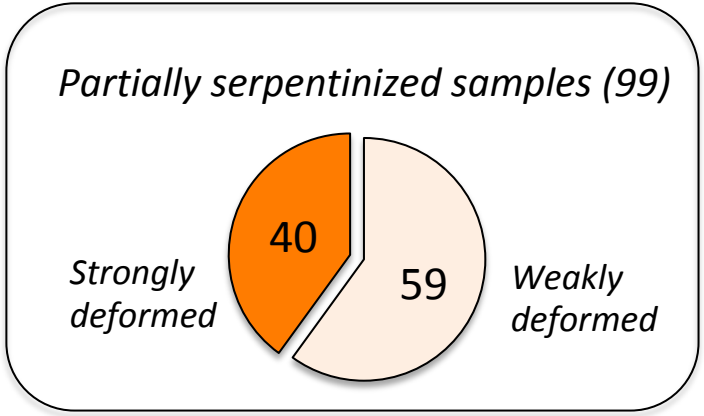
[Bickert et al., to be submitted]

385 samples of ultramafic rocks

↓

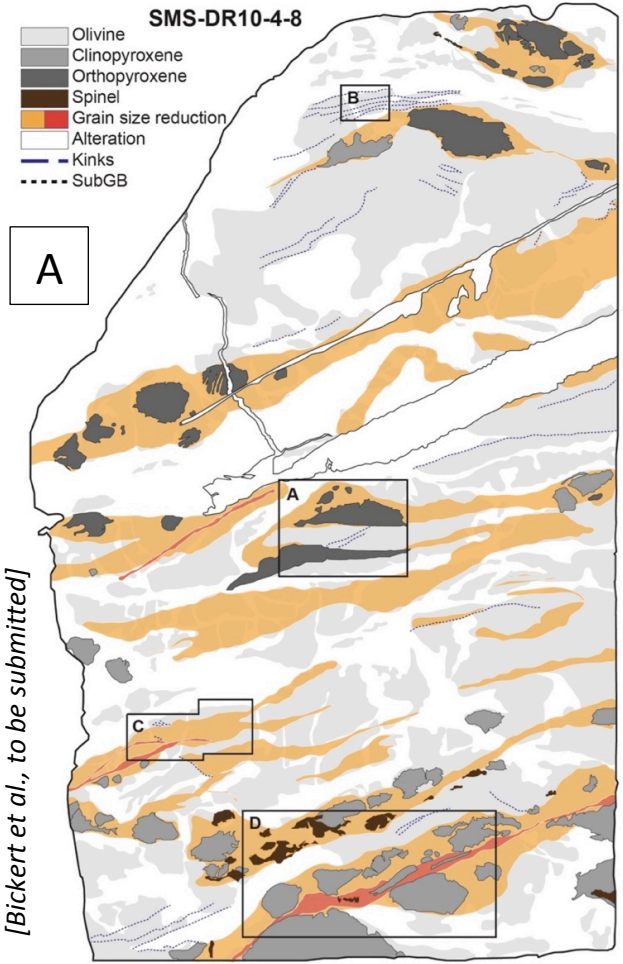
99 partially serpentinized samples

↓



40% of the samples are **strongly deformed,** with **planar fine-grained zones.**

