Final Technical Report for award G09AP00005

The 3-D strain-rate field in California and its implications for seismic hazard

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Principal Investigators: John P. Platt and Thorsten W. Becker

Institution: University of Southern California

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Summary

This proposal was to carry out a detailed analysis of the 3-D strain-rate field in California, with the aim of better defining the distribution of fault slip-rates and related deformation. The results of our research to date can be summarized as follows, and are presented under these headings.

1) A filtered velocity field for California, based on the 2009 PBO data-set, together with the results of a number of GPS campaign surveys.

2) A strain-rate intensity map of California, showing the second invariant of the 2D strain-rate tensor as a proxy for the overall rate of tectonic deformation.

3) Inversions of the velocity field on six swaths across the transform boundary, to determine fault slip-rates, with uncertainties based on the trade-offs between slip-rate and locking depth.

4) A slip-rate budget for California, showing how slip-rates are transferred from one fault segment to another.

5) A comparison between geodetically and geologically determined slip-rates.

Introduction

Our 2009 project funded by the USGS Earthquake Hazards Program was intended to follow up on the results of our previous research into the strain-rate field in California, published by Platt and Becker [2008]. Our new results (see below) have been presented at the 2009 SCEC Annual Meeting, the 2009 AGU Fall Meeting, and a paper has been submitted for publication in G-cubed [Platt and Becker 2010], and is now in revision. We will also present our results at the EGU General Assembly (May 2-7, 2010) in Vienna, Austria, and at the SCEC GPS/UCERF3 Workshop (April 1-2, 2010) in Pomona, California. We are active participants in the exercise to investigate the similarities and differences in strain rate maps derived from GPS data, organized by Professor David Sandwell at Scripps, we contributed to the presentation on this topic at the SCEC 2009 meeting [Sandwell et al., 2009] and the SCEC GPS/UCERF3 Workshop. We plan to continue with these investigations, focusing on time-dependent strain-rates, and on the role of rotating panels of E-W-trending sinistral faults in transferring slip-rate through the transform system.

1. The velocity field in California

Figure 1 shows the GPS velocities from EarthScope PBO (November 2009 MIT solution) merged with the compilation of continuous and campaign GPS data from Kreemer and Hammond [2007]. Both datasets were rotated into a half plate motion reference-frame [cf. Wdowinski et al. 2007] for visualization and analysis purposes, using the geodetically determined Euler pole for the Pacific plate relative to stable North America from Meade and Hager [2005]. We verified that our results are robust with respect to simple shifts in reference frame by rotating each data set into its own best-fit half plate motion frame before merging. The location of the swaths used for the fault slip-rate inversions are shown. Velocities plotted in this reference frame bring out (a) the rapid change in velocity across the transform zone, (b) the westward motion of the Sierra Nevada / GreatValley Block relative to the transform, and the accommodation of that motion by convergence in the Coast Ranges, and (c) the westward deflection of velocities within the Transverse Ranges due to the Big Bend in the SAF.

