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San Andreas fault zone, North Coast section (Class A) No. 1b

Last Review Date: 2002-12-10

Compiled in cooperation with the California Geological Survey

citation for this record: **Bryant, W.A., and Lundberg, M., compilers, 2002, Fault number 1b, San Andreas fault zone, North Coast 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 02:19 PM.**

Synopsis	**General:** The 1,100-km-long San Andreas fault zone is the principal element of the San Andreas fault system, a network of faults with predominantly dextral strike-slip displacement that collectively accommodates the majority of relative N-S motion between the North American and Pacific plates. Major elements of the San Andreas fault system include the Bartlett Springs [29], Maacama [30], Rodgers Creek [32], Green Valley [37], Calaveras [54], Hayward [55], San Gregorio [60], San Jacinto [125], Elsinore [126], and Imperial [132] fault zones. In this compilation, the San Andreas fault zone is considered to be the

Holocene and historically active dextral strike-slip fault that extends along most of coastal California from its complex junction with the Mendocino fault zone [18] on the north, southeast to the northern Transverse Range and inland to the Salton Sea, where a well-defined zone of seismicity (the Brawley Seismic Zone [124]) transfers slip to the Imperial fault [132] along a right-releasing step. Two major surface-rupturing earthquakes have occurred in historic time: the 1857 Fort Tejon (Sieh, 1978 #5775) and 1906 San Francisco (Lawson, 1908 #4969) earthquakes. Additional historic surface rupturing earthquakes include the unnamed 1812 earthquake along the Mojave section [1h] (Jacoby and others, 1988 #4962; Sieh and others, 1989 #5779; Fumal and others, 2002 #5726) and the northern part of the San Bernardino Mountains section [1i] (Weldon and Sieh, 1985 #5806; Jacoby and others, 1987 #4961; 1988 #4962), and a large earthquake in the San Francisco Bay area that occurred in 1838 that was probably on the Peninsula section [1c] of the San Andreas fault (Toppozada and Borchardt, 1998 #5493; Bakun, 1999 #4790). Historic fault creep at rates as high as 32 mm/yr characterizes the 132-km-long Creeping section [1e] in central California (Burford and Harsh, 1980 #4806). The creep rate gradually tapers off to 0 mm/yr at the northwestern and southeastern ends of this section. The northern and southern ends of the Creeping section [1e] are transitional to the surface-rupture termination points of the 1906 earthquake to the north and 1857 earthquake to the south. Creep at rates as high as 4 mm/yr also has been measured on the Coachella section [1j] (Sieh and Williams, 1990 #5780). The San Andreas fault zone is the most extensively studied fault in California, and perhaps in the world. The fault zone first gained international scientific attention immediately following the great 1906 San Francisco earthquake. Lawson's 1908 report summarizing the investigation of the 1906 earthquake contained the first integrated description of the San Andreas fault, which was recognized as extending from Point Delgada in the north to Whitewater Canyon southeast of San Bernardino in the south, and formed the underlying basis for our modern studies of paleoseismology and earthquake geology (Prentice, 1999 #5755). More than 5,000 articles, maps, and publications describing various aspects of the San Andreas fault that have been produced since Lawson's pioneering work. In addition, there are about 1,000 site-specific fault rupture investigation reports (and maps) filed with the California Geological Survey in compliance with the Alquist-Priolo Earthquake Fault Zoning Act (Hart and Bryant, 1997 #4856). For this compilation, 51 detailed paleoseismic study sites along the fault zone are summarized. The fastest, generally accepted Holocene slip rate for the San Andreas fault is along the Cholame-Carrizo section [1g], which lies in the medial portion of the 1,100-km-long fault zone. Here, Sieh and Jahns (1984 #5778) reported a preferred late Holocene dextral slip rate of 33.9±2.9 mm/yr. In and south of the San Francisco Bay area, a significant portion of dextral slip is partitioned onto several faults of the San Andreas fault system, including the San Gregorio [60] on the west, and the Calaveras [54] and Hayward [55] faults on the east. Hall and others (1999 #4954) reported a late Holocene slip rate of 17±4 mm/yr for the Peninsula section [1c]. North of the Golden Gate, dextral slip from the San Gregorio fault zone [60] may be transferred to the North Coast section [1b] along a right-releasing step. Reported late Holocene slip rates for the North Coast section [1b] range from a minimum value of 16–18 mm/yr reported by Noller and others (1996 #5748) to a maximum value of 25.5±2.5 mm/yr reported by Prentice (1989 #5754). To the south, the San Andreas fault zone is delineated by an extremely complex zone of dextral strike-slip, reverse-oblique, and thrust faults in the southeastern Transverse Ranges. Fault nomenclature in the San Gorgonio Pass area is complex and different workers have assigned faults different names. West-northwest of San Gorgonio Pass Dibblee (1964 #1340; 1968 #4817; 1982 #4841) termed the principal active strand of the San Andreas fault located along the foot of the San Bernardino Mountains the South Branch San Andreas fault, which is referred to as the San Andreas fault by Allen (1957 #4787) and San Bernardino strand San Andreas fault by Matti and others (1992 #5735). For this compilation, this strand will be referred to as the San Andreas fault (South Branch). A fault that strikes sub-parallel located to the north was called the North Branch San Andreas fault by Dibblee (1964 #1340; 1968 #4817) and is referred to as the Mill Creek fault by Allen (1957 #4787), Matti and others (1992 #5735), and Jennings (1994 #2878). This strand will be referred to as the Mill Creek fault in this compilation. East-southeast of San Gorgonio Pass two principal dextral strike-slip faults comprise the Holocene active San Andreas fault zone. The southern trace has been referred to as the South Branch San Andreas fault by Dibblee (1967 #1345; 1981 #4840) and Jennings (1994 #2878); Matti and others (1992 #5735) refer to this trace as the Coachella Valley segment, Banning fault. This branch will be referred to as the South Branch San Andreas fault (Banning strand) in this compilation. The northern trace is referred to as the North Branch San Andreas fault by Dibblee (1967 #1345; 1981 #4840) and Jennings (1994 #2878); Mission Creek fault by Allen (1957 #4787); Matti and others (1992 #5735) named this trace the Coachella Valley segment, San Andreas fault and will be referred to as the North Branch San Andreas fault (Coachella strand) in this compilation. Refer to Matti and others (1992 #5735) for a detailed discussion of San Andreas fault nomenclature for the Mojave [1h], San Bernardino [1i], and Coachella [1j] sections. Weldon and Sieh (1985 #5806) reported a Holocene slip rate of 24±4 mm/yr at the northern end of the San Bernardino Mountains section [1i]. Harden and Matti (1989 #4955) reported a preferred Holocene slip rate of 14 mm/yr to 25 mm/yr near Yucaipa along the San Andreas fault (South Branch). Keller and others (1982 #4964) reported a preferred late Quaternary slip rate of 23 mm/yr to 35 mm/yr for the Coachella section [1j] near Biskra Palms. Surface-exposure age constraints (10Be-26Al) of the offset alluvial fan complex at Biskra Palms yields a better constrained late Quaternary dextral slip rate of 23.3±3.5 mm/yr (van der Woerd and others, 2001 #5800). Several average values of recurrence have been reported for the fault zone; in general they range from a little more than 100 to as much as 450 yr. The North Coast section [1b] ranges from 180–260 yr (Niemi and Hall, 1992 #5747) to 200≠400 yr for the past 2 k.y. (Prentice, 1989 #5754). The Santa Cruz Mountains section [1d] is 247-266 yr (Schwartz and others, 1998 #5771) and the Cholame-Carrizo section [1g] is 160–450 yr (Sieh and Jahns, 1984 #5778; Grant and Sieh, 1994 #4950; Sims, 1994 #5787; Stone and others, 2002 #5792). Recurrence intervals for the Mojave section [1h] are well-constrained based on paleoseismic studies by Sieh and others (1989 #5779), Biasi and others (2002 #5724) and Fumal and others (1993 #624; 2002 #5725). Sieh and others (1989 #5779) reported an average recurrence interval of 132 yr for the time interval AD 734 to 1857 at Pallett Creek, whereas Biasi and others (2002 #5724) refined the average recurrence interval at 135 yr. Fumal and others (2002 #5725) reported an average recurrence interval of 105 yr for the past 500 yr at Wrightwood. An average recurrence interval of 150–275 yr has been reported for the northern San Bernardino Mountains section by Weldon and Sieh (1985 #5806), Seitz and Weldon (1994 #5772), and Yule and others (2001 #4948). The Coachella section [1j] averages large earthquakes about 207–233 yr based on Sieh (1986 #5777).

