



LOCATIONS AND AGES OF MIDDLE TERTIARY VOLCANIC CENTERS IN COASTAL CALIFORNIA

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This report includes a map (fig. 1) and three tables (tables 1, 2, and 3) that summarize available information on the locations and ages of late Oligocene to middle Miocene volcanic centers in coastal California. This information, in turn, provides supporting documentation for a planned formal publication by D.S. Wilson, P.A. McCrory, and R.G. Stanley on the implications of volcanism in coastal California for the tectonic history of western North America.

In this report, “coastal California” generally means the area west of the San Andreas fault from Point Arena to the northwestern tip of Mexico (fig. 1). However, the map and tables in this report also include a few localities that are east of the San Andreas fault, including (1) the Neenach Volcanic Formation (fig. 1, locality NV), which is thought to have been contiguous with the Pinnacles Volcanic Formation (fig. 1, locality PV) prior to about 315 km of right-lateral displacement along the San Andreas fault (Matthews, 1973a, 1973b); (2) volcanic rocks in the Diligencia Formation (fig. 1, locality DF), which may have been adjacent to volcanic rocks of similar lithology and age in the Plush Ranch Formation (fig. 1, locality PL) and the Vasquez Formation (fig. 1, locality VF) prior to right-lateral displacements of about 210 km along the San Andreas fault and 60 km along the San Gabriel fault (Crowell, 1962; Bohannon, 1975); and (3) volcanic rocks in the Tecuya Formation (fig. 1, locality TE) and in the Tunis Creek area (fig. 1, locality TU), which may have been adjacent to volcanic rocks in the northern Gabilan Range (fig. 1, locality GR) prior to about 280–305 km of right-lateral displacement along the San Andreas fault (Hill and Dibblee, 1953, p. 448–449; Dickinson and others, 1972; Weigand and Thomas, 1990).

Tables 1, 2, and 3 include many, but not all, of the volcanic centers listed in previous compilations by Turner (1968, 1970), Weigand (1982), Johnson and O’Neil (1984), Fox and others (1985), Stanley (1987), Cole and Basu (1995), Dickinson (1997), and Cole and Stanley (1998). Also included in tables 1–3 are several volcanic centers, mainly in southern California, that were not listed in these older compilations. Additionally, the tables contain many new isotopic age determinations contained in recent publications by Luyendyk and others (1998), Nourse and others (1998), and Stakes and others (1999), and a small number of unpublished, preliminary age determinations by the U.S. Geological Survey.

The volcanic centers listed in this report are divided on the basis of age into three groups—27–25 Ma (table 1), 25–20 Ma (table 2), and 20–10 Ma (table 3)—mainly to facilitate discussion and the construction of paleogeographic maps (currently in progress). In a few cases, some overlap between the three age groups is possible on the basis of the reported determinations of age and their ranges of analytical error. Nevertheless, it seems to us that the available age data are consistent with the hypothesis that episodes of relatively intense volcanic activity occurred about 27–25 Ma, 24–22 Ma, and 18–15 Ma, and that these episodes were separated by intervals of reduced volcanic activity about 25–24 Ma and 22–18 Ma. This hypothesis can be tested further by obtaining new age data from the many occurrences of volcanic rocks in coastal California that remain to be accurately dated using modern isotopic, biostratigraphic, and paleomagnetic methods (see examples below).

Many well-known volcanic occurrences in coastal California and vicinity are intentionally omitted from tables 1, 2, and 3. These omissions include the following:

- ***Volcanic rocks that are mostly or entirely younger than 10 Ma.*** Examples include volcanic rocks along the Elsinore fault zone in Riverside County, which have yielded K–Ar ages generally in the range of 6.7 to 11.9 Ma (Morton and Morton, 1979a, b); volcanic rocks along the Calaveras fault zone in Santa Clara County, which have yielded K–Ar ages generally in the range of 2.5 to 3.6 Ma (Nakata and others, 1993); and an andesite dike along the Silver Creek fault zone in Santa Clara County that has yielded K–Ar ages of 9.3 to 10.5 Ma (Nakata and others, 1993).
- ***Volcanic rocks that are mostly or entirely older than 10 Ma and that are inferred by Stanley (1987), McLaughlin and others (1996), and Dickinson (1997) to be related to northwestward migration of the Mendocino triple junction.*** Examples include the Page Mill Basalt in Palo Alto, which has yielded K–Ar ages generally in the range of 14 to 15 Ma (Turner; 1970, p. 106; Mark Mason, University of California, Berkeley, oral commun., 1989); an unnamed dacitic tuff breccia near Los Gatos, which has yielded a K–Ar age of 15.6 ± 0.4 Ma (McLaughlin and others, 1991, p. 13; Nakata and others, 1993, p. 28); the Quien Sabe Volcanics (Taliaferro, 1948; Leith, 1949) and related(?) volcanic rocks of Santa Clara and San Benito Counties, which have yielded K–Ar ages generally in the range of 7.4 to 12.3 Ma (Nakata and others, 1993); and numerous occurrences of volcanic rocks in the Berkeley–East Bay Hills, northern San Francisco Bay, and Clear Lake areas, which have yielded K–Ar ages ranging from about .04 Ma to about 12.3 Ma (McLaughlin and others, 1996, and references therein).
- ***Volcanic rocks whose ages are so poorly known that we could not confidently assign them to one of the three age groupings in tables 1, 2, and 3.*** Examples include unnamed basalt in an exploratory oil well near Point Reyes in Marin County (Clark and others, 1984); unnamed volcanic rocks described as “augite andesite” in the northern Santa Lucia Range (Trask, 1926, p. 145–146); unnamed volcanic rocks in the Monterey Formation in the southern Salinas Valley (Dibblee, 1971; Durham, 1974, p. 41; Graham, 1976, p. 121); many small intrusions of diabase that cut Mesozoic and Cenozoic sedimentary strata in northern Santa Barbara County (Vedder and others, 1995 and unpublished data); several occurrences of basaltic and andesitic rocks in the vicinities of Sunland, Pacoima, and the eastern Santa Susana Mountains in Los Angeles County (Eaton, 1957); and numerous reported occurrences of volcanic rocks in the California offshore (for example, Hoskins and Griffiths, 1971; Vedder and others, 1974, 1981; Epstein and Nary, 1982; Crain and others, 1987, p. 416; Ogle and others, 1987; McCulloch, 1987, 1989; Clark and others, 1991).

The locations of the volcanic centers in tables 1, 2, and 3 are intended for use in constructing page-size paleogeographic maps at scales of 1:5,000,000 or thereabouts. In most cases, information on the actual locations of ancient volcanic vents is unavailable, and the specific locations given are based on (1) occurrences of associated intrusive rocks, some of which may represent conduits that conveyed magma to the surface; (2) visual approximations of the centers of the thickest accumulations of volcanic rocks, or (3) visual approximations of the geographic centers of the most areally extensive masses of volcanic rocks.

Most of the locations given in tables 1, 2, and 3 were measured from 1:24,000-scale geologic maps, but the locations of some (for example, the areally extensive Pinnacles Volcanic Formation of Matthews, 1973b) were measured from

1:250,000-scale geologic maps. Latitudes and longitudes were determined from paper copies of the maps using "The Coordinator," a commercially-manufactured device designed for this purpose, and converted to digital degrees using a pocket calculator. The latitudes and longitudes are reported to the nearest .01 degrees, implying accuracies of about ± 1.1 km measured in a north-south direction and about ± 0.9 km measured in an east-west direction at latitude 36 degrees north.

