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Calaveras fault zone, Northern Calaveras section (Class A) No. 54a

Last Review Date: 1999-03-04

Compiled in cooperation with the California Geological Survey

citation for this record: **Bryant, W.A., and Cluett, S.E., compilers, 1999, Fault number 54a, Calaveras fault zone, Northern Calaveras section, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, https://earthquakes.usgs.gov/hazards/qfaults, accessed 12/14/2020 03:06 PM.**

Synopsis	**General:** Historically active major dextral strike-slip fault that is part of the larger San Andreas fault system. The fault zone extends for about 150 km from the San Ramon area southeast to about 30 km south of Hollister. The fault has a complex linkage to the San Andreas fault zone [1] along the subparallel Paicines fault, herein considered to be the southernmost part of the Calaveras fault zone. In general, the Calaveras fault zone is expressed as numerous strands that form a zone tens of meters to more than 500 m in width (1982 #5521). Locally the Paicines fault is expressed as a zone as much as 2 km wide. Various

segmentation models have been proposed by Simpson and others (1992 #5527), Taylor (1992 #5531), Petersen and others (1996 #4860), Working Group on Northern California Earthquake Potential (1996 #1216), and Kelson and others (1998 #5518). In this compilation the fault is divided into 4 sections: from north to south they are the Northern Calaveras [54a], Central Calaveras [54b], Southern Calaveras [54c], and Paicines [54d] sections. There is a distinct change in slip rate and fault behavior north and south of the vicinity of Calaveras Reservoir. North of Calaveras Reservoir, the fault [54a] is characterized by a slip rate of 5–6 mm/yr (Kelson and others, 1996 #5284; Simpson and others, 1999 #5528), sparse seismicity, and it probably ruptures to the surface in moderate to large earthquakes based on interpretation of trench exposures by Kelson and others (1996 #5284) and Simpson and others (1999 #5528). South of Calaveras Reservoir, the fault zone [section 54b] is characterized by historic surface fault creep of as much as 15 mm/yr near the southern end of the central Calaveras fault (Galehouse and Lienkaemper, personal commun. reported in Kelson and others, 1998 #5518). The preferred late Holocene slip rate is 14±5 mm/yr (Kelson and others, 1998 #5518) for the central part of the Calaveras fault [54b]. No slip rates have been reported for the southern part of the Calaveras fault [54c], but historic surface fault creep rates of 4–12 mm/yr have been reported in the Hollister area (Schulz, 1989 #5526; Galehouse, 1999 #5500). The Paicines fault [54d] locally has evidence of historic fault creep at about 5 mm/yr (Harsh and Burford, 1982 #5323), although a partial Holocene dextral slip rate of 9 mm/yr was reported by Perkins and Sims (1988 #5522). An average recurrence interval of between 125 and 850 years was determined for the northern part of the Calaveras fault [54a] (Kelson and others, 1996 #5284; Simpson and others, 1999 #5528). Kelson and others (1998 #5518) reported a preliminary recurrence interval estimate of about 530 yrs for the central part of the Calaveras fault [54b]. No recurrence intervals have been determined for the southern part of the Calaveras fault [54c] and the Paicines [54d] fault. The central part of the Calaveras fault has had two moderate magnitude historical earthquakes (Mw 5.8 1979 Coyote Lake; Mw 6.3 1984 Morgan Hill) associated with minor surface fault rupture (Armstrong, 1979 #5501; Harms and others, 1984 #5511; Hart, 1984 #5517). A moderate magnitude earthquake may have occurred along the northern Calaveras fault in July 1861 according to Rogers and Halliday (1992 #5523) as suggested by a zone of cracking as much as 13 km long. Alternatively, the area where the cracking was reported is