Sections: This fault has 10 sections. From north to south they are the Shelter Cove [1a], North Coast [1b], Peninsula [1c], Santa

	Cruz Mountains [1d], Creeping [1e], Parkfield [1f], Cholame-Carrizo [1g], Mojave [1h], San Bernardino Mountains [1i], and Coachella [1j] sections. Different behavior patterns along different parts of the San Andreas fault where first noticed when Steinbrugge and Zacher (1960 #5791) documented creep along the fault in central California. Since that time, other workers have proposed various segmentation models for the San Andreas fault including five segments by Allen (1968 #4788), eight segments by Wallace (1970 #1423), 12 segments by Sykes and Nishenko (1984 #5794), Petersen and others (1996 #4860), the Working Group on California Earthquake Probabilities (1988 #5494; 1995 #4945; 1999 #4946), and the Working Group on Northern California Earthquake Probabilities (1996 #1216). Some segment boundaries are well documented or constrained for the San Andreas fault zone, whereas others are not. For this compilation, boundaries generally are similar to those described in models adopted by the Working Group on California Earthquake Probabilities (1988 #5494; 1990 #549; 1995 #4945; 1999 #4946), the Working Group on Northern California Earthquake Probabilities (1996 #1216), and Petersen and others (1996 #4860).
Name comments	**General:** Traces of the San Andreas fault were first mapped in northern California by Lawson (1893 #4967) and were first named the San Andreas rift by Lawson (1895 #4968) after the type locality of the fault in the San Andreas Valley (San Mateo County, California). North of San Francisco, Anderson (1899 #4789) mapped traces of the fault on the Point Reyes Peninsula, but did not name the fault. Schuyler (1896–1897 #5769) described parts of the fault zone in southern California for a 200-mi (about 320-km) length through Kern, Los Angeles, and San Bernardino Counties and referred to the fault not as the San Andreas but as the "great earthquake crack", referring to surface fault ruptures associated with the 1857 Fort Tejon earthquake. The significance and extent of the San Andreas fault was not recognized until after the 1906 San Francisco earthquake. J.C. Branner and S. Tabor proposed the name Portola-Tomales for the fault zone, but A.C. Lawson (1908 #4969) preferred the term "San Andreas fault" (Hill, 1981 #4958). For this compilation, we use San Andreas fault zone owing to the complex nature and multiple strands (or faults) that comprise the structure. **Section:** This section extends from Point Area southeast to the Golden Gate and is similar to the segment designated by Sykes and Nishenko (1984 #5794). The southern boundary with the

