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The role of transform faults during back-arc spreading centre jumps

N. Schliffke[1*], J. van Hunen[1], F. Gueydan[2], M. Allen[1], V. Magni[3] 1) Durham University, 2) Université Montpellier, 3) CEED, University of Oslo
Corresponding Author: Nicholas.j.schliffke@durham.ac.uk

Take-home messages:
- Total deformation and length of transform faults limited in subduction zones
- The maximum transform fault length regulates timing of back-arc spreading jumps
- Timing and location match observations in Scotia, Caribbean and Tyrrhenian Sea

Episodic subduction with homogeneous plates

Motivation

➢**Jumps in the location of spreading centres towards a uni-directionally retreating trench are a common, but not universal feature of plate tectonics.**

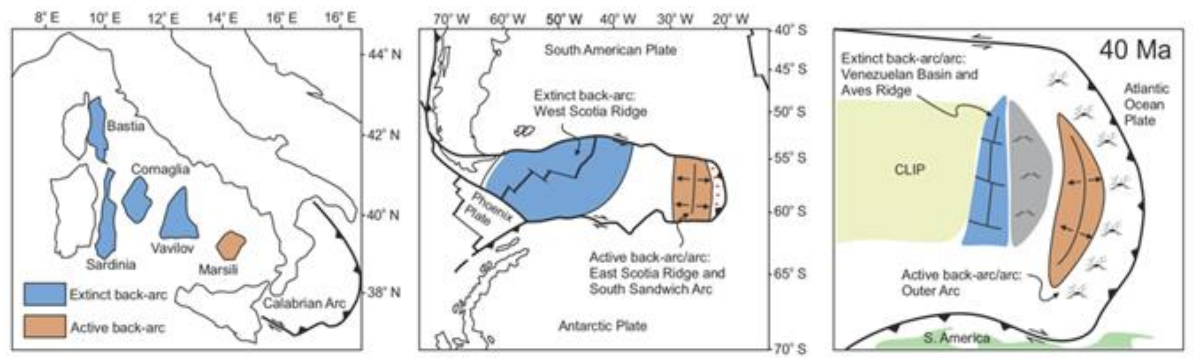


Figure 1: Sketch of back arc spreading centres and their newly formed basins in the central Mediterranean (plate width currently ~300km, based on Gueydan et al., 2017), Scotia (~750km wide trench, based on Eagles and Jokat, 2014) and Caribbean at 40 Ma (~820 km wide trench, based on Allen et al., 2019. All subduction zones are bound by STEP- and transform faults.

➢**Spreading centre jumps** with nearly **instantaneous** activity change in Scotia, Caribbean and central Mediterranean.

➢All subduction zones bound by prominent **transform faults.**

➢Rollback rates in these regions decreased before the spreading jumps and increase after.

➢Previous explanations include *adhoc events*, e.g. opening of slab-windows, the slab's inability to penetrate the 660 km, or inherited weakness: None are applicable to all regions presented above.

➢Whether such jumps can evolve in a rather homogenous subduction system, or if the transform faults play an active role is unknown

Problem: What triggers back-arc spreading jumps in absence of strength or buoyancy variations on subducting or overriding plates?

Controls on back-arc spreading

➢Opening of back-arc spreading centres either by

➢**Fluid- and/or melt-weakening** of the overriding plate (e.g. Baitsch-Ghirardello et al, 2014)

➢Or **trench rotation** around a continental bock localising stresses in overriding plate after lateral subduction of buoyant indentors (Wallace et al., 2009, Magni et al., 2014)

➢Wallace et al. (2009): **Scotia back-arc** is special **because no rapid fore-arc rotation** after collision with a buoyant neighbouring block could have triggered the plate rupturing.

Question:
Does a different mechanism involving the prominent transform faults open second back-arc spreading centres?

Model Evolution

Model Setup

➢Using **CITCOM** (Moresi and Gurnis, 1996): a long oceanic plate subducts between two continents

➢**Purely buoyancy driven** models

➢**No compositional strength differences** used

➢**Simple Rheology**: Diffusion creep, dislocation creep, pseudo-plasticity, and limiting viscosity rheology

➢Initial **imposed transform faults end** after 660km to allow for their physical creation