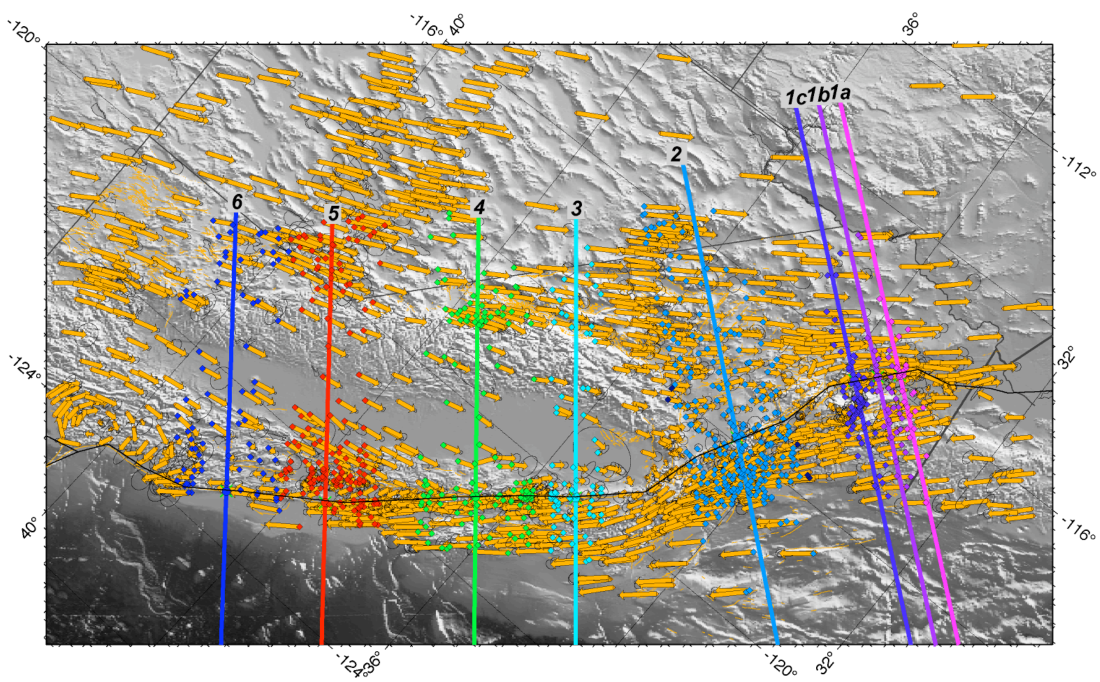


Figure 1. Velocity field in California.

2. Strain-rate intensity in California

Figure 2 shows the scalar strain rate (second invariant of the 2D strain-rate tensor) calculated using velocities interpolated from the data set shown in Figure 1. The map shows that the zone of highest strain rate does not everywhere coincide with the surface trace of the SAF, is straighter than the SAF, and has an overall trend that is closer to the plate motion vector than the SAF. This zone of high strain-rate reflects the cumulative effect of the various faults that carry the bulk of the slip-rate in the San Andreas transform system, and it provides the best overall characterization of the transform zone.