	Peninsula section [1c], adjacent to the Golden Gate, is characterized by a 3-km-wide, right-releasing step that has probably persisted for at least 3 m.y. (based on presence of the Merced Formation), the splaying off of the San Gregorio fault [60], a reduced slip rate south of the Golden Gate, and a distinct drop in geodetically modeled slip associated with the 1906 earthquake (Thatcher and others, 1997 #5795). This section has been described by Wallace (1970 #1423) who carried it north to Cape Mendocino and south to Los Gatos. The North Coast segment was delineated by Working Group on California Earthquake Probabilities (1988 #5494; 1990 #549), who designated the southern boundary near Lower Crystal Springs Reservoir. The North Coast segment designated by the Working Group on Northern California Earthquake Probabilities (1996 #1216; 1999 #4946) and Petersen and others (1996 #4860) is similar to the earlier ones of the Working Group on California Earthquake Probabilities (1988 #5494; 1990 #549), but the southern boundary was considered to be at the Golden Gate. **Fault ID:** Refers to Jennings (1994 #2878) numbers 87 (San Andreas fault (SAF) Shelter Cove), 116 (SAF splays), 119 (SAF Fort Ross to Manchester), 145 (SAF offshore), 147 (SAF offshore Bolinas), 162 (SAF boundary faults), 194 (SAF San Francisco to Watsonville), 217 (SAF 1989 ground fractures), 234 (SAF San Juan Bautista to Priest Valley), 240 (SAF historic creep), 278 (SAF Priest Valley to Cuyama), 311 (SAF Cuyama to Palmdale), 358 (SAF Palmdale to Cajon Canyon), 360 (SAF 1812 rupture), 427 (Mill Creek), 427A (SAF Cajon Canyon to Burro Flats), 452 (SAF South Branch), 453 (SAF North Branch), 472 (SAF Indio to Salton Sea), 477 (SAF Bombay Beach and vicinity), 452 (SAF South Branch), 449 (Banning fault western part), and 450 (Mission Creek fault), and numbers A1 (SAF 1906 rupture), A2 (SAF Peninsula), A3 (SAF Santa Cruz Mountains), and A7 (SAF creeping section) of the Working Group on Northern California Earthquake potential (1996 #1216).
County(s) and State(s)	MARIN COUNTY, CALIFORNIA MENDOCINO COUNTY, CALIFORNIA SONOMA COUNTY, CALIFORNIA
Physiographic province(s)	PACIFIC BORDER
Reliability of location	Poor Compiled at 1:750,000 scale.

	Comments: Location based on digital revisions to Jennings (1994 #2878) at 1:750,000 scale map using original mapping by Brown and Wolfe (1972 #4801), Clark and Brabb (1997 #4810), and Galloway (1977 #4845) at 1:24,000 scale; Wagner (1977 #5803) at 1:12,000 scale; and Blake and others (1971 #4797, 1974 #5272) at 1:62,500 scale.
Geologic setting	The San Andreas fault zone is a major dextral strike-slip fault zone that extends for about 1,100 km along the western side of California. It is near the coast in northern California, but stays entirely inland to the south of San Francisco, extending all the way to the northern Gulf of California in Mexico. The San Andreas fault zone is the principal element of a network of dextral strike-slip faults that constitute the San Andreas fault system that collectively accommodates the majority of relative N-S motion between the Pacific and North American plates (Wallace, 1990 #5804). Wilson (1965 #4947) first proposed that the San Andreas fault was a transform fault connecting two spreading oceanic ridges between the Pacific and North American plates. The San Andreas fault zone extends from the Salton Trough near Bombay Beach northwest to its complex junction with the Mendocino fault zone [18] near Punta Gorda. At the southern end of the fault zone near Bombay Beach, dextral slip is transferred to the Imperial fault [132] along a right-releasing step-over delineated by a zone of seismicity referred to as the Brawley Seismic Zone [124]. The San Andreas fault traverses the length of the Coast Ranges geomorphic subprovince and forms the boundary between the Transverse Range and Mojave Desert geomorphic subprovinces as well as the boundary between the Salton Trough and Mojave Desert geomorphic subprovinces. Noble (1926 #1592) was the first to suggest a large amount of dextral slip (38 km) on the San Andreas fault. Hill and Dibblee (1953 #923) postulated that as much as 560 km of dextral slip has occurred on the basis of proposed correlation of Mesozoic basement rocks. Post-early Miocene cumulative dextral slip is approximately 315 km, based on correlation of the Neenach Volcanic Formation (22.5–24.1 Ma minimum K-Ar age reported in Sims, 1993 #5786) on the east side of the fault zone with early Miocene Pinnacles Formation (24.2±0.5 Ma average K-Ar age reported in Sims, 1993 #5786) on the west side of the fault (Matthews, 1976 #931). Stanley (1987 #5790) reported 325–330 km of post late Oligocene dextral slip and 320–325 km of post-early Miocene dextral slip. Further discussions of the displacement history the San Andreas fault zone are included in

	Powell (1993 #5753), Weldon and others (1993 #5807), and Matti and Morton (1993 #5737).
Length (km)	This section is 244 km of a total fault length of 1082 km.
Average strike	N36°W
Sense of movement	Right lateral *Comments:* Well-defined geomorphic expression of dextral strike-slip fault (Brown and Wolfe, 1972 #4801), dextral offset of geologic units (for example, Prentice and Sieh, 1988 #5757; Prentice, 1989 #5754; Prentice and others, 1991 #5756; Baldwin, 1996 #4793; Baldwin and others, 2000 #4795; Prentice and others, 2000 #5758), dextral displacement associated with 1906 San Francisco earthquake (Lawson, 1908 #4969), and geodetically determined dextral slip (Thatcher and others, 1997 #5795).
Dip Direction	V *Comments:* Vertical dip based on linear geomorphic expression of fault, vertical to near vertical fault zone expressed in trench exposures by Prentice (1989 #5754), Noller and others (1996 #5748), Nimei and Hall (1992 #5747), and Hall and others (1986 #4952).
Paleoseismology studies	There are eight detailed study sites for the North Coast section. Bodega Harbor (1-6) and Bolinas Lagoon (1-9) are drilling sites of Knudsen and others (2002 #5727). Interpretation of marsh stratigraphy at both sites indicates that coseismic subsidence has occurred and allows identification of paleoearthquakes including the most recent event Dogtown site (1-11). Hall and others (1986 #4952) excavated both fault parallel and fault normal trenches at the Dogtown site south of Olema. Offset late Holocene deposits allowed determination of late Holocene recurrence intervals and identification of the most recent event on the North Coast section. Subsequent work by Wells and others (1999 #5809) involved the excavation of two new trenches and re-excavation of two former trenches in order to better constrain the slip history of the North Coast section during the past 2 k.y.

Scaramella Ranch site (1-15). Prentice (1989 #5754) excavated 17 trenches (13 fault normal and 4 fault parallel) into a Holocene alluvial fan at the Scaramella Ranch site near Point Arena. A buried Holocene stream channel has been dextrally offset a maximum of 64 m. Prentice (1989 #5754) identified at least 5 surface rupturing earthquakes in the past 2 k.y. at the Scaramella Ranch site.

