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Creepmeters on the Hayward fault

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ABSTRACT

Along most of the Hayward fault, roads and pipes are repeatedly cracked by surface creep of the fault. We measure ongoing creep at 10 minute intervals to 1/1000 inch precision to search for possible precursors to an earthquake, to learn more about the geometry of the creep process, and to estimate the reduction in seismogenic strain accumulation resulting from creep releasing plate boundary motions aseismically. The creep rates we measure are in all cases less than the total creep occurring across the fault because the creepmeters effectively sample a ±7.5 m width of the fault zone and creep is typically distributed over a diffuse surface zone (30 m long at 30 degrees to the fault). A slip deficit is developing along the entire fault at approximately 4 mm/year but less so at the southern end of the fault where the creep rate has hitherto progressed at 9 mm/year, but where recent creep rates have fallen to less than 4 mm/year. A small change in creep rate occurred at Temescal park in 1998-1999 perhaps related to a M≈4 local earthquake at Berkeley in Dec 1998. An abrupt spatial change of rate near Fremont exists which we calculate has resulted in considerable strain developing since the 1868 earthquake, perhaps sufficient to drive a local future Magnitude 6 earthquake. Throughout most of the fault the creep process is remarkably linear, a finding that in principal permits the forward prediction of creep and hence the detection of anomalous rates of creep on the fault. For this to be successful we believe it will be necessary to incorporate invar rods into all the creepmeters.

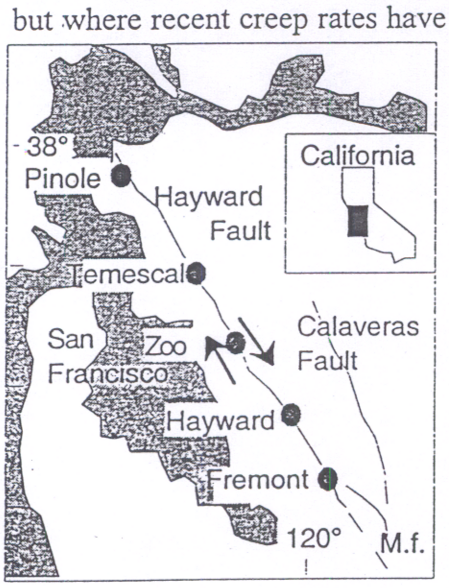

Figure 1 Distribution of Hayward fault creepmeters.

The Hayward fault is one of three sub-parallel dextral fault zones active within the San Andreas system in central California. It can be traced at a mean strike of N35W for a distance of 80 km from a releasing bend beneath San Pablo Bay to south of Fremont, where the locus of recent and geological slip is transferred east to the Calaveras fault via the Mission Fault. Microearthquakes occur near the fault to a depth of 12-13 km. Creep on the Hayward fault occurs both below and above a locked seismogenic zone. The deep slip rate below 12 km is estimated to be 9 mm/yr based on the offset of geological markers [Lienkaemper et al, 1994] and from the surface velocity field [Lisowski et al. 1993]. Surface creep in the upper 5 km at mean rates of 4-9 mm/yr is evident from the progressive offset of numerous fault crossing features, some of which have been in place since the time of an M≈7 earthquake on the southern half of the fault in 1868 [Lienkaemper et al, 1994].

The measurement of post-seismic creep in the Parkfield region in 1966 [Smith and Wyss, 1966], lead to corresponding efforts to monitor creep processes on the Hayward fault. A creep meter was installed across the fault beneath the Berkeley Stadium in 1966 [Bolt and Marion, 1966], and six more were installed between Hayward and Fremont between 1968 and 1970 [Nason et al. 1974]. Two more creepmeters were installed in Fremont in 1969, and in the Claremont water tunnel from 1972-4 [Schulz et al. 1986]. The resulting distribution of creepmeters was somewhat uneven geographically, with many measurements clustered along the southermost 20 km of the fault. By 1988 only three creepmeters remained in operation [Schulz et al 1989]. In 1980 a series of geodetic measurements of creep were initiated along the fault and these measurements, supplemented by more recent arrays, continue at present [Galehouse, 1996; Lienkaemper et al, 1994].

In 1993 we started installing a series of creepmeters along the fault. The objective was to overcome the anticipated high noise levels found by other investigators and to develop ways to learn more about the creep process in the Hayward region. The creepmeters have tested a number of geometries and sensors and attachment methods that have hitherto never been attempted. A major change at the onset of the investigations was to attempt to capitalize on the significant forces involved in the creep of the flanks of a fault. In the past creepmeters have been very delicate wire instruments installed in pipes that must be constantly aligned to prevent friction or signal errors when the wire touches the edge of the pipe. We have approached the concept of creep measurement by installing massive anchors and thick rods that slide in telescopic plastic pipes across the fault. The method allows us extend the length of the creepmeter to 30 m, and longer installations are possible, but it has its penalty in the form of possible frictional effects as the pipes and rods slide through the fault. We devised a method to avoid this which decouples the rod at each end from the mount, but this requires a doubling in the number of sensors needed to give the creep signal. Our greatest failure has been to waterproof the underground cabling to and from sensors. Although this is now rectified by removing all underground cable joints and connectors, several noisy or lost data segments have occurred through flooding of vaults in the months of January to March when the rain is heaviest in the Bay Area. From the various lessons we have learned we believe that the time is ripe to install identical sensors at each creepmeter. This was the subject of an unsuccessful proposal in 1998 for 1999 funding.