Appendix B—Geologic-Slip-Rate Data and Geologic Deformation Model

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Introduction

This report documents the development of the Uniform California Earthquake Rupture Forecast, version 3, (UCERF3) geologic deformation model (referred hereafter as DM3.1). Although model DM3.1 can be viewed as an update to the UCERF2 deformation model (Wills and others, 2008), it also represents a departure from UCERF2 in terms of the approach used in the development and ultimate purpose. The UCERF2 deformation model was primarily a geological model but also informally incorporated geodetic observations designed to match the total plate rate as defined by the NUVEL-1A model of DeMets and others (1994), as well as specific regionally observed geodetic rates for a kinematically and internally consistent deformation model (Wills and others, 2008). Although this approach served UCERF2 well, it was recognized that the wealth of geodetic observations and geodesy-based modeling approaches were underutilized in UCERF2 and that geodesy-based deformation models represented an approach that could be applied in UCERF3 as an alternative, or in conjunction with, a geology-based deformation model.

The current Working Group on California Earthquake Probabilities (WGCEP) decided to explore a range of different deformation models including several types of geodesy-based models, as well as a geologically based deformation model. However, because the UCERF2 deformation model integrated geologic and geodetic data with best-estimate rates developed through a consensus process over several WGCEPs (1995, 1999, 2002, 2008) and the National Seismic Hazard Map (NSHM) (for example, Petersen and others, 1996), it became clear that a simple update of the UCERF2 deformation model would not produce a model independent of the geodetic models. This geodetic independence is necessary because some geodetic models in UCERF3 use geologic constraints, so having a set of slip rates based only on geology provides an independent dataset to use in the geodetic models. Also, having a geologically based deformation model allows comparisons between geodetic and geologic rates, important because they represent rates observed over different time intervals, and there still exists debate over which is appropriate to use in seismic hazard models. The Eastern California Shear Zone was one such area, with a significant discrepancy between the geologic and geodetic rates, and was treated as a zone of distributed shear in UCERF2 (Wills and others, 2008), rather than having two alternative deformation models to represent the possibility that the rates could vary over different periods of observation. Thus, one goal of developing model DM3.1 was to deconstruct

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the consensus rates (informally called "Franken-rates," because of the various types of data used to construct them) and produce a set of slip rates and a deformation model based only on geologic data, regardless of whether or not it matches the slip-rate budget across the plate boundary.

Development of the UCERF3 Geologic-Slip-Rate Database

One task in the development of model DM3.1 consisted of compiling a database of geologic slip rates (table B1, provided online only at *http://pubs.usgs.gov/of/2013/1165/*). Because UCERF2 relied on past compilations of geologic slip rates, and then developed best-estimate rates that were applicable to entire fault sections, it is often unclear how the best-estimate rate evolved from the available data. One goal of this database is better documentation of the geologic data, as well as how the best-estimate rate applied to the fault section is developed from the data. Our focus was to go back through the literature and carefully document the slip rates that were used in UCERF2 and past WGCEPs, as well as include newly available rates that were published after UCERF2. As with past efforts (WGCEPs 1995, 2002, 2008; NSHM 1996) the focus was to use Quaternary slip rates, because these are thought to better represent current rates of deformation appropriate for use in a seismic hazard model. Also, because numerous fault sections have been added to the UCERF3 Model, we compiled available Quaternary slip rates for faults that were added to the fault model. Finally, we note that this database is not a database of all reported geologic slip rates in California. The emphasis was to add newly reported slip rates and to better document slip rates used by previous WGCEPs under the assumption that during the vetting process other (typically older) slip rates were rejected either because the slip rate has been superseded by newer data or the rate is considered unreliable.

In addition to reporting the geologic slip rates, table B1 includes other supporting data, including information about the site location, offset feature, dating constraints, number of events, reported uncertainties, interval of time over which the rate is calculated, comments, and separate quality ratings of the offset feature, dating constraints, and overall slip rate. In the majority of cases, these data were compiled from the original source, although we also made extensive use of the written summaries included in the U.S. Geological Survey Quaternary Fault and Fold Database (USGS QFFD) because many slip rates have been previously evaluated for inclusion in that database. Given the number of Quaternary active faults in California, the dataset of geologic slip rates is surprisingly sparse. This compilation includes ~320 reported slip rates of which about 200 reported rates are ranked as moderately to well constrained. Spatially, of the ~350 fault sections in the UCERF3 fault model, only about 170 fault sections have slip-rate data (fig. B1), and only about 60 fault sections have multiple reported slip rates.

In addition to reporting the offset and dating uncertainties, we have also compiled other types of data that can be used to assess the reliability of a reported slip rate. Examples of this include spatial biases (width of the zone, amount of offset) and temporal biases (longer term versus shorter term slip rates, unaccounted for open intervals, and biases introduced by rates calculated from a limited number of events).

