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3D thermo-mechanical models of continental break up

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Formation of passive margins has been thoroughly studied via 2D thermo-mechanical modelling and conceptual models which have been, and are continually enriched by more and more complex rheologies and initial stratification over the years in order to account for the diversity of their architecture: simple or multiple necking levels, evolution of the size of the tilted blocks, out of sequence faulting, shift in subsidence with time.

More recently, 3D numerical modelling of continental rifting has started to appear in the literature. In these models, oblique structures and more peculiarly, the formation of transform segment seems to only occur for very specific rheological parameters (very fast softening rheologies) and very specific initial spacing of the rift system, which does not seem to reflect the ubiquity of these structures along all of the passive margins on earth.

However, most of the published studies have limited their area of research to cylindrical boundary conditions with shifted notches or lateral inhomogeneities that were embedded in the initial condition of the models. Moreover, these studies are limited to continental extension and never include the rheological and thermal effects of continental break up and oceanisation. This limitation is imposed primarily by the computational cost associated with performing these numerical experiments, which need 1) sufficient resolution to capture a fault spacing of 50 km, 2) fast non linear solver, 3) stable time stepping scheme to perform computation over 10's of million years.

For geological applications, the aforementioned limitations are problematic because continental transform faults are very seldom on Earth and most of them are inherited, while transform margins exist everywhere and geological records support that most of them form during the continental break up. However, self-consistent models of oceanic transform fault exist and have been shown to develop as shear instabilities.

Here, instead of imposing the obliquity in the initial conditions, we utilise a pure shear (in map view) boundary condition to impose obliquity and vary the initial strength of the lower crust to control the spacing of the initial rifting structures. We then continue to extend the crust and monitor how the initial segmentation of the margin controls the structure in the newly formed oceanic crust and how these oceanic structures exert a feedback and modify the structures in the continental crust.

Making use of a new massively parallel computing approach based on a segregated multi-grid preconditioner and efficient non linear solver, we show preliminary results which model the formation of passive margin from rifting to drifting with a free surface.