

CREEP RATE, EPISODICITY, AND EARTHQUAKE POTENTIAL (CREEP) TECHNICAL ACTIVITY GROUP

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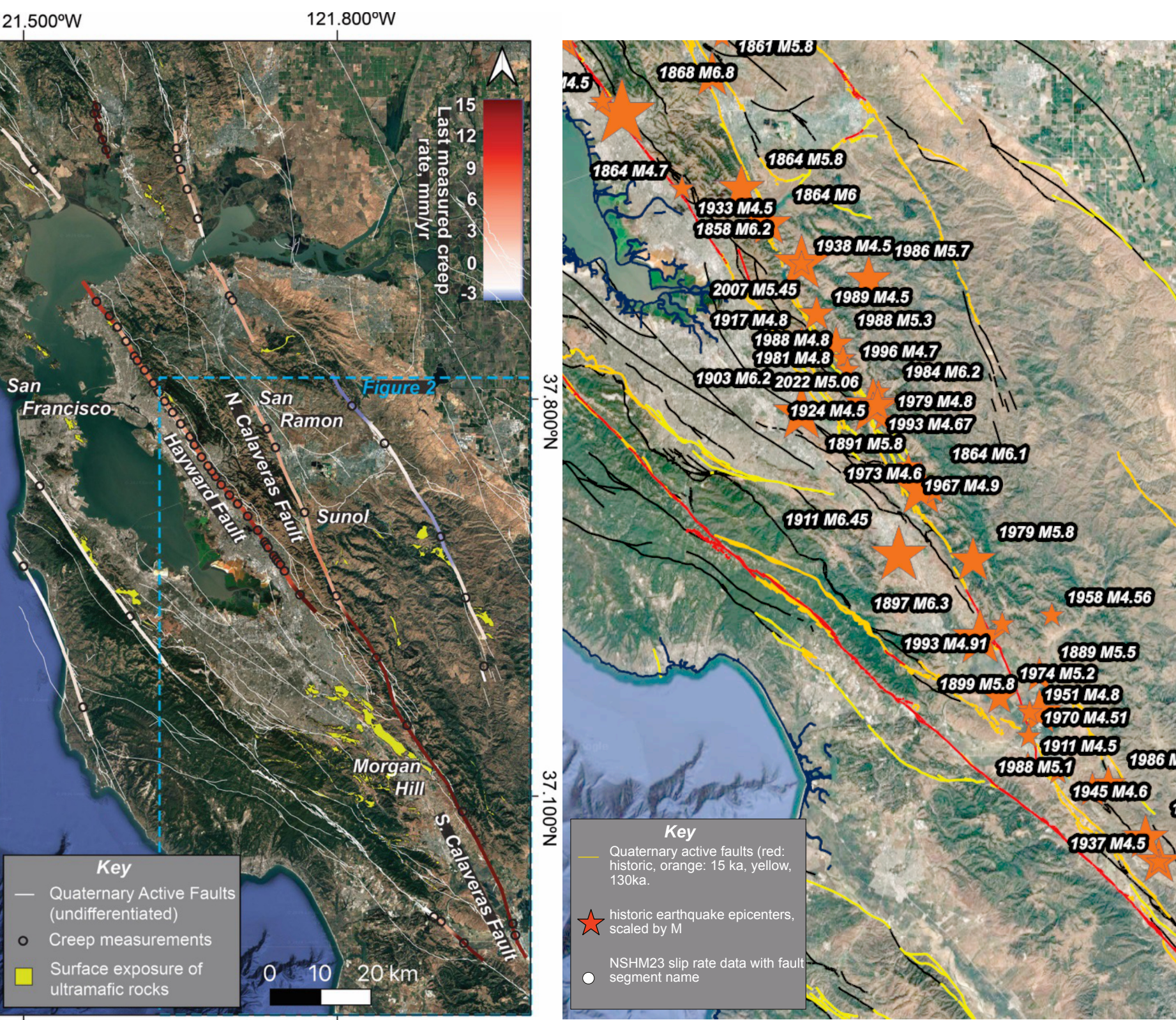