Vedanta Retreat site (1-23). Nimei (1992 #5746) and Nimei and Hall (1992 #5747) excavated 20 trenches (both fault normal and fault parallel) across traces of the North Coast section at the Vedanta Retreat site near Olema. The site is along the alluviated valley of Gravely Creek. Here, a wind gap cut across a medial ridge subsequently has been blocked by dextral offset along the North Coast section. Buried late Holocene stream channel deposits identified in trenches are dextrally offset. Evidence for 2 to 5 pre-1906 surface rupturing earthquakes was reported.

Alder Creek site (1-32). Baldwin (1996 #4793) excavated 3 fault normal and 3 fault parallel trenches across traces of the North Coast section at Alder Creek near Point Arena. A late Holocene terrace riser at Alder Creek is dextrally offset 9.5 m. Baldwin (1996 #4793) identified at least three earthquakes: the 1906 earthquake, event P (thought to have occurred between 680 A. D. and 1603 A. D.), and a pre-Holocene earthquake. Baldwin and others (2000 #4795) conducted ground-penetrating radar surveys and excavated two additional trenches at the Alder Creek site. Baldwin and others (2000 #4795) reported a stream channel dextrally offset a minimum of 8.5±0.5 m and a maximum of 9.0±0.5 m. The age of channel deposits is 400±100 cal yr BP, allowing estimate of 3.1-4.6 m dextral offset for the penultimate event.

Archae Camp site (1-33). Noller and others (1996 #5748) excavated 4 trenches across the North Coast section at the Archae Camp site near Fort Ross. Here the fault is expressed as a single trace delineated by a southwest-facing scarp, linear troughs, and closed depressions. Three trenches extended across an archeological site. Several test pits and borings were used to delineate the margins of the archeological site. Noller and others (1996 #5748) identified 3 to 5 late Holocene surface faulting events, based on upward fault terminations, truncated colluvium and scarp-derived colluvial wedges, fissure fills, and cross-cutting stratigraphic relationships.

	Mill Gulch site (1-42). Langridge and Prentice (2000 #4966) excavated one trench near Fort Ross that exposed an abandoned and filled channel of proto-Mill Gulch. Charcoal from the top of gravel deposits yielded an age of 4,530±40 14C yr BP.
Geomorphic expression	The North Coast section is marked by geomorphic features characteristic of Holocene dextral offset, such as dextrally offset stream channels, aligned linear valleys, closed depressions, shutter ridges, linear troughs and trenches in alluvium, linear scarps on alluvium, aligned benches and saddles, sidehill troughs, and linear vegetation contrasts (Brown and Wolfe, 1972 #4801; Wallace, 1990 #5804).
Age of faulted surficial deposits	Fault offsets late Holocene and historic fluvial and terrace deposits in the Point Arena area as determined from detailed studies including radiocarbon dating by Baldwin (1996 #4793) and Prentice (1989 #5754). Noller and others (1996 #5748) reported that anthropic deposits are displaced near Fort Ross. Nimei (1992 #5746) and Nimei and Hall (1992 #5747) identified late Holocene (1,800±78 yr BP) and historic fluvial deposits that are offset at the Vedanta paleoseismic site.
Historic earthquake	San Francisco earthquake 1906
Most recent prehistoric deformation	latest Quaternary (<15 ka) *Comments:* The most recent event occurred in 1906. For the penultimate event (most recent paleoevent), Prentice (1989 #5754) reported that event R/V at the Scaramella Ranch near Point Arena occurred between AD 1530 A. D. and 1906 A. D., with a preferred time after 1635 A. D., but before 1850, based on a historical record indicating no major earthquakes between 1850 and 1906. Noller and others (1996 #5748) reported that the most recent paleoevent at the Archae Camp occurred between 1170 A. D. and 1650, based on radiocarbon dating of charcoal sampled from a scarp-derived colluvial wedge. The most recent paleoevent at this site, based on dendrochronology, occurred between AD 1400 and AD 1648. Knudsen and others (2002 #5727) reported that the penultimate event occurred after AD 1600 at the Bodega Harbor. Nimei (1992 #5746) reported that the most recent paleoearthquake at the Vedanta Retreat site occurred during or after 1591 A. D. to 1661 A. D. Hall and others (1986 #4952) reported that the most recent paleoearthquake at the Dogtown site occurred between AD 1521 and AD 1688. Wells and others (1999

	#5809) identified deformation from the 1906 event but reported that extensive bioturbation in a paleosol obscured evidence of multiple pre-1906 earthquakes. They identified a series of faults that died out in the paleosol, representing at least one paleoearthquake between 300 14C yr BP and 1300 14C yr BP.
Recurrence interval	200–400 yr (<2 k.y.) *Comments:* Various studies of recurrence intervals for the past 2 k.y. range from 200 to 400 yr for this section. Prentice (1989 #5754) interpreted a minimum of 5 earthquakes in the past 2 k.y., based on trench exposures at the Scaramella Ranch site. Assuming a uniform recurrence model, Prentice concluded that an average recurrence interval of 200–400 yr best fits the data collected at the Scaramella Ranch site. Noller and others (1996 #5748) reported an average recurrence interval of 300–350 yr based on reconstruction of event chronology interpreted from trenches at the Archae Camp site near Fort Ross. Nimei (1992 #5746) recognized three earthquakes at the Vedanta Retreat site that yield an average recurrence interval of 240–318 yr. Nimei also reported a preferred average recurrence interval of 221±40 yr on the basis of the slip rate calculated for the Vedanta Retreat site and the assumption that the 4.9–5.5 m dextral slip reported for the 1906 earthquake is characteristic of previous events. Hall and others (1986 #4952) reported an average recurrence interval of 230–350 yr at the Dogtown site, based on event chronology.
Slip-rate category	Greater than 5.0 mm/yr *Comments:* Reported late Holocene slip rates for the North Coast section range from a minimum value of 16–18 mm/yr reported by Noller and others (1996 #5748) to a maximum value of 25.5±2.5 mm/yr reported by Prentice (1989 #5754). Minimum slip rate. The minimum slip rate value reported by Noller and others (1996 #5748 from Archae Camp site) is based on a dextrally offset margin of an archaeological site. Anthropic deposits were dated using radiocarbon, obsidian-hydration age estimates, and local archaeological chronology. The slip-rate value should be considered a minimum value because the location of the southwest margin of the archaeological site was not well constrained due to erosion. Maximum slip rate. A maximum slip rate value of 25.5 mm/yr reported by Prentice (1989 #5754 from Scaramella Ranc site) is based on 64±2 m maximum dextral offset of a 2.36- to 2.71-ka buried stream channel based on 14C