➢Slab width varied between 400-1000km

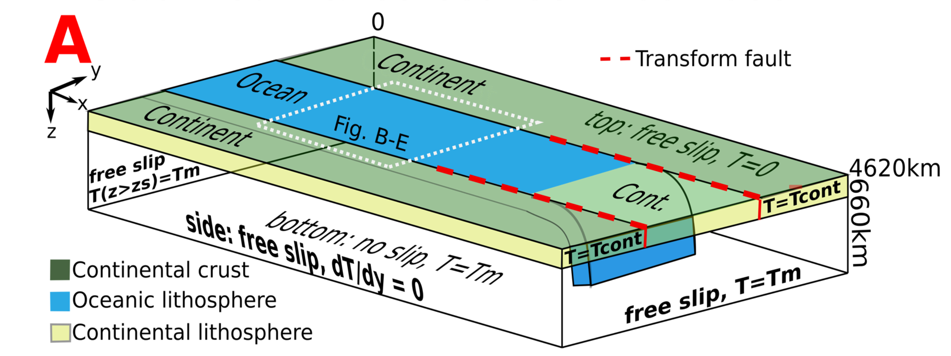


Figure 2: Model setup. A slab is subducting between two continents.

➢Initial subduction and rollback including the entire upper plate occurs between imposed transform faults.

➢Opening of first back-arc once imposed transform faults end, where **rollback is generally only feasible by tearing of the lithosphere at STEP (Subduction-transform-edge-propagator) faults.**

➢Models >600km form **transform faults** between back-arc spreading center and trench **self-consistently** by **localising stresses at plate boundaries** (Fig. 3B)

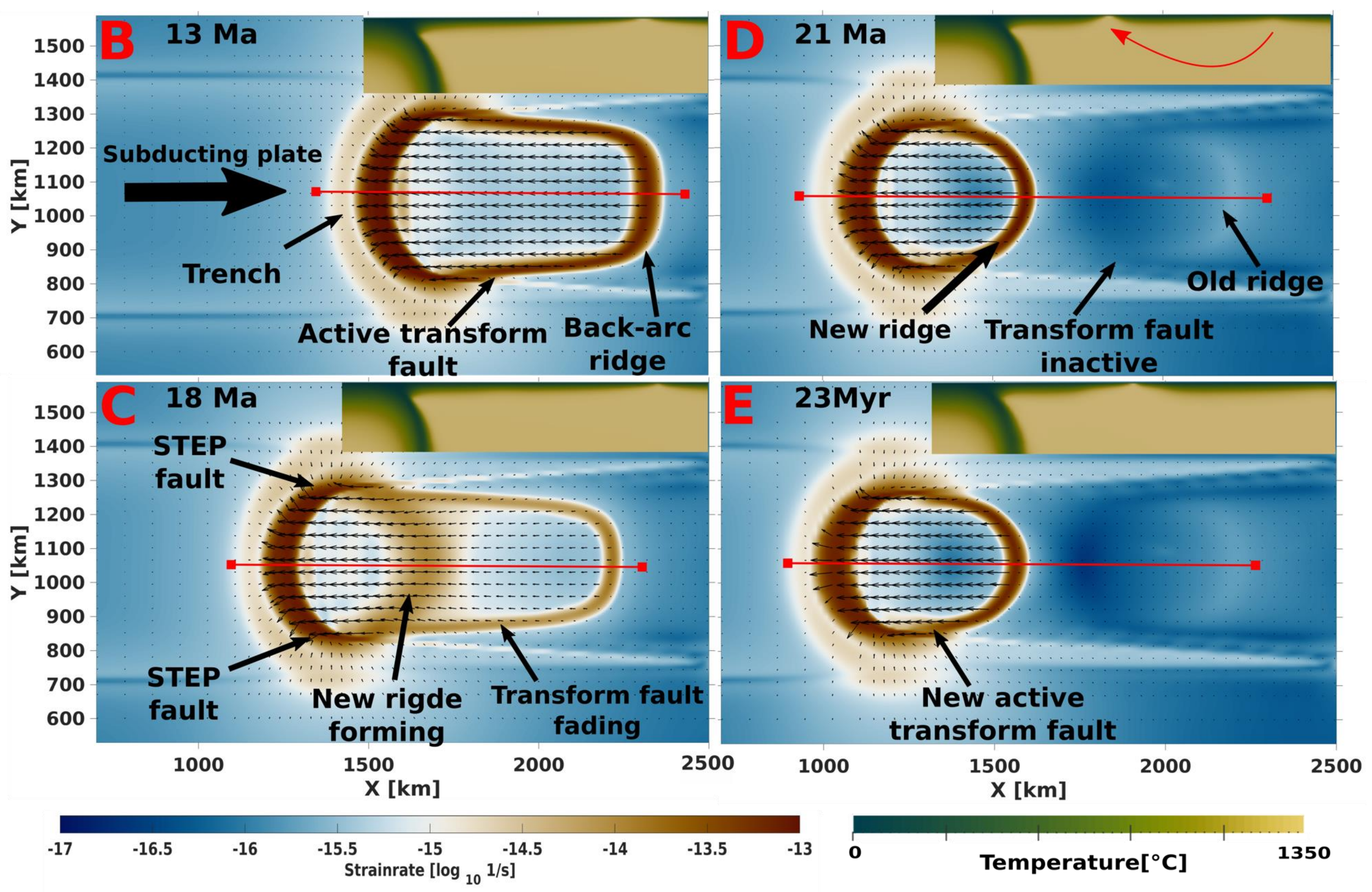
➢Rollback rates increases with the initial back-arc opening, but are reduced constantly after (Figure 4A)

