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Updating the SCEC Geologic Slip Rate Database and Assessing Potential Data Gaps

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Abstract

This project has added 94 new geologic slip rate estimates from California, Nevada, and northern Mexico to SCEC's Geologic Slip Rate Database and has updated 5 existing slip rates in the database. All new slip rates were from published peer-reviewed studies or master's or Ph.D. theses. The online GSRD Explorer is in the process of being updated with these new slip rates and will soon be available for download by geodesists and computational modelers who desire geologic slip rates as input to their models or for comparison to their results. The updated database and GSRD Explorer will be presented at the SCEC UNREST workshop in June 2026 to promote its use and to encourage feedback on its further development and its use for identifying geographic gaps in slip rate data within California. We will work with the SCEC IT and Web teams to update the GSRD homepage and to create a Zenodo archive. Furthermore, the GRSD sets an example of how geological data that is critical for the next generation of earthquake science models can be efficiently organized and served through web-based tools.

Project objectives

The purpose of this project was to update SCEC's Geologic Slip Rate Database (GSRD, https://southern.scec.org/research/gsrd) and its associated GSRD Explorer tool (https://central.scec.org/research/gsrd-explorer/).

Our 2025 objectives were to:

1. Perform a comprehensive literature review to identify new geologic slip rate publications since 2020 and to look for studies that may not be present in the current GSRD.
2. Extract the relevant information from the identified publications into the GSRD data format.
3. Analyze the slip rate data to identify any areas of critical data gaps.
4. Produce and release an updated GSRD for 2025 including an updated homepage and GSRD Explorer interface, and a kml version of the database.
5. Release the new GSRD with Zenodo archive with a citable doi and documentation.

Methodology

PI Sally McGill supervised three advanced undergraduate students in summer and fall 2025 to use GeoRef to conduct literature searches for slip rate studies from California published in peer-

reviewed journals and master's and PhD theses. Students were provided with an online shared spreadsheet listing all the faults in the USGS Fault Sections Database in California and Nevada. The students searched for slip rate studies on 460 faults in California and Nevada, from the Mexican border to a latitude of 39.58 degrees north, at which point the grant resources had been expended. Students updated the shared online spreadsheet with the references to any studies that contained slip rates that were not already included in the GSRD. PI Hatem also contributed several new slip rates. PI McGill reviewed all the new slip rate studies found by the students and entered the slip rates and their metadata (e.g., latitude, longitude, type of offset feature, age of offset feature, type of dating method, and study reference) into the raw spreadsheet version of the GSRD. McGill consulted with Marshall and Hatem to ensure that the approach and inclusion standards were consistent with the SCEC GSRD and the USGS National Seismic Hazard Model (NSHM) so that these updates can be used in future updates to the NSHM.

Once the database was completed, PI Marshall created a series of scripts to verify self-consistency of the database formatting and content. This process is essential as any human-written database will always contain unintended errors. Once database formatting errors were corrected (mainly removing non-ASCII characters), we ran scripts to visualize the model and to determine the distance to the nearest Community Fault Model (CFM) version 7.0 fault to each GSRD site. This ties the GSRD to the CFM, making these two critical datasets integrated. Finally, we produced a script that creates a .kml version of the GSRD with all metadata embedded as attributes (Figure 1). Kml files are useful to researchers that use Google Earth, QGIS, or other geospatial software and want to integrate the GSRD into their workflows. PI Marshall is currently working with the SCEC IT and Web teams to deploy the updated GSRD, create a new homepage, and to create a Zenodo archive of the model data.

Results

In total, we have added or updated 94 new slip rates to the existing 334 slip rates in the current version of the GSRD and updated 5 entries with newer data (Figure 2). This is significantly more than the 18 to 50 new slip rate studies we expected to find. The previous content in the GSRD was derived from the Earthquake Geology Database compiled for the 2023 National Seismic Hazard Model by Hatem and others (2022a,b; USGS data release, 2023). This content in the USGS slip rate database (EQGeoDB v3, 12-21-2023) (and in the SCEC GSRD) includes slip rate studies published between the 1970s and 2020 (with one study from 2021). The 2023 NSHM EQGeoDB focused on bringing the slip rate data from the rest of the country up to California standards (set by Dawson and Weldon 2013; UCERF3), therefore California was not prioritized for additional review in the 2023 update. The newly added slip rate entries are from studies

