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Supporting Information For Initiation of a Proto-Transform Fault Prior to Seafloor Spreading

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Additional Supporting Information (Files uploaded separately)

1. Captions for Dataset S1: This spreadsheet contains details of the mapped faults in the Giulietti Plain region.

November 28, 2018, 9:34pm
Introduction

The supporting information contains further figures detailing the data used in the 3-D velocity field inversion, the principal axes of horizontal shear strain, and the initial setup for the thermomechanical numerical model. In addition, it contains Table S1 which details the results of the numerical modelling under different starting conditions.
Figure S1. Data set and mesh used in the 3-D velocity field inversion for Afar. Taken from Pagli et al. (2014). Black rectangles delineate the InSAR tracks, black triangles are GPS sites (Kogan et al., 2012; McClusky et al., 2010; Saria et al., 2014; Vigny et al., 2007, 2006).
Table S1. Table of results from numerical modelling. Nu is the Nusselt number which controls hydrothermal circulation (Gerya, 2013), $\gamma_0$ is the upper strain limit for fracture-related weakening, max viscosity is the upper limit of the viscosity of the lithosphere. **Abbreviations:** SC = spreading centre, PTF = proto-transform fault, TF = transform fault (spreading-parallel), ORTP = orthogonal ridge-transform pattern, IRTP = inclined ridge-transform pattern, ZOT = zero offset transform (zero offset fracture zone).

| Run  | Continental Crust Density (kg/m³) | Mantle T (°C) | Nu  | Max. Viscosity (Pa s) | Final Water Depth (km) | Offset (km) | Perturbations Length (km) | Initial Rifting Pattern | Young Spreading Pattern (2–5 Myr) | Mature Spreading Pattern (5–20 Myr) |
|------|----------------------------------|--------------|-----|----------------------|------------------------|-------------|---------------------------|-------------------------|-----------------------------------|-----------------------------------|
| afaa | 3000                             | 1300         | 2   | 1                    | 10²¹                   | 0           | 20                        | 40                      | SCs facing each other            | ORTP with two TF with intra-transform spreading centre |
| afab | 3000                             | 1300         | 2   | 1                    | 10²¹                   | 0           | 40                        | 40                      | SCs linked by oblique PTF       | ORTP with intra-transform spreading centre |
| afaba| 3000                             | 1300         | 1   | 1                    | 10²¹                   | 0           | 40                        | 40                      | SCs linked by oblique PTF       | ORTP |
| afabb | 3000                           | 11300        | 2   | 1                    | 10²¹                   | 0           | 40                        | 40                      | SCs linked by oblique PTF       | ORTP |
| afabc | 3000                           | 1300         | 2   | mantle 1 crust 0.5   | 10²¹                   | 0           | 40                        | 40                      | SCs linked by oblique PTF       | ORTP |
| afabx | 3000                            | 1350         | 2   | 1                    | 10²¹                   | 0           | 40                        | 40                      | SCs linked by oblique PTF       | ORTP with decreasing offset between SCs, ORTP |
| afaby | 3000                            | 1400         | 2   | 1                    | 10²¹                   | 0           | 40                        | 40                      | SCs linked by oblique PTF       | ORTP with decreasing offset between SCs, ORTP |
| afabz | 3000                            | 1450         | 2   | 1                    | 10²¹                   | 0           | 40                        | 40                      | SCs linked by oblique PTF       | ORTP with decreasing offset between SCs, ORTP |
| afac  | 3000                             | 1300         | 2   | 1                    | 10²¹                   | 0           | 40                        | 40                      | SCs linked by oblique PTF       | ORTP with decreasing offset between SCs, ORTP |
| afad  | 3000                             | 1300         | 2   | 1                    | 10²¹                   | 0           | 40                        | 40                      | SCs linked by oblique PTF       | ORTP with decreasing offset between SCs, ORTP |
| afae  | 3000                             | 1300         | 2   | 1                    | 10²¹                   | 0           | 40                        | 40                      | SCs linked by oblique PTF       | ORTP with decreasing offset between SCs, ORTP |
| afaei | 2800                             | 1300         | 2   | mantle 1 crust 10    | 10²¹                   | 3           | 40                        | 40                      | SCs linked by oblique PTF       | ORTP with intra-transform spreading centre |
| afaej | 2800                             | 1300         | 2   | mantle 1 crust 3     | 10²¹                   | 3           | 40                        | 40                      | SCs linked by oblique PTF       | ORTP with intra-transform spreading centre |
| afe   | 2800                             | 1300         | 2   | mantle 1 crust 2     | 10²¹                   | 3           | 40                        | 40                      | SCs linked by oblique PTF       | ORTP with intra-transform spreading centre |
Figure S2. Initial model setup and boundary conditions for 3D thermomechanical numerical experiments simulating rifting in Northern Afar. Boundary conditions are constant spreading rate in x-direction ($v_{\text{spreading}} = v_{\text{left}} + v_{\text{right}}$, where $v_{\text{left}} = v_{\text{right}}$) and compensating vertical influx velocities through the upper and lower boundaries ($v_{\text{top}}$ and $v_{\text{bottom}}$) are chosen to ensure conservation of volume of the model domain and constant average 5 km thickness of the air layer $[(v_{\text{top}} + v_{\text{bottom}})/50 = (v_{\text{left}} + v_{\text{right}})/98]$, where $v_{\text{top}}/5 = v_{\text{bottom}}/45$; front and back boundaries in the x-y plane are free slip. The weak 5 km thick air/water layer has a low density (1 kg/m$^3$ above 5 km and 1000 kg/m$^3$ below 5 km, where 5 km is the assumed water level) and a viscosity of $10^{18}$ Pa s to ensure small stresses (<105 Pa) along the upper plate interface. The symmetric initial thermal structure is perturbed in two places where offset linear thermal anomalies (weak seeds) A and B are prescribed by an elevated geotherm. Thermal boundary conditions are insulating (zero heat flux) on all boundaries with except of the upper and lower boundaries, over which a constant temperature of 273 K and 1600 K is prescribed, respectively.