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The role of evaporites deposition in the morphology evolution of the Dead Sea Fault: a modeling approach

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The Dead Sea Fault (DSF) is a long and narrow morphological depression that extends from the Red Sea 1000 km northward to the Taurus Mountains. It is a transform plate boundary that separates the Arabian plate from the Sinai sub-plate. The DSF has accommodated ∼107 km of sinistral displacement since ∼13–18 Ma. A widespread change in the kinematics of the Africa-Arabia–Eurasia plates took place around 5 Ma, when the oceanic accretion in the Red Sea initiated. These changes introduced an addition of a small component of one-sided transverse extension (roughly in the eastern direction) over the Arabian plate.

The DSF displays a graben morphology, especially in its southern part between the Sea of Galilee and the Dead Sea. Here we investigate the role of salt deposition in this area in the formation of the morphology. The salt was deposited as a result of the dry out of the Sedom Lagoon which existed in this area about 4-5 Ma.

Our thermo-mechanical modeling demonstrates that the slow one-sided extension in the region resulted in origination of a narrow asymmetric half-graben over the track of the previously existing DSF, where the subsidence concentrated mainly on the eastern planar normal basin-bounding fault, and the western listric basin-bounding fault remained much less active. The existence of the DSF prior to initiation of the grabens predetermined a high strain weakening in the region that favored normal faults to localize on the previously existing strike-slip faults. Strain weakening coupled to the slow extension rate in the region precluded normal faults from migrating to adjacent locations.

Fast deposition of evaporites into the rift valley occurred within a short time period (∼0.5Ma), significantly accelerated the basin subsidence, despite the low density of the deposited salt. Specifically, starting from the beginning of the deposition of evaporites, the western listric fault was activated much more significantly than in the pre-evaporitic stage, although strain concentrations remained more enhanced on the eastern planar fault, thus preserving the initial asymmetric basin structure. In contrast, slow deposition of the post-evaporitic sediments into the rift basin did not insert a significant influence on the basin subsidence, and concentration of the deformations has been returning gradually to the eastern fault.

Topography evolution reproduced by the model reflects an asymmetric pattern observed in the field, where normal faults bound the narrow rift valley of ∼20km width, where the valley itself subsides and its flanks are uplifted. The elevation of the rift's eastern margin is bigger than that of the western one, while its overall shape resembles an uplifted shoulder. The rise of the rift's western flank is less sharp and its shape may resemble an asymmetric arch when eroded. Our modeling results demonstrate remarkable similarity to the field observations and confirm theoretical predictions of a basin mode emerged under the local conditions.