Another purpose of this database was to provide the geodetic deformation models with geologic constraints. This was done in two ways. First, a compilation of point measurements was provided to the geodetic deformation modelers. This compilation was a subset of the slip rates that appear in table B1, and point measurements were included if the sites were coincident with the UCERF3 block model boundaries (described in appendix C, this report) and were thought to be representative of the geologic rates along that fault (*Slip-rate quality rating*, categories A and B, see database description in next section). Also provided to the deformation modelers were slip-rate bounds, assigned based on a synthesis of the geologic data. For how these geologic rates were used as constraints in the geodetically based deformation models, the reader is referred to the descriptions of these models in appendix C (this report).

Reevaluation of UCERF2 Deformation-Model Rates

The next step was to develop best-estimate slip rates and slip-rate bounds that could be applied to each fault section, as defined in the California Reference Fault Parameter Database (appendix A, this report). For fault sections with assigned slip rates that were used in UCERF2, we compared the UCERF2-assigned rates to the geologic-slip-rate data, as well as to newly developed slip rates published or made available since UCERF2. We also checked the UCERF2 slip rates for consistency with other geologically based data such as the USGS QFFD slip-rate categories and recency of activity from the USGS QFFD and the Jennings and Bryant (2010) Fault Activity Map of California. Also, as with previous WGCEPs (for example, 2002, 2008), in addition to using available geologic data, slip rates were sometimes inferred based on along-strike continuity of structures. For example, the Offshore section of the San Andreas Fault lies largely offshore and has no geologic-slip-rate data. However, because of along-strike continuity with the North Coast section (a section with reported geologic slip rates), the slip rate from the adjacent North Coast section is assigned to the Offshore section. This was done with several other fault sections in the UCERF3 fault model that had no or poorly constrained geologic slip rates, and these are noted in the comments section of table B1. If necessary, the UCERF2 best-estimate rate and bounds were adjusted if there was reason to believe that the UCERF2 assigned rate was inconsistent with the other data. The reasoning behind the revision is explained in the comments sections. As noted in Wills and others (2008), it is difficult to quantify the error in slip-rate estimates from multiple types of data, but the approach here is similar to UCERF2 and attempts to represent the 2σ uncertainty in slip rate.

Assignment of Rates for Fault Sections Without Site Specific Data

A number of new fault sections were added to the California Reference Fault Parameter Database (appendix A, this report) and, where possible, published slip-rate data was used to assign a preferred rate and bounds to that fault section. However, the majority of fault sections added to the UCERF3 model have no published slip-rate estimate. Furthermore, in UCERF2 active faults without a site specific slip-rate study were assigned a slip rate of zero. Although this could be viewed as a conservative approach it is clearly wrong because these faults are known to be active and thus cannot have zero slip rate, and assigning them all a slip rate of zero produces both spatial and temporal bias to the resulting hazard model because some regions are better studied than others and high-slip-rate faults are more studied than low-slip-rate faults. This bias became even clearer when the decision was made to include geodetic deformation models because no slip rates were available to constrain or compare to geodetic results for many regions or block boundaries.