	dating of detrital charcoal. A late Pleistocene slip rate of less than 39 mm/yr was reported by Prentice on the basis of 1.7 km dextral offset of landslide deposits dated as older than 43 ka. Correlation of marine terrace risers across the North Coast section indicates 1.5–2.5 km of dextral displacement. U-series age of solitary coral and correlation with global sea-level high stands suggest ages between 83 ka and 133 ka for the terrace surfaces, which indicates a 18–19 mm/yr slip rate. Prentice and others (2000 #5758) reported a revised slip rate estimate of 16–24 mm/yr. Prentice also reported a Pliocene slip rate of 12–20 mm/yr based on tentative correlation of the Pliocene Ohlson Ranch Formation in northwest Sonoma County with deposits 50 km to the northwest near Point Arena. A fission-track age of 3.3±0.8 Ma determined from zircons in tuff unit within rocks of the Ohlson Ranch Formation limits the maximum time for the 50 km of displacement. Holocene slip rates. Baldwin (1996 #4793 from Alder Creek site) reported a preferred late Holocene slip rate of 25±6 mm/yr based on 9.6±3.5 m dextral offset of a terrace riser. Timing of the terrace riser offset is based on the time that paleo-Alder Creek abandoned cutting of the riser. Overbank fines deposited over channel gravels are assumed to mark abandonment of the terrace riser. The overbank fines are dated at 400±90 14C yr BP from detrital charcoal recovered from the overbank deposits. A late Holocene dextral slip rate of 18±3 mm/yr (best estimate) was reported by Prentice and others (2001 #5759) based on 80–100 m dextral offset of abandoned channel of Mill Gulch site that has an age of 4,290–5,290 cal yr BP. Nimei (1992 #5746) and Nimei and Hall (1992 #5747), from Vedanta Retreat site reported a minimum late Holocene slip rate of 24±3 mm/yr based on 42.5±3.5 m dextral offset of stream channel deposits dated at 1,800±78 14C yr BP. The slip rate is considered a minimum because the detrital organic matter recovered in the stream channel yields a maximum age for the channel deposits and additional distributed deformation may not be accounted for at the site.
Date and Compiler(s)	2002 William A. Bryant, California Geological Survey Matthew Lundberg, California Geological Survey
References	#4787 Allen, C.R., 1957, San Andreas fault zone in San Gorgonio Pass, southern California: Geological Society of America Bulletin, v. 68, no. 3, p. 315-350. #4788 Allen, C.R., 1968, The tectonic environments of seismically active and inactive areas along the San Andreas fault

system, *in* Dickinson, W.R., and Grantz, A., eds., Proceedings of conference on geologic problems of San Andreas fault system: Palo Alto, California, Stanford University Publications, Geological Sciences, v. XI, p. 70-82.

#4789 Anderson, F.M., 1899, The geology of Point Reyes Peninsula: Berkeley, California, University of California Publications in Geological Sciences, v. 2, p. 119-153.

#4790 Bakun, W.H., 1999, Seismic activity of the San Francisco Bay region: Bulletin of the Seismological Society of America, v. 89, no. 3, p. 764-784.

#4793 Baldwin, J.N., Jr., 1996, Paleoseismic investigation of the San Andreas fault on the North Coast segment, near Manchester, California: San Jose, California, San Jose State University, unpublished M.S. thesis, 127 p., 4 pls.

#4795 Baldwin, J.N., Knudsen, K.L., Lee, A., Prentice, C.S., and Gross, R., 2000, Preliminary estimate of coseismic displacement of the penultimate earthquake on the northern San Andreas fault, Pt. Arena, California, *in* Bokelmann, G., and Kovach, R.L., eds., Proceedings of the Third Conference on Tectonic Problems of the San Andreas system: Palo Alto, California, Stanford University Publications, p. 355-368.

#5724 Biasi, G.P., Weldon, R.J., II, Fumal, T.E., and Seitz, G.G., 2002, Paleoseismic event dating and the conditional probability of large earthquakes on the southern San Andreas fault, California: Bulletin of the Seismological Society of America, Special Issue on Paleoseismology of the San Andreas Fault System, v. 92, no. 7, p. 2761-2781.

#5272 Blake, M.C., Bartow, J.A., Frizzell, V.A., Jr., Schlocker, J., Sorg, D., Wentworth, C.M., and Wright, R.H., 1974, Preliminary geologic map of Marin and San Francisco Counties and parts of Alameda, Contra Costa and Sonoma Counties, California, San Francisco Bay Region Environment and Resources Planning Study: U.S. Geological Survey Miscellaneous Field Studies Map MF-574 (Basic Data Contribution 64), scale 1:62,500.

#4797 Blake, M.C., Jr., Smith, J.T., Wentworth, C.M., and Wright, R.H., 1971, Preliminary geologic map of western Sonoma County and northernmost Marin County, California: U.S.

Geological Survey Basic Data Contribution 12, 1 pl., scale 1:62,500.

#4801 Brown, R.D., Jr., and Wolfe, E.W., 1972, Map showing recently active breaks along the San Andreas fault between Point Delgada and Bolinas Bay, California: U.S. Geological Survey Miscellaneous Investigations Map I-692, 2 sheets, scale 1:24,000.

#4806 Burford, R.O., and Harsh, P.W., 1980, Slip on the San Andreas fault in central California from alignment array surveys: Bulletin of the Seismological Society of America, v. 70, no. 4, p. 1233-1261.

