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San Andreas fault zone, Coachella section (Class A) No. 1j

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Compiled in cooperation with the California Geological Survey

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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:** The Coachella section of the San Andreas fault extends from the vicinity between Thousand Palms and Myoma southeast to near Bombay Beach, which is near the southeastern end of the

	Salton Sea. The Coachella section's northern boundary with the San Bernardino Mountains section [1i] is marked by the oblique junction of the North Branch San Andreas fault (Coachella strand) and South Branch San Andreas fault (Banning strand) into one principal dextral strike-slip fault near Biskra Palms. This section was originally designated as the Coachella segment by the Working Group on California Earthquake Probabilities (1988 #5494, 1995 #4945) and was adopted by Petersen and others (1996 #4860). **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)	IMPERIAL COUNTY, CALIFORNIA RIVERSIDE COUNTY, CALIFORNIA
Physiographic province(s)	BASIN AND RANGE
Reliability of location	Good Compiled at 1:24,000 scale. *Comments:* Location based on digital revisions to Jennings (1994 #2878) 1:750,00-scale map using original mapping by Hope (1969 #4960), Clark (1984 #4812), and Bryant (1987 #5818) at 1:24,000 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 70 km of a total fault length of 1082 km.
Average strike	N47°W
Sense of movement	Right lateral *Comments:* Well-defined geomorphic expression of dextral strike-slip fault (Hope, 1969 #4960; Clark, 1984 #4812; Bryant, 1987 #5818), historic dextral creep displacement documented by Louie

	and others (1985 #5731) and Sieh and Williams (1990 #5780). Detailed studies (Keller and others, 1982 #4964; Sieh, 1986 #5777; Sieh and Williams, 1990 #5780) have documented the amounts of late Quaternary, late Holocene, and historic dextral slip.
Dip Direction	V *Comments:* Vertical dip based on linear geomorphic expression of fault. Vertical to near vertical fault zone expressed in trench exposures by Sieh (1986 #5777) and Sieh and Williams (1990 #5780).
Paleoseismology studies	There are six detailed study sites along this section that have been investigated by Keller and others (1982 #4964), Sieh (1986 #5777), Sieh and Williams (1990 #5780), and Shifflett and others (2002 #5774). In addition, there are about 65 site-specific fault rupture hazard investigations along this section involving trenching done in compliance with the Alquist-Priolo Earthquake Fault Zoning Act of 1972 (Hart and Bryant, 1997 #4856). Biskra Palms site (1-6). Studies by Keller and others (1982 #4964) involved detailed mapping and geomorphic analysis of a portion of the North Branch San Andreas fault (Coachella strand) near Biskra Palms; this strand has been referred to as the Mission Creek fault by Keller and others. Keller and others calculated a late Pleistocene slip rate from a dextrally offset alluvial fan-pediment complex. Age control for the offset alluvial fan was provided by van der Woerd and others (2001 #5800). Indio site (1-12). Sieh (1986 #5777) excavated several 3-D trenches across traces of the San Andreas fault east of Indio. The San Andreas fault at the Indio site is maked by four strands in a 50-m-wide zone. Holocene lacustrine, fluvial, and aeolian deposits are dextrally displaced as much as 21 m. Sieh (1986 #5777) recognized at least four major slip events at the Indio site between AD 1000 and 1700. Sieh and Williams (1990 #5780) used the data from the Indio site to constrain the amount of dextral displacement for the most recent event and calculated an average slip (creep) rate for the past 300 yr. Ferrum site (1-20). Sieh and Williams (1990 #5780) excavated and logged 12 fault parallel trenches between two recessional beach ridges at the Ferrum site in order to identify and measure

	dextral offset of stratigraphic piercing points in order to calculate a historic slip rate. Sedimentary unit 3 was interpreted as a seaward-dipping, foreset-bedded inner planar portion deposited in the nearshore zone of the swash zone. Unit 2 unconformably overlies and truncates beds of unit 3. Sieh and Williams used the traces of the intersection of two unit 3 beds with the base of unit 2 as piercing points. Salt Creek site (1-21). At Salt Creek Sieh and Williams (1990 #5780) excavated serial exposures of faulted lacustrine sediment deposited after the latest filling of the Salton Sea in 1905 flooded the Salt Creek channel. A 2-m-wide fault zone displaces these historic lacustrine deposits. Thousand Palms Oasis site (1-48). Studies by Fumal and others (2002 #5726) involved the excavation and logging of 14 trenches (both fault normal and fault parallel) at Thousand Palms Oasis in order to resolve slip and evidence for individual rupture events along the fault. The trenches, which were less than 3 m deep due to high groundwater, exposed fluvial sediment including six major stream channels that have been eroded and filled during the past 1,600 yr. Evidence was reported for four and probably five surface-rupturing earthquakes between AD 800 and 1700. Stone Ring Gullies site (1-49). Shifflett and others (2002 #5774) excavated trenches and completed geologic mapping at the Stone Ring Gullies site in order to determine late Pleistocene and Holocene slip rates. The trenches exposed faulted late Pleistocene lagoonal deposits and geologic mapping of a dextrally offset paleofan provided piercing points for determination of a Holocene slip rate.
Geomorphic expression	The Coachella section is delineated by geomorphic features characteristic of Holocene dextral offset such as dextrally deflected and offset drainages, linear ridges and valleys, benches, dextrally offset ridges, linear scarps on alluvium, shutter ridges, beheaded drainages, and linear vegetation contrasts (Hope, 1969 #4960; Clark, 1984 #4812; Bryant, 1987 #5818).
Age of faulted surficial deposits	At the Biskra Palms site, Keller and others (1982 #4964) documented evidence of 700 m of dextral slip in 20- to 30-ka alluvial-fan deposits whose age was based on soil profile development and surface morphology. Sieh (1986 #5777) used radiocarbon dates of peat deposits to document late Holocene offset at the Indio site. Sieh and Williams (1990 #5780)