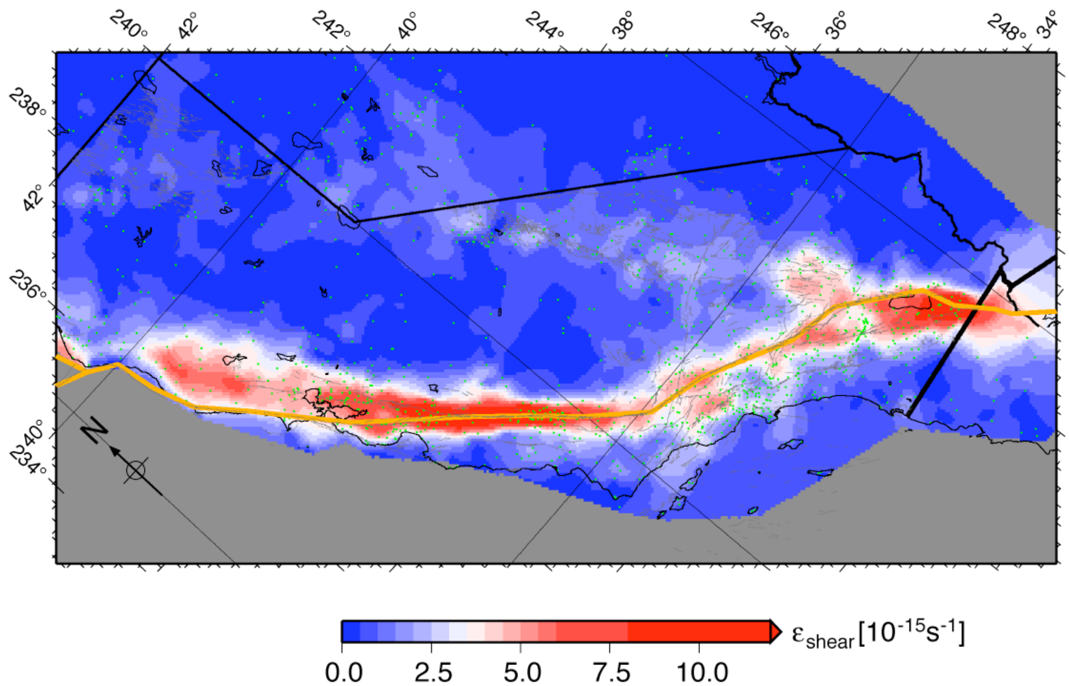


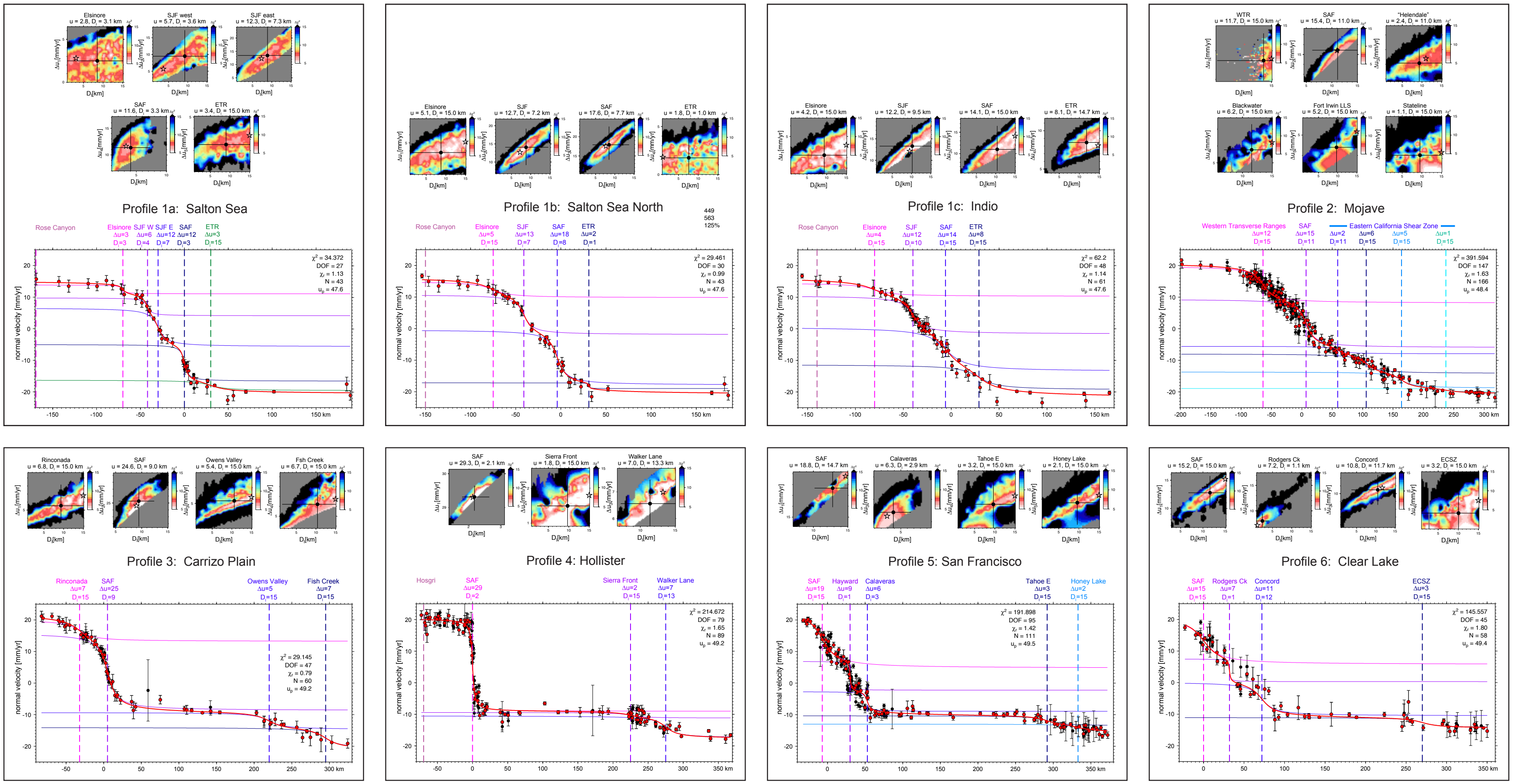
Figure 2. Strain-rate intensity in California

3. Fault slip-rate inversions

Figure 3 comprises velocity profiles along the six swaths shown in Figure 1, showing the horizontal component of velocity parallel to the Pacific – North America plate motion vector, with fault locations and slip-rate interpretations. Fault locations were prescribed; flexural parameters (locking depths) D_l were obtained by inversion, but constrained to lie between 1 and 15 km, and slip rates Δu were fit by means of non-negative least squares (ensuring dextral slip on all faults). Trade-off plots above each profile indicate the range of well-fitting models, with the best fit value (star), the median (open circle) and equivalent of one standard deviation (error bars). D_l for the creeping section of the Hayward Fault in Profile 5 was set to 1 km. ETR (Eastern Transverse Ranges) in Profiles 1a and 1c, and Western Transverse Ranges and Fort Irwin Fault System in Profile 2, represent rotating panels of E-W trending sinistral faults for which we estimate the net effective dextral slip rate.

