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Similarities and Differences of a Submarine Foreland Fold-and-Thrust Belt and Gravity Driven Delta Toe-Thrusting: A Case Study from the Central American Back-Arc

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The Limón Back-arc Basin in eastern Costa Rica, provides the unique possibility to compare two endmembers of fold-and-thrust belts in one and the same basin-system. In the southern part of the basin, an offshore fold-and-thrust belt (South Limón fold-and-thrust belt) is developed as a consequence of Neogene back-arc shortening, which is related to the high stress subduction in southern Central America. In the very north of the Limón Basin, close to the border of Nicaragua, a linked extensional and compressional fault system occurs in the Rio San Juan Delta. The base of the delta is characterized by toe-thrusting. A grid of 2D seismic reflection lines, oriented parallel and perpendicular to the coast allows a detailed assessment of the deformation style and structural evolution of the deformed areas in the Limón Basin. Well data was incorporated to get stratigraphic and lithologic control. The faults and the detachments were mapped on the individual seismic sections and 3D models were created. The models provide insight into the geometry of faults and folds, related offsets and the spatial and temporal evolution of the deformation.

The offshore South Limón fold-and-thrust belt can be divided into a northeastern and a southwestern part. Both parts are characterized by southwestward dipping listric thrusts and related hanging-wall anticlines. All thrusts sole out into a horizontal detachment. Below the detachment no deformation can be observed. Well data indicate that the position of this detachment is controlled by a lithological change from limestone to shale. Most of the deformation took place in Plio-Pleistocene times. A few thrusts reach the sea-floor and can be regarded as active. The South Limón fold-and-thrust is a typical foreland fold-and-thrust belt. Controlling factors for the deformation are (1) the regional geodynamic framework characterized by NE-SW compression, (2) the shallow subduction of the Cocos Ridge, (3) the location of the regional detachment, controlled by rheologic contrasts, (4) the propagation-to-slip ratio of the thrust faults, which controls the shape of hanging-wall anticlines, (5) the basal friction along the detachment, and (6) the interaction of the fold-and-thrust belt with a basement high (Brandes et al., 2007a). The South Limón fold-and-thrust belt shows strong along strike variations of the surface slope. The northeastern part of the fold-belt has a constant surface slope angle of 4°. In the southeast the slope angle is higher with 8°. The increase in the slope angle might be an effect of increasing friction along the basal detachment. In addition lateral variations in the deformation style can be observed. In the northeastern part of the fold-and-thrust belt most of the hanging-wall anticlines have a round and concentric shape. They are developed above in-sequence thrusts. In the southwestern part, back-thrusting occurs and a few hanging-wall anticlines show pronounced kinks in their shape.

The Río San Juan Delta in the very north of the Limón Basin, is a small delta with a diameter of 40 km, which is fed by the Río San Juan. It represents the only major river delta at the Caribbean coast of Costa Rica and southern Nicaragua. Delta evolution started in Middle Miocene times. The whole delta body was effected by intense growth-faulting, partly associated with roll-over structures (Brandes et al., 2007b). The normal faults in the shelf area show activity until Plio-Pleistocene times. The faults in the slope area have been active in the Late Miocene to Early Pliocene. At the base of the slope there are toe thrusts developed, which compensate the extension in the upper parts of the delta body. Southwestward dipping fault traces can be observed and thrust sheets that developed in the hanging-wall of the fault. Gravity induced deformation is very likely for the Rio San Juan Delta because of the linked extensional and compressional fault system. The fault pattern with Late Miocene to Early Pliocene activity on the slope and Plio-Pleistocene activity on the shelf indicates a progressive gravity spreading of the delta body with a upward migration of the delta failure. Extension started in the delta slope and later effected the shelf area. The intensity of normal faulting and toe thrusting decreases towards the northwest. The recent main channel of the delta is located close to the area with the highest deformation. This might indicate that deformation is strongly influenced by the amount and location of sediment input.

Though the South Limón fold-and-thrust belt and the Rio San Juan Delta are situated in two contrasting geodynamic settings and the deformation has completely different driving mechnisms (crustal shortening vs. gravity spreading), there are a few similarities like the basal detachment, which decouples the deforming sedimentary units from the underlying material. An even more important similarity is the significant lateral variation in the structural style, observed in both settings. In the Río San Juan Delta, these changes might be related to the sediment input, which enhanced the gravity spreading. In the South Limón fold-and-thrust belt, the variations in sediment input might have caused variations in friction along the basal detachment, which is expressed in the varying slope angles.The major difference between the two settings is the style of folding and thrusting. The offshore South Limón fold-and-thrust belt consists of fault-propagation folds. The folds developed in the hanging-wall of thrusts faults. Reasons for the prevalence of fault-propagation folds can be found in the low horizontal shortening and the listric geometry of the thrusts faults. The toe-thrusts in the Rio San Juan Delta in contrast are fault-bend folds. They show a high shortening. The occurrence of fault-bend folds is an effect of the linked extensional and compressional fault system, where a small area with compression at the delta toe (~ 6.5 km width) compensated a much larger area of extension (~ 15 km width). The pronounced flat-ramp-flat geometry gives evidence for two detachment levels, which are connected by a footwall ramp.

Comparing the South Limón fold-and-thrust belt and the deforming Río San Juan Delta shows the strong influence of the sediment input and the amount of horizontal shortening on the structural style. Lateral variations in deformation might be caused by changes in sediment input.

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