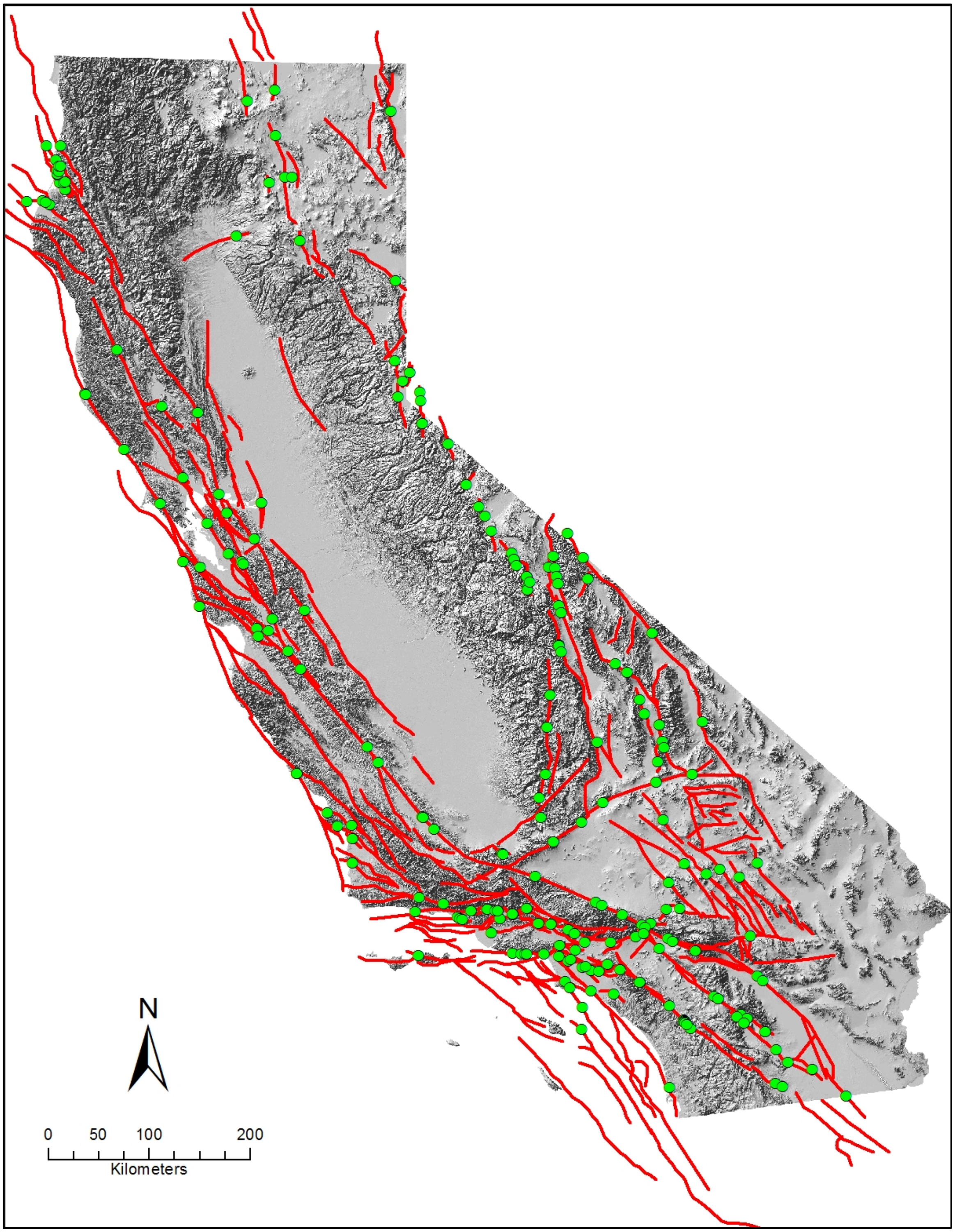

Figure B1. Map of Uniform California Earthquake Rupture Forecast, version 3, (UCERF3) geologic slip rates (green dots) plotted with UCERF3 fault sections (red lines). Only sites with known or estimated locations are plotted on this figure.

