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Passive margins getting squeezed in the mantle convection vice

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Passive margins often exhibit uplift, exhumation and tectonic inversion. We speculate that the compression in the lithosphere gradually increased during the Cenozoic. In the same time, the many mountain belts at active margins that accompany this event seem readily witness this increase. However, how that compression increase affects passive margins remains unclear.

In order to address this issue, we design a 2D viscous numerical model wherein a lithospheric plate rests above a weaker mantle. It is driven by a mantle conveyor belt, alternatively excited by a lateral downwelling on one side, an upwelling on the other side, or both simultaneously. The lateral edges of the plate are either free or fixed, representing the cases of free convergence, and collision or slab anchoring, respectively. This distinction changes the upper boundary condition for mantle circulation and, as a consequence, the stress field.

Our results show that between these two regimes, the flow pattern transiently evolves from a free-slip convection mode towards a no-slip boundary condition above the upper mantle. In the second case, the lithosphere is highly stressed horizontally and deforms. For an equivalent bulk driving force, compression increases drastically at passive margins provided that upwellings are active. Conversely, if downwellings alone are activated, compression occurs at short distances from the trench and extension prevails elsewhere. These results are supported by Earth-like 3D spherical models that reveal the same pattern, where active upwellings are required to excite passive margins compression. These results support the idea that compression at passive margins, is the response to the underlying mantle flow, that is increasingly resisted by the Cenozoic collisions.