#4810 Clark, J.C., and Brabb, E.E., 1997, Geology of Point Reyes National Seashore and vicinity, California—A digital database: U.S. Geological Survey Open-File Report 97-456, 17 p., scale 1:24,000.

#1340 Dibblee, T.W., Jr., 1964, Geologic map of the San Gorgonio Mountain quadrangle San Bernardino and Riverside Counties, California: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-431, 3 p. pamphlet, 1 sheet, scale 1:62,500.

#1345 Dibblee, T.W., Jr., 1967, Geologic map of the Morongo Valley quadrangle San Bernardino and Riverside Counties, California: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-517, 4 p. pamphlet, 1 sheet, scale 1:62,500.

#4817 Dibblee, T.W., Jr., 1968, Displacements on the San Andreas fault system in San Gabriel, San Bernardino, and San Jacinto Mountains, southern California, *in* Dickinson, W.R., and Grantz, A., eds., Proceedings of conference on geologic problems of San Andreas fault system: Palo Alto, California, Stanford University Publications in Geological Sciences, v. XI, p. 269-278.

#4840 Dibblee, T.W., Jr., 1981, Geologic map of the Palm Springs (15 minute) quadrangle, California: South Coast Geological Society, Geologic Map SCGS-3, scale 1:62,500.

#4841 Dibblee, T.W., Jr., 1982, Geology of the San Bernardino Mountains, southern California, *in* Fife, D.L., and Minch, J.A., eds., Geology and mineral wealth of the California Transverse Ranges—Mason Hill Volume: South Coast Geological Society

Guidebook 10, p. 148-169.

#5726 Fumal, T.E., Rymer, M.J., and Seitz, G.G., 2002, Timing of large earthquakes since A.D. 800 on the Mission Creek strand of the San Andreas fault zone at Thousand Palms Oasis, near Palm Springs, California: Bulletin of the Seismological Society of America, Special Issue on Paleoseismology of the San Andreas Fault System, v. 92, no. 7, p. 2841-2860.

#5725 Fumal, T.E., Weldon, R.J., II, Biasi, G.P., Dawson, T.E., Seitz, G.G., Frost, W.T., and Schartz, D.P., 2002, Evidence for large earthquakes on the San Andreas fault at the Wrightwood, California, paleoseismic site—A.D. 500 to present: Bulletin of the Seismological Society of America, Special Issue on Paleoseismology of the San Andreas Fault System, v. 92, no. 7, p. 2726-2760.

#4845 Galloway, A.J., 1977, Geology of the Point Reyes Peninsula, Marin County, California: California Division of Mines and Geology Bulletin 202, 72 p., scale 1:48,000.

#4950 Grant, L.B., and Sieh, K., 1994, Paleoseismic evidence of clustered earthquakes on the San Andreas fault in the Carrizo Plain, California: Journal of Geophysical Research, v. 99, no. B4, p. 6819-6841.

#4952 Hall, N.T., Hay, E.A., and Cotton, W.R., 1986, Investigation of the San Andreas fault and the 1906 earthquake, Marin County, California: Technical report to U.S. Geological Survey, Reston, Virginia, under Contract 14-08-0001-21242, 45 p.

#4954 Hall, N.T., Wright, R.H., and Clahan, K.B., 1999, Paleoseismic studies of the San Francisco Peninsula segment of the San Andreas fault zone near Woodside, California: Journal of Geophysical Research, v. 104, no. B10, p. 23,215-23,236.

#4955 Harden, J.W., and Matti, J.C., 1989, Holocene and late Pleistocene slip rate on the San Andreas fault in Yucaipa, California, using displaced alluvial-fan deposits and soil chronology: Geological Society of America Bulletin, v. 101, p. 1107-1117.

#4856 Hart, E.W., and Bryant, W.A., 1997, Fault-rupture hazard zones in California: California Division of Mines and Geology

Special Report 42, 38 p.

#4958 Hill, M.L., 1981, San Andreas fault—History of concepts: Geological Society of America Bulletin, v. 92, p. 112-131.

#923 Hill, M.L., and Dibblee, T.W., Jr., 1953, San Andreas, Garlock, and Big Pine faults, California: Geological Society of America Bulletin, v. 64, p. 443–458.

#4961 Jacoby, G.C., Sheppard, P.R., and Sieh, K.E., 1987, Was the 8 December 1812 California earthquake produced by the San Andreas fault?—Evidence from trees near Wrightwood [abs.]: Seismological Research Letters, v. 58, no. 1, p. 14.

#4962 Jacoby, G.C., Sheppard, P.R., and Sieh, K.E., 1988, Irregular recurrence of large earthquakes along the San Andreas fault—Evidence from trees: Science, v. 241, p. 196-199.

#2878 Jennings, C.W., 1994, Fault activity map of California and adjacent areas, with locations of recent volcanic eruptions: California Division of Mines and Geology Geologic Data Map 6, 92 p., 2 pls., scale 1:750,000.

#4964 Keller, E.A., Bonkowski, M.S., Korsch, R.J., and Shlemon, R.J., 1982, Tectonic geomorphology of the San Andreas fault zone in the southern Indio Hills, Coachella Valley, California: Geological Society of America Bulletin, v. 93, no. 1, p. 46-56.

#5727 Knudsen, K.L., Witter, R.C., Garrison-Laney, C.E., Baldwin, J.N., and Carver, G.A., 2002, Past earthquake-induced rapid subsidence along the northern San Andreas fault—A paleoseismological method for strike-slip faults: Bulletin of the Seismological Society of America, Special Issue on Paleoseismology of the San Andreas Fault System, v. 92, no. 7, p. 2612-2636.

#4966 Langridge, R.M., and Prentice, C.S., 2000, Mid-Holocene slip rate on the San Andreas fault near Fort Ross, California [abs.]: Seismological Research Letters, v. 71, no. 1, p. 228.

#4967 Lawson, A.C., 1893, The post-Pliocene diastrophism of the coast of southern California: Berkeley, California, University of California Publications in Geological Sciences, v. 1, p. 115-160.

#4968 Lawson, A.C., 1895, Sketch of the geology of the San Francisco peninsula, California: U.S. Geological Survey Annual Report, v. 15, p. 399-476.

