2022 Ada Lovelace Workshop
on Numerical Modelling of Mantle
and Lithosphere Dynamics

Héviz, Hungary

➢ **Section: Subduction and Spreading**

School of Earth and Environmental Sciences
Ysgol Gwyddorau'r Ddaear a'r Amgylchedd

Progressive weakening within the overriding plate during dual inward dipping subduction (DIDS)

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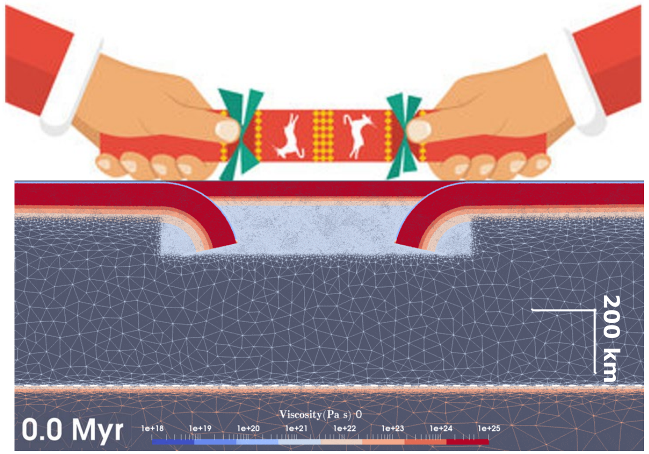

29/AUG/2022

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Motivation & Knowledge gaps

- Dual inward dipping subduction (DIDS) is a young research topic: ~5 years.
- Pioneering models gave an outline for DIDS's impact on: trench motion, slab velocity & morphology etc.
- Limitation: using a simplified constant or Newtonian rheology, which fails to simulate plate weakening processes.

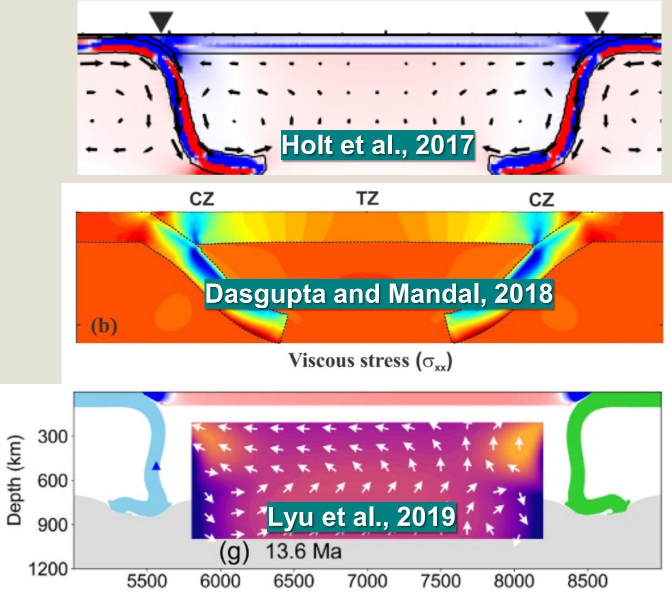

Figure 1. Pioneering simulations on DIDS.