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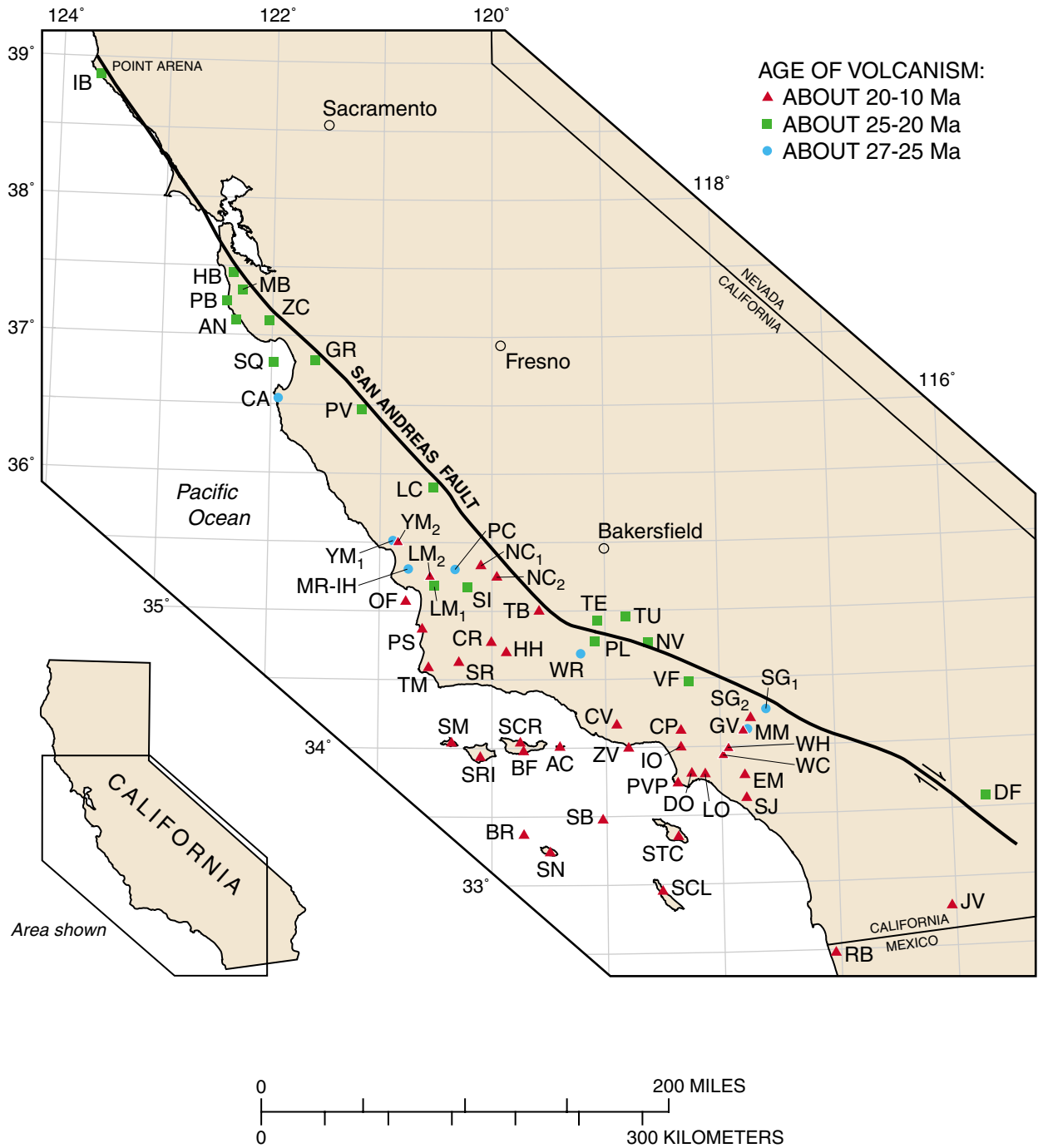


Figure 1. Map showing approximate locations of middle Tertiary volcanic centers in coastal California. See tables 1, 2, and 3 for explanation of letter symbols.

Table 1. Some occurrences in coastal California of volcanic rocks thought to represent volcanic centers that erupted approximately 27–25 Ma. See fig. 1 for locations

Latitude (°N)	Longitude (°W)	Map symbol	Occurrence	Basis for age assignment
36.56	-121.94	CA	Unnamed basalt of Carmel area, Monterey County	K–Ar ages (Clark and others, 1984): 27.1 ± 0.8 Ma and 27.0 ± 0.8, whole-rock(?)
35.49	-120.83	YM ₁	Unnamed felsic volcanic rocks of York Mountain area (older sequence), San Luis Obispo County	Field relations: volcanic rocks are interbedded with and overlain by sedimentary rocks of late Oligocene age (Seiders, 1982; Stanley and others, 1996a)
35.32	-120.73	MR–IH	Morro Rock–Islay Hill complex and Cambria Felsite of Ernst and Hall (1974), San Luis Obispo County	K–Ar ages (Turner, 1968): 27.1 ± 0.8 Ma* on biotite, 25.6 ± 1.2 Ma* and 22.7 ± 0.9 Ma* on plagioclase, 27.2 ± 0.8 Ma* on sanidine K–Ar age (Hall and others (1966): 24.1 ± 1.8 Ma* on plagioclase K–Ar ages (Buckley, 1986): 28.0 ± 1.0 Ma and 26.0 ± 0.8 Ma on biotite, 25.1 ± 0.8 Ma whole-rock ⁴⁰ Ar/ ³⁹ Ar single crystal laser fusion ages (J. D. Obradovich, M.A. Mason, and C.C. Swisher, cited by Cole and Stanley, 1998): 26.5–27 Ma on sanidine
35.32	-120.22	PC	Unnamed basaltic andesite of upper Pine Creek area, San Luis Obispo County	K–Ar age (Vedder and others, 1991): 26.5 ± 0.5 Ma on plagioclase
34.71	-119.20	WR	Unnamed felsic intrusive rocks of the Wagon Road Canyon area, Ventura County, (Vedder and others, 1973)	⁴⁰ Ar/ ³⁹ Ar single crystal laser fusion ages (R.J. Fleck and R.G. Stanley, U.S. Geological Survey, unpublished data): 25.2–25.0 Ma on sanidine
34.26	-117.60	SG ₁	Unnamed felsic intrusive rocks of the eastern San Gabriel Mountains, Los Angeles and San Bernardino Counties	⁴⁰ Ar/ ³⁹ Ar ages (Nourse and others, 1998): 26.30 ± 0.04 Ma and 25.7 ± 0.2 Ma on rhyolite dikes U/Pb age (May and Walker, 1989): 25.6 ± 1 Ma on zircon from granodiorite Rb/Sr ages (Hsu and others, 1963): 25 ± 15 Ma and 19 ± 15 Ma on biotite from quartz monzonite K–Ar ages (Hsu and others, 1963): 26 ± 3 Ma* and 17 ± 5 Ma* on biotite from quartz monzonite K–Ar ages (Miller and Morton, 1977): 19.1 ± 0.6 Ma*, 14.9 ± 0.4 Ma*, and 14.4 ± 0.4 Ma* on biotite from granodiorite [Note: the wide range of ages reported from these rocks is puzzling. There may have been multiple episodes of intrusion; alternatively, some of the reported ages may be erroneous]