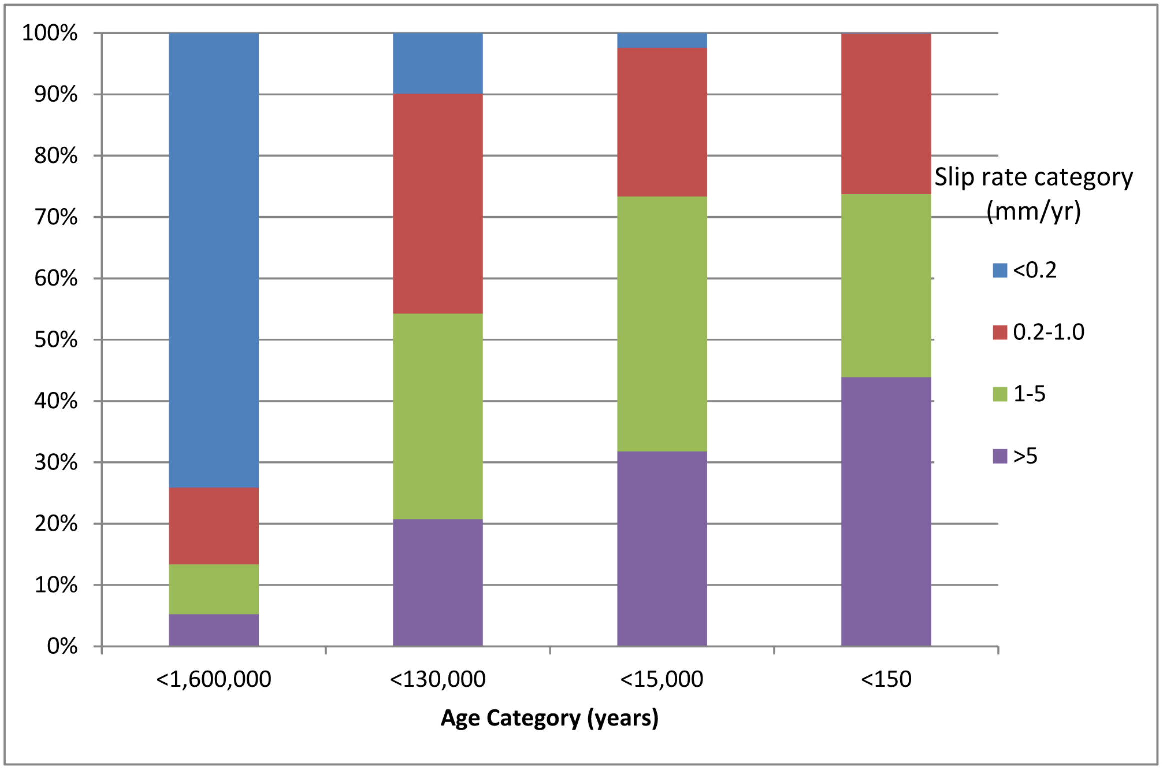

Figure B2. Histogram of California faults with U.S. Geological Survey (USGS) Quaternary Fault and Fold Database (USGS QFFD) assigned slip-rate categories binned by USGS QFFD age categories. In general, the assigned slip-rate category correlates with the recency of activity, with the slowest faults in the oldest age category and the fastest faults having moved more recently. (%, percent; mm/yr, millimeter per year.)

The only reasonably dense dataset available to assign slip rates to all the known active faults is the USGS QFFD. In addition to some site-specific slip rates, such as UCERF's compilation, the USGS QFFD contains slip-rate categories (or ranges in slip rate that the faults are placed into) and recency of surface rupture, again in four age categories (fig. B2). Before we decided to use the rate categories as slip-rate ranges for UCERF3, we examined the data in several ways. First, we checked that the slip rates in our existing site-based UCERF database were consistent with the rate categories assigned by the USGS. Eighty-three percent of the time they are consistent, and in the cases in which they do not agree, we reviewed the slip-rate data to ensure to ourselves that the UCERF rates were more consistent with the available data. This consistency was not too surprising because the USGS QFFD compilers had access to, and likely considered, essentially the same set of slip-rate studies that we did.

The second test was to look at the relation between slip-rate category and recency of surface rupture. One would expect higher slip rate faults to rupture more often than low-slip-rate faults and thus high-slip-rate faults are more likely to have ruptured more recently. As seen in figure B2, there is a strong correlation between slip rate category and recency of activity; approximately half of all historic ruptures are on the highest rate category faults whereas almost eighty percent of faults that only displace early to middle Pleistocene units are in the lowest rate category. Although we don't use this comparison to assign rates, it does support the quality of the data in the USGS QFFD and does allow us to identify outliers in activity that we reviewed individually.

Although the USGS QFFD provides slip-rate ranges, it does not provide a best estimate within the range for individual faults. Initially, in early versions of UCERF3, we simply used the mean value of the range as the best estimate. It became clear that this provides a significant overestimate of the total moment associated with these faults because low-slip-rate faults are much more common that high-slip-rate faults and thus, if a random fault is assigned the mean value of a slip-rate range, the sum of all of the faults in the category will be the number of faults times the mean of the category, which will be much greater than the sum of their actual slip rates if low-slip-rate faults are more frequent. To fix this problem, we need to have some idea of the relative frequency of faults with different slip rates. We examined this issue from several perspectives. One can look at the frequency of named faults, number of discrete fault traces, and lengths of faults in the USGS QFFD with different slip rates (or categories) and recency of activity. Biases in these numbers are instantly apparent. Younger faults (and especially historic ruptures) are mapped in much greater detail and thus have greater numbers of traces and lengths than older faults. Low-slip-rate faults (with older ruptures on average) can be covered by younger sediments (that higher slip rate faults break) and are more likely to be removed by erosion. Although all measures show that low-slip-rate faults are much more common than high, quantifying their relative frequency is challenging.

