Reply to comment by J. C. Savage on "Aseismic slip and fault-normal strain along the creeping section of the San Andreas Fault"

F. Rolandone, R. Bürgmann, D. C. Agnew, I. A. Johanson, D. C. Templeton, M. A. d'Alessio, S. J. Titus, C. Demets, B. Tikoff

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F. Rolandone,[1] R. Bürgmann,[2] D. C. Agnew,[3] I. A. Johanson,[2] D. C. Templeton,[2] M. A. d'Alessio,[4] S. J. Titus,[5] C. DeMets,[5] and B. Tikoff[5]

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[1] Most of the relative motion between the Pacific plate and the Sierra Nevada Great Valley microplate is accommodated by strike slip along the San Andreas Fault. On the central San Andreas Fault (CSAF), the strike-slip motion occurs nearly aseismically as fault creep [*Thatcher*, 1979; *Titus et al.*, 2006; *Rolandone et al.*, 2008; *Ryder and Bürgmann*, 2008]. However, distributed contractional and right-lateral strike-slip motions also occur in the California Coast Ranges on both sides of the San Andreas. CSAF-normal convergence is accommodated on contractional structures on both sides of the fault, as evidenced by the occurrence of thrust earthquakes and Late Cenozoic uplift and folding of the Coast Ranges. A recent example of such activity is the 2003 Mw 6.5 San Simeon blind-thrust earthquake 50 km west of Parkfield [*Rolandone et al.*, 2006].

[2] The amount of strain adjacent to the creeping segment is still a matter of debate. We therefore welcome the constructive comment of *Savage* [2009] regarding our original paper [*Rolandone et al.*, 2008], which relied on GPS measurements to constrain the distribution of slip on the San Andreas Fault and quantified the deformation rates not explained by slip on major strike-slip faults. *Savage* [2009] argues that the strain-rate estimates by *Rolandone et al.* [2008] are based in part on monument velocities inferred from short runs of data spanning less than two years. He used our published station velocities to re-compute strain rates that omit such stations. We appreciate the opportunity to consider a new GPS velocity field based on data spanning longer time intervals to further improve our estimate of the strain rate adjacent to the CSAF.

[1]Institut des Sciences de la Terre Paris, UMR 7193, Université Pierre et Marie Curie, CNRS, Paris, France.
[2]Berkeley Seismological Laboratory, University of California, Berkeley, California, USA.
[3]IGPP, Scripps Institution of Oceanography, University of California, San Diego, La Jolla, California, USA.
[4]Department of Geological Sciences, California State University Northridge, Northridge, California, USA.
[5]Department of Geology and Geophysics, University of Wisconsin-Madison, Madison, Wisconsin, USA.

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[3] In his analysis *Savage* [2009] considers the central 60-km-long segment of the creeping section where data are available to calculate the strain rate for the Benito network on the NE-side of the CSAF, as well as on the SW block [*Savage*, 2009, Table 1, Figure 1]. He eliminates all the stations that were observed for less than five years, as well as monument BITT, which he considers too close to the CSAF. On the NE block, for the San Benito network, his calculation gives a resulting fault-normal (perpendicular to the average fault strike, N41°W) contraction rate of 18 ± 20 nstrain/a (when the extension rate, 3 ± 4 nstrain/a, predicted by a dislocation model of *Rolandone et al.* [2008] of deformation from SAF slip is subtracted). Across this network we reported a resulting, residual, contraction rate of 58 ± 25 nstrain/a, which is comparable to the value found by *Savage* [2009] 49 ± 27 nstrain/a when including BITT.

[4] In our paper, we discussed the role of possible anomalous site motions in our estimates of strain rate adjacent to the CSAF. We argued that removing sites from a data set (outlier removal) in such analysis should be done with caution. However, to investigate to what degree near-fault or high-residual sites impact the strain calculation, we provided (auxiliary material, Figure S3 and also readme file of *Rolandone et al.* [2008]) two evaluations for the strain rate for the NE block. Considering all the data (from the residual GPS velocities) we obtained a resulting fault-normal shortening rate 85 ± 13 nstrain/a. If we remove all sites from within 5 km of the CSAF and the PBO data (that spanned less than one year) in the interior, the strain estimate goes down to 33 ± 14 nstrain/a. For the SW block we reported a much lower value of 17 ± 12 nstrain/a [*Rolandone et al.*, 2008], a value consistent with the estimates of *Savage* [2009, Table 1]. We will therefore focus our reply on the NE block of the creeping segment.

