

Paleoseismology of the 1912, 1944 and 1999 ruptures on the North Anatolian fault: Implications for late Holocene patterns of strain release

Rockwell, T.K.¹, Okumura, K.², Duman, T.³, Ragona, D.⁴, Seitz, G.⁴, Awata, Y.⁵, Ucar, G.⁶, Aksoy, E.⁶, Ferry, M.⁷, and Meghraoui, M.⁸

¹Geological Sciences, San Diego State University, San Diego, CA 92182
trockwell@geology.sdsu.edu, ²Hiroshima Univ, Hiroshima, Japan, ³MTA, Ankara, Turkey, ⁴San Diego State University, San Diego, CA 92182, ⁵GSJ, Tokyo, Japan, ⁶ITU, Istanbul, Turkey, ⁷ETH, Zurich, Switzerland, ⁸Strasbourg, France

We excavated over fifty trenches at five sites along the 1912, 1944 and 1999 surface ruptures to study the late Holocene rupture history along the North Anatolian fault east and west of the Marmara Sea. Two of these studies also bear on the late Holocene slip rate and can be compared with rates of strain accumulation determined from GPS. Along the 1912 rupture on the Galipoli peninsula, we excavated nearly 30 trenches near Kavakkoy to resolve cumulative slip of 9 m from the 1912 and 1766 earthquakes. We also found evidence for two additional surface ruptures after about AD 900, which probably correspond to the large regional earthquakes of 1063, and 1344. These observations suggest fairly periodic occurrence ($RI = \sim 250 \pm 75$ yrs for the past millennium and a rate of about 18 mm/yr if all events experienced similar slip.

Along the 1999 rupture, we excavated two sites near Kosekoy to resolve the occurrence of three events after AD 1650. In addition to 1999, one is almost certainly the large 1719 earthquake that had very similar damage distribution to 1999. The other event may be the poorly studied 1878 earthquake or one of several other moderately large events (such as 1754 or 1894) that are poorly located in the region. Radar surveys show a buried channel that is offset by all three events, with about three times the 1999 displacement at this site. These observations suggest that the Izmit-Sapanca segment fails more frequently, and with smaller displacements, than segments to the west and east.

Near Gerede along the 1944 rupture, we excavated about a dozen trenches to resolve six surface ruptures in the past two millennia, with events ca AD 480, 710, 1035, 1235, 1668 and 1944. The 1944 rupture expressed 5 m of slip at the trench site. The penultimate event also experienced a similar amount of slip, based on offset stream channels. Cumulative slip for all five events is about 21-26 m based on 3D trenching of a channel margin dated to AD 550, suggesting a slip rate of 14-18 mm/yr for the past 1500 years. Using the intervals between events for the past 6-7 surface ruptures (290 ± 83 years back to about AD 0) suggests a slightly higher average rate of about 19 mm/yr.

These paleoseismic results have implications in four main areas. First, individual segments appear to have quasi-periodic behavior, at least for the intervals tested. Second, 9-10 m of slip has occurred on fault segments both to the east and west of the Marmara Sea, whereas the last major earthquake in the central Marmara was in 1766, supporting the contention that the segment closest to Istanbul may be ripe for rupture. Third, the Izmit-Sapanca section of the 1999 rupture sustained less slip than at Gulcuk or east of Sapanca, consistent with the more frequent

occurrence of events at Kosekoy, suggesting that 1999 was a multi-segment or cascade event. Finally, all of the dated geologic offsets from our work suggest a late Holocene rate in the range of 14-19 mm/yr. These rates are lower than the ~23-25 mm/yr inferred from GPS measurements, suggesting that either there are periods when the fault “catches up” with more frequent events or that the GPS rate carries a transient signal, possibly related to rupture of most of the 1000 km of fault this past century.