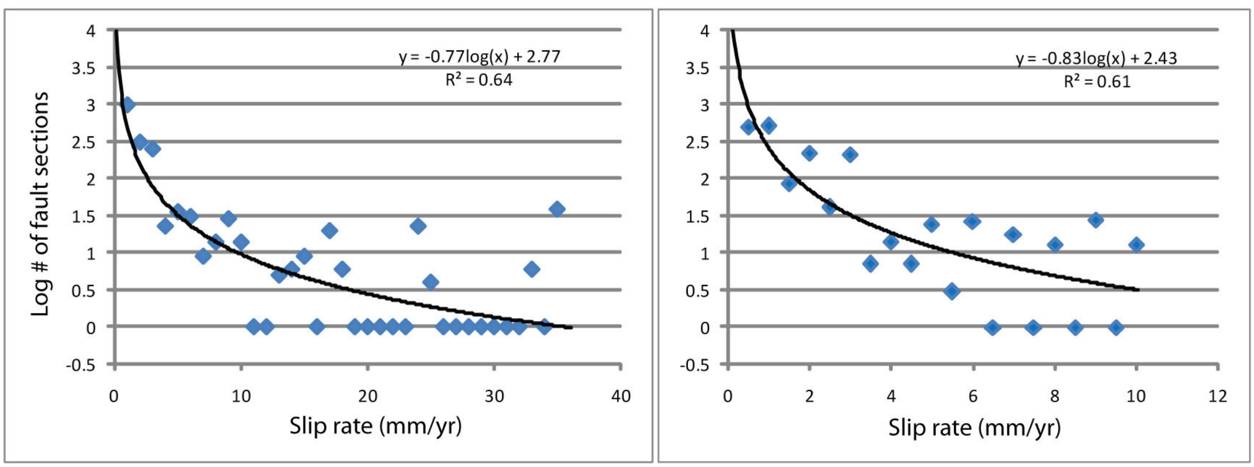

Figure B3. Graphs showing the relation between the number of Uniform California Earthquake Rupture Forecast, version 3 (UCERF3) fault sections and known slip rate. Left, the entire dataset, binned in 1 millimeter per year (mm/yr) increments. Right, sections with slip rates less than 10 mm/yr, binned in 0.5 mm/yr intervals. Note that bins without data are plotted as 0.

We concluded that the best approach to solving this problem was to use the frequency of fault sections with known slip rates in the UCERF fault model. Figure B3 plots the log of the number of fault sections against slip rate for (1) all sections with known slip rates and (2) those sections with slip rates less than 10 millimeters per yr (mm/yr). As expected, there are orders of magnitude more low-slip-rate fault sections than high, and the relative frequency for all sections and those with rates less than 10 mm/yr are quite consistent, so we used the average fit to these two datasets, $y=-0.8\log(x)+2.6$, to estimate the relative frequency of faults with different slip rates in each of our slip-rate categories. We then used this relative frequency to find the mean slip rate for all faults within each category (weighted by their frequency) and use this value as the best estimate for a random fault in the category. So for a slip rate range of 1 to 5 mm/yr, this will result in a best-estimate rate of 1.8 mm/yr rather than 3 mm/yr, which would be the mean of the range.

Although this is not a perfect approach, because fault sections vary in length (and thus frequency in our dataset) and the site-based slip-rate data has its own set of biases, we feel that this allows us a better estimate than all alternatives we have considered. Clearly, simply using the mean rate of the category produces a net excess in slip rate (and thus seismic moment) for the entire dataset. An alternative might be to take the lower end of each slip-rate range because this would be the most likely value for a single fault chosen from the category; however, this will produce a net rate that is too low for the entire fault population.

In summary, we believe that the approach outlined here, to use the USGS QFFD rate categories to assign ranges of slip rates for faults without site specific studies and to use a weighted mean frequency approach to assign the best estimate within this range, is the best we can do with the current dataset and brings far more information into the UCERF hazard model than simply using site-based slip rates.

Description of UCERF3 Geologic Database

The UCERF3 deformation model DM3.1 database is presented here as table B1. This table is organized first by information specific to the UCERF3 fault section, then by site specific data, and finally by two fields for comments—one pertains to the geologic slip rate and the other to the UCERF3 assigned slip rate for that fault section. Below, we provide descriptions of the database fields:

UCERF3 Fault Section: Name of the fault section as specified in the California Reference Fault Parameter Database (appendix A, this report).

ID #: Unique identification number of the fault section in the California Reference Fault Parameter Database (appendix A, this report).

Style: Qualitative style of faulting, abbreviations are as follows: RL, right lateral; LL, left lateral; N, normal; R, reverse or thrust faulting. Where slip is oblique, the dominant style of faulting, if known, is listed first. Often, the degree of obliqueness is not well constrained so we assume equal amounts of lateral and vertical components of slip. Most assignments are based on the rakes reported in UCERF2 (Wills and others, 2008). For fault sections added for UCERF3 style assignments are based on published literature, or if no published information exists, then based on fault orientation, geomorphic expression, and association with other faults with known faulting styles in the surrounding region.

Dip: UCERF3 fault section dip, as specified in the California Reference Fault Parameter Database (appendix A, this report).

Rake: Numerical value, reported in degrees, following the convention of Aki and Richards (2002). In general, rakes are highly generalized based on assumptions of faulting style (see Wills and others, 2008). For UCERF3, the majority of rake values are adopted from Wills and others (2008). However, a number of fault sections in the UCERF2 fault model lacked rake assignments and a number of fault sections were added to the model for UCERF3. For these fault sections, rakes were assigned based on the assumed faulting style (see *Style* category description), typically in 45-degree increments.

Recency of Activity: Category that describes the timing of the most recent deformation, based on the categories used by the USGS QFFD and Jennings and Bryant (2010), applied to each UCERF3 fault section. Where a fault section is assigned multiple categories, the category that represents most of the fault trace length is listed first, followed by a secondary category. Recency of Activity abbreviations are as follows: H, historic and Holocene displacement (<15,000 years); LP, late Quaternary (<130,000 years); Q, Quaternary Displacement (<1,600,000 years).

