——FINAL TECHNICAL REPORT——

02HQ-GR-0065

CONTINUOUS BROADBAND MONITORING OF STRAIN CHANGES NEAR THE SAN ANDREAS FAULT

February 1, 2002 — January 31, 2004

Submission date: September 13, 2004

Program Elements: II

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Abstract

This grant supported the operation of a 524-m-long laser strainmeter adjacent to the southern San Andreas Fault, funded by the US Geological Survey at this site since 1994. This device measures the change in distance between its ends to within a fraction of a wavelength of light. These measurements allow us (1) to measure the properties of the rocks in and around the fault zone, (2) to understand how ground deformation in this active area compares with that elsewhere in California, and (3) to detect small motions on the fault should they occur. These measurements provide information on behavior of the San Andreas Fault at its southern end: one end of that segment of the San Andreas which has the longest elapsed time since the last large earthquake. In the event of a large earthquake on this segment, this instrument would provide an unexcelled baseline measurement of precursory deformation.

Observations show the strainmeter to be faithfully recording the elastic build-up of fault strain, with occasional strain steps probably caused by nearby fault creep.

CONTINUOUS BROADBAND MONITORING OF STRAIN CHANGES NEAR THE SAN ANDREAS FAULT

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1. Introduction

This grant provided funds to operate a long-base laser strainmeter at a site (DHL) close to the southernmost section of the San Andreas Fault (**Figure 1**) and to analyze and model the data produced by this instrument and by other measurements in the area. This data collection and analysis provides important information about strain in seismic zones, especially near the termination of the Indio segment of the San Andreas Fault, identified as a likely initiation point for a future major earthquake on this segment of the San Andreas.

What do we get from the higher sensitivity of strainmeters that could not be measured with continuous GPS or other techniques? Our list includes:

1. Strain rates within a fault zone. Most geodetic data span the fault with an aperture of 10-30 km, leaving the details of the strain within this zone uncertain. If part of the observed motion on these scales is distributed in inelastic deformation close to the fault, the rate of elastic deformation, and the seismic hazard, would be lower. Secular strain measurements within the zone of possible inelastic deformation can establish if this is occurring.

2. Interseismic slip behavior. A continuous strain-measurement system allows us to detect (or at least to put limits on) the nature of fault motion over a wide range of frequencies, from minutes to years. This is not the same as looking for precursors (#4 below): rather, we aim to study aseismic fault slip, associated with large earthquakes or not, something much better done with strainmeters than geodetic measurements. Specifically, we want to ask if fault slip at depth is steady or not at periods of less than one year. Our results from PFO, which is not within an area immediately adjacent to a fault, have not shown convincing departures from steady strain accumulation, except postseismically (dramatically so for the Landers earthquake). With this measurement site (DHL) we aim to extend this to other settings. If measurements in an active fault zone reveal (no more than) the same level of strain fluctuations as we have seen at long-running PFO, it would imply that the PFO data are more probably representative of the rest of California, with profound consequences for what kind of overall strain monitoring should be undertaken.

3. Fault-zone rheology. A long-base strain measurement will give a good record of the earth tides and can provide us with a collection of teleseismic recordings, unaffected by the localized distortions present in borehole strain and tilt data. If fault zones are ‘‘soft’’ compared to the surrounding rock, thereby concentrating strain, this will be obvious in tidal and seismic data from such instruments.

4. Precursory anomalies. The most ‘‘applied’’ reason for making high-quality strain measurements along the southern San Andreas (or indeed in any other fault zone) is also the one with the