[5] We agree with Savage's point that the most reliable strain-rate estimates are likely to come from reliable geodetic observations that span the longest time intervals. We therefore consider a new GPS velocity field that encompasses the data used in our paper (until mid-2005) and adds continuous GPS data through March of 2009 and UC-Berkeley and UW-Madison GPS data from several GPS campaigns between 2005 and 2008. Based on analysis at UW-Madison using GIPSY software, the updated velocity field for the GPS sites spanning the Coast Ranges NE of the San Andreas is shown in Figure 1 with respect to the stable Sierra Nevada – Great Valley microplate. The strain rate estimates determined from the new velocities of stations on the NE block indicate a fault-normal contraction rate of 19 ± 18 nstrain/a. The fault-normal velocity profile is shown in

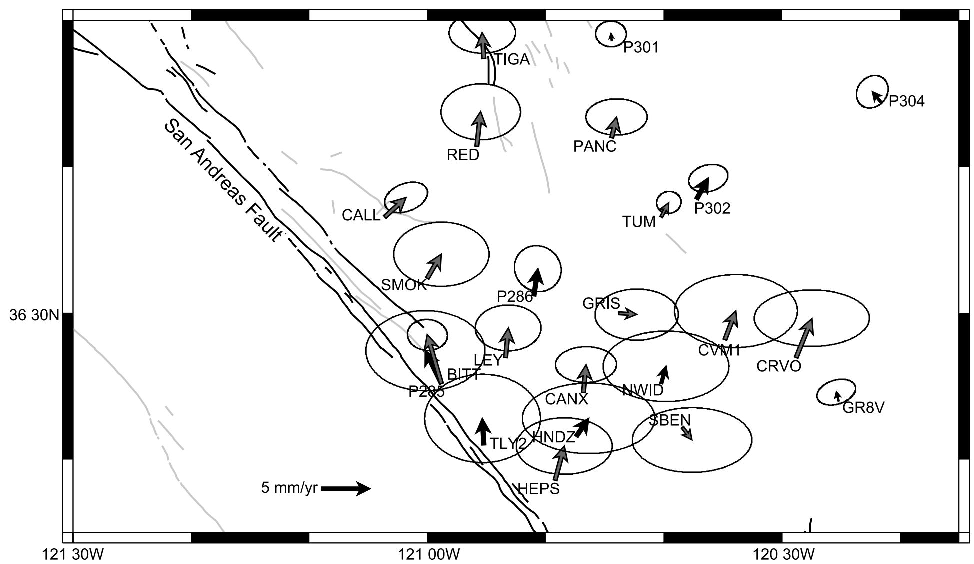

Figure 1. GPS velocities on the NE of the San Andreas fault relative to the Sierra Nevada-Great Valley microplate. Grey vectors indicate the Benito network.

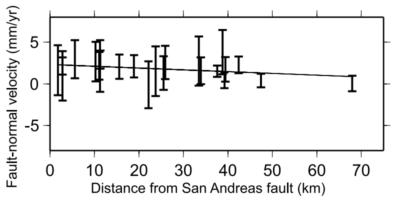

Figure 2. Plot of fault normal velocities as a function of distance from the San Andreas Fault (strike N41°W) for the sites spanning the Coast Ranges NE of the fault (as in Figure 1). The solid line shows the linear fit to the data.

Figure 2. The linear fit to the data gives 1.3 mm/yr, which over a 65 km wide zone corresponds to 20 nstrain/a.

[6] Based on his analysis of our longest GPS time series, Savage estimates that the off-fault strain rates are close to zero. Our new GPS data support his conclusion and affirm the importance of time for averaging down noise in geodetic time series, as emphasized by Savage. Efforts to measure and better understand the linkage between the small, but likely non-zero strain rates in the San Andreas fault borderlands and faulting and folding in those regions are ongoing and should benefit significantly from continued measurements at the many permanent and campaign stations now established in central California.

[7] **Acknowledgment.** This is BSL contribution 09–10.

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D. C. Agnew, IGPP, University of California, San Diego, La Jolla, CA 92093-0225, USA.

R. Bürgmann, I. A. Johanson, and D. C. Templeton, Berkeley Seismological Laboratory, 4767 McCone Hall, Berkeley, CA 94720-4760, USA.

M. A. d'Alessio, Department of Geological Sciences, California State University Northridge, 18111 Nordhoff Street, Northridge, CA 91330, USA.

C. DeMets, B. Tikoff, and S. J. Titus, Department of Geology and Geophysics, University of Wisconsin-Madison, 1215 West Dayton Street, Madison, WI 53706, USA.

F. Rolandone, Institut des Sciences de la Terre Paris, UMR 7193, Université Pierre et Marie Curie, CNRS, 4 place Jussieu, F-75252 Paris CEDEX, France. (frederique.rolandone@upmc.fr)