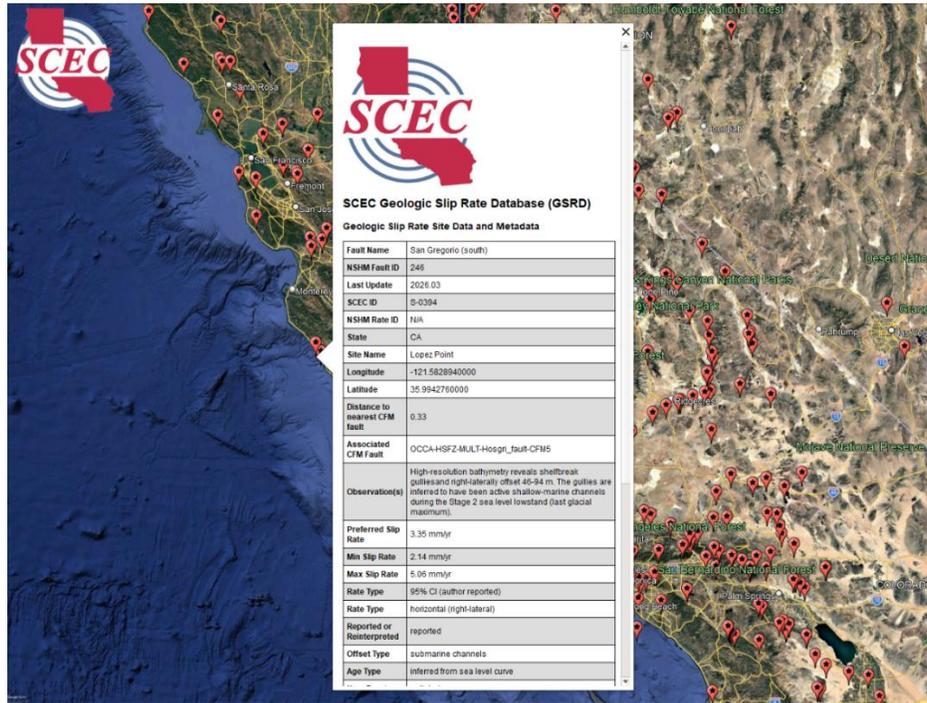dated from 1989 to 2025, with about half of the new entries from studies dating from 2013 or later.

Figure 1: *Screenshot of the .kml version of the updated GSRD as viewed in Google Earth. When a GSRD site is clicked on, a webpage pops up with the complete metadata for the site including hyperlinked references (when available). In QGIS, the metadata can be imported as attributes.*

Significance

This 26% increase (340 sites increased to 428) in the number of slip rate studies in the GSRD will be useful to deformation modelers, earthquake simulators, earthquake geologists, and seismic hazard efforts. The GSRD is an important resource that serves the SCEC community in several ways. For example, geologic fault slip rates are an important input to seismic hazards models, including the UCERF3 model (Field et al., 2013; Dawson and Weldon, 2013) and the 2023 (and future versions of) USGS NSHM (Petersen et al., 2023; Hatem et al., 2022a,b) because a fault's slip rate, averaged over thousands or tens of thousands of years, when combined with the fault length and an estimate of depth to the brittle-ductile transition, is a measure of the cumulative seismic moment release rate on that fault during the time spanned by the slip rate measurement (e.g., Brune, 1968). SCEC investigators also use geologic slip rates to constrain or to compare with geodetic deformation models (e.g., McCaffrey, 2005; Evans et al., 2015; McGill et al., 2015; Evans et al., 2016; Zeng and Shen, 2017; Beyer et al., 2018; Evans, 2018), Boundary Element Method mechanical models (e.g., Cooke and Dair, 2011; Herbert and Cooke, 2012; Fattaruso et al., 2016; Marshall et al., 2017; Resor et al., 2018, Dorsett et al, 2019; Hatch et al.,

