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Impact of different detachment topographies on pull-apart basin evolution – analog modelling and computer visualisation

M. Hoprich (1), K. Decker (1), B. Grasemann (1), D. Sokoutis (2), and E. Willingshofer (2)

(1) Department of Geodynamics and Sedimentology, University of Vienna, Austria, (2) Faculty of Earth and Life Sciences - TecLab, Vrije Universiteit Amsterdam, The Netherlands

Former analog modeling on pull-apart basins dealt with different sidestep geometries, the symmetry and ratio between velocities of moving blocks, the ratio between ductile base and model thickness, the ratio between fault stepover and model thickness and their influence on basin evolution. In all these models the pull-apart basin is deformed over an even detachment. The Vienna basin, however, is considered a classical thin-skinned pull-apart with a rather peculiar basement structure. Deformation and basin evolution are believed to be limited to the brittle upper crust above the Alpine-Carpathian floor thrust. The latter is not a planar detachment surface, but has a ramp-shaped topography draping the underlying former passive continental margin. In order to estimate the effects of this special geometry, nine experiments were accomplished and the resulting structures were compared with the Vienna basin. The key parameters for the models (fault and basin geometry, detachment depth and topography) were inferred from a 3D GoCad model of the natural Vienna basin, which was compiled from seismic, wells and geological cross sections. The experiments were scaled 1:100.000 ("Ramberg-scaling" for brittle rheology) and built of quartz sand (300 μm grain size). An average depth of 6 km (6 cm) was calculated for the basal detachment, distances between the bounding strike-slip faults of 40 km (40 cm) and a finite length of the natural basin of 200 km were estimated (initial model length: 100 cm). The following parameters were changed through the experimental process: (1) syntectonic sedimentation; (2) the stepover angle between bounding strike slip faults and basal velocity discontinuity; (3) moving of one or both fault blocks (producing an asymmetrical or symmetrical basin); (4) inclination of the basal detachment surface by 5°; (6) installation of 2 and 3 ramp systems at the detachment; (7) simulation of a ductile detachment through a 0.4 cm thick PDMS layer at the basin floor. The surface of the model was photographed after each deformation increment through the experiment. Pictures of serial cross sections cut through the models in their final state every 4 cm were also taken and interpreted. The formation of en-echelon normal faults with relay ramps is observed in all models. These faults are arranged in an acute angle to the basin borders, according to a Riedel-geometry. In the case of an asymmetric basin they emerge within the non-moving fault block. Substantial differences between the models are the number, the distance and the angle of these Riedel faults, the length of the bounding strike-slip faults and the cross basin symmetry. A flat detachment produces straight fault traces, whereas inclined detachments (or inclined ramps) lead to "bending" of the normal faults, rollover and growth strata thickening towards the faults. Positions and the sizes of depocenters also vary, with depocenters preferably developing above ramp-flat-transitions. Depocenter thicknesses increase with ramp heights. A similar relation apparently exists in the natural Vienna basin, which shows ramp-like structures in the detachment just underneath large faults like the Steinberg normal fault and the associated depocenters. The 3-ramp-model also reveals segmentation of the basin above the lowermost ramp. The evolving structure is comparable to the Wiener Neustadt sub-basin in the southern part of the Vienna basin, which is underlain by a topographical high of the detachment. Cross sections through the ductile model show a strong disintergration into a horst-and-graben basin. The thin silicon putty base influences the overlying strata in a way that the basin - unlike the "dry" sand models - becomes very flat and shallow. The top view shows an irregular basin shape and no rhombohedral geometry, which characterises the Vienna basin. The ductile base also leads to a symmetrical distribution of deformation on both fault blocks, even though only one fault block is moved. The stepover angle, the influence of gravitation in a ramp or inclined system and the strain accomodation by a viscous silicone layer can be summarized as factors controlling the characteristics of the models.