INFLUENCE OF SALT-RELATED, THIN-SKINNED DEFORMATION ON BASEMENT THRUST EVOLUTION: PHYSICAL MODELLING APPLIED TO THE KUQA BASIN (SOUTHERN TIAN-SHAN)

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Introduction

The Kuqa basin is a foreland basin located on the south flank of the Southern Tian-Shan mountains. The basin is about 300-400 km long and 20-70 km wide, and includes two evaporitic layers. To the West, the evaporites are of Paleogene age (kumugeliemu group) and had an original thickness of about 1000 to 1500 m. To the East, the evaporites are of Miocene age (Jidike Formation) and have thicknesses between 900 and 1000 m, and include halite, mudstone, and gypsum. The basin has been subjected to crustal shortening starting about 20-25 My ago, but the most vigorous shortening takes place since the Pliocene (5 My ago), when the suprasalt overburden had already reached thicknesses of about 3000-4000 m.

Figure 1: Schematic cross section across the Kuqa basin showing the stacked subsalt thrust sheets (Cheng et al., 2004).

The exact geometry of structures in the basin is yet to be delineated. Data about the geometry of subsalt structures come from seismic-reflection data, whereas the geometry of the suprasalt overburden can also be constrained by field observations. Beneath the salt are thrust sheets of Mesozoic pre-salt located mostly along the northern boundary of the basin, along the flank of the TianShan. The thrust sheets are piled up vertically, an unusual pattern for foreland basins. Deformation in the overburden is less localized and involves folds and diapirs located as far as 50 Km South of the Tian-Shan.

Likewise, the precise kinematic history of the emplacement of the subsalt thrust sheets remains poorly constrained, although it is known that most of them formed since Pliocene times, well after salt was deposited. We therefore undertook a series of systematic experiments in order to better understand how thick-skinned shortening could interact with thin-skinned, suprasalt deformation. Many similar experimental models have already been published (Bonini, 2001, Duerto and McClay, 2009, Leturny et al., 2000, Magnier et al., 1997), all of them focusing on how deformation in the sub salt “basement” influenced the behaviour of the salt and its sediment overburden. However, in the course of our experimental procedure, we discovered that the presence of salt in the sedimentary cover could, in turn, influence the kinematic evolution of the underlying basement thrusts sheets.
**Models design**

We designed four experiments specifically targeted at understanding the impact of the presence of a salt layer on the evolution of the underlying thrusts. All the models had identical initial total thickness of 28 mm (basement and cover), but some included a salt layer in the cover whereas others did not. All included a 2 mm thick layer of glass micobeads at the base of the basement. All models were deformed at a rate of 0.47 cm/h until a total amount of shortening of 54.6 cm was reached (i.e., after 116 h of deformation).

The first two models were built in a cylindrical fashion, the first one comprising only one 28-mm-thick layer of dry sand across the entire model (Figure 2, Top Left). The second model included a layer of viscous silicone, simulating salt in nature. This layer overlay a 13-mm-thick sand basement, was 5 mm thick, and was overlain by a brittle sand cover 10 mm thick (Figure 2, top right). The salt layer covered only part of the model (see Figure 2).

The design for the other two models was more three-dimensional because it included one lateral half that comprised a salt layer, and one other half that has sand only, or had a layer of glass micobeads, simulating a lateral facies change of the Jidike Formation, were salt was replaced laterally by a less efficient décollement layer.

**Model results**

The first model, having only one potential décollement beneath the basement layer deformed in a manner similar to "classic" models of fold-and-thrust belts and accretionary prisms published previously (Malavieille, 1984, Yamada, 1999), with, one a stable critical taper of about 8-10° formed, new thrusts forming below old ones and carrying them in a piggy-back fashion (Fig. 3, top).
Figure 3. A: Overhead photographs of the surface deformation in all models. Lines indicate the location of cross sections in Figure 4.

The second model had two distinct stages of evolution. First, the model evolved as the first one, until the deformation front reached the hinterland pinch-out of the salt basin (formation of basement thrust 6 in Figs 3 and 4). From that stage, the deformation front propagated rapidly forward into the suprasalt overburden. However, no new basement thrust formed at depth. The “basement” belt stopped propagating forward, and all the shortening was accommodated by great amounts of slip along Thrust 6. The overall surface slope angle was much less than in Model 1.
In the third and fourth models, having two different compartments, the structural evolution varied along strike, but some amount of lateral influence occurred. In both models, deformation in the cover and in the basement changed radically once the deformation front hit the salt-bearing compartment. In the cover, shortening propagated fast forward, whereas in the basement, no new thrust formed. Laterally, this translated by forcing one basement thrust (Thrust 5) slipping for a long period of time. Eventually, during the latest stages of deformation, one new basement thrust formed (Thrust 6), allowing the foldbelt to advance forward. In both models, the average taper was lower in the salt-bearing compartment than in the salt-free one (Figs. 5 and 6).

Figure 4. Final cross sections in all models (see text for explanation). For 3-D models (Models 3 and 4), one section cuts across the salt-bearing compartment and another section cuts across the salt-free compartment.
Discussion / Conclusion

The main observation about the evolution of salt-bearing models is that forward propagation of the basement thrusts halts, at least temporarily, when the deformation front reaches the salt pinch out. The reason for this change in behaviour can be explained using the critical taper theory. In order to advance, the basement foldbelt requires that the topographic slope reaches a critical value related to the frictional properties along the basal décollement. This can be achieved as long as there is no salt in the deforming section. By contrast, salt exerts little to no shear resistance at the base of the cover, hence the cover’s critical taper is low. Any uplift of the cover, such as the one caused by thickening of the underlying basement, leads to cover to glide downslope forward, generating thin-skinned thrusts and anticlines that thicken the cover distally. This process, in turn, lowers the general topographic slope of the system, thus preventing the formation of new basement thrusts. In effect, the presence of salt within the sedimentary section, whilst favoring rapid advance of the cover deformation, opposes the advance of the subsalt basement deformation. As illustrated by the 3-D models, this influence can also apply laterally, in the regions devoid of salt, but adjacent to the salt basin.

REFERENCES