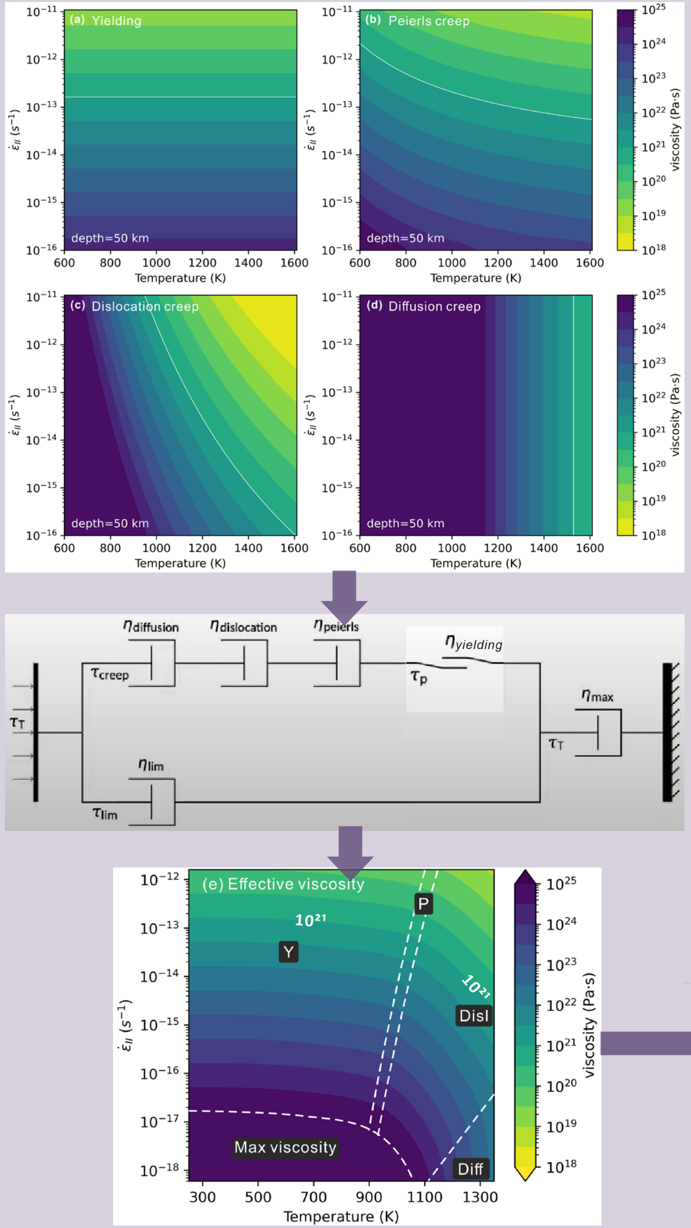

Figure 2. Improved composite rheology (Based on Garel et al., 2014).

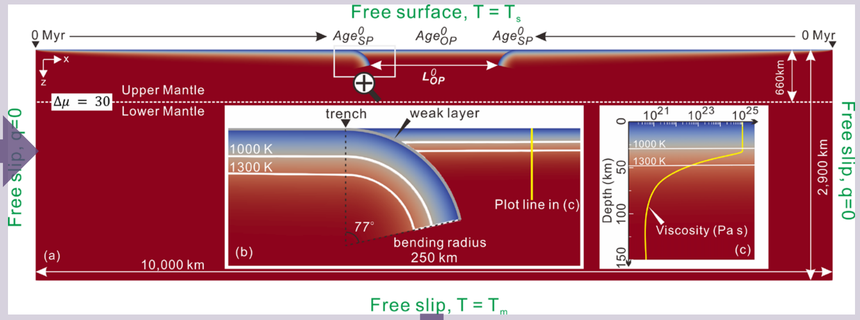

Figure 3. Model setup.

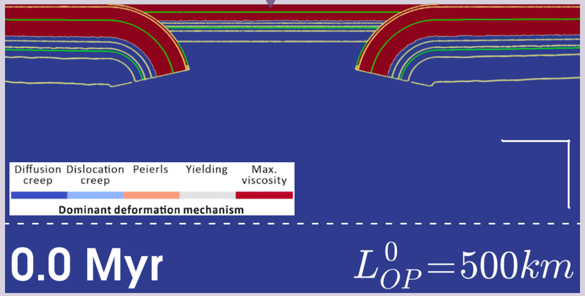

Figure 4. Enabling viscosity reduction within the overriding plate. Yellow contours are iso-viscous contours of $10^{20}, 10^{21}, 10^{22}, 10^{23}, 10^{24}$ $Pa \cdot s$ from the innermost to outermost layer.

Major improvement here:

- implement composite rheology, incorporating non-Newtonian rheology laws;
- further evaluate each deformation mechanism's contribution to the viscosity reduction in the overriding plate.