	characterized by large-scale landsliding and the fractures could be interpreted as secondary shaking or landsliding rather than primary surface fault rupture. **Sections:** This fault has 4 sections. There is insufficient data to document seismogenic segments. Petersen and others (1996 #4860) and the Working Group on Northern California Earthquake Potential (1996 #1216) proposed two segments for the Calaveras fault: a northern segment from Calaveras Reservoir north to the San Ramon area, and a southern segment from Calaveras Reservoir to south of Hollister. Taylor (1992 #5531) previously had proposed a similar segmentation model. Simpson and others (1992 #5527), proposed that the Calaveras fault north of the Calaveras Reservoir could be divided into three shorter segments: the Sunol segment, the San Ramon segment, and the Alamo segment. The Working Group on Northern California Earthquake Potential (1996 #1216) also considered these segments as comprising the Northern Calaveras fault. More recently, Kelson and others (1998 #5518) divided the Calaveras fault zone into 3 sections: the Northern Calaveras fault (Danville to Calaveras Reservoir), the Central Calaveras fault (Calaveras Reservoir to San Felipe Lake), and the Southern Calaveras (San Felipe Lake to just south of Hollister). The section boundaries described by Kelson and others (1998 #5518) are adopted for this compilation with the addition of a fourth section south of Hollister that comprises the Paicines fault. The Paicines section extends from the vicinity of the junction of the San Benito River and Tres Pinos Creek south to the vicinity of Stone Canyon. Thus, from north to south the sections are Northern Calaveras [54a], Central Calaveras [54b], Southern Calaveras [54c], and Paicines [54d].
Name comments	**General:** The Calaveras fault zone was first mapped, but not named, by Lawson (1908 #4969). Wood (1916 #5259) named the structure the Sunol fault. This name was used until about 1951, when Crittenden (1951 #5509) used the combined name Sunol-Calaveras fault. The simpler name Calaveras fault is preferred herein. **Section:** Named by Kelson and others (1998 #5518), the Northern Calaveras section extends from the San Ramon area southeast to Calaveras Reservoir. **Fault ID:** Refers to number 227 (Paicines fault) of Jennings (1994 #2878) and numbers C1, C2, C2a, and C2b of Working

	Group on Northern California Earthquake Potential (1996 #1216).
County(s) and State(s)	ALAMEDA COUNTY, CALIFORNIA CONTRA COSTA COUNTY, CALIFORNIA
Physiographic province(s)	PACIFIC BORDER
Reliability of location	Good Compiled at 1:24,000 scale. *Comments:* Location based on digital revisions to Jennings (1994 #2878) using original mapping by Hart (1979 #5514; 1980 #5515; 1981 #5516), Bryant (1981 #5504), Herd (1977 #5484; 1978 #5485), and Dibblee (1973 #5480)) at 1:24,000 scale.
Geologic setting	Major dextral strike-slip fault zone of the larger San Andreas fault system. The Calaveras fault zone is located in the eastern San Francisco Bay region and generally trends along the eastern side of the East Bay Hills, bounds the western side of San Ramon Valley, extends into the western Diablo Range, bounds the eastern side of Santa Clara Valley, extends into Hollister Valley, and eventually joins the San Andreas fault zone [1] along the eastern part of the Gabilan Range. The northern extent of the fault zone is somewhat conjectural. One theory is that the fault zone transfers slip to the Concord fault zone [38] in a right-releasing step-over (Oppenheimer and MacGregor-Scott, 1992 #5520; Working Group on Northern California Earthquake Probabilities, 1996 #1216). Alternatively, the slip may continue northward along reverse and dextral-reverse faults in the East Bay Hills (Page, 1982 #5521). Page (1982 #5521) estimated that cumulative late Cenozoic dextral offset is about 20±4 km. Sarna-Wojcicki (1992 #5265) reported about 13±7 km of cumulative dextral offset in the past 6 m.y. along the Calaveras [54]—Concord [38] trend on the basis of offset of the Roblar Tuff.
Length (km)	This section is 43 km of a total fault length of 156 km.
Average strike	N26°W (for section) versus N31°W (for whole fault)
Sense of movement	Right lateral *Comments:* Traces of the Northern Calaveras section are marked by geomorphic features characteristic of dextral strike-slip displacement. Studies by Simpson and others (1999 #5528), and Kelson and others (1996 #5284) document late Holocene dextral