ABSTRACT

Creeping faults impact seismic hazard in two ways. First, accounting for displacement that occurs during fault creep may reduce the moment expected to be released in earthquakes, reducing the estimated hazard. Second, creep is an important mechanism for redistributing stress, which may impact heterogeneous loading and bring faults nearer to, or further from, failure. This contrast underscores the need to better understand the mechanisms and role of creep, including afterslip, in the earthquake cycle. High precision records are needed, as creep was only discovered a few decades ago and still is rarely measured. The San Francisco Bay Area has one of the world's richest instrumental records, revealing complex patterns in time and space. However, the continuity of this dataset is threatened by mounting capacity gaps and lack of funding. We will train a cohort to continue building this extraordinary dataset. This training also will prepare the cohort for high-precision, rapid response measurements after a major earthquake. The field and instrumental skills required for both tasks overlap substantially. The primary data arising from these efforts will provide the basis for modeling across the earthquake cycle, including complex rheological models that are yet to be realized. We draw on expertise from the California and U.S. Geological Surveys, academia across a variety of disciplines, and public utilities, who have significant interest in creeping faults due to displacement hazards to underground infrastructure. Knowledge transfer will be accomplished through contributions to SCEC Community Earth Models, journal articles and training modules.

CREEPING FAULTS

CONTINUOUS AND TRANSIENT CREEP IS OBSERVED ON MAJOR BAY AREA FAULTS



Figures from 2026 NEHRP USGS External Grants Program proposal - Christie Rowe and Hannah Martin.

How does interseismic creep impact seismic hazard?

Does accounting for creep reduce the effective loading rate?

Does creep affect the size of earthquakes, or the timing?

Does creep increase stress heterogeneity?

Can monitoring creep help map asperities?

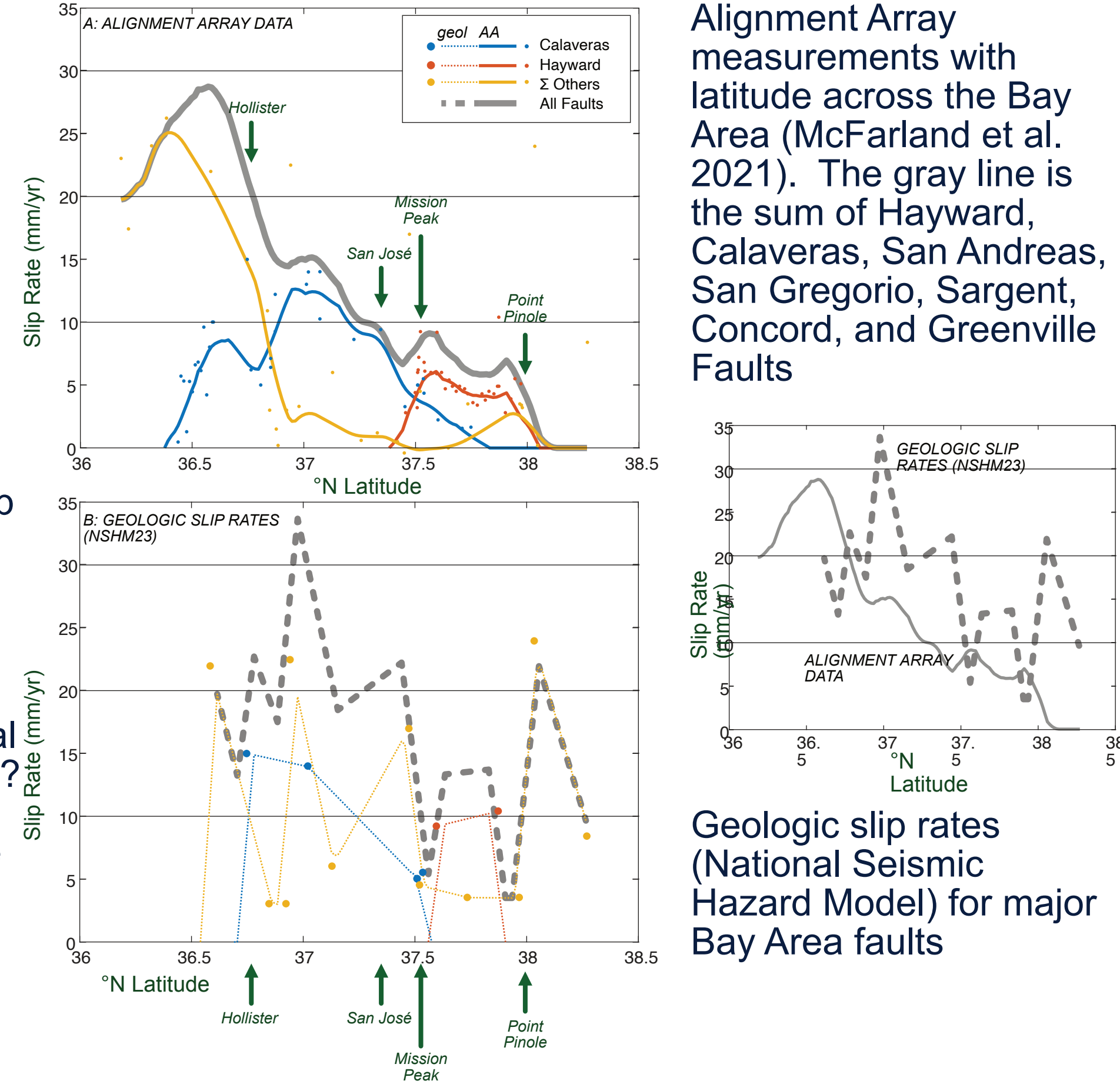
Can creep be explained by geologic factors?

