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Lithospheric-scale structures from the perspective of analogue continental collision

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The Alpine-Himalayan orogen system results from northward migration of Gondwana fragments and their suturing with Eurasia. The current convergence rate varies from 1 cm/yrbetween Africa and Europe to 3 to 5 cm/yr between India and Asia. The structure of an orogen, generated by continental collision depends, on the strain rates, the geometrical boundary conditions and the rheology. Many analogue and numerical modelling studies investigated the Alpine-Himalayan orogenic belt by addressing the role of lateral and vertical escape of crustal wedges during deformation. Previous works have demonstrated the strong influence of lateral variations in crustal thickness on the collisional deformation pattern. These considerations suggest that adjacent parts of an orogen may exhibit different deformation styles depending on the local conditions. They further suggest that the rheological properties of the lithosphere-asthenosphere system are essential for understanding mountain-building processes.

To tackle this problem we designed analogue experiments addressing the role of i) a suture zone between blocks with different thickness, ii) a weak crustal layers and iii) mantle strengths. Modelling focused exclusively on continental collision and assumed that slabs play no role after ultimate closure of the intervening oceans.

These models confirmed that low-amplitude lithospheric and crustal buckling is the primary response to shortening with a wavelength mainly controlled by the strong upper crust and/or lithospheric mantle.

With increasing shortening, bivergent thrusts formed across the brittle layers (equivalent to upper crust) at inflection points of the buckles while ductile layers (lower crust and mantle) continued being folded. The resulting geometry displayed pop-ups and pop-downs above the boundaries (sutures) between blocks.

Further shortening led to wider, thrust-bounded deformation zones (Σ-belts) in front of the stronger blocks identified as “effective indenters”. During-shortening upward extrusion into Σ-belts allowed exhumation of deep material. Weak layers enhanced strain localisation. These modelling results have similarity in large-scale structures of modern orogens and are relevant to the understanding of natural collisional processes.

This reproducible mechanism should be an important process accommodating shortening between colliding continents; it also sheds new light on structures and material brought down into the roots of collision orogens. In addition, models have shown that mid-crustal, low viscosity and low-density material may be transferred from mid-crustal to near surface depths during compression and shortening, making use of movement zones such as thrusts in front of effective indenters. Consequently, orogenic granites are not necessarily indicating extension.