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Asian collisional subduction: A key process driving formation of the Tibetan Plateau

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DR1

Scaling

A laboratory analogue of a two-layer linear viscous lithosphere-upper mantle system is established in a silicone putty-glucose syrup tank model sized 75 × 75 × 25 cm3 (Fig. 2). Glucose syrup is a transparent Newtonian low viscosity fluid. The silicone putty, made of polydimethylsiloxane and iron fillers, is a viscoelastic material that can be considered as a quasi-Newtonian fluid since the applied strain rates during experiments are low enough to neglect its elastic component (Davy and Cobbold, 1991). The use of silicone, which thickens by pure shear, does not adequately reproduce the complex thickening process of the Tibetan upper crust, which could be duplicated under Tibet by underthrusting (e.g., DeCelles et al., 2002) or thickened by shortening operating through intracrustal décollement (e.g. Meyer et al., 1998), but silicone adequately simulates the subduction of the lower lithosphere (i.e., lower crust and lithospheric mantle), and the overall lithospheric-mantle dynamics.

The experimental setting consists of 11 cm of glucose syrup, corresponding to the upper mantle in nature (660 km), on the top of which there are three silicone plates. The experiments are scaled for gravity, length, density, viscosity and velocity according to Funiciello et al. (2003). The scaling factor for length is $11/6.6 \times 10^{7} = 1.7 \times 10^{-7}$. Considering that the density and viscosity ratios between the oceanic silicone putty and glucose syrup are 1.05 and 1.5×10^{3} respectively and scaling for viscous stresses we obtain

$$t_{model}/t_{nature} = (\Delta\rho\ h\ /\ \eta_{l})_{nature}\ /\ (\Delta\rho\ h\ /\eta_{l})_{model}\ , \qquad (1)$$

and, in turn,

$$U_{model}/U_{nature} = t_{nature} / t_{model} \times L_{model} / L_{nature} \,. \qquad (2)$$

Hence, 1 min in experimental time corresponds to 0.55 m.y. in nature, and the piston's velocity is scaled to 0.54 cm/min corresponding to 5.7 cm/yr of convergence in nature.

Measurement Methods

Each experiment is monitored over its entire duration by top and lateral view photos taken at regular time intervals (Fig. 2). From the top views, a squared grid of passive markers drawn on the silicone layers enables to quantify the amount of subducted lithosphere and the area variation of each square during the experiment. For one given square, the thickening is calculated using the initial and final values of area, and the initial thickness of the plate, assuming homogeneous thickening. Using sub-pixel correlation of images (Cosi-Corr), we compute the displacement field for a 1 min time-step (Ayoub et al., 2009).

Forces Equilibrium

The resisting forces of the subduction process are the slab resistance to bending, the slab-mantle interface forces and the resistance to sliding along the subduction fault (e.g., Conrad and Hager, 1999). The absolute magnitude and interaction between these forces are still poorly understood and difficult to be experimentally defined (Funiciello et al., 2008). We did not quantify these forces in our experiments.

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DR2: 13 experiments

	Indenter (India)	Ocean1 (Tethys)	Upper Plate (south Asia)	Back wall plate (north Asia)	Ocean2 (asian ocean)	Subduction indenter	Subduction backwall plate
DS1	20·25·1,2 cm^3 ρ = 1402 kg/m^3	20·7·1,2 cm^3 1508	40·10·0,8 cm^3 1350	40·20·0,8 cm^3 1397	40·3·1,2 cm^3 1508	yes	yes
DS2	20·25·1,2 cm^3 ρ = 1402 kg/m^3	20·7·1,2 cm^3 1508	40·10·0,8 cm^3 1350	40·20·0,8 cm^3 1420	40·3·1,2 cm^3 1508	yes	yes
DS3	20·25·1,2 cm^3 ρ = 1402 kg/m^3	20·7·1,2 cm^3 1508	40·10·0,8 cm^3 1350	40·20·0,8 cm^3 1402	40·3·1,2 cm^3 1508	yes	yes
DS4 Exp. 2	**20·25·1,1 cm^3 1402**	**20·7·1,1 cm^3 1508**	**20·10·0,8 cm^3 1397**	**20·20·0,8 cm^3 1402**	**20·3·1,1 cm^3 1508**	**yes**	**yes**
DS5	20·25·1,1 cm^3 1402	20·7·1,1 cm^3 1508	20·10·0,8 cm^3 1397	20·20·0,8 cm^3 1402		yes	yes
DS6	20·25·1,1 cm^3 1402	20·7·1,1 cm^3 1508	20·10·0,8 cm^3 1306	20·20·0,8 cm^3 1402		yes	yes
DS7	26·25·1,1 cm^3 1402	26·7·1,1 cm^3 1508	26·10·0,8 cm^3 1306	26·20·0,8 cm^3 1402		yes	yes
DS8		20·25·1,1 cm^3 1508	20·10·0,8 cm^3 1397	20·20·0,8 cm^3 1402		No indenter	no
DS9	20·25·1,1 cm^3 1402		20·10·0,8 cm^3 1397	20·20·0,8 cm^3 1402		yes	no
DS10	20·12,5·1,1 cm^3 1402	20·12,5·1,1 cm^3 1508	20·10·0,8 cm^3 1397	20·20·0,8 cm^3 1402		no	no
DS11 Exp.1	**20·25·1,1 cm^3 1402**	**20·7·1,1 cm^3 1508**	**20·10·0,8 cm^3 1397**	**20·20·0,8 cm^3 1402**		**yes**	**yes**
DS12 Exp. 3	**20·25·1,1 cm^3 1402**	**20·7·1,1 cm^3 1508**	**20·10·0,8 cm^3 967**	**20·20·0,8 cm^3 1402**		**no**	**yes**
DS13	20·25·1,1 cm^3 1402	20·7·1,1 cm^3 1508	20·10·0,8 cm^3 967	20·20·0,8 cm^3 1435		no	yes

The Indian lithosphere subducts in almost all our experiments, except when the upper plate is so deformable (white silicone) that it sticks to the oceanic plate 1 and reduce the slab pull preventing the subduction of the continent (experiments DS11, presented in the paper as experiment 3, and DS13), or when ocean 1 is much longer so that its subduction absorbs all the convergence (experiment DS10). It also subducts when it is not attached to an ocean (experiment DS9), but in that case the slab is short, similar to the asian slab of experiments presented in the paper.

The Asian lithosphere also subducts in almost all our experiments, except when ocean 1 is much longer so that its subduction absorbs all the convergence (experiments DS9 and DS10) or when there is no ocean attached to India and Asia. In that case, no manual curving of the edge plates has been done to none of the plates, and only the indenter subducts, with a very short slab.

No manual curving have been applied to the asian side in experiments DS8, DS9, DS10, DS12, which does not prevent the asian subduction in DS12 (presented in the paper as experiment 2) but suggests that such curved initial shape (see the initial shape of Asian lithosphere in experiment DS11= experiment 1 on Fig. 3a) favor the subduction of the asian plate.