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Mode of thickening of weak Precambrian lithospheres: insights from analogue experiments

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Many Precambrian orogenic belts present some structural peculiarities that are difficult to integrate within a frame of large-scale thrust tectonic. These are in particular (1) distributed shortening associated with pervasive thickening of ductile domains, (2) vertical transpressive shear-zones associated with steeply dipping stretching lineations, and (3) gravity-driven vertical motions. The latter are generally attributed to body forces controlled by local inverted density profiles (sagduction of greenstones belts and/or rising of gneiss domes). All these features suggest weak lithospheres, and are consistently frequent within Precambrian juvenile domains where rather high geotherms, with a possibly entirely ductile lithospheric mantle, can be expected.

We present analogue models that provide constraints on deformational processes within weak lithospheres in compression. The models consist of three rheological layers: a thin brittle upper crust, a thick low-viscosity ductile crust, and a ductile lithospheric mantle. The model-lithosphere floats on a Newtonian fluid model-asthenosphere. The density of the layers increases from top to bottom. A series of experiments was performed in order to examine strain pattern variations in function of two boundary conditions: the temperature and the strain rate. Changes in temperature and strain rate induce changes in the viscosity contrast between silicone layers and in the brittle-ductile coupling, respectively.

After 50% shortening, cross-sections made within models show wide undeformed upper-crustal domains bounded by sub-vertical zones where pop-downs of upper crust develop. Individual pop-downs are bounded by localised shallowly dipping thrusts and are successively buried into the vertical zones. Except below zones of pop-down stacks, model ductile crust and lithospheric mantle are homogeneously thickened, the

Moho and the base of the lithosphere showing an overall flat-lying attitude. The contrasting structural evolution of ductile and brittle layers reflects their strong decoupling. The overall model strength decreases with increasing temperature or decreasing shortening rate, which leads to an increase in the degree of strain localisation within vertical zones.

Experiments show that important vertical downward motions of upper-crustal bodies are not necessarily related to inverted density profiles, but can simply result from regional shortening and upper crust thrusting. More generally, the experimental results may account for a number of structural features observed in many Archaean or Paleoproterozoic belts.