



Field characteristics of active tectonics in NW Turkey: The 1999 earthquake sequence of the Marmara region

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The Marmara region is a tectonically very active belt in northwestern Turkey with a paleogeographical evolution related to the collision and the escape tectonics accompanied by development of the strike-slip North Anatolian Fault. The effect of active tectonics on the modification of coastal and morphological features in NW Turkey is, however extensive, relatively unknown and much less appreciated.

In 1999, the region was affected by the Golcuk earthquake of August 17 ($M_w=7.4$) and the Kaynasli earthquake of November 17 ($M_w=7.2$). These earthquakes caused a surface rupture to develop between the west of Golcuk (Izmit) and the east of Kaynasli (Bolu), where a range of geological units in ages from Ordovician up to Quaternary are exposed. Along its 200 km long path, at over 75 consecutive work stations where properties of the rupture were recorded in detail by measurements, the surface rupture was either localized or occurred in a broad zone (up to several tens of meters). In places, it splayed into branches and showed discontinuities.

The rupture of the earthquakes either traced the morphological expression of the North Anatolian Fault or occurred in the alluvial plains overlying the fault and its splays. It consisted of many individual cracks with a range of orientations from $N80^\circ E$ to $N45^\circ W$. It exhibited variable patterns; some included ridges and others depressions (and/or sag-ponds), indicating the occurrence of transtensional and transpressive segments along the underlying fault. In the transpressive segments, the rupture was nearly continuous and linear, and it roughly followed the fault morphology. Surface rupture comprised many ridges besides cracks, indicating that a strike-slip and a reverse dip-slip were predominant components of the movement. In the transtensional segments,

the rupture was discontinuous and splayed, and observed mostly in the alluvial plains. Rupture comprised cracks with large opening and/or depression, indicating a normal dip-slip component was predominant aside from the strike-slip.

Active tectonics in the region has forms of uplift, subsidence and lateral displacement. While the uplift is routinely attributed to the ongoing compression between the African and Eurasian plates and the subsidence is linked to extensional processes due to southwesterly movement of the Anatolian plate and/or to the retreat of the Aegean Arc, these tectonic effects are also reflected in the geometry of the NAF and the mode of lateral movement along it. All three tectonic effects, as is directly demonstrated by the 1999 Marmara earthquake sequence, have caused morphological and coastal transformations ranging from the formation of bays, lakes, alluvial depressions and elongate ridges to the diversion of the present drainage system in the area where multiple examples including the Sakarya River, Sapanca Lake, Izmit Bay and Gazikoy (Ganos) Mountain are located.