34.10	-117.78	MM	Mountain Meadows Dacite Porphyry, Los Angeles County	⁴⁰ Ar/ ³⁹ Ar ages (Nourse and others, 1998): 28.0–27.5 Ma on biotite ⁴⁰ Ar/ ³⁹ Ar single crystal laser fusion age (L.A. Beyer, R.J. Fleck, T.H. McCulloh, and R.G. Stanley, U.S. Geological Survey, unpublished data): 27.3 ± 0.1 Ma on biotite
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* Isotopic age from original reference has been corrected for changes in decay constants using the method of Dalrymple (1979).

Table 2. Some occurrences in coastal California of volcanic rocks thought to represent volcanic centers that erupted approximately 25–20 Ma. See fig. 1 for locations

Latitude (°N)	Longitude (°W)	Map symbol	Unit	Basis for age assignment
38.86	-123.65	IB	Iversen Basalt of Weaver (1944), Mendocino County	K–Ar ages (Turner, 1970): 24.9 ± 1.3 Ma*, 23.4 ± 1.1 Ma*, and 23.2 ± 1.2 Ma* on plagioclase
37.47	-122.38	HB	Unnamed basalt near Half Moon Bay, San Mateo County	Field relations: basaltic rocks are interbedded with sedimentary rocks of late Oligocene and (or) early Miocene age (Mack, 1959; Classen, 1959; Stanley, 1987)
37.33	-122.25	MB	Mindego Basalt and related volcanic rocks, San Mateo and Santa Cruz Counties	K–Ar age (Turner, 1970): 20.2 ± 1.2 Ma* on plagioclase, interpreted by Turner as minimum age owing to incipient alteration of the dated plagioclase Field relations: basaltic rocks are interbedded with sedimentary rocks of late Oligocene and (or) early Miocene age (Cummings and others, 1962; Stanley, 1987)
37.27	-122.41	PB	Volcanic rocks (andesite?) in Vaqueros(?) Formation of Clark (1981), Pescadero Beach, San Mateo County	K–Ar age (Taylor, 1988, 1990; Stanley, 1987): 22.0 ± 0.7 Ma on plagioclase
37.12	-122.02	ZC	Basalt in Vaqueros Sandstone, Zayante Creek, Santa Cruz County	K–Ar age (Turner, 1970): 23.7 ± 0.7 Ma* on plagioclase
37.11	-122.32	AN	Volcanic rocks (andesite and basalt) in Vaqueros(?) Formation of Clark (1981), Point Año Nuevo, San Mateo County	Field relations: volcanic rocks apparently overlie sedimentary rocks of late Oligocene age and are overlain by sedimentary rocks of early Miocene age (Brabb and others, 1977; Clark, 1981; McDougall, 1983; Stanley, 1987)
36.82	-121.55	GR	Unnamed volcanic rocks (andesite, dacite, rhyolite, basalt) of the northern Gabilan Range, Monterey and San Benito Counties	K–Ar age (Turner, 1968): 22.2 ± 0.7 Ma* on biotite K–Ar ages (Weigand and Thomas, 1990): 23.5 ± 1.4 Ma on biotite, 21.3 ± 1.3 Ma whole–rock on andesite
36.80	-122.00	SQ	Unnamed basaltic andesite in Soquel Canyon, Monterey Bay	$^{40}\text{Ar}/^{39}\text{Ar}$ incremental heating age (Stakes and others, 1999): 23.7 ± 0.5 Ma on plagioclase