	documented offset of lacustrine and colluvial sediments at the Salt Creek site that post-date the latest desiccation of Lake Cahuilla about AD 1690.
Historic earthquake	
Most recent prehistoric deformation	latest Quaternary (<15 ka) *Comments:* Sieh (1986 #5777) reported that the most recent paleoevent along the Coachella section occurred between AD 1640 and 1720, with a preferred date of AD 1680. Sieh and Williams (1990 #5780) reported a date of AD 1676 (±35 yr) at the Indio site. Fumal and others (2002 #5726) identified the most recent event at Thousand Palms Oasis site that occurred after AD 1520-1680, with a preferred date of AD 1676.
Recurrence interval	150–300 yr (late Holocene) *Comments:* Sieh (1986 #5777) identified at least four major slip events between AD 1000 and 1700 at the Indio site. The event dates, based on radiocarbon dates of fluvial and lacustrine deposits, are AD 1680 (±40 yr), AD 1450 (±150 yr), AD 1300 (±90 yr), and AD 1020(±20 yr). The Working Group on California Earthquake Probabilities (1995 #4945) used data reported in Sieh (1986 #5777) to calculate an average recurrence interval of 220±13 yr. At the Thousand Palms Oasis site, at least four and probably five large earthquakes have occurred between AD 800 and 1700 (Fumal and others, 2002 #5726). Fumal and others (2002 #5726) reported a preferred average recurrence interval of 215±25 yr. Event dates at the Thousand Palms Oasis site are AD 1676 (+35, -156 yr), AD 1502 (±52 yr); AD 1231 (+59, -61 yr); AD 983 (+168, -142 yr), and AD 825 (+65, -55 yr).
Slip-rate category	Greater than 5.0 mm/yr *Comments:* Keller and others (1982 #4964) reported a preferred late Quaternary slip rate of 23–35 mm/yr for the North Branch San Andreas fault (Coachella strand) near Biskra Palms site. Keller and others (1982 #4964) called this trace the Mission Creek strand of the San Andreas fault. An alluvial fan-pediment complex is dextrally offset about 700 m. The age of the displaced fan complex was estimated from degree of dissection, relative soil profile development, and formation and preservation of desert pavement. Keller and other (1982 #4964) reported that the fan complex could be as old as 70 ka, but they preferred an age of

	about 20–30 ka. Subsequent age control based on ^{10}Be-^{26}Al surface exposure dating (van der Woerd and others, 2001 #5800) indicated an average age of 30.1±2.4 k.y. for the displaced fan complex. This new age determination suggests a late Quaternary slip rate of 23.3±3.5 mm/yr. Sieh (1986 #5777) identified about 21 m of dextral slip on the San Andreas fault at the Indio paleoseismic site. The 21 m of dextral slip occurred between AD 1000 and 1700 , based on radiocarbon dates of peat. This data indicated a late Holocene slip rate of about 30 mm/yr. Shifflett and others (2002 #5774) determined a minimum late Pleistocene dextral slip rate of 5–8 mm/yr, based on 185–275 m dextral offset of lagoon deposits at the Stone Ring Gullies site. The age of the lagoonal deposits is based on a coral-corrected date from algae (34,100 yr BP). A Holocene slip rate of 12±0.5 mm/yr was estimated using dextral offset of 28.4 m of an eroded edge of a paleo fan surface and the time of displacement was inferred from a 2,340±70 yr BP radiocarbon age on pedogenic CaCO3 from a soil horizon. Aseismic creep characterizes the Coachella section near to and southeast of Indio. Sieh and Williams (1990 #5780) calculated an average dextral slip (creep) rate of 3.4±0.7 mm/yr for the past three centuries at the Indio site. Sieh and Williams (1990 #5780) reported an average slip (creep) rate of 1.9±0.2 mm/yr at the Salt Creek site. Here a 2-m-wide zone of faults offset lacustrine sediment deposited in the Salt Creek channel after the latest filling of the Salton Sea, which occurred in 1905. Sieh and Williams (1990 #5780) correlated a stratigraphic pinch out of a lacustrine bed and measured 150±21 mm of post 1905 dextral slip, which occurred between 1906–1908 and April 1987 (82 yr). At the Ferrum site, Sieh and Williams (1990 #5780) identified and measured 1.15±0.15 m dextral offset of two reference planes in lacustrine unit 3. Sieh and Williams suggest that the displacement occurred after the latest desiccation of Lake Cahuilla about AD 1690 (±22 yr), which indicates a slip (creep) rate of 4.0±1.0 mm/yr.
Date and Compiler(s)	2002 William A. Bryant, California Geological Survey Matthew Lundberg, California Geological Survey
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