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# Evolution of active faulting and morphology in a lithospheric scale pull-apart: the Sea of Marmara (North Anatolian Fault)

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The Sea of Marmara is the largest pull-apart basin along the North Anatolian transform fault and one of the clearest examples of nested pull-apart structure in the world. Morphological observations of submarine fault scarps at a range of scales (height between 1m to 1 km) allow us to constrain the structural evolution of the Sea of Marmara over the Pliocene-Quaternary. To study the distribution and geometry of scarps we combine high-resolution bathymetry data at a range of scales, acquired from the sea surface with a vessel (30 m-resolution, 1 m vertical accuracy) and close to the sea-floor with a ROV (0.5 m-resolution, 0.1 m vertical accuracy). To constrain the long-term evolution of the basins we also use seismic reflection information. The submarine fault scarps have varying proportions of strike-slip and normal faulting, consistent with the pull-apart structure. Well-preserved sea-floor ruptures associated with recent large earthquakes (M~7, offsets up to 6 m) can be identified. The nested morphology of normal faults at the edges of the pull-apart structure contains evidence for cumulative scarps that result from vertical slip associated with many earthquakes. A set of large scarps (10-50 m high) offsets the sea floor, with morphology similar to that of individual earthquake scarps. The stratigraphy is determined with 3.5 kHz seismic profiles and 14C dated cores. It documents precisely the scarp evolution during the last 20 kyr. The morphology of scarps results from accumulation of slip under competing tectonic, erosion and sedimentation processes subject to climatic change. Scarps across the sea floor appear to have emerged progressively after the occurrence of catastrophic

sedimentary events, associated with the late Pleistocene-Holocene deglaciation. Sedimentation rates are fast (1-3 mm/yr), but they do not keep up with even faster fault rates and associated subsidence that create the 1200-m-deep bathymetric sinks in Marmara. The normal faulting rates are up to 6 mm/yr at the pull-apart margins, consistent with the slip rates deduced for the Marmara pull-apart at large scale. The morphology of the 1-km-high scarps is similar to that of the 50-m-high scarps. The largest scarps are associated with about 6 km of sedimentation in the basins. The total structural relief in Marmara appears to have formed under uniform tectonic and morphological processes over the last 3 to 6 Myrs.