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What controls thickness of sediments and lithospheric deformation at a pull-apart basin?

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Pull-apart basins belong to a special type of sedimentary basins associated with continental transform faults. They are depressions that are formed as a result of crustal extension in domains where the sense of fault overstepping or bending coincides with the fault motion sense. The outstanding classic example of a pull-apart basin is the 150 km long Dead Sea basin, which is located at the Dead Sea Transform and where more than 8 km of sedimentary cover has accumulated since 15-17 Ma. It remains unclear what determines the length of a pull-apart basin and the thickness of its sediments and how the associated extension strain is distributed at depth beneath the basin. We present a simplified three-dimensional thermomechanical model of a pull-apart basin formed at an overstepping of an active continental transform fault. The modeling shows that for a given strike-slip displacement and friction on the faults, the major parameter that controls basin length, thickness of sediments, and deformation pattern beneath the basin is the thickness of the brittle layer. The unusually large length and sediment thickness of the Dead Sea basin, the classical pull-apart basin associated with the Dead Sea Transform, can be explained by 100 km of strike-slip motion and a thick (20-22 km, up to 27 km locally) brittle part of the cold lithosphere beneath the basin. The thinner sedimentary cover in the Gulf of Aqaba basin, located at the southernmost part of the Dead Sea Transform, close to the Red Sea Rift, is probably due to a thinner brittle part (<15 km) of the warmer lithosphere. The modeling also suggests no more than 3 km of Moho uplift beneath narrow (10-15 km) pull-apart basins formed in cold lithosphere, such as the Dead Sea basin. We also infer that a pull-apart basin may only form if a several-kilometer-thick ductile detachment zone exists between the brittle crust and upper mantle. Modeling shows that this would not be the case for the Dead Sea basin if the surface heat flow there were indeed as low as 40 mW/m2 as previously reported. We consider this result as an indication that the surface heat flow at the Dead Sea might have been underestimated.