Geophysical Research Abstracts
Vol. 13, EGU2011-5799, 2011
EGU General Assembly 2011

Physical models of base-salt detachments in thin-skinned thrust belts under fluid overpressure

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We have used existing apparatus, in the experimental modelling laboratory at Geosciences-Rennes, to investigate whether flat-lying detachment faults can appear and persist at the base of a layer of ductile evaporite, during the development of a thin-skinned fold-and-thrust belt. Possible applications are to fold belts in Southern Tunisia or in the deepwater Gulf of Mexico.

Our experimental models consisted primarily of quartz sand, which failed according to a linear Coulomb envelope. The angle of internal friction was about 40° and the cohesion was about 10 Pa. In the absence of fluid flow, models consisting of pure sand responded to horizontal shortening by forming Coulomb wedges, in which deformation propagated sequentially, away from an advancing piston. To simulate fluid flow through pore space in nature, we drove compressed air upward through the models, from an underlying reservoir. As in previously published experimental work, the resulting Darcy flow and seepage forces reduced the apical angle of the thrust wedge and facilitated basal detachment.

More complex models included a layer of ductile silicone putty, which simulated an evaporite in nature. The viscosity of the silicone (about 104 Pa s) set the time scale for the experiments. We studied two configurations, in which the maximal overpressure was either beneath a single ductile layer, or between two such layers. In both configurations, as maximal overpressure approached lithostatic values, so detachment faults appeared and persisted at the bases of the ductile layers, even though some ductile deformation occurred simultaneously within these layers. For models where maximal overpressure was between two ductile layers, detachment occurred at the base of the upper ductile layer. As for models of pure sand, the overpressure and detachments led to smaller apical angles for the Coulomb wedges and to larger spacing between thrust faults and hanging-wall anticlines. In the experiments, the location and efficiency of detachments appeared to depend strongly on local variations in thickness and possibly in permeability of the overburden.

On comparing our models with structures in Southern Tunisia or in the Gulf of Mexico, we find strong similarities, which lead us to suspect that detachment is indeed possible at the base of an evaporite sequence in nature. This conclusion has strong implications, not only for the understanding of petroleum systems, but also for better management of petroleum production from sedimentary basins.