Technical Report:

Session 1, Introduction to Parkfield and State of Knowledge, consisted of presentations on the history of the Parkfield earthquake prediction experiment up through the occurrence of the 2004 earthquake (John **Langbein** (USGS)), geodetic observations and implications for the "earthquake cycle" (Jessica **Murray** (USGS)), 2D and 3D seismic and magnetotelluric images of the structure around Parkfield at several scales (Cliff **Thurber** (University of Wisconsin-Madison)), and the current status of instrumentation and observational activities at Parkfield (Elizabeth **Hearn** (USGS)). These presentations helped set the stage for developing a vision for future earthquake-related research at Parkfield.

Session 2, Geology and SAFOD Legacy, focused on the complex structural characteristics of the San Andreas Fault (SAF), the ongoing scientific debate regarding the potential for large ruptures in the creeping section, and the future of the San Andreas Fault Observatory at Depth (SAFOD). Speakers in this session were organized to cover a broad spectrum of scales, from geologic and paleoseismic observations (Nathan **Toké** (Utah Valley University), and Belle **Phillibosian** (USGS)), to insights gained from the SAFOD borehole (Stephen **Hickman** (USGS)), and finishing at laboratory scales (Sara Beth **Cebry** (USGS)). As with the other sessions, these talks were followed by a moderated discussion on unresolved questions and future directions.

A primary theme in Session 2 was the difficulty of distinguishing between paleoseismic evidence of gradual creep and sudden, large-magnitude ruptures in the central creeping section. Researchers noted that at the Topo Creek site, trenching revealed a 10-meter-wide fault zone where deformation appears consistent with gradual creep over at least the last 2,200 years, without evidence of major ground deformation from large ruptures. The Topo Creek site's record covers a similar time period as the Dry Lake Valley site and Miller's Field sites which had similar findings. Investigations like these are critical for the National Seismic Hazard Model to determine if the creeping section acts as a persistent rupture barrier or over what timescales it might participate in an M8+ earthquake.

The session also highlighted the significant legacy and modernized future of SAFOD, which penetrates the SAF at a depth of ~3.1 km. Measurements from the borehole revealed that active creep is accommodated by two remarkably narrow zones, only about 2 meters wide, embedded within a much larger 200-meter-wide damage zone. In March 2026, the observatory was upgraded with a Distributed Acoustic Sensing (DAS) array complemented by a downhole seismometer, allowing for near-field monitoring of earthquake rupture behavior and fault-stress interactions. Discussions are underway regarding future proposals for SAFOD, including drilling new multilateral core holes to directly penetrate the rupture patch of a M~2 repeating earthquake, which would allow for high-resolution comparison between seismogenic patches and adjacent creeping portions of the fault.

Finally, the session integrated findings from laboratory rock mechanics, which use core samples (from SAFOD) to quantify frictional and hydrogeologic behavior. These studies explore how heterogeneous frictional properties interact to facilitate complex rupture sequences or create barriers to rupture. Laboratory experiments controlling interface topography or stepovers have also provided insights into how geometrical heterogeneities promote high-frequency ground motions. Workshop participants emphasized that Parkfield serves as a vital scaling step to bridge the gap between small-scale laboratory results and full-scale crustal earthquake phenomena.

Session 3: Parkfield Earthquakes and Fault Behavior

The Parkfield region provides a unique natural laboratory for studying the full spectrum of fault slip behavior. This session explored how earthquakes, aseismic creep, afterslip, tremor, and slow slip interacted across a fault system that exhibited remarkable spatial and temporal variability. The presentations (David **Shelly** (USGS), Steve **Delong** (USGS,) Sue **Hough**, (USGS), and Hamid **Haddadi** (CGS)) highlighted how Parkfield's rich geophysical record has continued to provide fundamental insights into the mechanics of fault loading, earthquake rupture, and deformation over a wide range of timescales.

The presentations discussed fault slip processes at both shallow and deep levels of the crust. Studies of tremor and low-frequency earthquakes (**Shelly**) illuminated the lower crustal conditions, revealing diverse slip patterns that ranged from episodic events to nearly continuous deformation and demonstrating an exceptional sensitivity to small stress perturbations. Complementing these deep observations, investigations of surface creep, surface rupture, and afterslip (**Delong**) documented the sharp transition from locked to creeping fault behavior near Parkfield and emphasized how modern monitoring tools, including lidar, InSAR, and dense geodetic networks, could capture future earthquakes and postseismic deformation with unprecedented resolution.

The session also revisited the long history of Parkfield earthquakes to better understand rupture behavior and earthquake recurrence. Reexamination of historical observations (**Hough**) supported the concept of recurring Parkfield earthquakes while highlighting variability in rupture initiation, propagation direction, and slip distribution. Evidence for alternating rupture directivity and changing recurrence intervals suggested that stress interactions among successive earthquakes may influence where and how future ruptures begin. These findings provided new perspectives on the characteristic earthquake model and the factors controlling earthquake nucleation on segmented faults.

