3D Discrete Element Simulation of Faulting and Crustal Thickening during the India-Asia Collision

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Understanding the discontinuous nucleation, growth, and interaction of large faults within continental collision zones remains a challenge. From 55 Ma onwards, the India-Asia (I-A) collision has produced the largest present-day continental deformation zone. The collision activated large strike-slip fault zones, and generated mountain ranges and the Tibetan plateau. Previous 2D analog experiments simulating the India-Asia collision successfully modeled the development and kinematics of large strike-slip faults within the Eurasian plate, but were dynamically unscaled with gravity and did not allow the development of topographic relief. Here, we use the YADE Discrete Element Modeling (DEM) code to produce a suite of 3D models scaled with gravity. These 3D DEM models simulate two plate-boundary size strike-slip faults that extrude and rotate coherent continental blocks. The locations, lengths, ages and offsets of these modeled faults are consistent with those of the Red River (RR) and Altyn Tagh (AT) mega-faults. In the model, the RR fault is observed to change sense after the activation of the AT fault, as was the case for the Red River fault. This is the first time any type of model or simulation of the I-A collision reproduces such a fundamental geological change. As in the Asian collision zone, the deformation of the model is observed to be fully 3D. In addition to strike-slip movement, large-scale thrust faults progressively generate the growth, from south to north, of a large plateau. This is in general agreement with the stepwise, northwards rise of the Tibet-Qinghai plateau. Analyzing the timing of the shortening accommodated by vertical and horizontal deformations suggests that they partly alternate. Our model results are thus broadly consistent with the observed topographic, tectonic and geological evolution of Eastern Asia in the last ~50 million years.

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