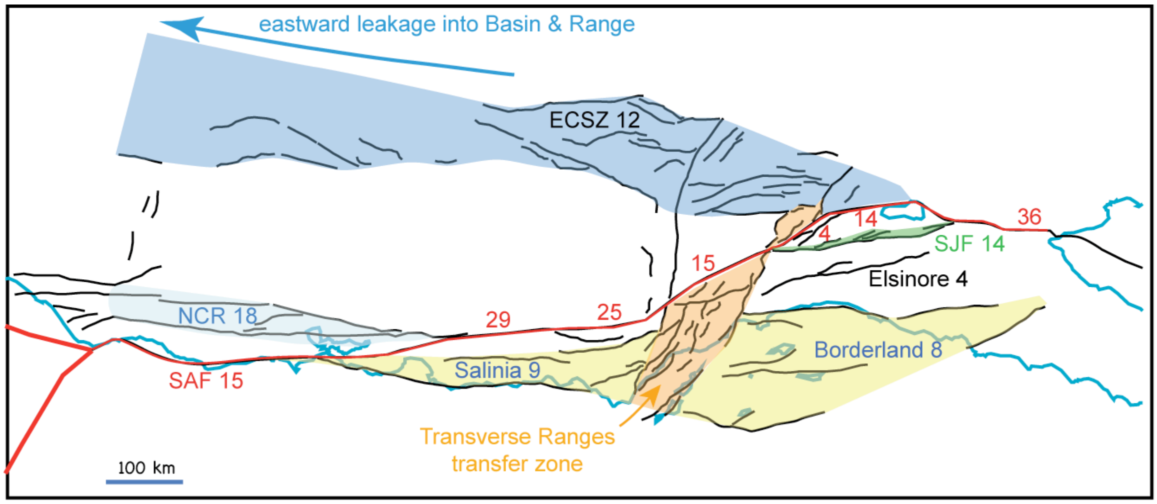
Platt & Becker Figure 3

Note that the individual profiles need to be viewed and reproduced at page size



4. Slip rate budget for California

Figure 4 shows a slip-rate budget for the transform system, showing major faults and bands of grouped faults, based on the values determined by the inversion shown in Figure 3. The lower part of the figure shows the slip rates in tabular form for each profile, including the additional slip rate at the ends of each profile needed to bring the total to the Pacific – North America relative plate velocity. The color bands show schematically how the slip is transferred along strike. The map in the upper part of the figure shows in simplified form how the slip is distributed among the different parts of the system, together with their linkages.



	offshore	SAF	RC/M	Concord	NCR total	ECSZ	B&R	TOTAL
Profile 6	3	15	7	11	18	3	10	49
Profile 5	1	19	Hayward 9	Calaveras 6	15	5	9	50
Profile 4	4	29				9	7	49
Profile 3	2	Rinconada 7		SAF 25		12	3	49
Profile 2	3		WTR 12		SAF 15	15	3	48
Profile 1	8		Elsinore 4	SJF 14	SoSAF 14	4	3	48

Figure 4. Slip rate budget for California. Rates are in mm/yr. NCR, Northern Coast Ranges; ECSZ, Eastern California Shear Zone; B&R, Basin and Range; RC/M, Rodgers Creek – Maacama Fault system; SAF, San Andreas Fault; SoSAF, Southern San Andreas Fault; SJF, San Jacinto Fault; WTR, Western Transverse Ranges.

5. Comparison between geodetically and geologically determined slip-rates

Table 1 shows a comparison of our slip-rate estimates with current geologic estimates. Most of the geologic estimates are taken from the values tabulated by Bird [2007]. This compilation eliminates estimates that are based partly or wholly on geodetic data, which is essential if our comparison is to be valid. The values we quote are the upper and lower bounds of the 95% confidence range of the probability density function as calculated by Bird [2007] from multiple geologic estimates. Where only one geologic estimate is available, we quote that value with the uncertainty, or the upper or lower bounds, as given by the original author cited in Bird [2007]. Our slip rates generally match the geologically determined rates well; the main discrepancies are on some sections of the SAF, and in the Mojave Desert.

	offshore	**SAF**	**RC/M**	**Concord**
Profile 6	3	15+1-7	7±0	11+0-3
		18.4 ± 2.4	11 to 18	3.4 ± 0.7
	H-SG	**SAF**	**Hayward**	**Calaveras**
Profile 5	1	19+0-4	9±0	6±1
	1 to 9	13.8± 0.9	8±0.3	5 to 13
	H-SG	**SAF**		
Profile 4	4	29		
	7.2 ± 1.1	33.4 ± 3.0		
	H-SG	**Rinconada**	**SAF**	**ECSZ**
Profile 3	3	7+2-4	25±3	12
	3.1 ± 3.1	1 to 5	35.6 ± 0.4	11.0 ± 0.4
			SAF	**ECSZ**
Profile 2			15 ± 2	15.7
			28.5 ± 1.8	6.2 ± 1.9
	Elsinore	**SJF**	**SAF**	
mean pro 1	4±1	14±3	14±3	
	5.8 ± 1.3	13.6 ± 1.3	18.4 ± 1.9	

Table 1. Comparison of geodetically and geologically determined slip-rates for California

References

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