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Episodic Subduction arising from convection in a complex-rheology fluid: insights from laboratory experiments

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We report here new laboratory experiments on mantle convection using a fluid, whose rheology varies from brittle to viscous when its water content changes. So as an analogy to cooling from above, the fluid is dryed from above, its surface being kept at a constant humidity. Humidity, temperature, fluid thickness and solution concentration are systematically varied, which results in changing the intensity of convection and the rheological properties of the fluid. The entire process is monitored by means of cameras. As the fluid dries at the surface, a chemical boundary layer (CBL) develops, constituted of a thin brittle film on top of a more ductile layer. Folds and cracks are visible on the surface film. When the CBL reaches a critical negative buoyancy, subduction starts and the surface is cut into plates. The subduction is always asymmetric and is an episodic phenomena. The variation of the fluid's rheology, and especially the existence of a brittle state, depending on the experimental parameters such as temperature, humidity rate and concentration, is the key ingredient to exhibit convection with plate-like behavior.

Those experiments show that there is no dichotomy between plates and mantle convection. Tectonic plates constitute the upper thermal boundary layer (TBL) of the Earth's mantle, and they subduct as the cold TBL becomes unstable under gravity. The localization of surface deformation on plate boundaries, the rigidity of plates and the asymmetry of subduction is the result of the complex rheology (from brittle to ductile) of mantle material.