



Submarine fault scarps in the Sea of Marmara pull-apart (North Anatolian Fault): implications for seismic hazard in Istanbul

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Earthquake scarps associated with recent historical events have been found on the floor of the Sea of Marmara, along the North Anatolian Fault (NAF). The MARMARAS-CARPS cruise using an unmanned submersible (ROV) provide direct observations to study the fine-scale morphology and geology of those scarps, their distribution and geometry. The observations are consistent with the diversity of fault mechanisms and the fault segmentation within the north Marmara extensional step-over, between the strike-slip Ganos and Izmit Faults. Smaller strike-slip segments and pull-apart basins alternate within the main step-over and earthquake scarps commonly combining strike-slip and extension. Rapid sedimentation rates of 1-3 mm/yr appear to compete with normal faulting components of up to 6 mm/yr at the pull-apart margins. In spite of the fast sedimentation rates the submarine scarps are preserved and accumulate relief. Sets of youthful earthquake scarps extend offshore from the Ganos and Izmit Faults on land into the Sea of Marmara. Our observations suggest that they correspond to the submarine ruptures of the 1999 Izmit (Mw 7.4) and the 1912 Ganos (Ms 7.4) earthquakes. While the 1999 rupture ends at the immediate eastern entrance of the extensional Cinarcik Basin, the 1912 rupture appears to have crossed the Ganos retraining bend into the Sea of Marmara floor for 60 km with a right-lateral slip of 5 m, ending in the Central Basin step-over. From the Gulf of Saros to Marmara the total 1912 rupture length is probably about 140 km not 50 km as previously thought. The direct observations of submarine scarps in Marmara are critical to defining barriers that have arrested past earthquakes as well as defining a possible segmentation of the contemporary state

of loading. Incorporating the submarine scarp evidence modifies substantially our understanding of the current state of loading along the NAF next to Istanbul. Coulomb stress modelling shows a zone of maximum loading with at least 4-5 m of slip deficit encompassing the strike-slip segment 70 km long between the Cinarcik and Central Basins. That segment alone would be capable of generating a large magnitude earthquake (M_w 7.2). Other segments in Marmara appear less loaded.