➢After a period of rollback and spreading, the **transform faults become inactive** at a **critical distance** and couple overriding to neighboring plate due to insufficient stress localization. This ceases spreading. (Fig. 3C).

➢Stress localisation closer to the retreating trench **opens a second, new back-arc spreading centre** (Fig. 3C).

➢Stresses localise where toroidal flow at the base of the lithosphere induce highest stresses.

➢Rollback velocities increase briefly again with back-arc spreading jumps (Figure 4A).



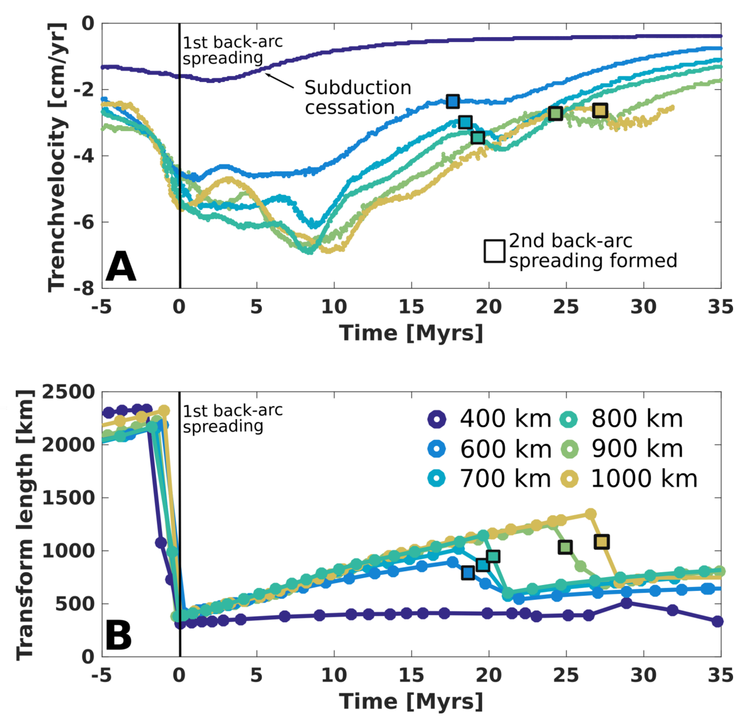


Figure 3(left): *Model evolution represented by the second invariant of strain rate and temperature profile through relevant areas.* **Figure 4 (above):** *Evolution of rollback velocities and transform fault lengths for all models.*

Comparison to nature

➢**Models** with 600-1000km wide plates with **linear trend** for characteristics of spreading duration and max. length of transform faults (Figure 5).

➢Observed data of **spreading centre jumps** (blue points) close to regression line.

➢Other regions with only **a single back-arc spreading centre** (grey points) plot clearly under the regression line.

