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Particle based modeling of pull-apart basin development with different initial master fault configurations

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Pull-apart basins form in extensional structures or releasing sidesteps and bends where a left-lateral strike-slip fault steps to the left or a right-lateral fault steps to the right [Fossen, 2016]. A pull-apart basin can evolve from different initial fault geometries (30° underlapping, 90° non-overlapping, and 150° overlapping releasing sidesteps). It can also develop from various initial fault kinematics such as pure strike-slip and transtension. This study establishes a scale-independent modeling approach based on the Discrete Element Method to investigate crack propagation and pull-apart basin development. Modeling results are compared with well-studied basins in nature. Main findings can be summarized as below. In 30° underlapping releasing sidestep, Riedel-shears are initiated at the tips of the master strike-slip faults. 30° underlapping pure strike-slip model produces pull-apart basins that evolve through a sequence of closely related states, from spindle-shaped through lazy-Z-shaped to rhomboidal and stretched rhomboidal basin, which is in agreement with the development of pull-apart basins proposed by Mann et al. [1983]. Transtensional models produce an oblique, wider, rhomboidal depression which is consistent with sandbox modeling [Wu et al., 2009] and Central basin in the Sea of Marmara [Armijo et al., 2002]. In 90° non-overlapping and 150° overlapping releasing sidesteps with pure strike-slip and transtensional master faults, Riedel-shears always form at the tips of master faults when peak stress is reached. Then, the Riedel-shears propagate and link with the master faults, forming a rhomboidal-shaped depression. The non-overlapping and overlapping systems directly generate rhomboidal pull-apart basins, without evolving through spindle and lazy-Z-shaped stages. Basin width does not change significantly and is governed by the separation of the master strike-slip faults. Basin length increases with increasing strike-slip displacements. The shape of a pull-apart basin in nature is the consequence of the initial fault geometry, initial fault kinematics, and its various evolution stages.

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