	strike-slip displacement.
Dip Direction	V *Comments:* Trench exposures at the Welch Creek (Simpson and others, 1999 #5528), and Leyden Creek (Kelson and others, 1996 #5284) sites show near-vertical faults in unconsolidated alluvium and colluvium.
Paleoseismology studies	There are 2 detailed studies for the Northern Calaveras section. Leyden Creek (site 54-2). A study by Kelson and others (1996 #5284). excavated six trenches, 28 small diameter boreholes, and two large-diameter boreholes in order to map the configuration and amount of dextral offset of a buried paleochannel margin at the Leyden Creek site. Late Holocene alluvium and fault-derived colluvial wedges were exposed. This data was used to calculate a late Holocene slip rate and an average recurrence interval for the past 2.5 k.y. Welch Creek (site 54-4). Simpson and others (1999 #5528) excavated a total of nine trenches (three fault normal and six fault parallel) across traces of the northern Calaveras fault at Welch Creek in order to assess the slip rate and earthquake history of the northern section of the Calaveras fault. Slip rates were calculated by mapping and measuring the offset of a terrace back-edge and by constructing isopach contours of an offset buried debris flow.
Geomorphic expression	The Northern Calaveras section generally is marked by geomorphic features characteristic of Holocene dextral strike-slip offset, such as dextrally deflected and offset drainages, linear troughs, linear scarps on alluvium, side-hill benches, beheaded drainages, and closed depressions (Herd, 1977 #5484; 1978 #5485; Bryant, 1981 #5504; Hart, 1981 #5516). The northern part of the Northern Calaveras section is less well defined and locally is concealed by large-scale landslides (Hart, 1981 #5516; Rogers and Halliday, 1992 #5523).
Age of faulted surficial deposits	Faulted late Holocene alluvial and colluvial deposits were exposed at Leyden Creek (Kelson and others, 1996 #5284). These faulted deposits range in age from pre-Holocene to modern. Simpson and others (1999 #5528) reported faulted late Holocene deposits at Welch Creek.

Historic earthquake	
Most recent prehistoric deformation	latest Quaternary (<15 ka) *Comments:* The most recent event identified at the Welch Creek occurred between 1425 AD and 655 AD (Simpson and others, 1999 #5528). The most recent event identified at the Leyden Creek occurred between 1861 A.D. and 1160 A.D. A younger event between 1861 A.D. and 1670 A.D. was identified, but may be related to surface fault creep (Kelson and others, 1996 #5284).
Recurrence interval	125–850 yr (average recurrence for past 5 k.y.) *Comments:* Average recurrence interval based on preferred values from Kelson and others (1996 #5284) and Simpson and others (1999 #5528). Kelson and others (1996 #5284) determined an average recurrence interval of 550±300 years at the Leyden Creek. They reported that stratigraphic and structural relationships of fluvial deposits and scarp-derived colluvial wedges at Leyden Creek show 5 or 6 surface-rupturing events have occurred in the past 2.5 k.y. Simpson and others (1999 #5528) recognized as many as 7 surface-rupturing earthquakes at the Welch Creek site. Timing for events Zwc (525–1295 cal yr BP), Ywc (925–1900 cal yr BP), Xwc (1900–2730 cal yr BP), and Wwc (4840–5325 cal yr BP) are well constrained, but three additional events prior to event Wwc are less well defined. Simpson and others (1999 #5528) determined a maximum recurrence interval between 1375 yrs and 3425 yrs based on the broad age range constraints of the four most recent events. Using the 39±1 m dextral offset of the 5–13 ka terrace back-edge at Welch Creek and an inferred coseismic displacement of 1–2 m per event, Simpson and others (1999 #5528) derived an average recurrence interval of 125–685 yr. The recurrence interval used herein reflects the minimum (125 yr) of Simpson and others (1999 #5528) and the maximum of (850 years) of Kelson and others (1996 #5284).
Slip-rate category	Greater than 5.0 mm/yr *Comments:* Simpson and others (1999 #5528) reported a preferred Holocene dextral displacement rate of 6±1 mm/yr at the Welch Creek. This slip rate is based on 39±1 m dextral offset of a terrace backedge. The age of the terrace backedge is between 5 ka and 13 ka. Simpson and others (1999 #5528) also constructed isopach

	contours for a buried debris flow (4840–5325 cal yr BP) that is dextrally offset 27±1 m. Kelson and others (1996 #5284) reported a preferred dextral slip rate of 5±2 mm/yr at the Leyden Creek. This slip rate is based on 54 m (+18 m, -14 m) of dextral displacement of a buried paleochannel margin. Radiocarbon dates from detrital charcoal recovered from deposits above the paleochannel surface range from 10.5 ka to 14.5 ka. Kelson and others' (1996 #5284) preferred age is 11.5±1 ka.
Date and Compiler(s)	1999 William A. Bryant, California Geological Survey Sereyna E. Cluett, California Geological Survey
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