2023), historical seismic moment models (e.g., Kagan, 2005), maximum magnitude earthquake models (e.g., Scharer et al., 2020) and earthquake simulators (e.g., Tullis et al., 2012). It is important for modelers of deformation and earthquakes to have easy access to reliable and up-to-date geologic slip rate estimates. Modeling experts often lack the disciplinary knowledge to accurately parse the geologic slip rate literature, and it is an inefficient use of time for them each to compile and continually update their own databases of geologic slip rate measurements for use in their modeling efforts. Since September 2023, the GSRD explorer has had 299 views from 93 active users.
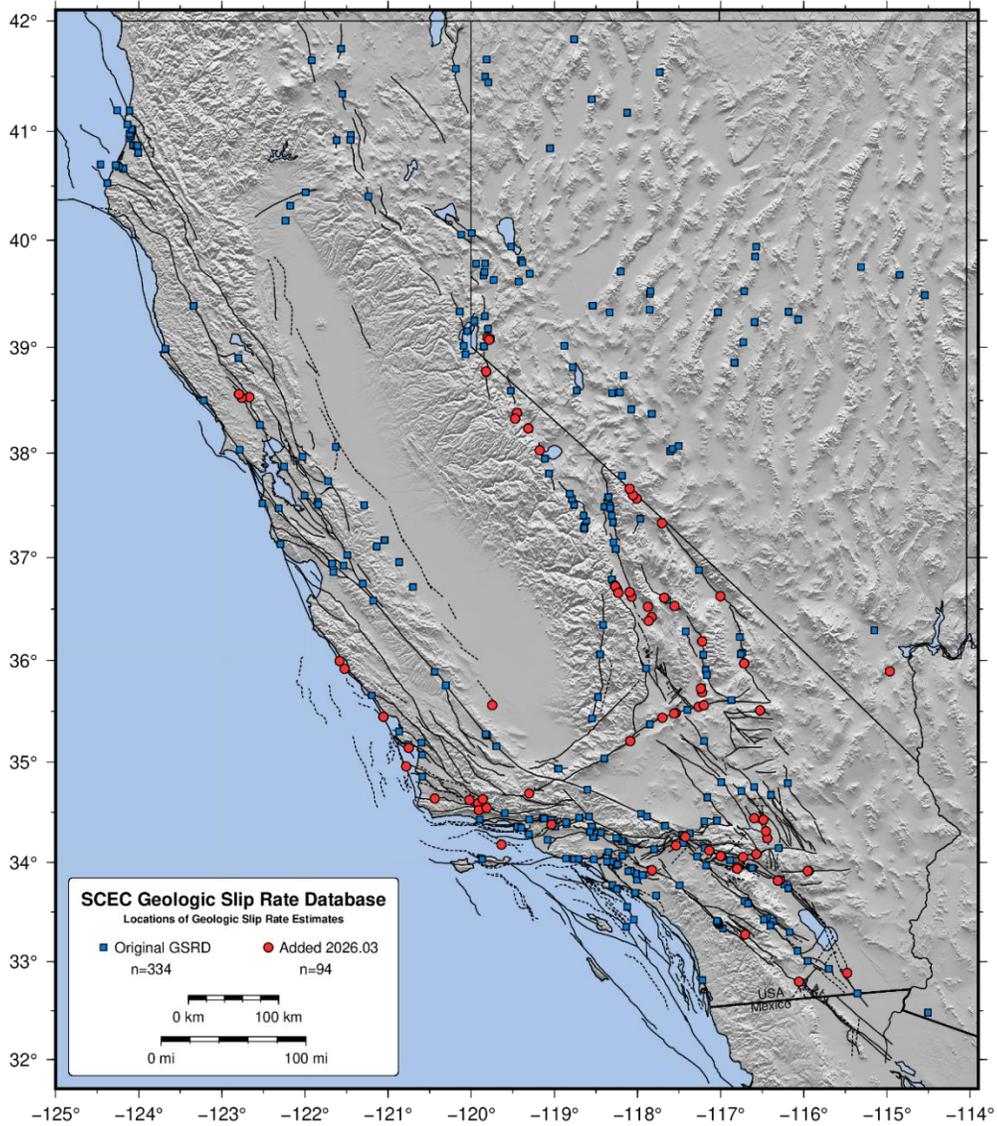

Figure 2: Map of GSRD sites in the latest 2026.03 release. Sites that have been added or updated are shown with red circles with unchanged sites in blue squares. Note that locations above 39.58 latitude were not evaluated due to limited resources and the surprisingly large number of new sites identified.

The updated GSRD will be presented at the SCEC UNREST (Understanding Natural Recurrence of Earthquakes and Slip over Time) workshop June 2-3, 2026, to ensure that modelers and geologists are aware of the database and how to retrieve data from it, as well as the substantial new updates. This will also provide an opportunity for geologists who measure fault slip rates to review the database entries, and for all who are present to discuss potential geographic gaps in slip rate data. Furthermore, we designed the GSRD Explorer to be somewhat modular, so we can use the GSRD as an example of how to efficiently organize and serve critical data for high-priority SCEC objectives. We hope that the GSRD and the GSRD Explorer will serve as the template for future critical geologic databases.

Intellectual Merit

This work has increased from 340 to 434 the number of Holocene and Pleistocene geologic slip rates that are easily available earthquake modelers, geodesists and geologists via the SCEC GSRD. The results will be presented at the SCEC UNREST workshop in June 2026, where it will support discussions of geographic gaps in slip rate data. It will also be presented at the annual SCEC meeting in 2026. We hope that this database will inspire other geologists to create additional well-organized databases to provide critical information to a range of SCEC-focused efforts.

Broader Impacts

This project supported three undergraduate students who gained experience conducting literature searches to seek new slip rate studies that were not previously included in the SCEC GSRD. We also hope that this database will be the first of other critical geological databases that will serve a wide range of SCEC community needs.

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