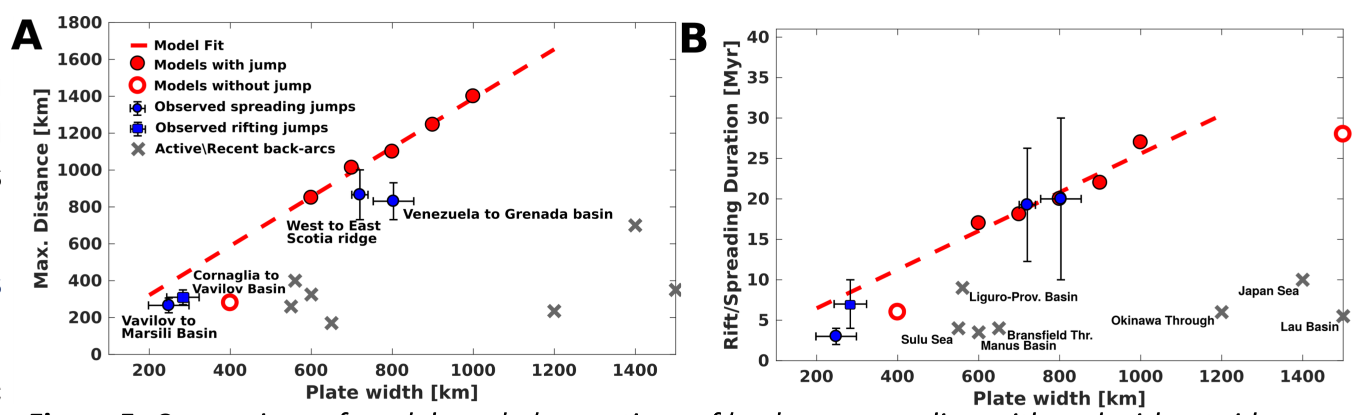


Figure 5: *Comparison of models and observations of back-arc spreading with and without ridge jumps. Model data in red, observations with spreading in black, with jumps in blue. The extrapolated linear relationship neglects the 400 km model.*

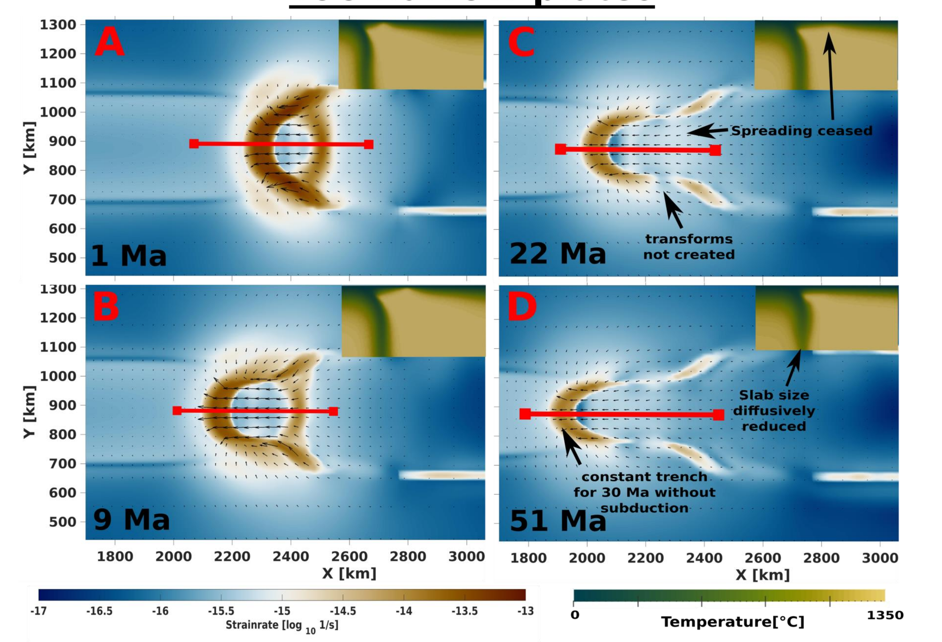
No spreading centre jumps if…

1) The slab is **too narrow** to localise sufficient stresses to create STEP-fault at subduction hinge and enable any subduction.

2) The slab is **too wide**, so long transform faults are possible and spreading jumps would not occur within a tectonic cycle.

3) **Plate interfaces are too weak**. In such case deformation and relative plate motion is simple, and, subducting and overriding plate can retreat along neighbouring plates without localised stresses. No back-arc spreading occurs at all.