#4969 Lawson, A.C., chairman, 1908, The California earthquake of April 18, 1906—Report of the State Earthquake Investigation Commission: Washington, D.C., Carnegie Institution of Washington Publication 87.

#931 Matthews, V., III, 1976, Correlation of Pinnacles and Neenach volcanic formations and their bearing on San Andreas fault problem: Bulletin of the American Association of Petroleum Geologists, v. 60, no. 12, p. 2128-2141.

#5737 Matti, J.C., and Morton, D.M., 1993, Paleogeographic evolution of the San Andreas fault in southern California—A reconstruction based on a new cross-fault correlation, *in* Powell, R.E., Weldon, R.J., II, and Matti, J.C., ed., The San Andreas fault system—Displacement, palinspastic reconstruction, and geologic evolution: Geological Society of America Memoir 178, p. 107-160.

#5746 Niemi, T.M., 1992, Late Holocene slip rate, prehistoric earthquakes, and Quaternary neotectonics of the northern San Andreas fault, Marin County, California: Palo Alto, California, Stanford University, unpublished Ph.D. dissertation, 199 p.

#5747 Niemi, T.M., and Hall, N.T., 1992, Late Holocene slip rate and recurrence of great earthquakes on the San Andrea fault in northern California: Geology, v. 20, no. 3, p. 196-198.

#1592 Noble, L.F., 1926, The San Andreas rift and some other active faults in the desert region of southeastern California: Carnegie Institution of Washington Year Book 25, p. 415-428.

#5748 Noller, J.S., Simpson, G.D., and Lightfoot, K., 1996, Paleoseismic and geoarchaeologic investigations of the northern San Andreas fault, Fort Ross, California, *in* National Earthquake Hazards Reduction Program, Summaries of technical reports: U.S. Geological Survey, National Earthquake Hazards Reduction Program External Research Program, Annual Project Summaries, v. 37, http://erp-web.er.usgs.gov/reports/annsum/vol37/nc/g2474.htm.

#4860 Petersen, M.D., Bryant, W.A., Cramer, C.H., Cao, T., Reichle, M.S., Frankel, A.D., Lienkaemper, J.J., McCrory, P.A., and Schwartz, D.P., 1996, Probabilistic seismic hazard assessment for the State of California: California Department of Conservation, Division of Mines and Geology Open-File Report 96-08 (also U.S. Geological Open-File Report 96-706), 33 p.

#5753 Powell, R.E., 1993, Balanced palinspastic reconstruction of pre-late Cenozoic paleogeology, southern California—Geologic and kinematic constraints on evolution of the San Andreas fault system, *in* Powell, R.E., Weldon, R.J., II, and Matti, J.C., ed., The San Andreas Fault System—Displacement, palinspastic reconstruction, and geologic evolution: Geological Society of America Memoir 178, p. 1-106.

#5754 Prentice, C.S., 1989, Earthquake geology of the northern San Andreas fault near Point Arena, California: Pasadena, California Institute of Technology, unpublished Ph.D. dissertation, 252 p.

#5755 Prentice, C.S., 1999, San Andreas fault—1906 earthquake and subsequent evolution of ideas: Geological Society of America Special Paper 338, p. 79-85.

#5757 Prentice, C.S., and Sieh, K.E., 1988, Prehistoric seismic events on the northern San Andreas fault near Point Arena, California [abs.]: Eos, Transactions of the American Geophysical Union, v. 69, no. 16, p. 492.

#5758 Prentice, C.S., Langridge, R., and Merritts, D.J., 2000, Paleoseismic and Quaternary tectonic studies of the San Andreas fault from Shelter Cove to Fort Ross [abs.], *in* Bokelmann, G., and Kovach, R.L., ed., Proceedings of the Third Conference on Tectonic Problems of the San Andreas System: Palo Alto, California, Stanford University Publications, p. 249-350.

#5756 Prentice, C.S., Niemi, T.N., and Hall, N.T., 1991, Quaternary tectonic studies of the northern San Andreas fault, San Francisco Peninsula, Point Reyes, and Point Arena, California [field trip guidebook]: California Division of Mines and Geology Special Publication 109, 25-34 p.

#5759 Prentice, C.S., Prescott, W.H., Langridge, R., and Dawson, T., 2001, New geologic and geodetic slip rate estimates on the north coast San Andreas fault—Approaching agreement? [abs.]: Seismological Research Letters, v. 72, no. 2, p. 282.

#5769 Schuyler, J.D., 1896-1897, Reservoirs for irrigation: U.S. Geological Survey, 18th Annual Report, part IV, p. 711-712.

#5771 Schwartz, D.P., Pantosti, D., Okumura, K., Powers, T.J., and Hamilton, J.C., 1998, Paleoseismic investigations in the Santa Cruz Mountains, California—Implications for recurrence of large-magnitude earthquakes on the San Andrea fault: Journal of Geophysical Research, v. 103, no. B8, p. 17,985-18,001.

#5772 Seitz, G.G., and Weldon, R.J., II, 1994, The paleoseismology of the southern San Andreas fault at Pitman Canyon, San Bernardino, California, *in* McGill, S.F., and Ross, T.M., eds., Geologic investigations of an active margin: Cordilleran Section Annual Meeting, San Bernardino, California, Field trip guidebook, v. 27, p. 152-156.

#5775 Sieh, K.E., 1978, Large prehistoric earthquakes produced by slip on the San Andreas fault at Pallet Creek, California: Journal of Geophysical Research, v. 83, no. B8, p. 3907-3939.

#5777 Sieh, K.E., 1986, Slip rate across the San Andreas fault and prehistoric earthquakes at Indio, California [abs.]: Eos, Transactions of the American Geophysical Union, v. 67, no. 55, p. 1200.

#5778 Sieh, K.E., and Jahns, R.H., 1984, Holocene activity of the San Andreas fault at Wallace Creek, California: Geological Society of America Bulletin, v. 95, p. 883-896.

#5780 Sieh, K.E., and Williams, P.L., 1990, Behavior of the San Andreas fault during the past 300 years: Journal of Geophysical Research, v. 95, no. B5, p. 6629-6645.