Extracting P-T conditions from grain size reduction zones

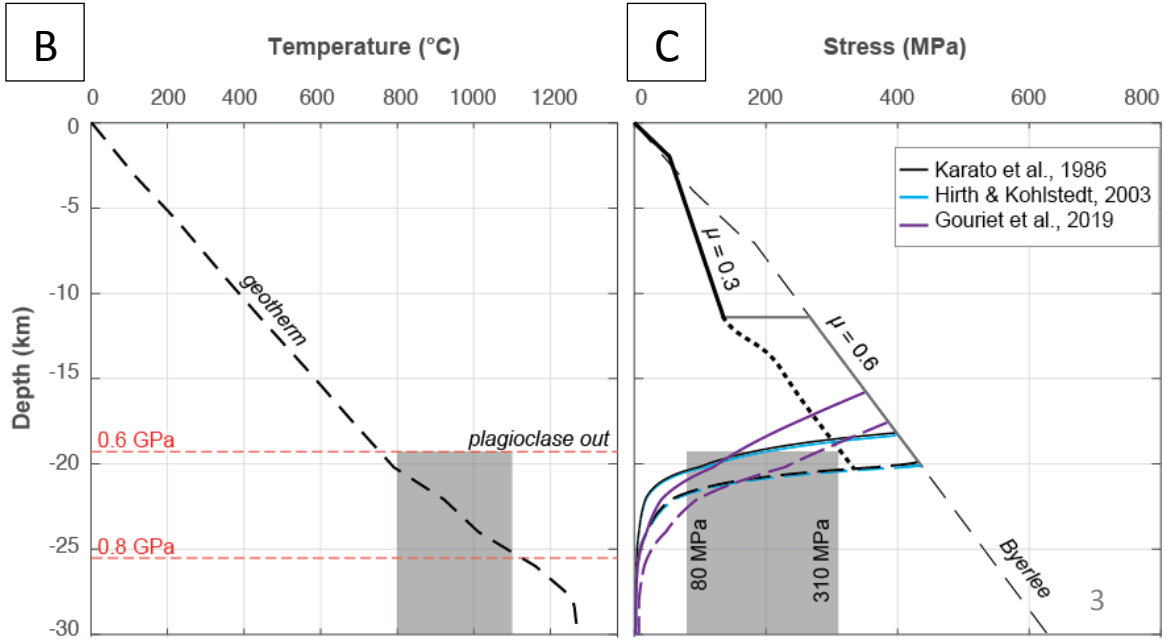


[Bickert et al., to be submitted]

Heterogeneous deformation *combining brittle and ductile mechanisms (Fig. A):*

- *Pressures in the* ***spinel field*** *i.e. at depths > 20 km (Fig. B)*
- ***High temperature*** *(800-1000°C, Fig. B) from orthopyroxene thermometry*
- ***High deviatoric stresses*** *(80-270 MPa, Fig. C) from olivine grain size*

We propose that this deformation characterizes ***the root of SWIR axial detachments.***

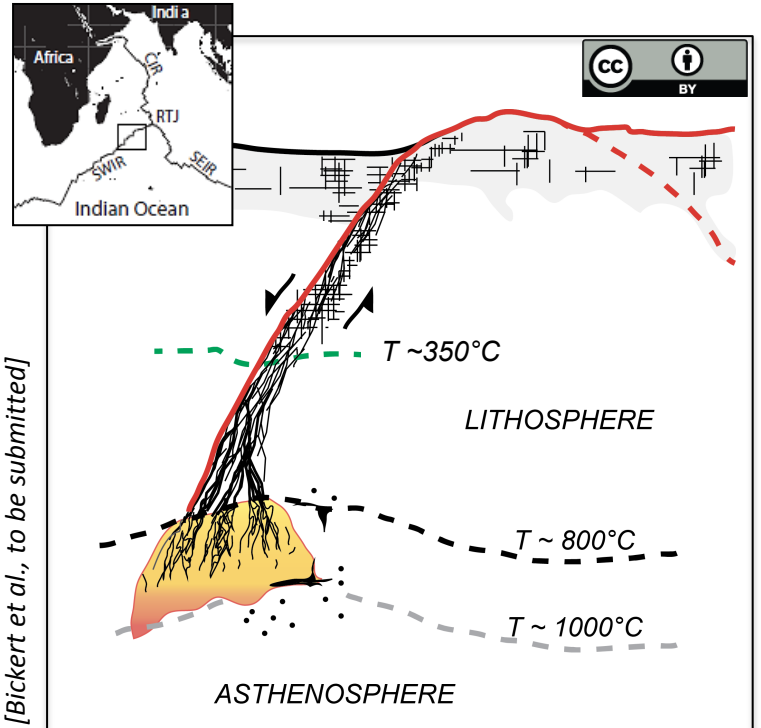


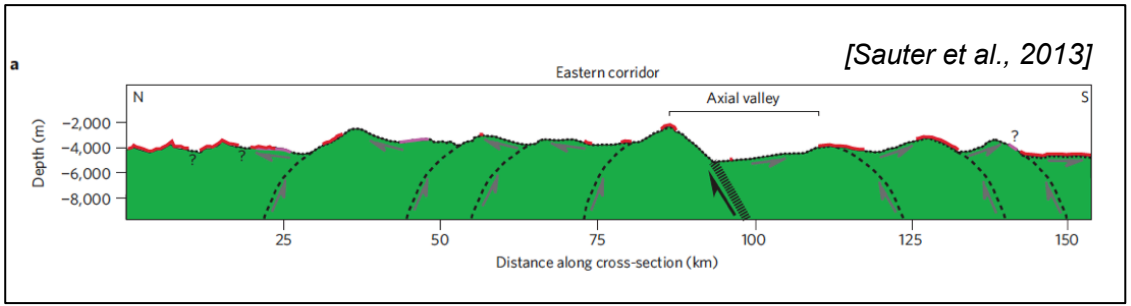
From the microscale to the macroscale:

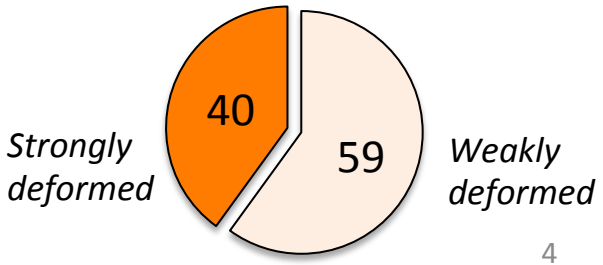
Plate scale deformation models

Is it possible to obtain flipflop detachment faults with similar life-spams as those observed in nature by considering:

- *A thick brittle lithosphere (~ 20 km)*
- *Two strain softening mechanisms observed in the samples:*
  - ✓ *Serpentinization (T≤ 350°C)*
  - ✓ *Grain size reduction (800-1000°C)*







Serpentinization alone …
does not produce flipflop detachments.

1) When conditions are appropriate:

$$T \leq 350°C$$

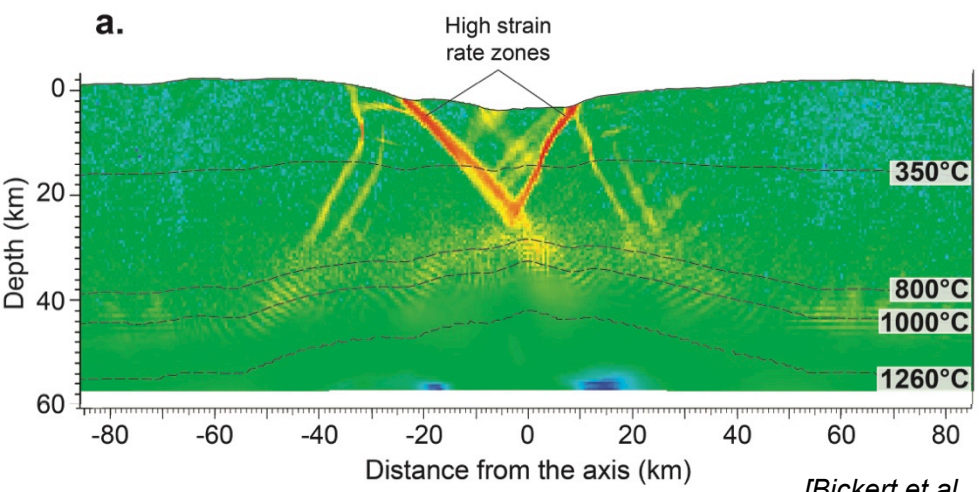
$$\varepsilon^{II} . \sigma^{II} = 10^8 \text{ J}$$

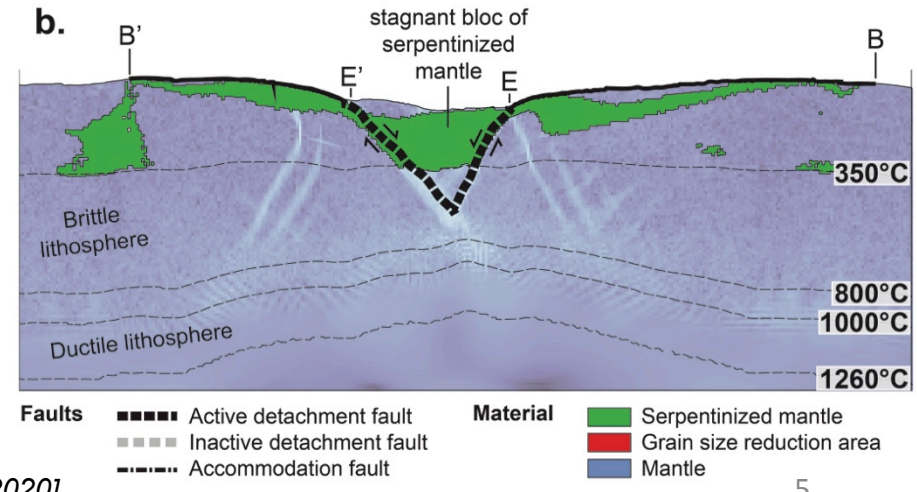
2) Decrease of cohesion and friction:

$$\tau = \mu . \sigma_n + C$$

3) Decrease of activation energy:

$$\dot{\varepsilon} = A . \sigma^n . \exp\left(\frac{-Q}{RT}\right)$$





[Bickert et al., 2020]