36.47	-121.18	PV	Pinnacles Volcanic Formation of Matthews (1973b) (mainly andesite, dacite, and rhyolite), Monterey and San Benito Counties	K–Ar ages (Turner, 1968): 22.1 ± 3.2 Ma* on biotite, 24.1 ± 0.7 Ma* on plagioclase, 24.5 ± 1.2 Ma* and 24.3 ± 0.7 Ma* whole–rock on rhyolite ⁴⁰ Ar/ ³⁹ Ar incremental heating ages (Weigand and Swisher, 1991; Weigand, 1991, written commun.): 22.82 ± 0.16 Ma on plagioclase, 23.24 ± 0.06 Ma on matrix from rhyolite
35.92	-120.50	LC	Unnamed volcanic rocks (mainly rhyolite) of Lang Canyon, Monterey County	K–Ar age (D.L. Turner, cited by Sims, 1993): 23.8 ± 0.7 Ma whole–rock on rhyolite
35.15	-120.47	LM ₁	Unnamed basaltic rocks near Lopez Mountain (older sequence), San Luis Obispo County	Field relations: basaltic rocks are interbedded with and overlain by fossiliferous sedimentary rocks of earliest Miocene age (McLean, 1995)
35.18	-120.21	SI	Basalt in Simmler Formation, Alamo Creek, San Luis Obispo County (Vedder and others, 1988)	K–Ar ages (Ballance and others, 1983): 23.4 ± 0.8 Ma and 22.9 ± 0.7 Ma whole–rock
34.97	-118.79	TU	Unnamed volcanic rocks (mainly basalt, andesite, and dacite) of Tunis Creek area, Kern County (Dibblee, 1973c)	⁴⁰ Ar/ ³⁹ Ar incremental heating ages (Plescia and others, 1994): 23.0 ± 1.0 Ma, 22.9 ± 0.9 Ma, and 22.3 ± 0.7 Ma whole–rock on basalt
34.93	-118.98	TE	Volcanic rocks (basalt, andesite, dacite, rhyolite) in Tecuya Formation, Kern County (Dibblee, 1973a, b, d, e; Cole and DeCelles, 1991)	K–Ar ages (Turner, 1968, 1970): 25.2 ± 2.9 Ma*, 24.6 ± 7.2 Ma*, and 18.1 ± 7.6 Ma* on plagioclase; 22.9 ± 0.7 Ma*, 22.5 ± 0.7 Ma*, 22.4 ± 0.7 Ma*, and 22.1 ± 0.6 Ma* on biotite
34.78	-119.09	PL	Volcanic rocks (mainly basalt and andesite) in Plush Ranch Formation of Carman (1964), Ventura County	K–Ar ages (Crowell, 1973): 20.1 ± 1.1 Ma* and 17.9 ± 3.7 Ma* on plagioclase K–Ar ages (Frizzell and Weigand, 1993): 26.5 ± 0.5 Ma, 25.3 ± 0.6 Ma, 24.2 ± 0.4 Ma, 23.9 ± 0.3 Ma, 23.1 ± 0.3 Ma, 20.9 ± 0.9 Ma, and 20.4 ± 0.9 Ma whole–rock [Note: the 20.9 Ma and 20.4 Ma ages reported by Frizzell and Weigand (1993) and the 20.1 Ma and 17.9 Ma ages reported by Crowell (1973) fail a critical value test and therefore are considered unreliable by Frizzell and Weigand (1993, p. 279)]