Do patterns in creep rate reveal stages of the earthquake cycle?

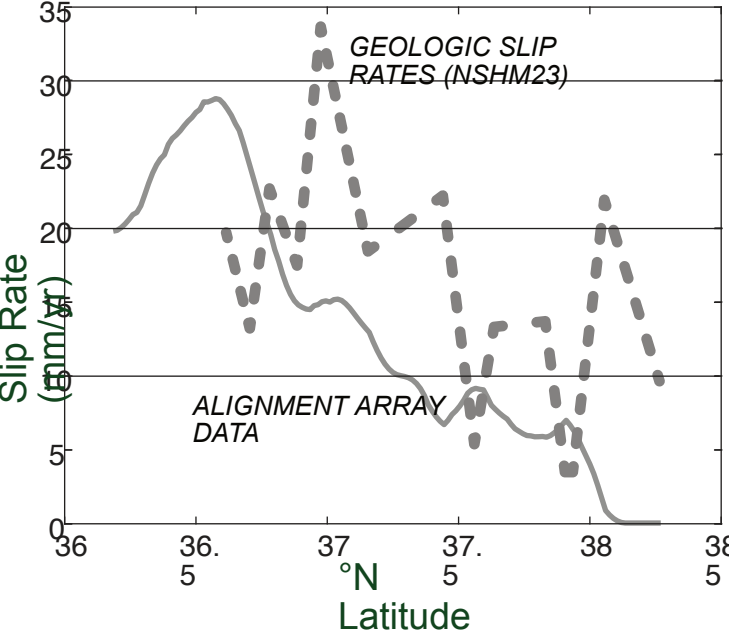
How do creep patterns change in time and space over time?

Could accelerations be precursor to large quakes?

GEOLOGIC SLIP RATES > CURRENT CREEP RATES, BOTH DECLINE TO THE NORTH



Alignment Array measurements with latitude across the Bay Area (McFarland et al. 2021). The gray line is the sum of Hayward, Calaveras, San Andreas, San Gregorio, Sargent, Concord, and Greenville Faults