Grain size reduction alone …
does produce flipflop detachments.

2) Set up of new grain size:

$$d = 0.015.\sigma^{-1.33}$$

[Van der Wal et al., 1993]

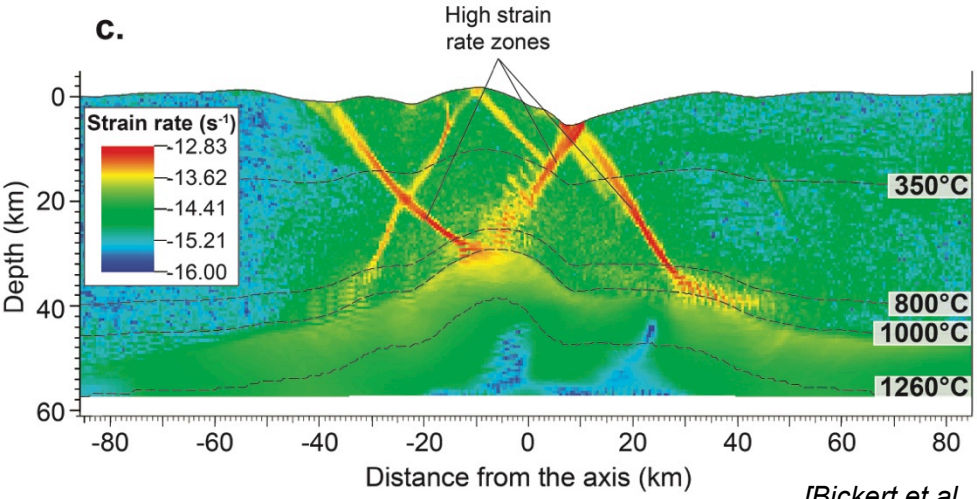
1) When conditions are appropriate:

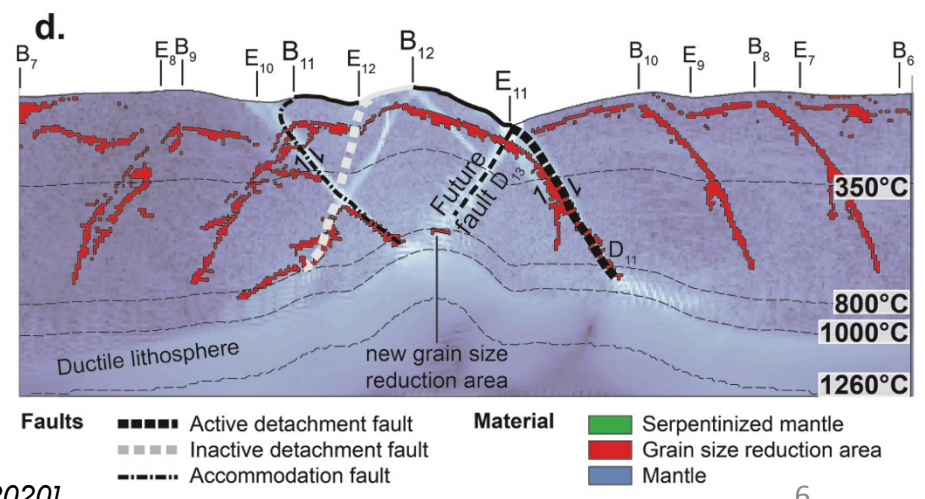
$$T = 800 - 1000°C$$

$$\dot{\varepsilon}.\sigma = 200.10^{-8}\ Pa.s^{-1}$$

3) New viscosity using diffusion creep law:

