# Structural styles in the Salt Range and Potwar Plateau, northern Pakistan: constraints from physical (centrifuge) modeling

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The ENE-trending Himalayan fold-thrust belt in Pakistan exhibits contrasting deformation styles both along and across strike. Centrifuge analogue modeling has been used to investigate these structural variations. For modeling purposes, the Salt Range and Potwar Plateau (SR/PP) stratigraphy is grouped into four mechanical units. From bottom to top, these are the Salt Range Formation, carapace unit (Cambrian-Eocene platform sequences), Rawalpindi Group and Siwalik Group. These stratigraphic units of alternating competence, composed of thin layers of plasticine modeling clay and silicone putty, rest on a rigid base plate that represents the crystalline basement of the Indian plate. The models are built at a linear scale ratio of ~$10^{-6}$ (1mm=1km) and deformed in a centrifuge at 4000g. To examine the effects of frontal/or lateral ramp systems of various geometries, the ramp systems are pre-cut in the model stratigraphic package before each experiment. The models are subjected to horizontal shortening by collapse and lateral spreading of a "hinterland wedge" which simulates overriding by the Himalayan orogen (above the Main Boundary Thrust). The models are deformed in stages so that the kinematic evolution of structures can be monitored. Matched models are serially sectioned transversely and longitudinally to constrain the structure in 3-D. The models of the central and eastern SR/PP show that the accretionary wedge develops a prominent culmination structure with fault-bend fold geometry over the frontal ramp. The main ramp, localized by a basement normal fault, is responsible for the deflection of the hanging-wall package to the surface and repetition of the whole stratigraphic sequence. In the presence of a basement ramp/step deformation readily transferred to the ramp region. As a result, the fault-bend fold over the ramp formed out-of-sequence with respect to other folds and thrusts. Although the main decollement in the models remained within the ductile Salt Range Formation, the eastern SR/PP is characterized by more internal deformation including detachment folds, fault-propagation folds, and pop-up and pop-down structures. Model results show that the transition from fault-bend fold to detachment-fold and fault-propagation-fold geometry in the prototype may take place in a transfer zone marked by an S-bend structure (Chambal Ridge and Jogi Tilla) at the surface and the lateral ramp in the subsurface. The deformation style in the models illustrates the importance of mechanical stratigraphic and basement ramp systems in the evolution and the structural styles of the SR/PP.