34.75	-118.55	NV	Neenach Volcanic Formation of Dibblee (1967) (mainly andesite, dacite, and rhyolite), Los Angeles County	<p>K–Ar minimum ages (D.L. Turner, cited by Matthews, 1973a): 24.1 Ma*, 23.0 Ma*, 22.5 Ma*, 19.3 Ma*, and 19.0 Ma*</p> <p>K–Ar ages (Weigand and Thomas (1990, who say that these are “improbably old”): 44 ± 1.3 Ma and 35 ± 1 Ma on plagioclase</p> <p>⁴⁰Ar/³⁹Ar incremental heating ages (Weigand and Swisher, 1991; Weigand, 1991, written commun., who says that only the plagioclase dates are believed to represent the age of eruption): 23.55 ± 0.25 Ma and 21.30 ± 0.22 Ma on plagioclase, 13.34 ± 0.16 Ma and 11.95 ± 0.24 Ma on matrix from andesite, 14.28 ± 0.20 Ma on matrix from rhyolite</p>
34.47	-118.29	VF	Volcanic rocks (mainly basalt, andesite, and dacite) in Vasquez Formation, Los Angeles County	<p>K–Ar age (Woodburne, 1975): 20.7 ± 0.8 Ma* on plagioclase</p> <p>K–Ar ages (Crowell, 1973): 25.6 ± 2.1 Ma* and 24.5 ± 0.8 Ma* on plagioclase</p> <p>K–Ar ages (Frizzell and Weigand, 1993): 23.6 ± 0.4 Ma, 25.4 ± 0.6 Ma, 20.6 ± 0.4 Ma, 19.6 ± 1.5 Ma, 17.2 ± 0.4 Ma, 17.0 ± 0.5 Ma, 15.2 ± 0.4 Ma, and 14.7 ± 0.4 Ma whole–rock; 37.5 ± 1.0 Ma on biotite</p> <p>[Note: Frizzell and Weigand (1993, p. 279) accept only the 23.6 Ma age reported by them and the 25.6 Ma and 24.5 Ma ages reported by Crowell (1973); all other ages are rejected as unreliable by Frizzell and Weigand (1993, p. 279) because they are inconsistent with biostratigraphic data and (or) fail a critical value test]</p>
33.55	-115.68	DF	Volcanic rocks (mainly basalt and andesite) in Diligencia Formation, Riverside County	<p>K–Ar age (Spittler, 1974): 19.1 ± 1.9 Ma* on plagioclase</p> <p>K–Ar ages (Crowell, 1973): 23.0 ± 2.9 Ma* and 20.6 ± 8.9 Ma* on plagioclase</p> <p>K–Ar ages (Frizzell and Weigand, 1993): 23.6 ± 0.5 Ma, 22.9 ± 0.5 Ma, 22.6 ± 0.3 Ma, 22.2 ± 0.5 Ma, 22.0 ± 0.5 Ma, and 21.3 ± 0.6 Ma whole–rock</p> <p>[Note: the 19.1 Ma age of Spittler (1974) is rejected as unreliable because it is inconsistent with biostratigraphic data (Frizzell and Weigand, 1993, p. 280)]</p>

* Isotopic age from original reference has been corrected for changes in decay constants using the method of Dalrymple (1979).

Table 3. Some occurrences in coastal California of volcanic rocks thought to represent volcanic centers that erupted approximately 20–10 Ma. See fig. 1 for locations

Latitude (°N)	Longitude (°W)	Map symbol	Unit	Basis for age assignment
35.49	-120.83	YM ₂	Unnamed basaltic rocks of York Mountain area (younger sequence), San Luis Obispo County	Field relations: basaltic rocks intrude sedimentary rocks of early Miocene age (Seiders, 1982; Stanley and others, 1996a)
35.33	-120.09	NC ₁	Unnamed basaltic rocks of the northwestern Caliente Range, San Luis Obispo County	Field relations: basaltic rocks overlie and are interstratified with fossiliferous sedimentary rocks of late early Miocene age and are overlain by sedimentary rocks of late early Miocene to middle Miocene age (Bartow, 1991)
35.26	-120.55	LM ₂	Unnamed volcanic rocks (basaltic andesite and vitric tuff) near Lopez Mountain (younger sequence), San Luis Obispo County	K–Ar age (McLean, 1994): 17.0 ± 0.5 Ma on plagioclase from basalt
35.22	-119.95	NC ₂	Unnamed basaltic rocks of the northwestern Caliente Range, San Luis Obispo County	Field relations: basaltic rocks overlie and are interstratified with fossiliferous sedimentary rocks of late early Miocene age and are overlain by sedimentary rocks of late early Miocene to middle Miocene age (Bartow, 1991)
35.08	-120.77	OF	Obispo Formation and related volcanic rocks (mainly rhyolite and dacite, with subordinate andesite and basalt), San Luis Obispo and Santa Barbara Counties	K–Ar ages (Turner, 1970): 16.9 ± 0.8 Ma*, 16.9 ± 1.2 Ma*, 16.7 ± 0.5 Ma*, 15.8 ± 0.5 Ma*, 15.7 ± 0.5 Ma*, 15.7 ± 0.5 Ma*, and 15.7 ± 0.9 Ma* on plagioclase Field relations: volcanic rocks overlie fossiliferous sedimentary rocks of early Miocene (Saucesian) age and are interbedded with and overlain by fossiliferous sedimentary rocks of late early Miocene to middle Miocene (Relizian) age (Hall and Corbató, 1967; Hall, 1973; Cole and Stanley, 1998) [Note: the location of the eruptive center of the white tuff that constitutes the bulk of the Obispo Formation is unknown (Schneider and Fisher, 1996) but may have been in the offshore and (or) Diablo Canyon area (Cole and Stanley, 1998). Other, subordinate eruptive centers (not shown on fig. 1) also probably existed but have not been documented]

