Seventy-two years of Surface Creep on the North Anatolian fault at Ismetpasa: Implications for the southern San Andreas and Hayward faults.

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Surface creep on the North Anatolian fault was first recognized in 1969 in the form of an offset wall that had been constructed across the fault 13 years after the 1944 Mw=7.4 Bolu/Gerede earthquake. Publications by Ambraseys (1970) and Aytun (1982), however, reported this offset as 24 cm and 18 cm respectively resulting in an apparently unresolvable ambiguity in 1957-1944 fault creep rate. Sub-pixel measurements conducted on high resolution photographs of the wall taken on the same day in 1969 by Clarence Allen, however, reveal the true offset to have been 12.5±0.5 cm, a value quite close to sub-pixel measurements of offsets shown in photos published by the first two authors. Ambraseys (1970) relates also that the nearby railroad had been offset 1.5 m by the 1944 earthquake, and that a subsequent repair was needed in 1950 to fix an additional offset of 30 cm. The combined offset is almost a factor of three smaller than the 5 m 1944 offsets of nearby trees, tracks, field boundaries and aqueducts across the fault reported by Kondo et al., (2005). These inconsistencies can be reconciled by recognizing that Ambraseys' numbers refer to misalignment of the railroad, and not to offset of the fault. When corrected for a 20° obliquity the 1944 coseismic offset increases to 3.7 m, and pre-1950 afterslip increases to 0.74 m, that when summed with 50 cm of post 1969 creep, approximates the 1944 offsets reported by Kondo et al. A carbon-rod creepmeter installed across the fault in 2014 reveals that slip occurs episodically at a mean decadal rate of ≈6 mm/yr (Figure 1), with creep confined to the uppermost 4 km of the fault. Anecdotal reports indicate that for some major North Anatolian Fault earthquakes coseismic slip has been manifest as surface slip only after several hours. We consider this may also have occurred at Ismetpasa and that surface slip during the seismic cycle here may be considered entirely aseismic. Models of the ≈270 year earthquake cycle suggest that a steady background creep of 4.5 mm/yr now dominates the afterslip process (Figrue 2), and that a further ≈1 m of surface slip will precede the next Mw≈7.4 earthquake. Surface creep events currently load the top of the seismogenic zone, each 1.5-4.5 mm event incrementing strain by 1-2 μstrain in a few hours. We consider it probable that a creep event will contribute to future nucleation of seismic rupture between 5 and 14 km depths. The processes on the North Anatolian fault parallel those on the Hayward and southern San Andreas faults.

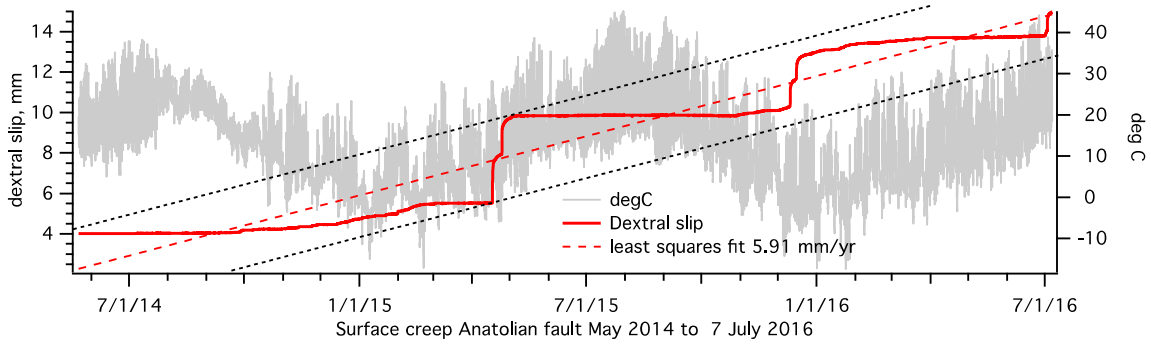

Figure 1 Two years of creep on the North Anatolian fault at Ismetpasa (40.8698°N, 32.6250°E). Creep doublets slip 2-4 mm with transient velocities of 2.5 mm/minute and 80% durations of 2 hours. The black dashed lines indicate ±2 mm bounds to creep-event lag and lead. The carbon-fiber rod creepmeter is effectively insensitive to temperature