Geologic slip rates (National Seismic Hazard Model) for major Bay Area faults

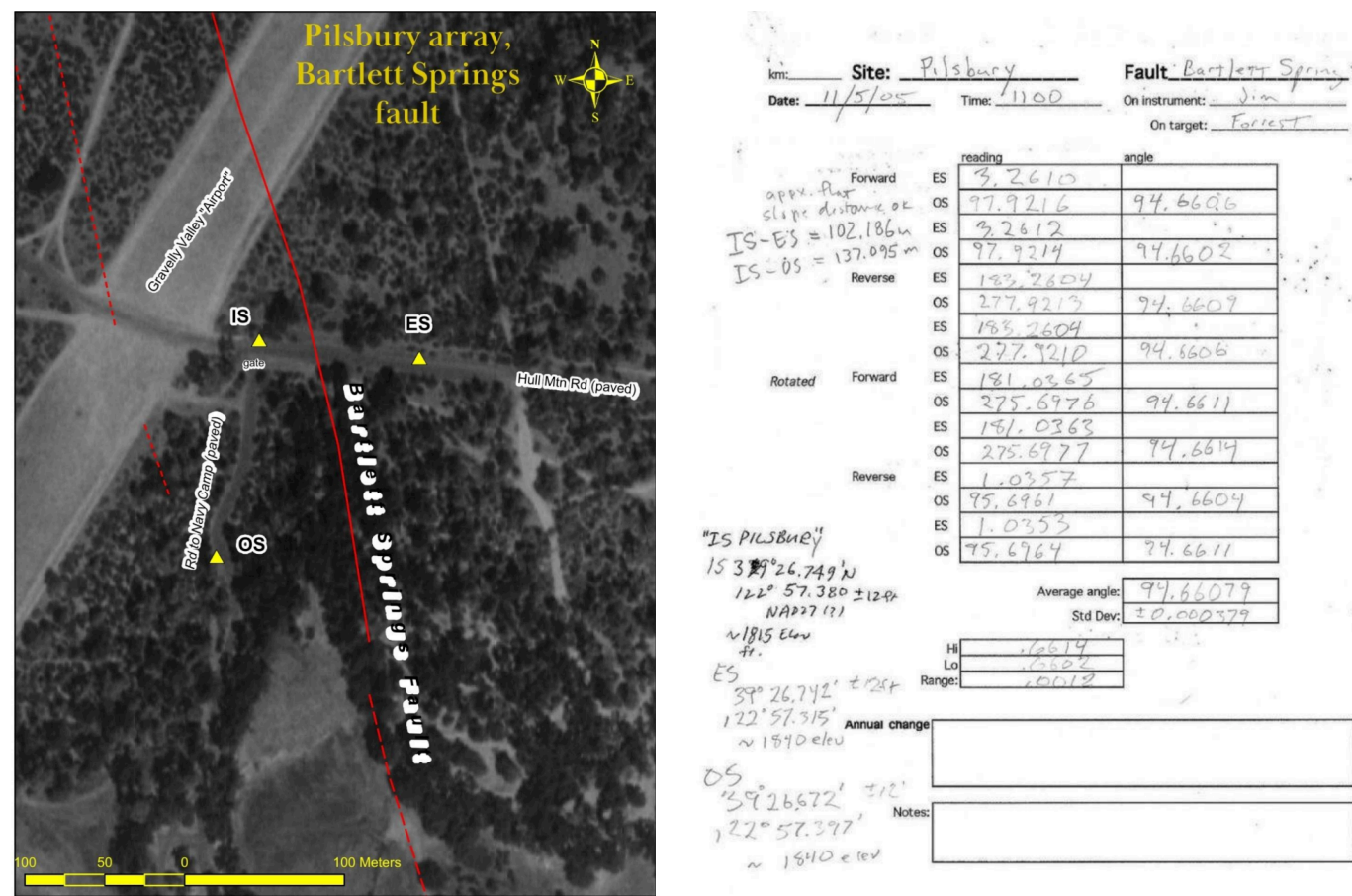
ALIGNMENT ARRAYS

HIGH RESOLUTION MEASUREMENTS REQUIRE SIGNIFICANT SKILL AND TIME TO COLLECT

Alignment Array measurements began in the mid-20th century and expanded to ~90 arrays on 10 faults.

Key contributors (Forest McFarland, SFSU; Jim Lienkaemper, USGS, Galehouse, Caskey, Cardiff, Grove) are retired or doing other things. Funding was through USGS scientist time and USGS external grants -- no longer dedicated to creep monitoring.

Project was driven by dedication of individual researchers - and the hope of catching a precursory creep anomaly - which went out of fashion.