35.00	-119.59	TB	Triple Basalts of Eaton (1939), Caliente Range, San Luis Obispo County	K–Ar ages (Turner, 1970): 16.5 ± 1.3 Ma*, 14.8 ± 0.8 Ma*, and 14.6 ± 0.6 Ma* on plagioclase Field relations: basalt flows are interstratified with fossiliferous nonmarine and marine strata of late early Miocene to middle Miocene age (Turner, 1970; Vedder, 1970)
34.89	-120.64	PS	Trachybasalt sill in Point Sal Formation near Point Sal, Santa Barbara County	Field relations: sill intrudes fossiliferous sedimentary rocks of late early Miocene to middle Miocene (Relizian) age (Woodring and Bramlette, 1950; Stanley and others, 1996b; Cole and Stanley, 1998)
34.76	-119.98	CR	Unnamed volcanic rocks (mainly basalt) of Catway Road area, Santa Barbara County	K–Ar age (Vedder and others, 1994): 18.8 ± 1.5 Ma on plagioclase K–Ar ages (Hall, 1981) 20.3 ± 1.6 Ma* and 17.2 ± 2.5 Ma* on whole-rock(?) Field relations: volcanic rocks overlie fossiliferous sedimentary rocks of early Miocene age, and are overlain by fossiliferous sedimentary rocks of late early Miocene to middle Miocene age (Stanley and others, 1996a; Cole and Stanley, 1998)
34.70	-119.88	HH	Unnamed basalt near Hells Half Acre, Santa Barbara County	K–Ar age (Fritsche and Thomas, 1990): 18.5 ± 2.0 Ma on whole-rock
34.61	-120.26	SR	Unnamed basaltic andesite of Santa Rosa Creek, Santa Barbara County	K–Ar age (Turner, 1970): 17.4 ± 1.2 Ma* on whole-rock Field relations: basaltic andesite overlies and is overlain by fossiliferous sedimentary rocks of late early Miocene age (Cole and Stanley, 1998)
34.58	-120.56	TM	Tranquillon Volcanics of Dibblee (1950), related volcanic rocks in Lospe Formation of central Santa Maria basin, and related volcanic rocks in lower part of Monterey Formation near Santa Barbara (mainly rhyolitic and dacitic tuffs), Santa Barbara County	$^{40}\text{Ar}/^{39}\text{Ar}$ single crystal laser fusion ages (Stanley and others, 1996a): 18.42 ± 0.06 Ma, 17.80 ± 0.05 Ma, and 17.70 ± 0.02 Ma on sanidine; 17.39 ± 0.06 Ma on plagioclase K–Ar ages (Turner, 1970): 16.5 ± 0.6 Ma* and 17.2 ± 0.5 Ma* on plagioclase Field relations: volcanic rocks are interbedded with fossiliferous sedimentary rocks of late early Miocene (Saucesian) age (Dibblee, 1950, 1966; De Paolo and Finger, 1991; Stanley and others, 1992, 1994, 1996a; Cole and Stanley, 1994, 1998)
34.20	-117.75	SG ₂	Andesitic and basaltic intrusive rocks of eastern San Gabriel Mountains, Los Angeles County	Correlated with Glendora Volcanics on the basis of similarities in geochemical composition (Nourse and others, 1998) Field relations: andesite and basalt intrude late Oligocene felsic intrusive rocks and are offset by late Miocene and younger right-lateral strike-slip faults (Nourse and others, 1998)

