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SUPPLEMENTARY MATERIAL

1. Methods

1.1. Model set-up

We employed crustal-scale analogue models to investigate the influence of a rheologically weak zone within the lower crust during oblique extension. The varying parameter is the degree of obliquity of the weak zone, which ranges from 0° to 45° (by increments of 15°) with respect to the extension direction (Fig. 1a). The models have been scaled according to the geometric, kinematic, dynamic and rheologic similarities (Hubbert, 1937; Ramberg, 1981; Weijermars and Schmeling, 1986; Brun, 1999; Sokoutis et al., 2005).

The experimental work was carried out, by using the large capacity centrifuge, at the Tectonic Modeling Laboratory of the Institute of Geosciences and Earth Resources (National Research Council of Italy), University of Florence. The models have been built within a 25x16x7 cm Plexiglas box equipped with moving lateral spacers. Each experiment consisted of 5 spinning sessions, where the gravity field increased up to 18 times the normal gravity field. In between each session, 1.5 mm thick spacers were removed from each side of the box allowing the models to expand and fill the lateral voids. This generated extension at increments of 3 mm per session. In every experiment, the bulk extension was 15 mm (Fig. 1b).

The models consisted of a two-layer system, in which the brittle behavior of the upper crust was simulated by dry K-feldspar powder while the ductile behavior of the lower crust was reproduced by a mixture of Plasticine and polydimethylsiloxane (PDMS) polymer (Sokoutis et al., 2005)(Fig. 1b). Within the lower crust, a mixture of silicone, corundum sand and oleic acid simulated the central weak zone (Table 1). For these experiments, the geometric scale ratio was 6.7×10^{-7} (1 cm in the models was equivalent to 15 km in nature) and consequently our analogue models simulated 22.5 km (15 mm in the model) of extension of a 35 km-thick continental crust. Dynamic and kinematics similarities of gravitational, viscous and frictional stresses acting in the system (Ramberg 1981), ensured that the velocity of extension in the models (2-6x10⁻⁵ m s⁻¹) scaled to natural values of 2–6 mm.y⁻¹, a good proxy for continental extension systems (e.g., Saria et al., 2014).

The experiments have been repeated several times and a similar fault pattern has been observed underling the robustness of the obtained results.

1.2. Analyses of single faults kinematics

In order to constrain the displacement field along the structures that developed during the experiments we analyzed the top view images of the models with particle image velocimetry (P.I.V.). At the scale of individual faults, this technique is based on identifying markers in the footwall and the hangingwall of a fault at the initial step of the experiment (Fig. 2a, step 0). Subsequently, the particle trajectories have been monitored between 0 and 6 mm of extension, as well as between 6 and 15 mm of extension both in the footwall and hangingwall of the faults (Fig. 2a, step 1) (Fig. 2a, step 2). For each monitored segment of the fault, a vector given by the difference in displacement between the footwall and hangingwall of the fault is calculated and corresponds to the displacement vector. The average dip of fault plane is 60° and measured in cross sections (Fig. 2b). Projected on the fault plane, the displacement vector is a good proxy to the slip vector and gives an estimate of the amount (size of the arrow) and direction of slip that occurred along the fault plane (Fig. 2a). The stress tensors have been calculated using the right dihedron inversion method using the slip vector, and strike and the dip of the fault (Angelier, 1979). Stress inversion has been applied to single faults. Thereafter, faults have been grouped in each model according to their

obliquity to the extension direction in "border faults" trending oblique and "inner faults" trending orthogonal to it. Finally, stress inversion has been applied to both populations in order to obtain the bulk kinematics of both fault populations.



Supplementary Fig.1. Experimental setup. (a) Top-view of the ductile crust containing a weak zone. Strength profiles illustrate the difference in strength among model domains. (b) Cross section of the apparatus showing how extension is applied. Arrows indicate the direction of extension.



Supplementary Fig. 2. Top-view images (a) of a model to illustrate the principle of Particle Image Velocimetry, along a single fault showing the initial (step 0), intermediate (step 1) and final (step 2) positions of the markers on the footwall and hangingwall. The difference between the displacement in the footwall and the hanging wall corresponds to the slip vector along the fault plane. Subsequently, this vector has been projected on the fault plane and paleostress directions have been computed from them through inversion. (b) Cross section of an experiment, showing the average dip of 60° of the faults that develop in the brittle upper part of the analogue model.

2. Supplementary tables

Layer	Analogue material	Thickness (mm)	Density (kg.m-3)	Φ (coef. Internal friction)	Cohesion (Pa)	Power-law parameters and strength
upper	K-Feldspar powder	15	1220	0.6	50	
crust						
lower	white plasticine-PDMS	10	1500			n=2.4, A=2.10 ⁻¹¹ ,
crust	(100:45 wt%)	10	1000			µ=4 Pa.m
weak	silicone-corundum sand-oleic	10	1500			n=1.5, A=3.10 ⁻⁶ ,
zone	acid (100:70:5 wt%)	10	1200			µ=0.05 Pa.m

TABLE 1. Properties of the analogue materials used in the experiments.

Methods		Orientation	References	
GPS		E-W to N94°	Fernandes et al., 2004; Stamps et al., 2008; Kogan et al., 2012; Saria et al., 2014	
Earthquakes	Internal faults	N91°	Keir et al., 2006	
mechanisms	Boundary faults	N113°		
Paleostress	Internal faults	N94°	Agostini et al., 2011	
inversions	Boundary faults	N108°		
Global plate motion inversions		N110°	Calais et al., 2003; Horner-Johnson et al., 2007; Royer et al., 2006	
Structural geology and Geochronology		Change from N125° to N100° Between 6.6 and 3.5 Ma	Wolfenden et al., 2004	

 TABLE 2. Estimations of Somalia kinematics from GPS, earthquakes focal mechanisms, paleostress, and global plate kinematic models.

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