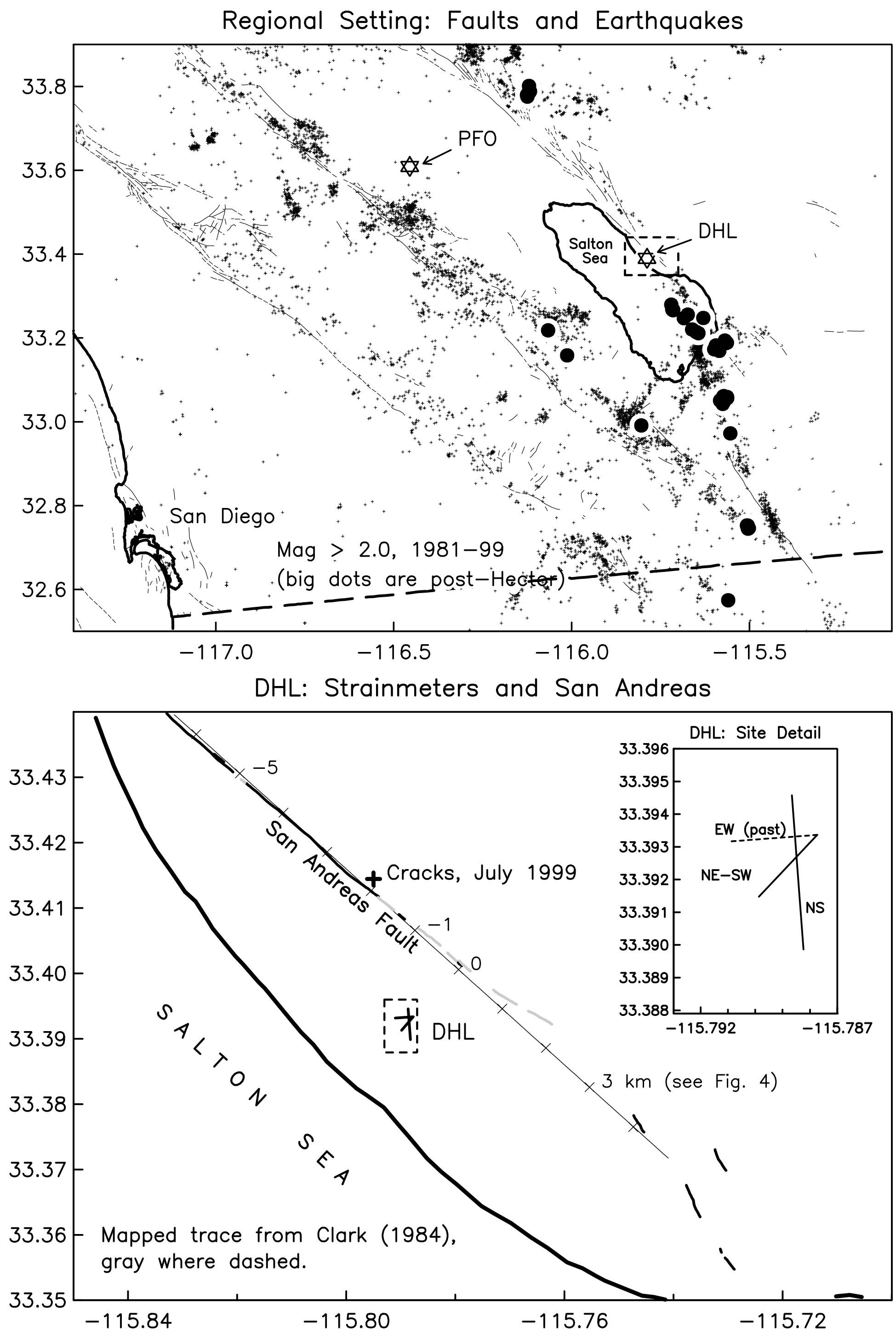

Figure 1

least chance of happening: to detect deformation premonitory to an impending great earthquake. The likelihood of a big earthquake during the next few years, while high relative to other locations, is still so low that the odds are heavily against this occurring in any given year. We thus must plan our measurements around the results described above, rather than staking all on such an unlikely chance. One aspect that improves our chances of learning something about precursory signals (and applies equally to aims (#2) and (#3)) are the concurrent observations from PFO—the search for such signals is strengthened greatly by having instruments at two locations.