Finally, observations from the dense Parkfield strong motion network (**Haddadi**) demonstrated the extraordinary complexity of near fault ground shaking. Recordings from the 2004 Mw 6.0 Parkfield earthquake revealed dramatic variations in ground motion over distances of only a few kilometers, providing an invaluable dataset for evaluating ground motion prediction and site response models. Together, the studies presented in this session showcased how decades of monitoring and repeated earthquakes at Parkfield have transformed it into one of the world's best observed fault systems, offering critical insights into fault zone processes, earthquake hazards, and the continuum of slip behavior that governs earthquake generation.

Session 4: Geodesy and Earthquake Cycles

This session discussed the role of fault zone properties and their spatial heterogeneity in modulating earthquake cycles at Parkfield through the examination of numerical simulations based upon the physics of earthquakes and inversions of geodetic data. Talks were given by Semechah **Lui** (University of Toronto), Yuri **Fialko** (UC San Diego, Scripps), Yihe **Huang** (University of Michigan) and Nadia **Lapusta** (Cal Tech). There were consistent themes emanating from the studies which all examined how velocity strengthening (creeping) areas of the fault interact with velocity weakening (locked) patches of the fault, presenting results that are consistent with what is known about rate and state friction.

From geodetic observations of and following the 2004 earthquake (**Fialko**), we learned that afterslip occurs in areas of the fault that have lower background seismicity and areas which had low coseismic slip in 2004, highlighting the importance of the distribution of velocity strengthening and velocity weakening areas in controlling the spatial heterogeneity of coseismic and post-seismic slip (Figure 1). This geodetic modeling shows that moment release is accommodated by multiple interacting fault traces in the shallow crust and suggests that the coefficients of friction in rate strengthening areas are consistent with laboratory coefficient of friction measurements from SAFOD. The geodetic results showed that the moment released due to post-seismic creep was about a factor of 100 greater than the seismic moment attributed to aftershocks. This turns out to be quite important, given the findings from the numerical earthquake simulations (**Lui, Lapusta, and Huang**), which demonstrate significant stress transfer and fault interaction due to creep. Dynamic earthquake-cycle modeling simulations across areas with small (Mw ~2) repeating earthquakes (**Lui**) demonstrated significant feedback where rupture leads to post-seismic creep and creep promotes ruptures due to stress transfer. Scaled up modeling approaches (**Lapusta**) agree, and both scales of analysis also highlighted the importance of fault asperities in patterns of earthquake recurrence at Parkfield. A new class of earthquake simulations that includes the temporal evolution of fault zone structure and the development of fault damage (**Huang**) reproduced the scaling of earthquake magnitudes, stress drop, and fracture energy. These simulations suggest that even a relatively weak fault zone hosts significant earthquakes and undergoes substantial fault damage and that these areas of damage act as energy sinks that tend to stop rupture propagation, potentially explaining the creeping section of the San Andreas Fault as an endpoint to ruptures. In summary, the interaction between velocity strengthening and velocity weakening parts of the fault zone explain much of what we observe over recent earthquake cycles at Parkfield, and these studies suggest that further knowledge of these types of asperities might lead to greater understanding about the propagation and arrest of earthquakes here and elsewhere.