DIDS effect & plate weakening origin

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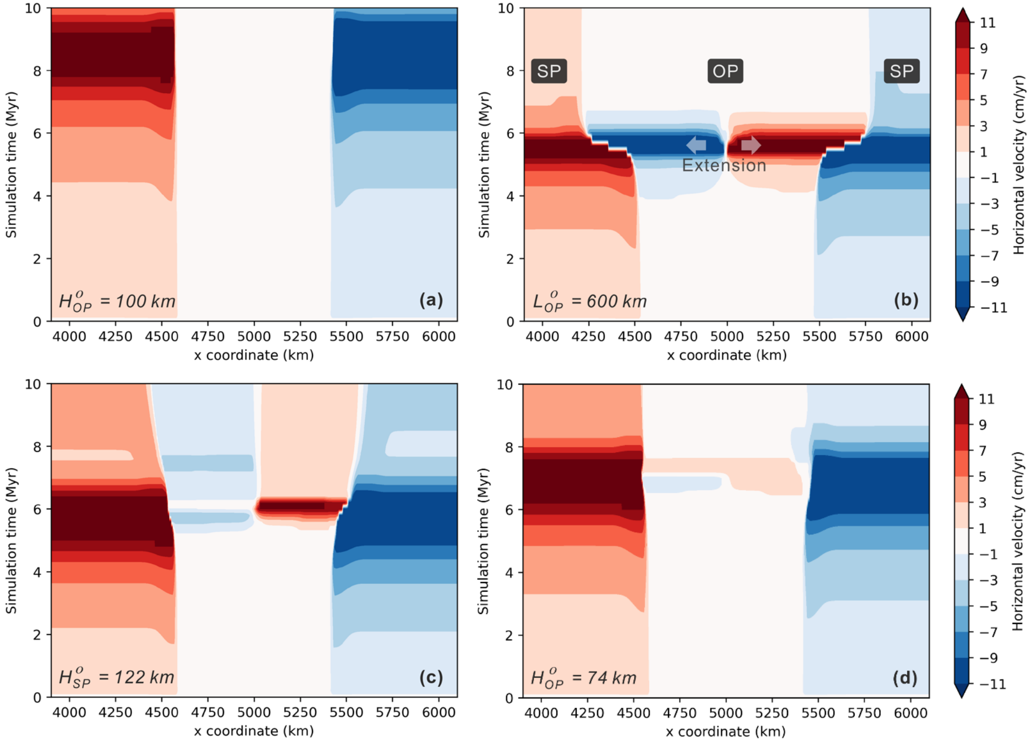

Figure 5. Temporal evolution of horizontal velocity along a lateral slice, at the depth of 20 km from the surface, across the trenches within the lithosphere.