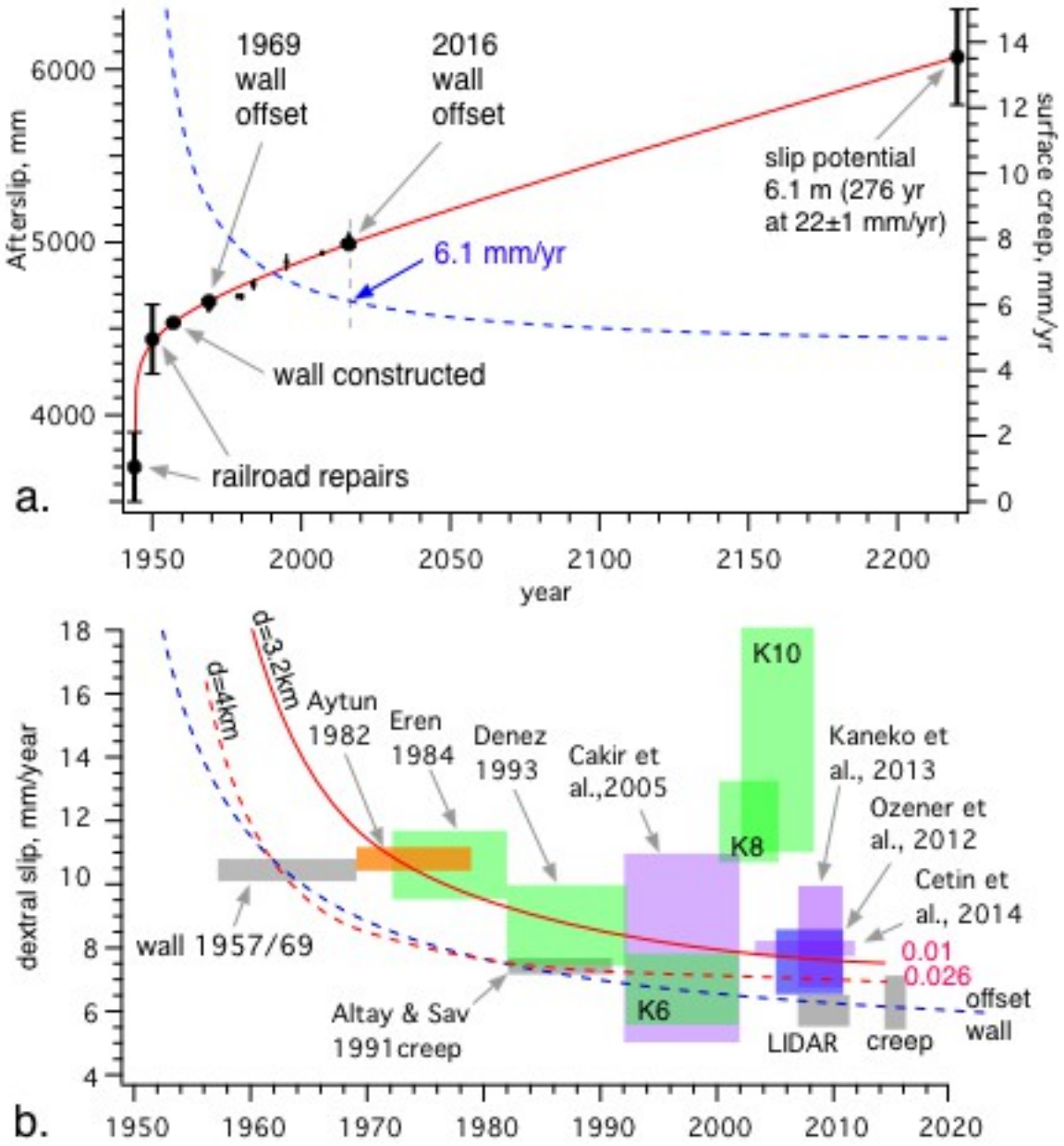

Figure 2a**.** Ismetpasa railroad and wall offsets as a function of time. The best fit red line to the displacement data is obtained by simultaneously solving for a linear creep velocity (4.65 mm/yr) and afterslip. **b.** Compilation of observed fault slip velocities. While continuous creep measurements and LIDAR (Karabacak et al., 2011) generally agree with velocities derived from wall offsets (grey boxes and blue dashed line from Figure 14a), most geodetic estimates prefer a ≈1.25 faster velocity close to the solid red line (predicted velocity decay curve for (a-b) = 0.01 and locking depth of 3.2 km from Kaneko et al., 2013). The dashed red line corresponds to their prediction for locking depth of 4 km and a-b=0.026. Measurements with narrow aperture indicate a present-day (2016) creep rate of 6.1 mm/yr whereas large scale measurements (orange ≈160 m triangulation; green and blue ≈800 m GPS array, violet >30 km InSAR) favor a rate closer to 7.6 mm/yr. Some of these geodetic measurements include velocity estimates from regions to the east where slip rates are higher.