USGS Slip-Rate Category: The USGS QFFD assigns faults a slip-rate category based on published data, geomorphic expression, and the summaries compiled in the USGS QFFD. These categories are as follows: <0.2 mm/yr, 0.2–1.0 mm/yr, 1.0–5.0 mm/yr, and >5.0 mm/yr. This field lists the USGS QFFD-assigned slip-rate category for each UCERF3 fault section.

UCERF2 Section Slip Rate: This field lists the UCERF2 assigned slip rate (mm/yr) as listed in Wills and others (2008). For fault sections without UCERF2-assigned slip rates, “n/a” is entered.

UCERF3 Slip Rate Bounds: This field lists the UCERF3-assigned slip-rate bounds. In most cases, we rely on either the reported USGS rate category or the UCERF2 bounds to assign the slip-rate bounds. However, for fault sections with no reported USGS slip-rate category, a UCERF3 rate category was assigned based on primarily recency of activity, and to a lesser extent, geomorphic expression and comparison to other similar nearby faults with known or assigned rates. In general, when using recency of activity to assign slip-rate bounds, the following criteria were used: (1) for faults categorized as Quaternary active (< 1.6 Ma), the rate category was assigned as <0.2 mm/yr, (2) faults categorized with deformation in the late Pleistocene (<~130,000 years) were placed in the 0.2–1.0 mm/yr category, and (3) faults with latest Pleistocene and Holocene movement (<~15,000 years) were placed in the 1.0–5.0 mm/yr category. Very few faults without assigned slip-rate categories were placed into this last category, likely because the fastest slipping faults are likely well characterized throughout California. The exception to this are faults in the offshore, which are difficult to study by virtue of their location, yet may have relatively high but unknown slip rates. As noted earlier, there is relatively good agreement between recency of activity and slip-rate category (fig. B2), so using this criteria as a proxy for slip rate allows us to assign slip-rate bounds to faults with no reported slip-rate information. Finally, to document what specific criteria influenced the slip-rate category assignments, specific comments are provided in the ***UCERF3-assigned rate comments*** section of the database.

UCERF3 Best-estimate Rate: As with the other deformation models (described in appendix C, this report), we provide a best-estimate slip rate. This rate is applied to the entire fault section, similar to how slip rates were applied to fault sections in UCERF2. In general, the best-estimate value was adopted from UCERF2. Exceptions to this include fault sections with newer published slip rates, faults that had hybrid slip rates (geology and geodesy) in UCERF2, and fault sections with UCERF2 rates inconsistent with other types of data such as the USGS rate category and published slip rates. For faults that were not in UCERF2, the best estimate is assigned based on the methodology described in the previous section.

UCERF3 assigned rate comments: Comments specific to the UCERF3 assigned fault section rate. This includes descriptions of which and why certain values and ranges were assigned.

The following database fields are for site-specific geologically derived slip-rate data:

Site Name: For fault sections with site-specific slip-rate data, a site name is provided, based on the name of the site from the source. If no name is provided, then site is referred to by principal investigator name.

Longitude: Site coordinates are provided if known. For many of the sites, coordinates were estimated using the published study site map and Google Earth Pro to obtain the site coordinates. For most sites, the reported coordinates were located to within a few hundred meters or less. However, a number of sites were difficult to locate from the published description and may have much greater location uncertainties, which are noted in the comments section.

Latitude: Site coordinates are provided if known. For many of the sites, coordinates were estimated using the published study site map and Google Earth Pro to obtain the site coordinates. For most sites, the reported coordinates were located to within a few hundred meters or less. However, a number of sites were difficult to locate from the published description and may have much greater location uncertainties, which are noted in the comments section.

Local Strike: Strike of fault in the vicinity of the site. Typically measured over an along-strike length of several hundred meters for small-scale (<20 meter) displacements, or between piercing points for larger offsets.

UCERF3 Geologic Site Slip Rate: Reported site slip rate, corrected for UCERF3-assigned fault dip (if different than assumed in the original study). Numerous reported slip rates in this compilation report only the vertical component of slip or assume a dip that is different from the fault section dip assigned in the UCERF3 fault model, so rates are recalculated to account for this. The *UCERF3 Site Slip Rate* value is intended to represent the preferred geologic slip rate derived from the available data at a site. Note that uncertainties are not recalculated, as they are inferred to be represented by the values reported in the study. However, for where there are adequate data available, the database is intended to provide the data from which formalized uncertainties can be calculated from the uncertainties reported for the offset feature and dating constraints.

Reported Geologic Rate: The reported geologic rate from the original study. Because investigators report rates in a variety of ways (for example, vertical slip rates versus rates that account for fault dips) this column reports what was originally reported in the referenced study, rather than the standardized fault-parallel rate reported in the *UCERF3 Site Slip Rate* column. The type of slip rate is noted in the comments section. The reported rate is recorded in the database in order to compare published rates with UCERF3 recalculated geologic rates.