From Forest McFarland's presentation which kicked off our March workshop.

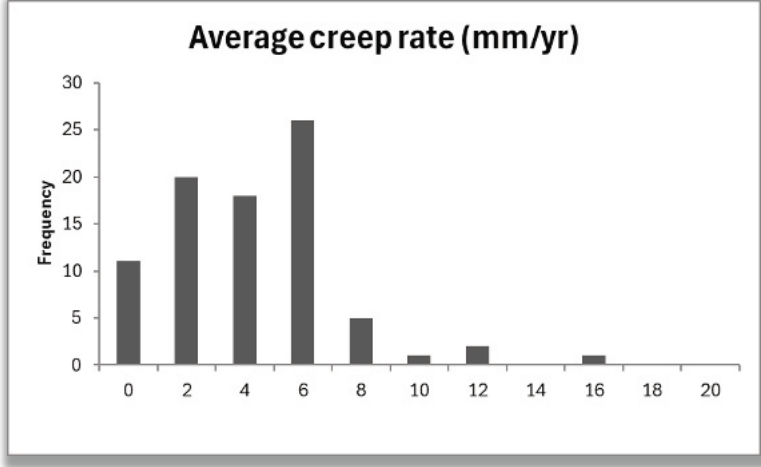
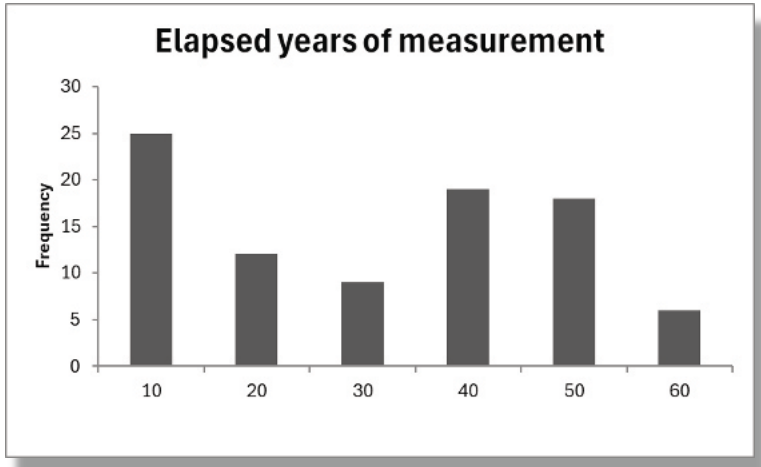
Most arrays are triangulation - 3 monuments across the fault, measure precise angle between them. Better - line of many monuments - capture dilation, creeping zone width and multiple strands.

Assume any change in angle is due to dextral horizontal displacement

Measurement frequency varies from months to years

AA measurements reveal complex creep patterns which accommodate a significant fraction of farfield slip rates.

Classic high precision instruments are finicky and require highly skilled operator to achieve measurement quality.



left: AA stats. (S. DeLong) right: Wild T2000 theodolite: Angular resolution 0.5" or ~0.24 mm at 100 m.



CAPACITY GAP AND URGENCY OF CONTINUING MEASUREMENTS

The Alignment Arrays need upkeep - some have been lost or destroyed. Of 90 arrays constructed, 60 are considered active, 15 are known lost, and 15 are unknown status (Steve DeLong).

Extremely detailed local map is needed to find correct measurement points (see example, right column).

The detailed knowledge is partially with the USGS, partially in binders in McFarland's house (left) and hasn't been completely inventoried or field checked.

Inventory of the existing arrays is essential for future planning.



Capacity building in action -- Steve DeLong showed the March 2026 workshop how to find the Alignment Array markers (NOT TRIVIAL!). Jessie Vermeer USGS demonstrates high precision measurement to Travis Orloff. Gareth Funning (UCR) enthusiastically operates the laser scanner to collect point clouds on displaced curves. Rezagene Milani (USGS/SJSU) with the GPS Antennae Dylan Cardiff debates the set up with Belle Philibosian.

SFSU Personnel measuring alignment array at Mendoza Ranch, across the axial trough of the central Calaveras Fault. Photo presented by Forest McFarland.