#5779 Sieh, K.E., Stuiver, M., and Brillinger, D., 1989, A more precise chronology of earthquakes produced by the San Andreas fault in southern California: Journal of Geophysical Research, v. 94, no. B1, p. 603-623.

#5786 Sims, J.D., 1993, Chronology of displacement on the San Andreas fault in central California—Evidence from reversed positions of exotic rock bodies near Parkfield, California, *in*

Powell, R.E., Weldon, R.J., II, and Matti, J.C., ed., The San Andreas fault system—Displacement, palinspastic reconstruction, and geologic evolution: Geological Society of America Memoir 178, p. 231-256.

#5787 Sims, J.D., 1994, Stream channel offset and abandonment and a 200-year average recurrence interval of earthquakes on the San Andreas fault at Phelan Creek, Carrizo Plain, California, *in* Prentice, C.S., Schwartz, D.P., and Yeats, R.S., ed., Proceedings of the workshop on paleoseismology: U.S. Geological Survey Open-File Report 94-568, p. 170-172.

#5790 Stanley, R.G., 1987, New estimates of displacement along the San Andreas fault in central California based on paleobathymetry and paleogeography: Geology, v. 15, no. 2, p. 171-174.

#5791 Steinbrugge, K.V., and Zacher, E.G., 1960, Creep on the San Andreas fault—Fault creep and property damage: Bulletin of the Seismological Society of America, v. 50, no. 3, p. 389-396.

#5792 Stone, E.M., Grant, L.B., and Arrowsmith, J.R., 2002, Recent rupture history of the San Andreas fault, southwest of Cholame in the northern Carrizo Plain, California: Bulletin of the Seismological Society of America, v. 92, no. 3, p. 983-997.

#5794 Sykes, L.R., and Nishenko, S.P., 1984, Probabilities of occurrence of large plate rupturing earthquakes for the San Andreas, San Jacinto, and Imperial faults, California: Journal of Geophysical Research, v. 89, no. B7, p. 5905-5927.

#5795 Thatcher, W., Marshall, G., and Lisowski, M., 1997, Resolution of fault slip along the 470-km-long rupture of the great 1906 San Francisco earthquake and its implications: Journal of Geophysical Research, v. 102, no. B3, p. 5353-5367.

#5493 Toppozada, T.R., and Borchardt, G., 1998, Re-evaluation of the 1836 "Hayward fault" and the 1938 San Andreas fault earthquakes: Bulletin of the Seismological Society of America, v. 88, no. 1, p. 140-159.

#5800 van der Woerd, J., Klinger, Y., Sieh, K., Tapponnier, P., and Ryerson, F.J., 2001, First long-term slip rate along the San Andreas fault based on 10Be-26Al surface exposure dating—The

Biska Palms site, 23 mm/yr for the last 30,000 years [abs.]: Eos, Transactions of the American Geophysical Union, v. 82, p. 934.

#5803 Wagner, D.L., 1977, Geology for planning in western Marin County, California: California Division of Mines and Geology Open-File Report 77-15SF, 40 p. pamphlet, scale 1:12,000.

#1423 Wallace, R.E., 1970, Earthquake recurrence intervals on the San Andreas fault: Geological Society of America Bulletin, v. 81, p. 2875–2890.

#5804 Wallace, R.E., 1990, General features, *in* Wallace, R.E., ed., The San Andreas fault system: U.S. Geological Survey Professional Paper 1515, p. 3-12.

#5806 Weldon, R.J., II, and Sieh, K.E., 1985, Holocene rate of slip and tentative recurrence interval for large earthquakes on the San Andreas fault, Cajon Pass, southern California: Geological Society of America Bulletin, v. 96, no. 6, p. 793-812.

#5807 Weldon, R.J., II, Meisling, K.E., and Alexander, J., 1993, A speculative history of the San Andreas fault in the central Transverse Ranges, California, *in* Powell, R.E., Weldon, R.J., II, and Matti, J.C., eds., The San Andreas fault system—Displacement, palinspastic reconstruction, and geologic evolution: Geological Society of America Memoir 178, p. 161-198.

#5809 Wells, D.L., Hall, N.T., Thornberg, J., Niemi, T.M., Zhang, H., Mansoor, N., and Gierke, J.C., 1999, Paleoseismic investigations of the northern San Andreas fault at Dogtown, Marin County, California: Geological Society of America Abstracts with Programs, v. 31, no. 6, p. 107.

#4947 Wilson, J.T., 1965, A new class of faults and their bearing on continental drift: Nature, v. 207, p. 343-347.

#5494 Working Group on California Earthquake Probabilities, 1988, Probabilities of large earthquakes occurring in California on the San Andreas fault: U.S. Geological Survey Open-File Report 88-398, 62 p.

#549 Working Group on California Earthquake Probabilities,

	1990, Probabilities of large earthquakes in the San Francisco Bay region, California: U.S. Geological Survey Circular 1053, 51 p. #4945 Working Group on California Earthquake Probabilities, 1995, Seismic hazards in southern California—Probable earthquakes, 1994 to 2024: Bulletin of the Seismological Society of America, v. 85, no. 2, p. 379-439. #4946 Working Group on California Earthquake Probabilities, 1999, Earthquake probabilities in the San Francisco Bay region; 2000 to 2030—A summary of findings: U.S. Geological Survey Open-File Report 99-517, 60 p. #1216 Working Group on Northern California Earthquake Potential (WGNCEP), 1996, Database of potential sources for earthquakes larger than magnitude 6 in northern California: U.S. Geological Survey Open-File Report 96-705, 40 p. #4948 Yule, D., Fumal, T., McGill, S., and Seitz, G., 2001, Active tectonics and paleoseismic record of the San Andreas fault, Wrightwood to Indio: Working toward a forecast for the next "big event", *in* Dunne, G., and Cooper, J., eds., Geologic excursions in the California deserts and adjacent Transverse Ranges: Geological Society of America Fieldtrip Guidebook and Volume prepared for the Joint Meeting of the Cordilleran Section GSA and Pacific Section AAPG, p. 91-126.