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Along-strike complex geometry of subduction zones – an experimental approach

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Recent knowledge of the great geometric and dynamic complexity insubduction zones, combined with new capacity for analogue mechanical and numerical modeling has sparked a number of studies on subduction processes. Not unexpectedly, such models reveal a complex relation between physical conditions during subduction initiation, strength profile of the subducting plate, the thermo-dynamic conditions and the subduction zones geometries. One rare geometrical complexity of subduction that remains particularly controversial, is the potential for polarity shift in subduction systems.

The present experiments were therefore performed to explore the influence of the architecture, strength and strain velocity on complexities in subduction zones, focusing on along-strike variation of the collision zone. Of particular concern were the consequences for the geometry and kinematics of the transition zones between segments of contrasting subduction direction. Although the model design to some extent was inspired by the configuration along the Iberian – Eurasian suture zone, the results are also of significance for other orogens with complex along-strike geometries. The experiments were set up to explore the initial state of subduction only, and were accordingly terminated before slab subduction occurred.

The model wasbuilt from layers of silicone putty and sand, tailored to simulate the assumed lithospheric geometries and strength-viscosity profiles along the plate boundary zone prior to contraction, and comprises two 'continental' plates separated by a thinner 'oceanic' plate that represents the narrow seaway. The experiment floats on a substrate of sodiumpolytungstate, representing mantle. 24 experimental runs were performed, varying the thickness (and thus strength) of the upper mantle lithosphere, as well as the strain rate. Keeping all other parameters identical for each experiment, the models were shortened by a computer-controlled jackscrew while time-lapse images were recorded. After completion, the models were saturated with water and frozen, allowing for sectioning and profile inspection.

The experiments were invariably characterized by different along-strike patterns of deformation, so that three distinct structural domains could be distinguished in all cases. Model descriptions are subdivided accordingly, including domain CC, simulating a continent-continent collision, domain OC, characterized by continent-ocean-continent collision and domain T, representing the transition zone between domain CC and domain OC. The latter zone varied in width and complexity depending on the contrast in structural style developed in the two other domains; in cases where domain OC developed very differently from domain CC, the transition zone was generally wider and more complex.

A typical experiment displayed the following features and strain history: In domain CC two principal thrust sheets are displayed, which obviously developed in an in-sequence foreland-directed fashion. The lowermost detachment nucleated at the base of the High Strength Lithospheric Mantle analogue, whereas the uppermost thrust was anchored within the "lower crust". The two thrusts operated in concert, the surface trace of the deepest dominating in the west, and the shallowest in the east. The kinematic development of domain CC could be subdivided into four stages, including initiation of a symmetrical anticline with a minute amplitude and situated directly above the velocity discontinuity defined by the plate contact (stage 1), contemporaneous development of the two thrusts (stage 2) and an associated asymmetrical anticline (stage 3) with a central collapse graben in the latest phase (stage 4).
It is noted that the segment CC as seen in a clear majority of the experiments followed this pattern of development.

In contrast, the configuration of domain OC displayed greater variation, and included north and south-directed subduction, folding, growth of pop-up-structures and triangle zones. In the "ocean crust" domain, stage

1 was characterized by the growth of a fault-propagation anticline with an E-W-oriented fold axis, ending with the surfacing of a north-vergent thrust. In stage 2, the contraction was concentrated to the south in the oceanic domain, again ending with the surfacing of a thrust, here with top-south transport. By continued movement (stage 3), the thrust fault propagated towards the east, crossing into the “continental” domain and linking with the fault systems of the segment CC.

The structure of domain T is dominated by the interference of faults propagating westwards from the domain CC and eastwards from the domain OC, respectively. The zone of overlap in the experiment was significant, and its central part had the geometry of a double “crocodile structure” (sensuMeissner 1989), separating the two areas of northerly and southerly subduction. Hence, its development is less easily subdivided into stages.

Reference:

Meissner,R., 1989: Rupture, creep lamellae and crocodiles: happenings in the continental crust. Terra Nova, 1, 17-28.