MARCH 1-4 2026: CREEP WORKSHOP AT SAN JOSÉ STATE UNIVERSITY

Meeting held at San José State University, with field trip to Fremont and Hayward, led by experienced creep measurers including USGS Deformation Project members and the OG Creep Project personnel.

Participants (n=58) from federal and state agencies, utilities, consultants, and insurance companies, university researchers from 10 different states.

Talks on the history of how the Alignment Arrays were established and the hopes for what measuring creep could do (precursory warnings for The Big One??) - how it grew to ~90 stations from 1970s-today.

Old and new instrumentation - what is target precision, what methods can achieve this but also be reliably executed by a new cohort of creep measurers?



What data do we actually need to leverage creep observations for deep insights?

How can we maximize benefit from measurement plan with minimal resources?

Is it worth the community effort to keep the Alignment Arrays going?

<https://www.scec.org/events/2026-fault-creep-workshop/>



HUGE WHITE PAPER IN PREPARATION...

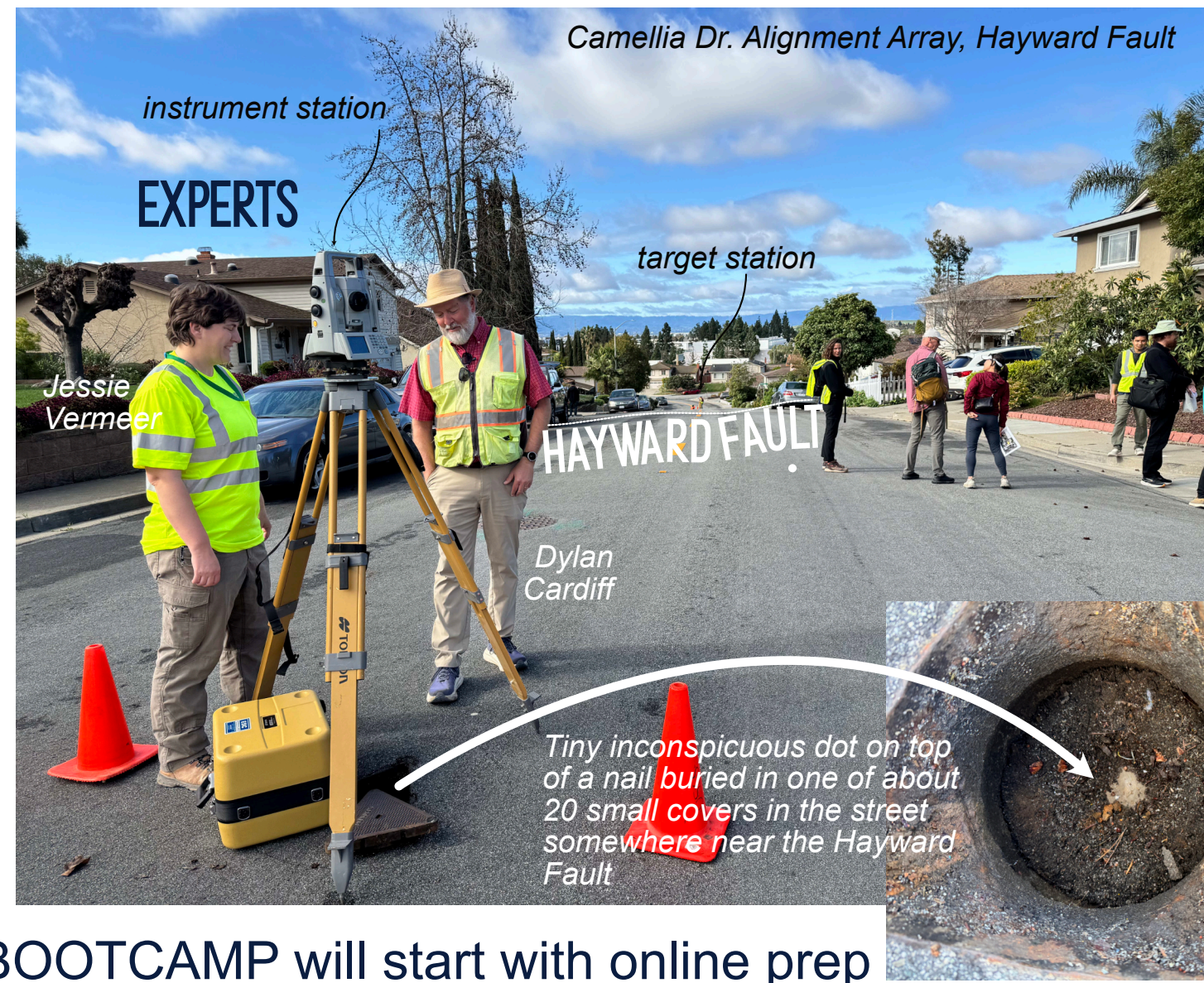
Assembled 58 researchers were enthusiastic about creep monitoring in general and keeping the Alignment Arrays measurement time series going. It was agreed that no remotely sensed or alternative field measurements would replace these data (with current technologies).

