

## **Theodolite survey monitoring of fault creep on San Francisco Bay Region faults**

U.S. Geological Survey  
National Earthquake Hazards Reduction Program

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### INVESTIGATIONS UNDERTAKEN

During the grant period from October 1, 2006 through September 30, 2007, we continued to measure aseismic slip (i.e., creep) on San Francisco Bay region faults, extending a project that was begun by Jon Galehouse in 1979 (Galehouse, 2002; Galehouse and Lienkaemper, 2003). At each measurement site, we determine the amount of strike-slip movement within a width of about 55-280 m across faults to provide long-term observations about creep behavior and unusual or noteworthy fault movement. Monitored faults include the San Andreas, Hayward, Calaveras, Concord-Green Valley, Maacama, Rodgers Creek, and San Gregorio-Seal Cove faults. The surveying is largely conducted by undergraduate Research Assistants under the supervision and training of several long-term project employees and the Principal Investigators. We presently collect regular measurements at 30 localities along alignment arrays on active faults, and have data from additional sites that have had to be abandoned. We are continuing to re-measure most sites with a history of creep about once every eight to ten weeks and most sites without any creep history about every three to four months.

In addition to our ten regular sites on the Hayward fault, we annually measure 23 other Hayward sites in conjunction with J. Lienkaemper of the USGS. Jon Galehouse began measuring these additional sites in 1994, and our team completed its seventh collaborative set of measurements in October 2006. The team also monitors three additional sites on the northern Calaveras fault with J. Lienkaemper. Detailed information about the fault creep alignment arrays and measurement procedures can be found in Galehouse et al., 1982. We have created a new web site that includes the following information: project description, project personnel, creep characteristics and measurement, map of creep measurement sites, and creep site table with data plots and site descriptions. The web site makes our results accessible to anyone in the scientific community and to the general public; site URL: <http://funnel.sfsu.edu/creep/>. Site

numbers cited below refer to site numbers on the interactive creep site map on our website.

## MAJOR GOAL(S) & ACTIVITIES OF THE GEODETIC PROJECT

The primary purpose of the proposed investigation is to measure fault slip and creep rates on San Francisco Bay region faults, continuing the detailed monitoring program started by J. Galehouse in 1979 and assumed by K. Grove and J. Caskey in 2001 and Caskey in 2006. The creep monitoring project continues to expand the long-record database that is used to determine "normal" or average creep rates and creep characteristics on Bay Region faults and to detect any deviations from the norm. We use a digital theodolite to measure more than 34 sites on these Bay Region faults using triangulation alignment arrays. Once a year we measure an additional 21 sites that were established on the Hayward fault in participation with J. Lienkaemper of the USGS. Our data delineate the amount of movement within a width of about 55-280 m across faults, a width range not usually covered by other monitoring methods or measuring instruments. The precision of our measurements of fault movements is generally on the order of  $\pm 1.2 - 2.5$  mm (between successive surveys) depending on the across-fault width of the array. However, over time spans of numerous surveys the details of creep behavior and average rates of movement can be determined with a much greater degree of confidence.

## ACCOMPLISHMENTS & CHANGES IMPLEMENTED IN THIS REPORTING PERIOD

We have critically analyzed our data in an effort to improve our coverage and quality (Figure 1). Consequently, we have reduced the frequency of measurements of existing sites in northern California to approximately one-year intervals in accord with the USGS/EHP data management practices outlined in the 2007 Networks Announcement. We have also made plans to install several new arrays on the Rodgers Creek, Maacama, Green Valley and Calaveras faults.

## DATA ANALYSIS AND DISSEMINATION

We continue to develop analytical and interpretive phases of the project that will involve the P.I.s with undergraduate and graduate student research. In addition to disseminating our fault creep data via reports to NEHRP (e.g., Grove and Caskey, 2005), we also maintain a web site with information about the fault creep project. The web site makes our results accessible to anyone in the scientific community and to the general public; site URL: <http://funnel.sfsu.edu/creep/>. At any time, information about the project can be requested via email: [fltcreep@sfsu.edu](mailto:fltcreep@sfsu.edu). Our most up-to-date data compilations are available through U.S. Geological Survey Open-File Report 2007-1367 (McFarland et al., 2007; <http://pubs.usgs.gov/of/2007/1367/>). Plots of time-series data shall be updated and made available to USGS annually, and tables or computer files of those time series shall be included in the Final Report and released in a publicly available form at the end of the final year of the agreement.

## REFERENCES CITED

Galehouse, J.S., 2002, Data from Theodolite Measurements of Creep Rates on San Francisco Bay Region Faults, California: 1979–2001: U.S. Geological Survey Open-File Report 02–225 (on line report) <http://geopubs.wr.usgs.gov/open-file/of02-225/>

Galehouse, J.S., and Lienkaemper, J.J., 2003, Inferences drawn from two decades of alignment array measurements of creep on faults in the San Francisco Bay region: Bulletin of the Seismological Society of America.

Galehouse, J.S., Brown, B.D., Peirce, B., and Thordsen, J.J., 1982, Changes in movement rates on certain east bay faults: California Division of Mines and Geology Special Publication 62, p. 236-250.

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Lienkaemper, J.L., Galehouse, J.S., and Simpson, R.W., 2001, Long-term monitoring of creep rate along the Hayward fault and evidence for a lasting creep response to 1989 Loma Prieta earthquake: Geophysical Research Letters, v. 28, pg. 2265–2268.

McFarland, F.S., Lienkaemper, J.J., Caskey, S. J., and Grove, K., 2007, Data from theodolite measurements of creep rates on San Francisco Bay region faults, California: 1979-2007, U.S. Geological Survey, Open-File Report 2007–1367, 118 p., <http://pubs.usgs.gov/of/2007/1367/>

## NON-TECHNICAL SUMMARY

We are measuring the rate of aseismic slip (i.e., creep) at 30 sites that cross faults in the seismically active San Francisco Bay region. Our primary purpose is to determine the rates of present fault movement and to discover any changes that might occur before, during, or after a seismic event

## DATA AVAILABILITY

Creep data collected from all of our sites between 1979 and 2001 are available online in Open-File Report 02-225 (<http://geopubs.wr.usgs.gov/open-file/of02-225/>) and in the 2001 NEHRP Final Technical Report (<http://erp-web.er.usgs.gov/reports/annsum/vol42/nc/g0084.htm>).

Our most up-to-date data compilations are available through U.S. Geological Survey Open-File Report 2007-1367 (McFarland et al., 2007; <http://pubs.usgs.gov/of/2007/1367/>).

Data plots and site maps through 2006 are available on the project web site:  
<http://funnel.sfsu.edu/creep/>

For additional information about our creep data, please contact John Caskey (Project P.I.) 415-405-0353, [caskey@sfsu.edu](mailto:caskey@sfsu.edu); or Forrest McFarland (Project Operations Manager), [fltcreep@sfsu.edu](mailto:fltcreep@sfsu.edu).