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The aim of this project is to study plate-scale (several thousand km) factors controlling the deformation processes of the Dead Sea Transform, and thus to a support smaller scale (several hundred km) detailed 3D DST model. Therefore we have prepared a two-step strategy. First we developed a present-day (with predefined faults) thin-shell mechanical model of the Middle-East consistent with data on lithospheric structure, surface heat flow, gravity, GPS and stress field observations. Secondly we are switching into a more-detailed 3D evolutional thermo-mechanical model of one of the most studied regional/local features of the DSTF, the Dead Sea Basin, to explain **unusually low heat flow** at the DST.

In the first part of the work we concentrated on the question: What should the rheological properties of the lithosphere beneath the DST be, to allow it to work as a transform plate boundary with the slip rate of a few millimeters per year? We addressed the above question using a thermo-mechanical model in an extended 2-D approximation (thin-shell approach, Bird et al., 1998; Kong & Bird 1995) focused on the deformation processes on the scale of several thousands of kilometers.

Topography and surface heat flow data, together with the assumptions of local isostasy and steady-state thermal regime, were used to estimate crustal and lithospheric mantle thickness. Kinematic boundary conditions, computed assuming rotation poles and angular velocities from recent geodetic studies, have been applied at the lateral boundaries of the model to represent the motion of the adjacent plates with respect to our region.

The slip rate at the DST is controlled by far-field plate motions, thickness of the lithosphere beneath the fault, and friction coefficient at the fault. The far-field plate motions are provided by plate tectonics models. The thickness of the lithosphere directly beneath the DST is not well constrained by seismic data, but thermo-mechanical modelling study (Sobolev et al., 2005) suggests that the thickness of mantle lithosphere beneath the DST can be as low as 20-30 km. The fault friction coefficient has not been extensively examined at this region yet. In this work we computed a two-parameter suite of models with different fault friction coefficient and mantle lithosphere thickness values beneath the DST to find out the range of parameters compatible with the slip rates at the DST of 0.3-0.6 cm/yr.

A variety of models were tested with different fault friction coefficient values (varying from 0.05 up to 0.40) and different mantle lithosphere thickness values (varying from 20 km to 40 km) beneath the Dead Sea Transform. We also analyzed the effect of the shape of fault by considering (i) a large segment of the DST extending from the Gulf of Aqaba, going through Dead Sea and the Lebanon Mountain Belt until the East Anatolian Fault and (ii) a short segment without considering the bending northern part, which comprises the region from the Lebanon Mountain Belt until the East Anatolian Fault.

Based on the plate velocity field, which is one of the model's predictions, we conclude on possible rheology in terms of the trade-off between fault friction coefficient and lithospheric thickness.

Modeling shows that the observed slip rate of 0.3-0.6 cm/year at the DST can be achieved only if the average friction coefficient at the DST is lower than 0.10 (see Fig. 2, right).

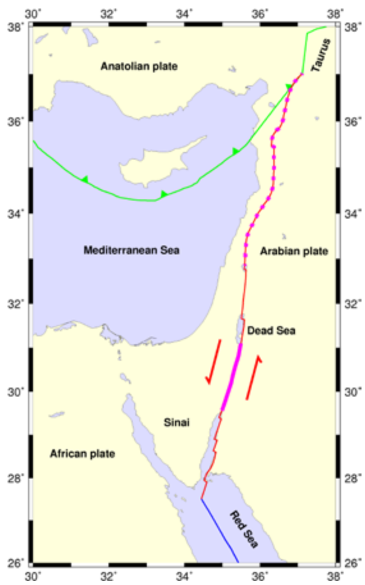

Fig. 1: Region of study. Red line represents Dead Sea Transform Fault extending from the Gulf of Aqaba, going through the Dead Sea and the Lebanon Mountain Belt until the East Anatolian Fault. Pink dots highlight the northern bending part of the fault.

Hence, the friction at DST appears to be as low as for the world's weakest transform fault, the San Andreas Fault in California. The reason why such low friction is required at the DST, to allow observed slip rates, is its irregular shape, especially its bending in the northern part. Without its bending northern segment, the DST would allow observed slip rates being much stronger (see Fig. 3, right). Model results also suggest that the mantle lithosphere below DST must be thinner than 30 km, in accordance with the prediction of the thermo-mechanical model.