Too narrow plates



Too wide plates

Too weak plate interfaces

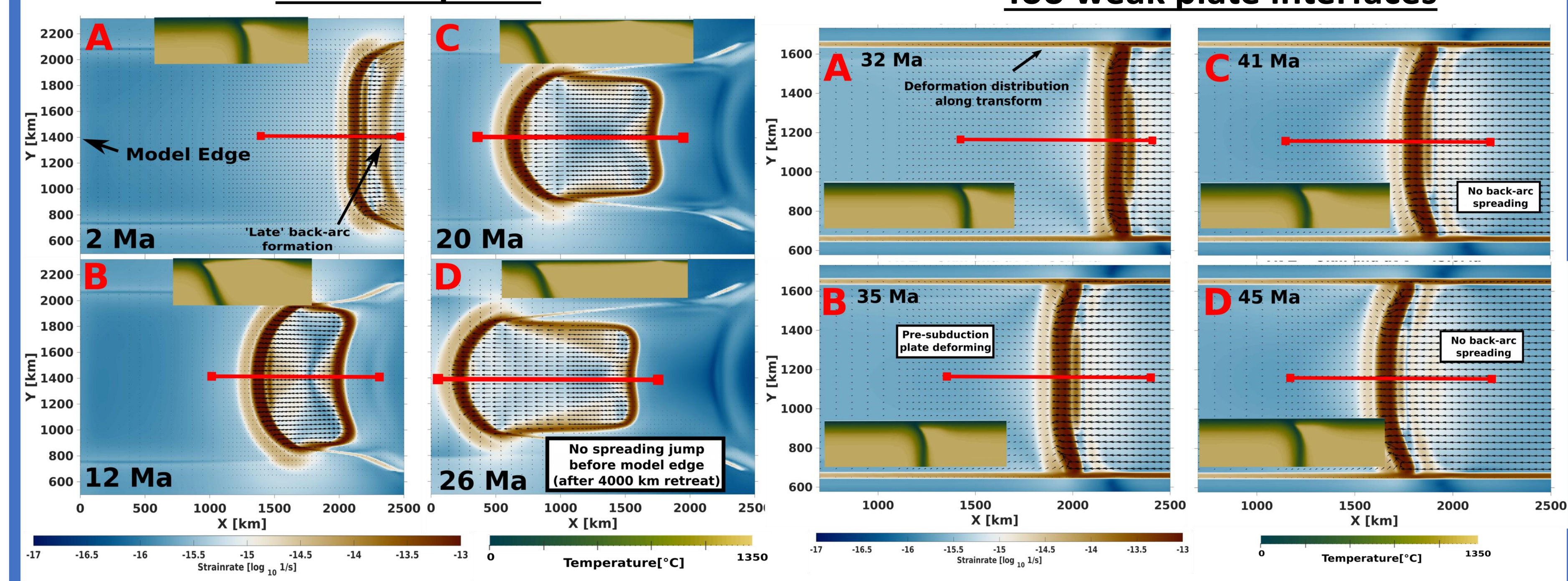


Figure 6-8: Model evolution for models without spreading jumps

Summary

➢Transform faults have a limited length in retreating subduction systems

➢Transform faults locking close to spreading center trigger spreading jumps

➢Wide slabs can sustain transform creation and keep their activity running for a longer period

➢Data matches data and evolution of the study areas in Caribbean, Scotia and Tyrrhenian Sea

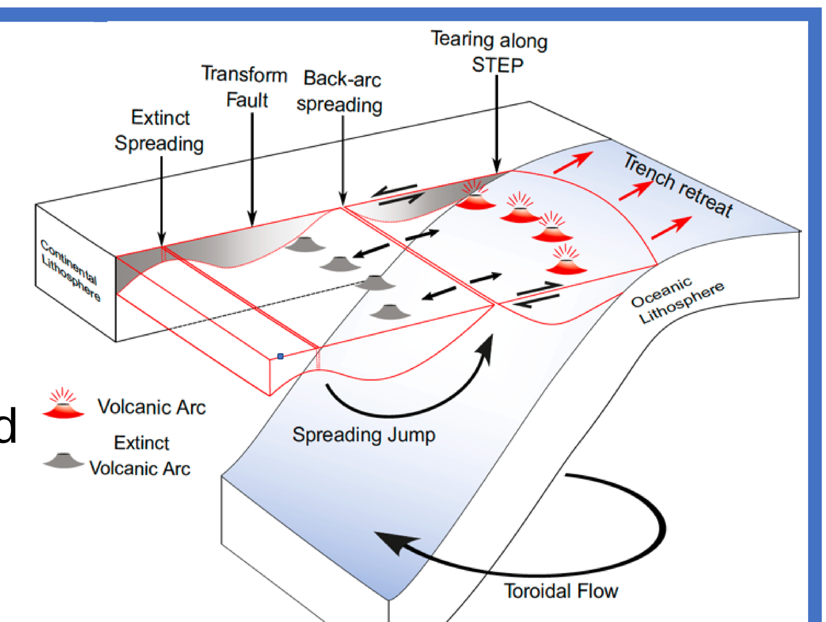


Figure 9: Summary sketch

Literature

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Acknowledgements

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