$$\dot{\varepsilon} = A\,.\,\sigma\,.\,d^{-p}.\exp\left(\frac{-Q}{RT}\right)$$

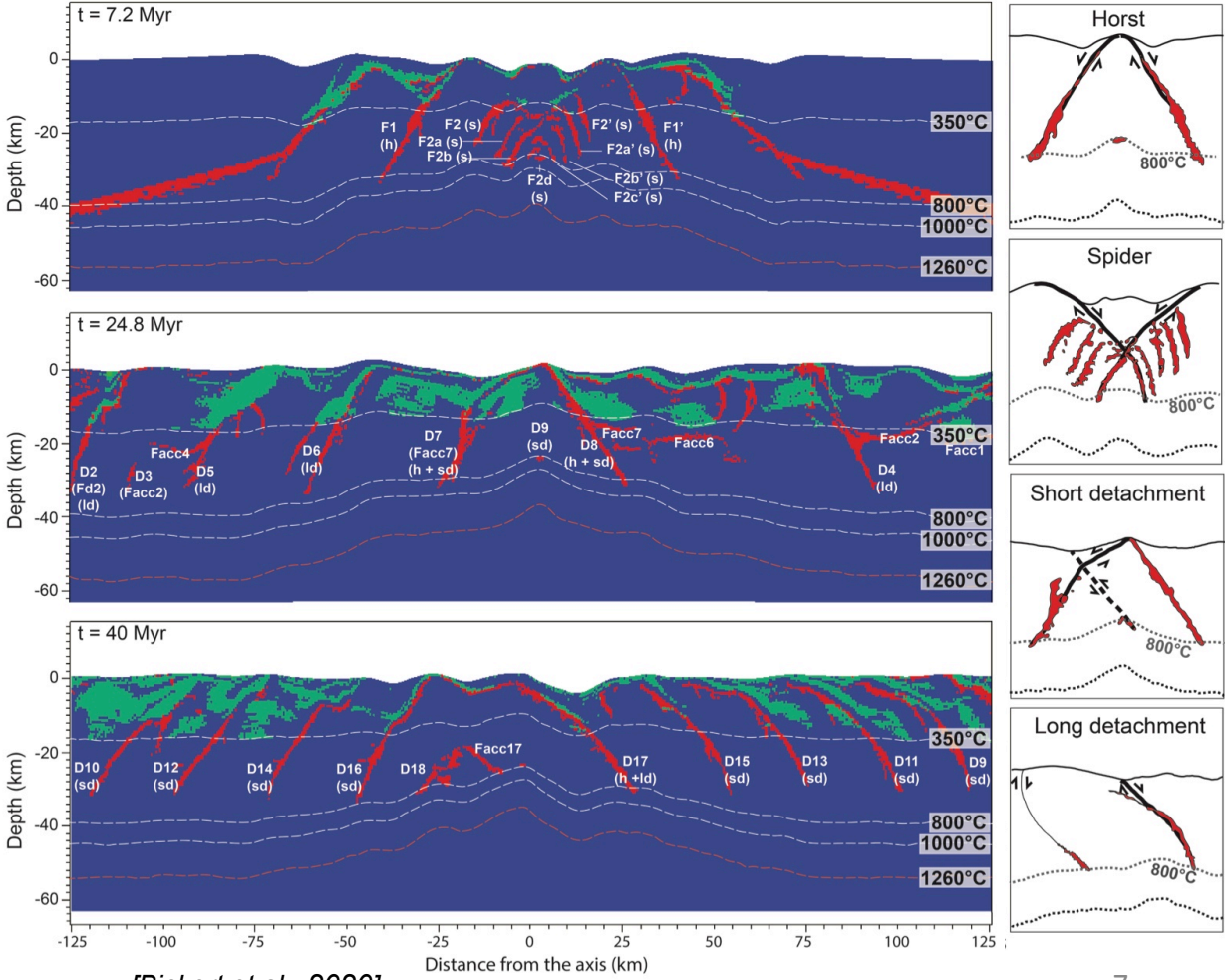




[Bickert et al., 2020]

Models with serpentinization + grain size reduction …

- … ***develop four faulting modes***, *including 2 detachment modes.*
- *Serpentinization alone does not produce flipflop detachments.*
- *Grain size reduction makes flipflop detachments possible in a thick lithosphere.*
- ***By combining the two***, *the resulting fault patterns approach the flipflop detachment faulting pattern at the Eastern SWIR.*



[Bickert et al., 2020]

Questions ? Comments ?
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