Identified the local measuring capacity challenge - instruments and skilled people

Motivated the submission of TAG proposal to SCEC to take the next steps



EARLY 2027: CREEP BOOTCAMP AT SAN JOSÉ STATE UNIVERSITY



Basic skills to make repeat field measurements of earth deformation serve many purposes -- Bay Area creeping faults are a PERFECT training ground to assemble a trained team, contribute to the AA time series, and establish a cohort who can respond to earthquakes, other transient events.

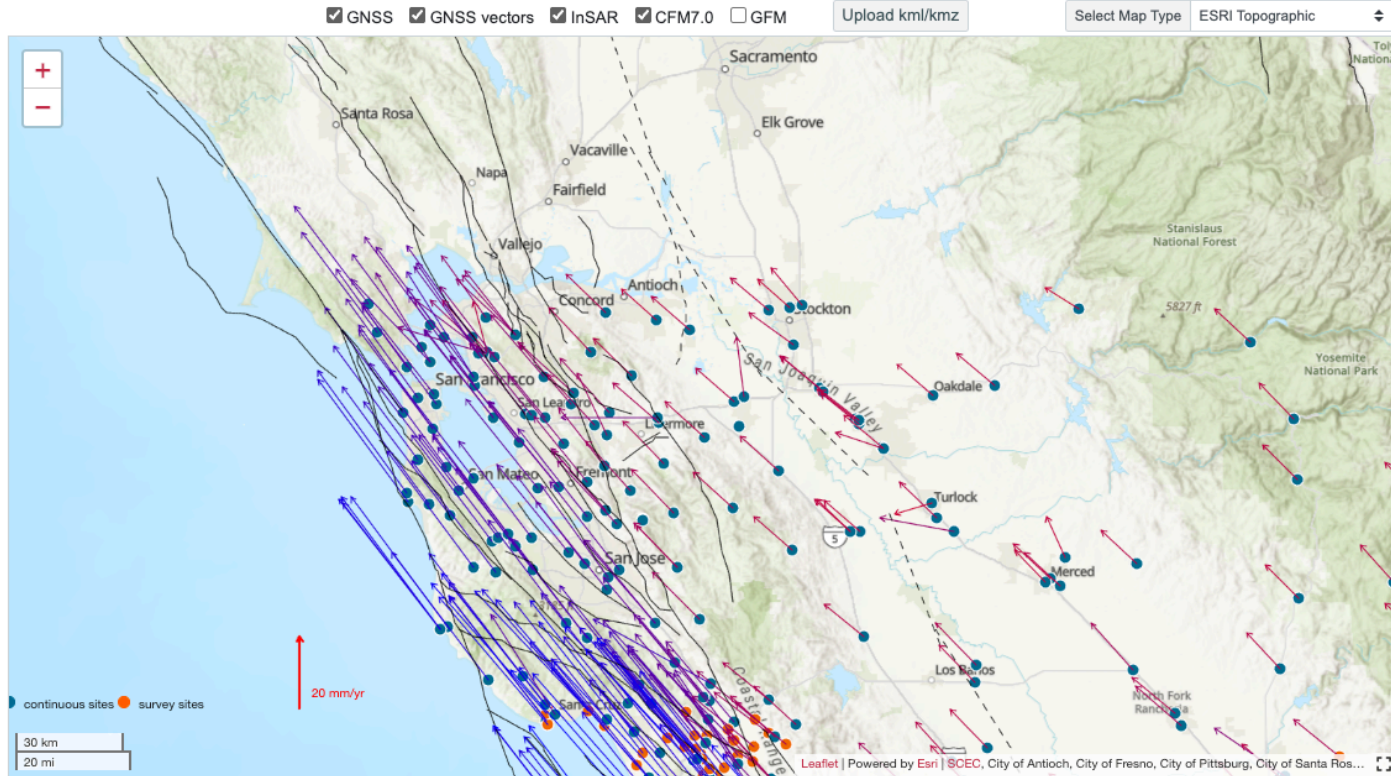
BOOTCAMP will start with online prep

There is no substitute for hands-on instruction with experts in the field

Complete workflow from planning and coordinating to data collection to processing, analysis, sharing and archiving.

SKILL	PRACTICE	LEADERS	EQUIPMENT, SOURCE	OUTCOMES
Field Preparation (online)	Packing list, safety, planning for sharing data	Christie, others	Self-provided	Proper preparation for safe and effective field work, consistent data
Data sharing, coordination between people and agencies (online)	Clearing houses, plans for communication, recruitment and participation, data sharing, identifying agencies	CGS, USGS, researchers	Access to shared folders, daily standups	Workplan - regional contact and mobilization list for event response
Geomorphic indicators on DEM, imagery and INSAR interpretation (online)	Identifying geomorphic features related to faulting, estimate uncertainty, relate geometry and sense of slip	Chelsea, Earthscope	Participants' computers, QGIS or ArcPRO, Map on DEMS before	Repeatability, familiarity with sites, field prep, geomorphic terminology on multiple scales, compare to other creep and rupture field observations
Field observations - built environment displacement (1 day)	Detection of offset features, photography and datum for SM, quantitative measurements and repeatable documentation	Gareth, Betsy, Christie	TLS; Phone cameras, drone	Simple, widespread repeat measurements, potential for public and student engagement