Maximum and Minimum Slip Rates: If the maximum and minimum rates are reported, these values are recorded here. Alternatively, if the maximum and minimum rates can be derived from the offset feature and dating constraints, this is calculated and recorded in the database.

Slip-rate quality rating (QR1: offset feature, QR2: dating, QR3: overall): The compilation of Clark and others (1984) placed qualitative uncertainties on the estimate of the slip and dating uncertainties. For this compilation we adopt a similar qualitative rating of the offset and dating components of the slip rate, using the A-D categories of Clark and others (1984). For UCERF3, we also have a third category for an overall rating, which is based on the first two categories, plus other criteria such as number of events and whether the slip rate is representative of the entire fault zone. Although the ratings follow the general criteria described in Clark and others (1984), our ratings also take into account the reporting of uncertainties, which are important for seismic hazard analysis. For example, an offset feature with large reported uncertainties can still receive a high ranking, because the uncertainties can be propagated through the slip-rate calculation, which hopefully leads to the higher confidence that the rate has captured the true uncertainties in the slip rate. Although not done in this compilation, such data can be used to build probability density functions to represent the slip rates (for example, Zechar and Frankel, 2009). The category ratings are described below:

QR1 Offset feature:

A—Well constrained: Identifiable piercing line or feature (typically at or near the surface) is well documented or can be independently verified from mapping or logs. If offset feature is in the subsurface, data is presented and correlations appear reliable. Offset feature is described or documented. A range and (or) best-estimate value with uncertainties is provided or can be obtained from the data.

B—Moderately constrained: For surficial or near-surficial features, only a best estimate or single value is given for the feature offset, and documentation does not allow for a range of values to be determined. For other determinations of offset (for example, cross sections, seismic lines), offset value may be determined indirectly and may be somewhat model dependent. For cases where no range of offset values reported, there is some confidence that there are relatively small uncertainties on the offset feature. An example of this would be an uplifted marine terrace that is correlated to a known sea-level high stand. Such features typically have small measurement uncertainties, because uplift is usually measured relative to current sea level.

C—Poorly constrained: Major assumptions are involved in measuring the offset. Correlation of the feature may by suspect, or other alternatives possible, but not described well enough to understand the range of possible values.

D—Very poorly constrained: Reported offset is suspect, or so poorly constrained, that the slip rate calculated is not considered reliable.

QR2 Dating:

A—Well constrained: Radiometric dates, or correlation to a well-dated datum (such as the Bishop ash in eastern California). Uncertainties reported or can be estimated from other studies.

B—Moderately constrained: A general correlation to a known datum or climatic event such as a glaciation. If uncertainties are reported, they are not formal uncertainties and only loosely constrained.

C—Poorly constrained: Highly uncertain correlation or dating constraints poorly documented or not described. Slip rates based on relative soil development and correlation to regional soil chronosequences are typically considered poorly constrained, especially for older studies.

D—Reported age is suspect or so poorly constrained that the slip rate calculated is not considered reliable.

QR3 Overall rating:

A—Well constrained: Offset feature and dating are well constrained. Slip rate is believed to represent deformation across the entire width of the fault zone. Offset is also believed to have accumulated over enough earthquakes sufficient to provide a robust average rate.

B—Moderately constrained: One or both components of the slip rate are less than well constrained. Offset feature may not span full width of the fault zone, but investigators provide an assessment to the degree of this.

C—Poorly constrained: One or both components of the slip rate are poorly constrained, and the rate may not be reliable. Offset may not span entire fault zone or may represent only a limited number of earthquakes, so that the reported slip rate is unlikely to represent the fault slip rate or a long-term average over multiple earthquakes.

D—Unreliable: The slip rate calculated is not considered reliable, because the offset or dating constraints are unreliable. Typically, if either the feature or dating constraint is assigned a "D" quality rating, the overall rating will be "D." However, other factors that suggest the rate is not representative of the fault section could give a rate a "D" overall rating, such as the offset feature not spanning the fault zone or the offset only representing a limited number of earthquakes. Details of how a rate is assigned this rating are described in the comments section.

Reported component of slip: Component of slip on the offset feature either reported, or inferred, from the study. Many studies only report one component of slip (such as vertical offset), which means net slip (used for UCERF) must be calculated. Other studies report components of slip separately, so those must be combined to obtain an estimate of net slip. Other studies may report only one component of slip and then state their assumptions regarding the slip rate calculation to report the net slip rate.

Preferred Offset (m): Reported preferred offset in meters, or if not reported, middle of reported range.

Maximum Offset (m): Maximum offset in meters, if reported.

Minimum Offset (m): Minimum offset in meters, if reported.

Offset Feature: Type of feature that is offset.