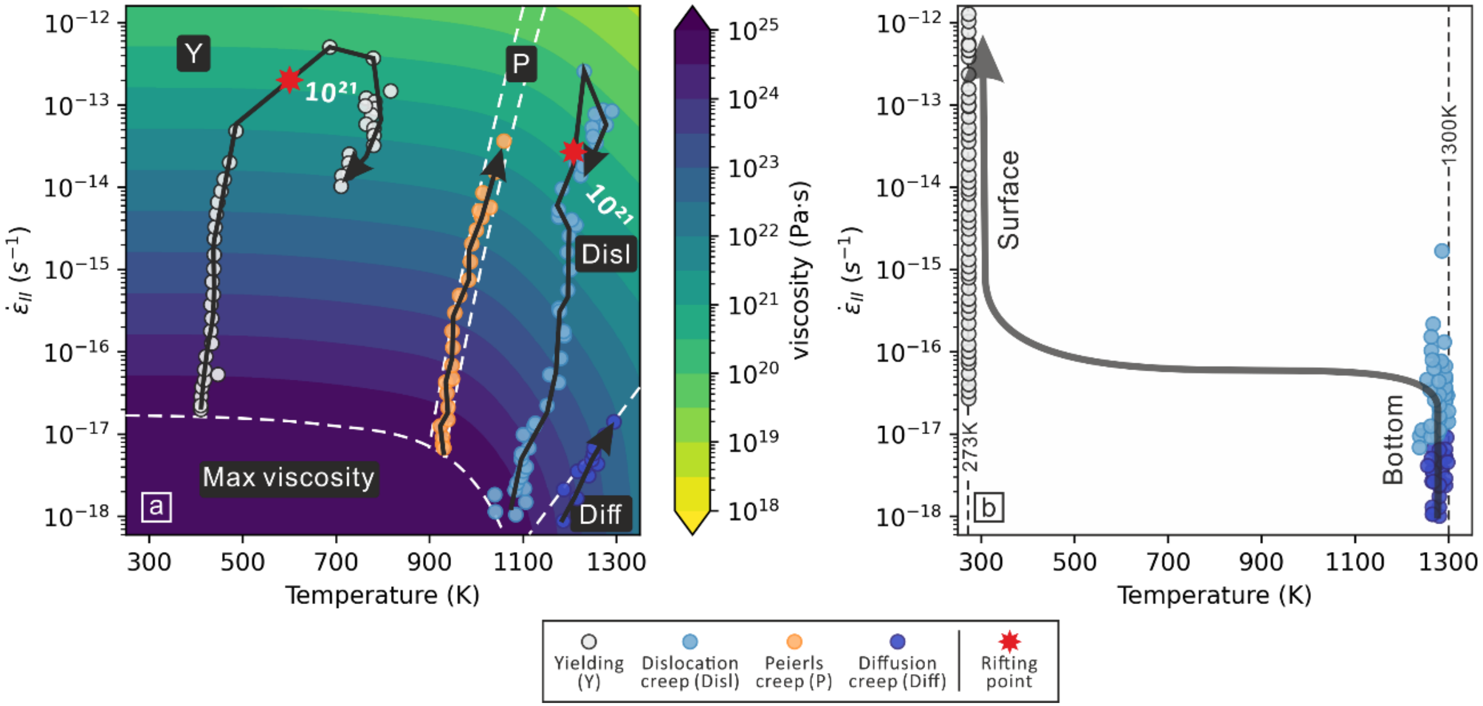

Figure 6. (a) Temporal paths of effective viscosity for each dominant deformation mechanism along the midline of the overriding plate, where plate weakens and strain localises. (b) Temporal paths of the deformation mechanism that yields minimum viscosity within the overriding plate.

- ❖ **DIDS can self-consistently form a fixed boundary condition & strong mantle wedge flow, which can lead to necking/strain localisation within the overriding plate (Fig. 5).**
- ❖ **Temporal paths of effective viscosity show that dislocation creep and yielding contribute most to plate weakening (Fig. 6, a). In addition, the necking and plate thinning initiates from the bottom of the plate (Fig. 6, b).**
- ❖ **The quantitative method proposed here to evaluate each deformation mechanism's contribution to viscosity reduction (Fig. 6) can be a powerful tool to understand other strain localisation processes, e.g., formation of new plate boundaries as subduction or rift initiates.** ✨

Outlook

- **Explore the parameterization of individual rheology law's role in contributing to the magnitude of viscosity reduction in the overriding plate.**

- **Consider other processes that may significantly alter the rheology of the lithosphere, e.g., melt weakening, grain size reduction, reorientation of minerals etc.**

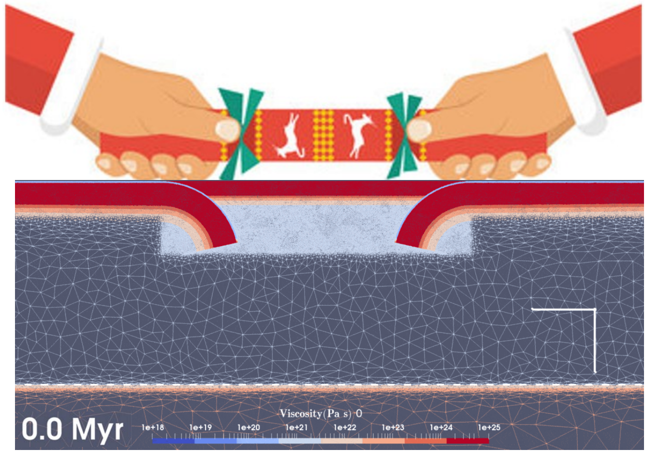

Photo taken in London by Dr Erin Scott, 2019

Discussions are very welcome!

References

- Dasgupta, R., Mandal, N., 2018. Surface topography of the overriding plates in bi-vergent subduction systems: A mechanical model. Tectonophysics 746, 280–295. https://doi.org/10.1016/j.tecto.2017.08.008
- Garel, F., Goes, S., Davies, D.R., Davies, J.H., Kramer, S.C., Wilson, C.R., 2014. Interaction of subducted slabs with the mantle transition-zone: A regime diagram from 2-D thermo-mechanical models with a mobile trench and an overriding plate. Geochemistry, Geophys. Geosystems 15, 1739–1765. https://doi.org/10.1002/2014GC005257
- Holt, A.F., Royden, L.H., Becker, T.W., 2017. The Dynamics of Double Slab Subduction. Geophys. J. Int. 209, ggw496. https://doi.org/10.1093/gji/ggw496
- Lyu, T., Zhu, Z., Wu, B., 2019. Subducting slab morphology and mantle transition zone upwelling in double-slab subduction models with inward-dipping directions. Geophys. J. Int. 218, 2089–2105. https://doi.org/10.1093/gji/ggz268

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