Field observations - natural landscape (1 day)	Identification of historic or setup of new geodetic benchmarks	Christie	TLS; Phone cameras, drone, handheld GPS	Discovery of new faults or documentation of displacement in landscapes, event response, pre-event baseline mapping
High-precision (survey and/or RTK), GNSS (2 half days with field obs)	Reoccupation of historic or setup of new geodetic benchmarks	Gareth, Mike, Cassie, Jessie	GNSS equipment, UCR, USGS, Earthscope	GNSS data to data centers, processing updated post-seismic positions and continuing afterslip measurements
Terrestrial Lidar, Total Station, Build a creepmeter (2 days)	Use several different field methods for high-precision measurements	Steve, Todd, Roger	USGS Equipment, training, Earthscope equipment pool	Core competencies for quantitative field measurements
SM, post-field data processing (online)	Construction of point clouds from workshop photos, analysis of field collected GNSS data, archiving and sharing	Gareth, Jessie, Cassie	Cameras, computer, software	Sharable point clouds for repeat differencing

INCORPORATING ALIGNMENT ARRAY DATA INTO SCEC CGM



Alignment Array Data is permanently archived by USGS on ScienceBase and free to download

Incorporation into SCEC CGM would enable concurrent analysis with other geodetic databases and SCEC visualization tools.



STRIKE TASK FORCE FOR FUTURE OF ALIGNMENT ARRAYS

The March 2026 workshop confirmed significant community buy-in for ongoing measurements of the Alignment Arrays and the shared sense of urgency to confirm priorities and develop a plan for augmenting the USGS efforts with additional capacity from the research community.

The Workshop attendees recommended striking a Task Force to perform a detailed AA site inventory, establish monitoring priorities, develop workflows that can be applied by contributing researchers, and develop an approach for funding gaps. The Task Force will confirm membership and scope of work in Year 1.

THANK YOU TO MARCH 2026 WORKSHOP PARTICIPANTS AND CONTRIBUTORS

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