2. Recent Events

The award provides funding solely for operation of the strainmeter at DHL. The period funded is included in the longer span of data shown in **Figure 2**. This is from the only fully-anchored strainmeter (NS), which shows a secular trend of −0.31 $\mu\varepsilon$/yr. Fitting a spatially uniform strain to velocities of geodetic stations nearby gives a rate of −0.41±0.09 $\mu\varepsilon$/yr; a dislocation model of the San Andreas fault and Brawley Seismic Zone, gives −0.27 $\mu\varepsilon$/yr. We conclude that the strainmeter is recording the secular strain correctly, even in the poorly consolidated material around Durmid Hill. Parts of the strain record show an annual cycle, with an amplitude of 35 nε, and a phase of 37° relative to January 1. (The local air temperature has an annual cycle of 10.7°C, phase −199.8°.) We do not yet know whether the cycle in strain comes from thermoelastic deformation, or (quite possibly) incomplete correction of end-motion by the fiber anchors. Compared to any other near-surface strain record the annual cycle is small. Removing the secular rate and annual cycle gives the residual series of **Figure 2**. This shows that for much of the time, the strain fluctuations close to a fault zone are comparable to what we have observed at PFO, well outside any fault zone. The DHL record does show aseismic events, most lasting a few minutes, which we ascribe to local creep events on the nearby San Andreas fault: e.g. Events A, B, and H. (B, and other smaller events around that time, were also recorded on the other long-base strainmeter then running at DHL, so we are sure these were not instrumental artifacts.)

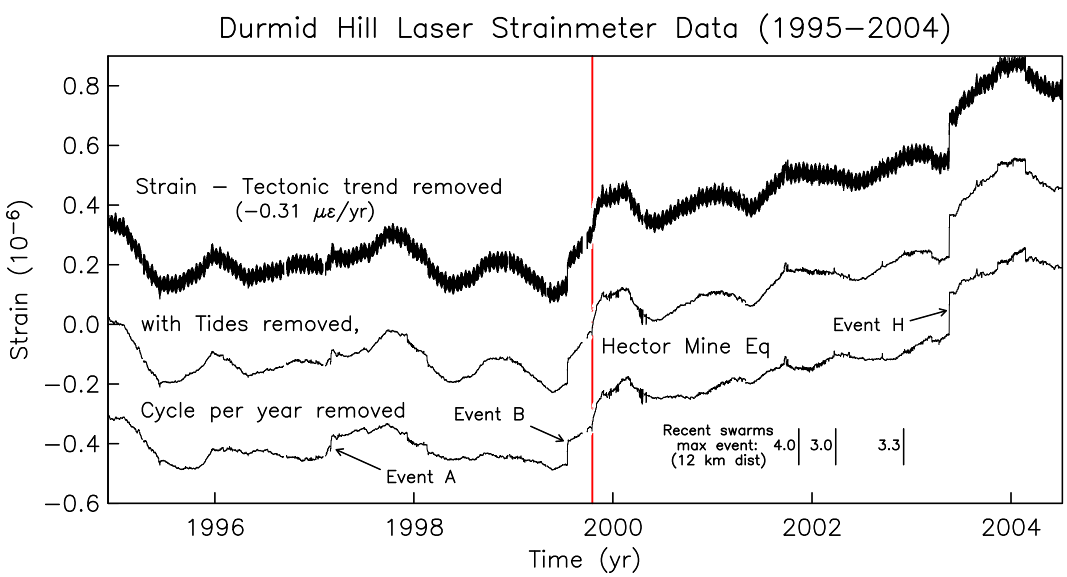

Figure 2

We continued to have a real-time high-speed telemetry link, courtesy of the Anza Seismic Network. On day 123 of 2003 we installed one of our new PC-based dataloggers, developed for Yucca Mountain, that meets our special needs (over 20 channels, low cost, moderate accuracy, and absolute time), while using as much commercial hardware and software as possible. The base system is a PC running Windows 2000, and incorporating commercial hardware, mostly from National Instruments. The main digitizing program was written for us by a small software house (Ice-9); it creates the data files, which are both saved as a data record and available for real-time streaming. These files are also used by the various control routines, for which we use LabVIEW, also from National Instruments. LabVIEW routines display all the data, and can operate the control systems that include steering of the main laser beam, remote control of the laser adjustments, and remote control of the vacuum system. We have requested funds from NSF Instruments and Facilities for the hardware needed to interface these control systems to the strainmeter.