Start Age (Preferred, Maximum, Minimum): Age of the offset, based on the dating or age constraints. In most cases, the offset is assumed to have accumulated soon after the dated feature formed. However, an additional uncertainty is that offset may start a considerable amount of time after the feature formed. This amount of time is usually not addressed in most studies and, for the purposes of this compilation, ignored unless specifically addressed in the study. This unknown amount of time biases the slip rate to be too low.

End Age (Preferred, Maximum, Minimum): Ideally in a slip rate study, both a start and end time would be used in the slip rate calculation, providing a true closed interval of time over which the offset accumulated. However, in most slip rate studies, the timing of the last earthquake is unknown, or not accounted for, and the open interval is included in the slip rate calculation. Although this potentially biases the slip rate to be low, it is considered to have a negligible effect on the slip rate if the interval of time is long. Reported end times are more common in trenching studies where there is event timing data and is especially important for rates calculated based on a limited number of offsets.

Dating Method: Method used to constrain time component of slip-rate estimate. A variety of methods are used including various radiometric methods, as well as relative methods such as soil development, correlation to other geologic features, and climatic events, such as past glaciations.
Abbreviations for radiometric methods:
Ar-Ar—Argon-Argon
10Be—Berylium-10 cosmogenic
C14—Radiocarbon
36Cl—Chlorine 36 cosmogenic
3He—Helium 3 cosmogenic
K-Ar—Potassium-Argon
OSL—Optically Stimulated Luminescence
TL—Thermo-Luminescence
230Th—Uranium–Thorium dating

Slip rate time category: Generalize time intervals over which the slip rate applies based on time categories used in the USGS QFFD. This compilation uses the following categories:
<1,000 years
1,000–11,000 years
11,000–130,000 years
130,000–750,000 years
750,000–2,600,000 years
> 2,600,000 years

For faults sections with multiple reported slip rates over different intervals, these general subdivisions are being used to assess if slip rates are constant or vary with time.

Number of events (Pref Num Events; Num Events (max); Num Events (min)): Number of events involved with creation of the offset feature. Typically, this is unknown. However, these fields may be further populated once the UCERF3 paleoevents database is revised.

Comments regarding geologic slip rate: Comments specific to the geologic slip rate including additional background information and any special issues that are noted by the investigators or compilers.

Citation: Abbreviated citation; full citation is included at the end of this report.

Tapering of Fault Section Slip Rates

We note that for many fault sections a single slip rate is unrealistic and that slip rates likely taper near fault ends. How this issue is treated in the UCERF3 model is described in the main report, but at the time of this writing, it appears the issue will be dealt with in the inversion, rather than applying a slip-rate taper in the deformation model. However, we have defined custom tapers for two special case areas in California, where the assignment of a constant slip rate for a fault section becomes problematic for fault sections that are essentially contiguous structures with high slip rates (>5 mm/yr) but have a large overlap distance over which the slip rate is thought to transfer from one structure to another. One of these areas is between the Cerro Prieto and Imperial Faults, which have a high degree of overlap (~45 kilometers, km) as slip is transferred between these two faults. Similar to this is the overlap area between the Rodgers Creek and Maacama Faults (~40 km of overlap). In both cases, we have applied a linear taper in the overlap zone, so that as one fault's rate decreases to the end of the section, the other fault's slip rate increases by a corresponding amount until it reaches the full rate outside of the overlap zone. In this way, we avoid a double counting of slip rates that would lead to an excess of seismic moment in the overlap zones.

Data Completeness and Sources

The main purpose of this database is to document the geologic data that past WGCEPs used in developing the consensus slip rates, as well as provide an update to use for UCERF3, including slip rates for fault sections added to the UCERF3 model and slip rates newly developed since UCERF2. As with past WGCEPs, we have drawn on a number of data sources including peer-reviewed published articles, conference abstracts, field-trip guidebooks, consulting reports, technical reports, other slip-rate compilations, studies in progress, and unpublished studies. Although peer-reviewed published studies are considered the “gold standard” for source material, we (as with past WGCEPs) recognize that it is impractical to construct a seismic hazard model based on this limited set of data. Furthermore, even peer-reviewed published studies can be superseded by newer data or deemed unreliable, requiring continual evaluation by compilers of this type of data to ascertain if a reported slip rate is still appropriate to use. In general, published studies were given a higher weight in slip-rate assignments for a fault section, followed by “grey” literature, which was used more as a consistency check. Because the deformation model requires an assigned rate for each fault section, many sections rely solely on grey literature and a number of fault sections lacked any reported Quaternary slip-rate data and were assigned rates based only on a slip rate category, recency of activity, or geomorphic expression. Although we have tried to be as complete as possible, there are likely a number of reported rates that exist but that are not reported here because we are not aware of them or they were not used in past WGCEPs (either because those WGCEPs were unaware of those rates or the WGCEPs thought there were issues with the reported rates and therefore not used). We regard this compilation as a living document that will be updated as new information becomes available or as users of this compilation point us to data that has be overlooked or that is new.

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