Extinction of Pull-apart Basins in the Sea of Marmara: Transition from Pull-apart Mechanism to a Single, Through-going Fault

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Like most other structures in the earth's crust, pull-apart basins do not suddenly come into existence but evolve through a sequence of closely related stages. A single pull-apart, as it is exposed today, represents only one time frame in its development. The evolution of pull-apart basins can be separated into three stages of development: incipient, early, and mature (Rahe et al., 1998). Incipient pull-apart basins are characterized by closely spaced boundary faults that form parallel to the step angle between the main strike-slip zones. The beginning of the early stage in the evolution of pull-apart basins is marked by the formation of the cross-basin strike-slip faults which begin to transect the interior of the developing pull-apart basin. Progressive widening of pull-apart basins is accommodated by formation of additional normal faults. During the early stage, main displacement strike-slip faults are not linked with the normal faults that bound the edges of the pull-apart basin. Pull-apart basins attain their mature stage of development once cross-basin faults link the main strike-slip displacement zones. Commonly, normal faults bounding pull-apart basins become extinct in the late mature stage of growth.

Strike-slip faults with releasing bend geometries show tendencies toward straightening by constructing cross-basin faults (Zhang et al., 1989; Dooley and McClay, 1997). A cross-basin fault, therefore, can be considered as a contributing factor to the extinction of a pull-apart basin. At early stage of development, cross-basin faults form as separate, small faults having orientations and sense of slip similar to those of Riedel shear fractures in strike-slip settings. With further displacement, strike-slip displacement is concentrated toward the center of the basin developing a linkage between the main strike-slip zones at the tips of the basin. During this process, normal faults bounding the pull-apart basin on the side experiencing less absolute displacement (with respect to the basement) typically become inactive and do not cut late synkinematic fill. In the extinction model of Zhang et al. (1989), development of a single cross-basin fault is coupled with the extinction, or inactivity, of extensional faults bounding the basin. The observations from analog models (Dooley and McClay, 1997; Rahe et al., 1998) are consistent with natural examples. The analog models indicate the extinction of bounding normal faults occurs during the mature stages of pull-apart basin development.

Because the creation of this northern Sea of Marmara appears to be related to the passage of the northern branch of the North Anatolian fault, it was generally assumed that this part of the sea is a pull-apart basin created by the distension between the Izmit and Ganos offset portions of the fault (Armijo et al., 1999, 2002) as previously has been anticipated by Barka and Kadinsky-Cade (1988). Briefly, in this model, the Sea of Marmara has opened in a uniform manner as a pull-apart during the last 5 Myr and the present pattern of deformation is similarly governed by the pull-apart logic.

Le Pichon et al. (1999, 2001) made a proposition based on a completely different approach and suggested that it is possible to join the İzmit segment to the Ganos segment through the Sea of Marmara along a single fault and besides, the pull-apart structure is not active any

more. Rather, the basin was cut by a single continuous strike-slip fault that may have been broken in its entirety during earlier earthquakes in 1509 and 1766.

These two ideas seemingly opposing, in fact, are not so much conflicting with each other, instead, they define successive events. What has happened in the Sea of Marmara regarding the fault geometry is simply a transition from complex pull-apart basins into single, through-going strike-slip faults. All of the pull-apart basins, regardless of offset geometry, evolve progressively from narrow grabens bounded by the oblique-slip link faults to wider rhombic basins flanked by terraced basin sidewall fault systems. The analog models (Dooley and McClay, 1997) reveal that in the later stages of this widening, the cross-basin faults cut the floor of the pull-apart basins and link the offset principal displacement zones. The jogs and therefore pull-apart basins extinct and strike-slip faults become straight as time passes. This development history of the faults and accompanying basins along is valid for the entire North Anatolian fault as well as the basins in the northern Sea of Marmara, where one can observe two sets of faults, the older being inactive – now.

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