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# Integrating Geologic and Geodetic Estimates of Slip Rate on the San Andreas Fault System

PAUL SEGALL

*Department of Geophysics, Stanford University, Stanford, California 94305*

## Abstract

Interseismic deformation measurements are generally interpreted in terms of steady slip on buried elastic dislocations. Although such models often yield slip rates that are in reasonable accord with geologic observations, they are inconsistent with our expectation of fault structure at depth, and cannot explain transient postseismic deformation following large earthquakes. An alternate two-dimensional model of repeating earthquakes that break an elastic plate of thickness $H$, overlying a Maxwell viscoelastic half-space with relaxation time $\tau_R$ (Savage and Prescott, 1978) involves five parameters; $H$, $\tau_R$, $t$, $T$, and $\dot{s}$ , where $t$ is the time since the last quake, $T$ is the earthquake repeat time, and $\dot{s}$ is the slip rate. Many parts of the San Andreas fault (SAF) system involve multiple parallel faults, which further increases the number of parameters to be estimated. All hope is not lost, however, if we make use of geologic constraints on slip rate, as well as the measured time-dependent strain following the 1906 earthquake, in addition to the present-day spatial distribution of deformation rate.

GPS data from the Carrizo Plain segment of the SAF imply a considerably larger relaxation time than inferred from the post-1906 strain rate transient recorded by repeated triangulation surveys. This may indicate that the simple Savage-Prescott model is deficient, or that the crustal structure and/or thermal profile differs significantly between northern and central California. The data are consistent with an average recurrence interval of ~280 years, which agrees reasonably well with paleoseismic estimates.

To test the effect of regional variations in $H$ and $\tau_R$, I analyze GPS-derived velocities from the northern San Francisco Bay area (Prescott et al., 2001), and include the SAF, the Hayward-Rodgers Creek (HRC), and Concord-Green Valley faults (CGV). Optimization using constrained non-linear least squares yields: $H$ ~18 km, $\tau_R$ ~35 years, $T_{SAF}$ = 280 years, $\dot{s}_{SAF}$ , ~25 mm/yr, $t_{HRC}$ = 225 years, $T_{HRC}$ = 429 years, and $\dot{s}_{HRC}$ ~7 mm/yr. The effect of the Concord–Green Valley faults is modeled kinematically; the optimal model involves 8 mm/yr of slip beneath 2 km. While neither the average recurrence interval on the SAF or HRC is well resolved, the optimal inter-event time for the SAF is in reasonable agreement with paleoseismic results, which indicate that the most recent event prior to 1906 occurred in the mid-1600s. The geodetic data also favor the latest date allowed by historical data (~1775) for the most recent HRC earthquake, a result not inconsistent with the paleoseismic finding that the most recent event there occurred in the interval 1670–1776. The conclusion of this study is that by combining the present-day deformation field, post-1906 strain data, and geologic bounds on slip rate and maximum earthquake slip, it is possible to estimate parameters of considerable geophysical interest, including time since the most recent earthquake and average recurrence intervals.

## Introduction

INTERSEISMIC DEFORMATION DATA collected along the San Andreas fault system reveals a broad zone of strain that extends roughly 100 km perpendicular to the strike of the principal faults (e.g., Johnson et al., 1994). Approximately 35 mm/yr of relative displacement is accommodated across this region (e.g., Prescott et al., 2001). Geodetic strain data such as these are important components of seismic hazard evaluations. Simply stated, the higher the strain rate the bigger, or more frequent, the earthquakes must be to relieve that strain. More quantitative information about earthquake occurrence can only be made through reference to a mechanical model of the deformation field. The simplest, and most widely used, model is that of an infinitely long screw dislocation in an elastic half-space introduced by Savage and Burford in 1970. In this case the