After finishing this 2D large-scale thermo-mechanical model, we changed to a more detailed modeling technique. Using LAPEX3D code, which is a 3D evolutional thermo-mechanical model, we get into much more detail of the Dead Sea Transform region, in particular the Dead Sea Basin (DSB) itself. While the first part of the work was focused on the lithospheric rheology at the scale of the entire DST, this second part of the work focuses on the role of the lithospheric rheology and thermal parameters in development of the regional/local features like the DSB. In order to successfully accomplish this, LAPEX3D code needs improving, by incorporating for instance a temperature- and pressure-dependent thermal conductivity.

This part of the study currently in progress, involves a parameter search to see how this impacts upon the surface heat flow. The surface heat flow paradox at the Dead Sea Transform Fault is an issue that has been the object of lengthy discussions in the last years. There have been as a part of this ongoing debate several suggestions made as to how to better understand the discrepancies between former observed values of surface heat flow, and values suggested by recent thermal and thermo-mechanical models.

In the framework of the heat flow paradox we plan to take three different steps to study the conditions we would have to set to reach the observed values of the surface heat flow at the DST and so as to assess the impact of the variation of the parameters controlling the dynamics of the DSB on the surface heat flow.

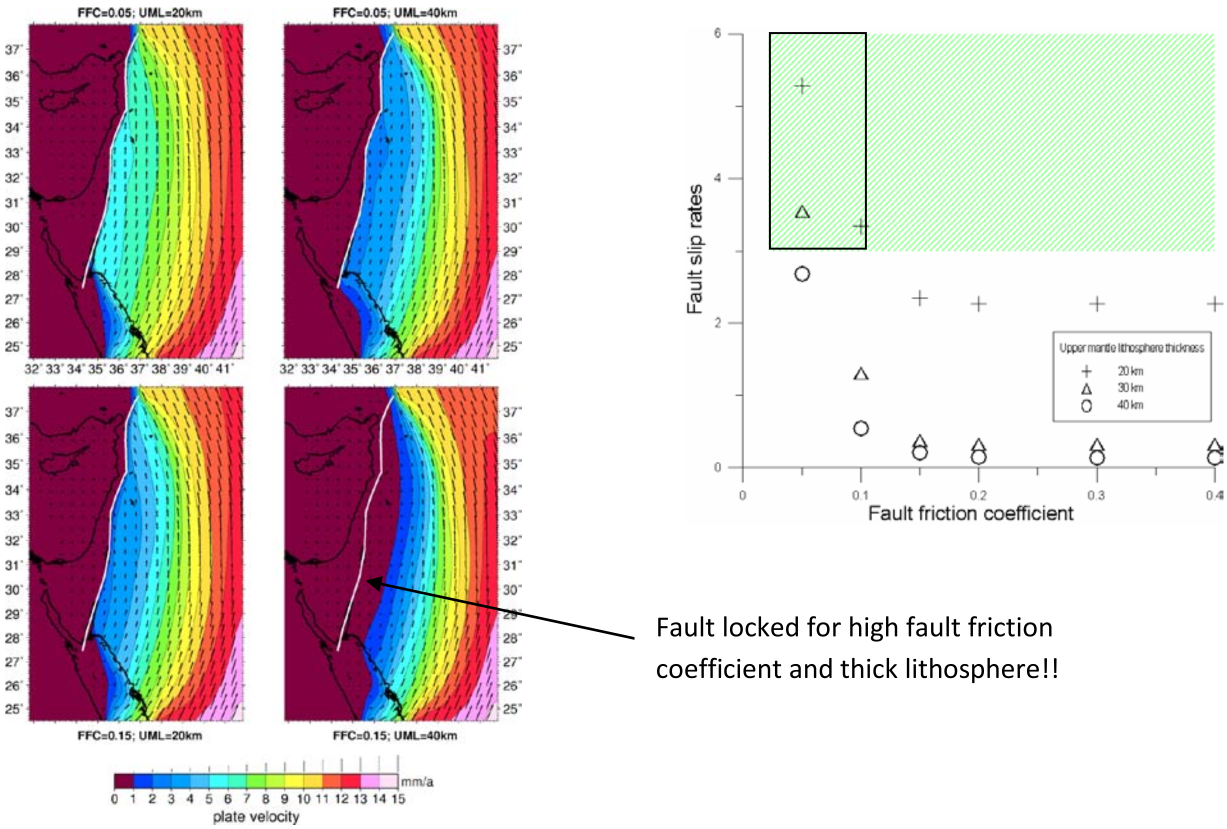

Fig. 2 (left): Four different scenarios of plate velocity field obtained for different parameter sets of fault friction coefficient (FFC) and mantle lithosphere thickness (UML) beneath the DST. Fault is depicted with white line. (Right) the corresponding fault slip rate versus fault friction coefficient. Green rectangle represents the area where fault slip rate values are expected to be correct.

