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Evolution of the North Anatolian Fault, the Aegean and of the Sea of Marmara pull-apart

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The North Anatolian Fault (NAF) has grown by westward propagation through continental lithosphere over a time range of ˜10 m.y. As the Arabia/Europe collision progressed in eastern Turkey, it caused Anatolia to move to the West and the NAF to propagate westwards across the Pontides. At ˜5 Ma it has started opening the Sea of Marmara pull-apart. After crossing the Marmara releasing bend the NAF propagated into the northern Aegean. Behind the Hellenic Arc, the pre-existing back-arc extension in the Aegean started then to be modified. At ˜1 Ma the process of propagation increased the activity of the Corinth Rift in Greece and decreased extension rates in the central Aegean. Long-term geological constraints and present-day GPS velocities can be incorporated in dislocation modelling that allows for internal deformation in regions between major structures. The superposition of two deformation fields now interacting in the Anatolia-Aegean region (the propagation of the North Anatolian fault associated with the extrusion of the Anatolian plateau, and the north-south stretching of the Aegean associated with back-arc extension) can be unravelled. A large-scale damage zone at the western end of the NAF can be defined and slip rates determined for the main structures. The contemporary slip-rate profile of the NAF shows that it behaves like a transform fault for 75% of its length. The damage zone corresponds to a rapid southwestward tapering of the NAF slip rate in the Aegean. The present-day deformation observed by GPS today is consistent with the continuation of the geological processes that started in the Tertiary and both are consistent with the lithosphere preserving long-term elastic strength and with concepts of linear elastic fracture mechanics applying at a large scale. The Sea of Marmara is the most prominent releasing bend along the NAF. Large right-lateral offsets are well identified on land on both sides

of the Marmara pull-apart. The offsets of geological structures during the last 5 Myr amount to 85 km +/- 10 km. The submarine morphology and the seismic reflection profiles reveal a segmented fault system including pull-apart features at a range of scales, which indicate a dominant transtensional tectonic regime. Extension has caused significant overall subsidence and large Pliocene-Quaternary sediment accumulation. (up to 5-6 km). GPS-based models predict a right-lateral slip rate of about 18-20 mm/yr and extension of 8 mm/yr across faults in the northern Marmara basin. Geological evidence is found for a stable kinematics consistent both with the long-term displacement field determined for the past 5 Myr and with present-day Anatolia/Eurasia motion determined with GPS. The fault kinematics involve asymmetric slip partitioning throughout the evolution of the Marmara pull-apart. The loading associated with the westward propagation process of the NAF may have provided a favourable initial geometry for such a slip separation. The NAF has almost entirely ruptured during a series of large destructive earthquakes in the past century. The sequence propagated 800 km westward between 1939 and 1999; an observation that has stimulated studies of fault interaction and stress transfer. Assessment of seismic hazard in the city of Istanbul, which is located by the Sea of Marmara near the western tip of the propagating sequence, is no independent issue. Youthful earthquake scarps associated with recent historical events have been found on the floor of the Sea of Marmara, using an unmanned submersible (ROV). The most prominent of those scarps correspond to the submarine ruptures of the 1999 Izmit (Mw 7.4) and the 1912 Ganos (Ms 7.4) earthquakes. The 1912 rupture on land appears to have crossed an important restraining bend, then entered into the Sea of Marmara floor for 60 km, with a right-lateral slip of 5 m. Its end is at a prominent step-over in the centre of the basin. The direct observations of submarine scarps in Marmara are critical to defining barriers that have arrested past earthquakes as well as defining the contemporary state of loading along the NAF next to Istanbul.