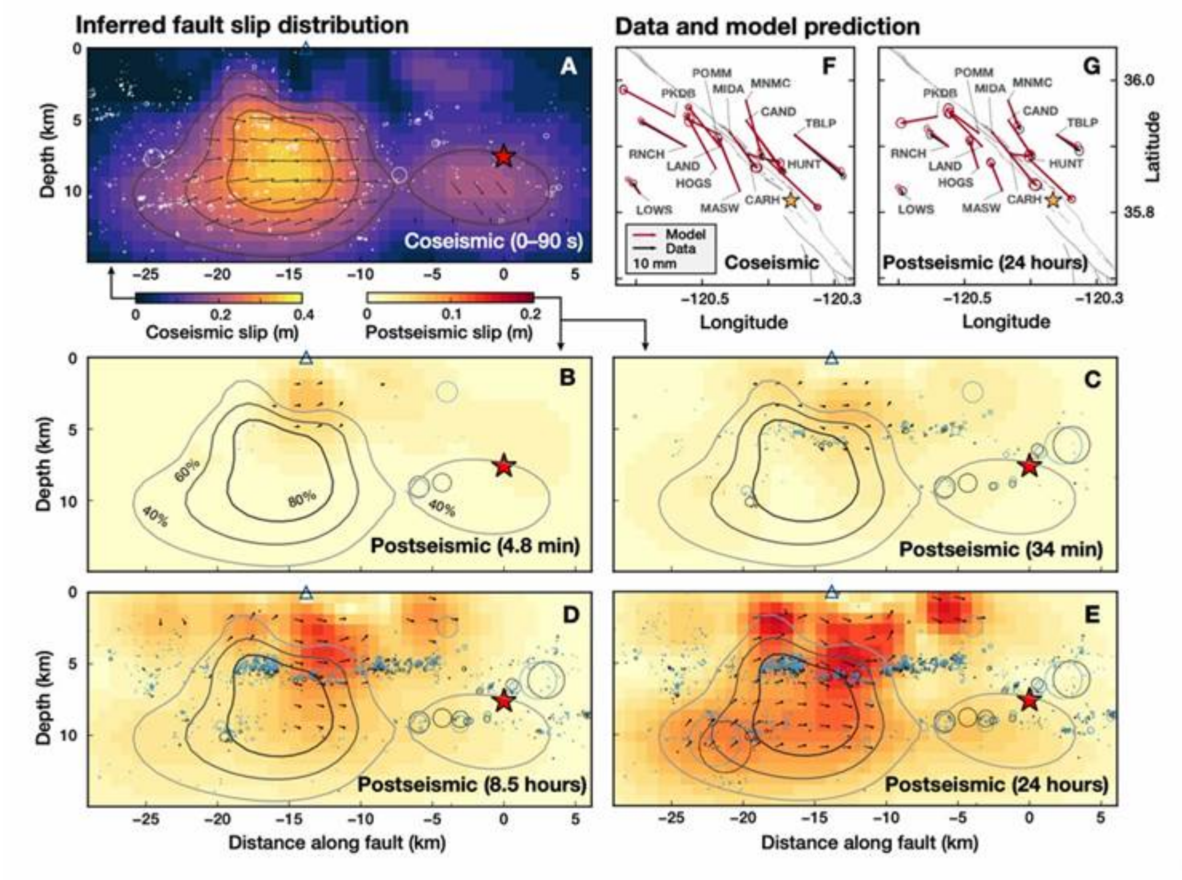

Figure 1. (Presented by Yuri Fialko, from Jiang et al., 2021) Coseismic and post-seismic slip from the 2004 earthquake demonstrate the spatial segregation of areas of the fault zone with velocity weakening and velocity strengthening properties. This work and other studies suggest that stress transfer can drive afterslip and creep can subsequently transfer stress that may trigger rupture.

Session 5: Critical Research Needs and Opportunities

The discussion in this session centered around a panel of experts. This was a forward-looking session focused on identifying critical research gaps, emerging tools, and opportunities for coordinated community efforts. Short introductory remarks and discussion emphasized alignment with national priorities and pathways for future collaborative activities centered on Parkfield. Some of the unique research opportunities at Parkfield include:

- The sequence of repeating magnitude 6 earthquakes, six since the great 1957 earthquake with the most recent one now 22 years ago, present a strong target for investigation of the earthquake preparation process using tools and methods developed since the original Parkfield Earthquake Experiment (Bakun, 2026).
- The San Andreas Fault at Parkfield displays the full range of the seismic slip spectrum: slow slip events, tremor and low frequency earthquakes, making it an accessible target for a wide range of research questions.

- Situated at the transitions to the creeping section of the San Andreas Fault to the northwest and the fully locked “1857” section to the southeast, it plays a key but largely unknown role in the initiation of the 1857 earthquake and possibly future great earthquakes.
- The San Andreas Fault Observatory at Depth (SAFOD), which has now been instrumented with a DAS array that reaches to the bottom of the accessible part of the borehole, is opening new research possibilities for studying both earthquake sources and crustal structure.
- With magnitude ~2 repeating earthquakes that are now being observed from a few hundred meters away, drilling into their sources as originally planned during EarthScope remains a potential experimental target.

Panelists: Tim **Dawson** (CGS), Kim **Blisniuk** (San Jose State), Elizabeth **Cochran** (USGS), Ahmed **Elbanna** (USC), Allison **Faris** (USGS)

Breakout session:

On the final day of the meeting 6 breakout groups met to discuss a range of topics related to challenges and opportunities for science at Parkfield.

1. Modernizing the Observatory: Existing Networks, and New Instrumentation
2. Operational Readiness
3. Earthquake Precursors, Nucleation and Rupture
4. Defining Parkfield 2.0
5. Parkfield Earthquakes and Interaction with 1857-Type Events
6. Earthquake Cycles

Each breakout group summarized their topics in this document.

References:

Bakun, W.H., 2026. Memories of the Parkfield Earthquake Prediction Experiment. *Seismological Research Letters*. DOI: https://doi.org/10.1785/0220260131

Jiang, J., Block, Y., Klein, E., 2021, Coevolving early afterslip and aftershock signatures of a San Andreas fault rupture, Science Advances, 7: https://www.science.org/doi/10.1126/sciadv.abc1606