Firstly, in the context of this 3D thermo-mechanical model and the search for a more realistic model, we are incorporating a realistic temperature and pressure- dependent thermal conductivity. Thermal conductivity and radiogenic heat production values were taken from recent studies conducted by (Foerster et al. 2009) in the eastern part of the DST. Subsequently, and strongly related with the parameters controlling the dynamic of the pull-apart basin, we plan to examine the variation of the following parameters with regard to the surface heat flow paradox: the width of the basin, the thickness of the sedimentary layer, the thickness of the brittle part of the model, and forces acting at the boundaries, which are reflected in the kinematic boundary conditions.

A second way of examining this is to consider a thermal erosion of the lithosphere. In other words to consider that at a certain point in time a thermal erosion occurred, i.e. lithospheric thickness was reduced from the initial 140-160 km to the present 70 km estimated by seismic methods. In this case present day temperature in the mantle may be rather high, but the “heat wave” has still not reached the surface and the surface heat flow remains very low. As temperature strongly effects rheology and therefore the strength of the lithosphere, thermal erosion of the lithosphere might have a significant effect on the tectonic evolution of the region.

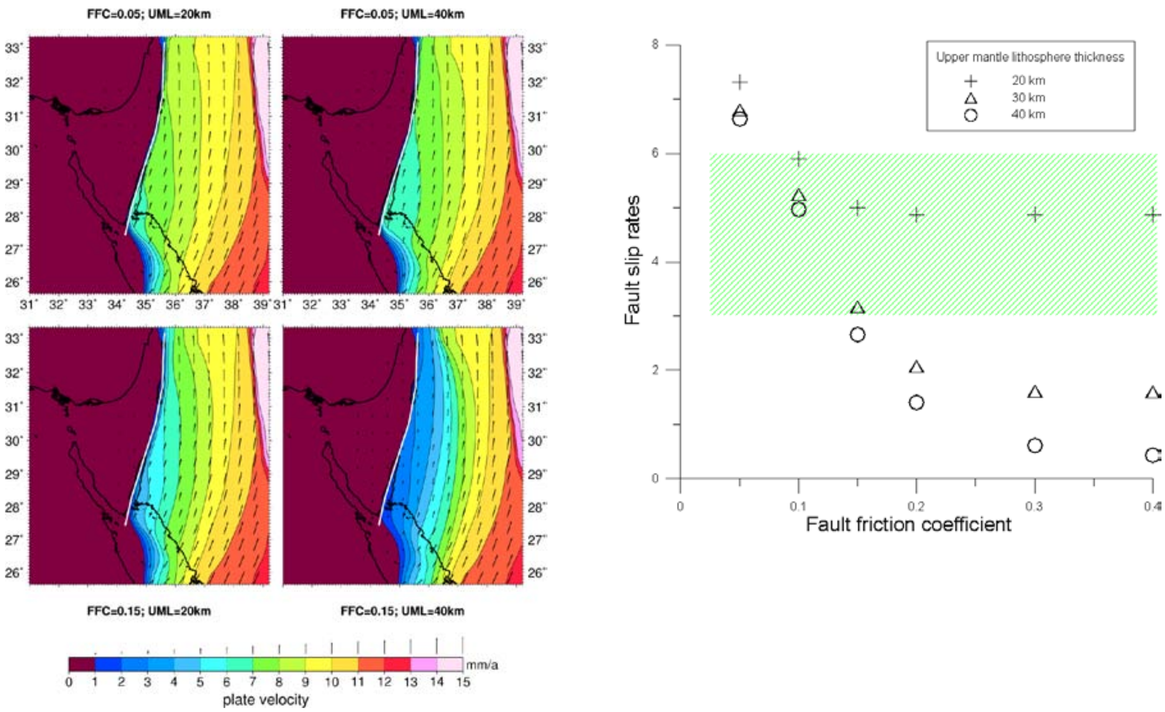

Fig. 3: Analogous to Fig. 2 but now the northern bending part of fault is taken out of consideration.

Finally, we plan to investigate the effect of rheological parameters on the evolution of the Dead Sea Basin. For instance it is known that there are three different creep mechanisms: diffusion creep, dislocation creep, and Peierls creep. Peierls creep takes place mostly in zones of high stress and low temperature, i.e. is likely to be very important in the lithosphere of the Dead Sea Basin.