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Evidence for active creep on the Alto Tiberina low angle normal fault inferred using GPS geodesy

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The Alto Tiberina fault (ATF) in central Italy is an upper crustal discontinuity dipping ~20° to the east-northeast. This structure is imaged by seismic reflection lines constrained by deep boreholes, and highlighted by intense microseismicity between latitudes ~43.2ºN and 43.5ºN. Outside of this latitude range, a more regional continuation of the structure is hypothesized, but is not well imaged by geophysical data. Balanced restored geological cross sections show that the structure represents a major fault accommodating up to 10 km of regional extension in central Italy since 3 Ma. However, no large earthquakes have been attributed to the ATF. Instead, large earthquakes in the area occur on high angle west dipping normal faults that cut the ATF hanging wall. Several lines of evidence, including fine grained foliations composed of velocity strengthening phyllosilicate minerals in exhumed fault rocks, high fault fluid over-pressures observed in footwall boreholes (~85% lithostatic pressure at 3.7-4.8 km depth), persistent microseismicity coincident with the ATF fault plane, and pattern of geodetically observed crustal motions suggest that the ATF may accommodate slip primarily by aseismic creep below ~4 km depth in the crust. Previous studies comparing GPS velocity data with a simple fault model consisting of an infinitely long edge dislocation buried in an elastic halfspace supported the shallow creeping hypothesis. But a newer more precise set of crustal motion data obtained from long-running campaign and continuous GPS stations is not adequately explained by an infinitely long creeping-fault model. To investigate whether the finite along-strike length of the ATF fault may help reconcile models for a shallow creeping ATF fault with the current GPS velocity data set, we used the TDEFNODE software to parameterize the ATF fault using the available high-resolution constraints on fault geometry provided by seismic reflection data and seismicity in the latitude range ~43.2ºN and 43.5ºN. We also test the regional extent of the fault by extending the fault model to the north and south of the well-imaged portion of the fault, assuming a 20º dip. We estimated fault coupling along-strike and down-dip to assess spatial variations in creep on the model fault. Our modeling suggests that the portion of the model fault in the latitude band ~43.1ºN to ~43.7ºN, encompassing the geophysically imaged ATF fault, creeps at nearly the full fault slip rate of ~2 mm/yr below a depths of 3-5 km. Our model corroborates previous inferences, suggesting active creep at shallow depth on the well-imaged portion of the ATF. However, outside of this range of latitudes, where the existence of a regional low angle normal fault is speculative, the model fault appears to be coupled to greater depths (7-8 km or deeper). Interestingly, the apparent locked zones to the north and south of the creeping zone correlate with the locations of instrumentally recorded large magnitude hanging wall earthquakes. In contrast, there have been no instrumentally recorded large magnitude earthquakes in the hanging wall overlying the creeping portion of the fault.