34.17	-118.92	CV	Conejo Volcanics of Yerkes and Campbell (1979) (basalt, andesite, and dacite), Ventura County	<p>K–Ar ages (Turner and Campbell, 1979): 16.0 ± 0.6 Ma*, 15.9 ± 0.8 Ma*, 15.2 ± 0.4 Ma*, 15.0 ± 0.7 Ma*, 14.3 ± 0.4 Ma*, and 13.4 ± 0.9 Ma* on plagioclase</p> <p>K–Ar ages (Turner, 1968; Turner, 1970): 16.6 ± 2.4 Ma* and 14.5 ± 1.0 Ma* on plagioclase</p> <p>Field relations: volcanic rocks overlie fossiliferous sedimentary rocks of late early Miocene to middle Miocene (Saucesian to Relizian) age, and interfinger with and are overlain by sedimentary rocks of middle Miocene (Luisian) age (Turner and Campbell, 1979; Dibblee and Ehrenspeck, 1993)</p>
34.13	-118.38	CP	Extrusive and minor intrusive rocks (basalt and andesite) in Middle Topanga Formation of Dibblee (1991a, b) near Cahuenga Pass, eastern Santa Monica Mountains, Los Angeles County	<p>Field relations: basaltic and andesitic rocks are interstratified with and intrude sedimentary rocks of late early Miocene to middle Miocene (Relizian and Luisian) age (Eaton, 1957)</p>
34.10	-117.80	GV	Glendora Volcanics (andesite and subordinate basalt, dacite, and rhyolite), Los Angeles County	<p>K–Ar ages (Nourse and others, 1998; P.W. Weigand, written commun., 1998): 19.6 ± 1.1 Ma, 18.8 ± 1.2 Ma, 18.2 ± 1.1 Ma, and 13.2 ± 0.4 Ma whole-rock on andesite and dacite</p> <p>$^{40}\text{Ar}/^{39}\text{Ar}$ ages (Nourse and others, 1998; P.W. Weigand, written commun., 1998): 16.3 ± 1 Ma and 15.9 ± 0.3 Ma on plagioclase</p> <p>Field relations: Glendora Volcanics overlie late Oligocene dacite, and are interstratified with fossiliferous sedimentary rocks of late early Miocene and middle Miocene age (Shelton, 1955; T.H. McCulloh, oral and written commun., 1998)</p>
34.03	-119.77	SCR	Santa Cruz Island Volcanics of Nolf and Nolf (1969) (mainly andesite, with subordinate dacite and basalt)	<p>$^{40}\text{Ar}/^{39}\text{Ar}$ incremental heating ages (Luyendyk and others, 1998): 17.12 ± 0.12 Ma, 16.9 ± 0.2 Ma, and 16.33 ± 0.26 Ma whole-rock on andesite; 17.0 ± 0.1 Ma and 16.9 ± 0.2 Ma on plagioclase from andesite</p> <p>K–Ar ages (Crowe and others, 1976): 19.9 ± 0.9 Ma* on plagioclase from dike; 15.9 ± 0.7 Ma* whole-rock on dike</p> <p>K–Ar ages (Turner, 1970): 16.5 ± 0.8 Ma* and 16.1 ± 0.9 Ma* on plagioclase from andesite</p> <p>Field relations: volcanic rocks are interbedded with and overlain by fossiliferous sedimentary rocks of late early Miocene to middle Miocene (Relizian) age (Crowe and others, 1976)</p>

34.03	-120.30	SM	San Miguel Volcanics of Avila and Weaver (1969), San Miguel Island (basalt, basaltic andesite, and dacite)	<p>$^{40}\text{Ar}/^{39}\text{Ar}$ incremental heating ages (Luyendyk and others, 1998): 18.5 ± 1.0 Ma and 17.0 ± 0.8 Ma whole-rock on basalt</p> <p>Field relations: volcanic rocks overlie fossiliferous sedimentary rocks of early Miocene (Saucesian) age and are overlain by fossiliferous sedimentary rocks of late early Miocene to middle Miocene (Relizian) age (Weaver and Doerner, 1969)</p> <p>[Note: the following published K–Ar ages are rejected as too old because they are contradicted by field relations and $^{40}\text{Ar}/^{39}\text{Ar}$ ages: 31.8 ± 3.5 Ma and 28.6 ± 3.2 Ma whole-rock on basalt (Kamerling and Luyendyk, 1985); 25.0 ± 3.0 Ma* on plagioclase from dacite (Crowe and others, 1976)]</p>
34.02	-119.36	AC	Unnamed volcanic rocks (basalt) of Anacapa Island	<p>$^{40}\text{Ar}/^{39}\text{Ar}$ incremental heating ages (Luyendyk and others, 1998): 16.28 ± 0.18 Ma and 16.15 ± 0.20 Ma on plagioclase; 15.8 ± 0.2 Ma whole-rock</p>
34.00	-118.37	IO	Unnamed intrusive and extrusive rocks (basalt and andesite) in subsurface, Inglewood oil field, Los Angeles County	<p>Field relations: extrusive rocks apparently are interstratified with sedimentary rocks of late early Miocene to middle Miocene (Relizian to Luisian) age (Eaton, 1958; Wright, 1987, 1991); intrusive rocks cut sedimentary rocks of middle Miocene (Luisian) age (Wright, 1991, p. 98)</p>
34.00	-118.80	ZV	Zuma Volcanics of Yerkes and Campbell (1979) (basalt and andesite), Los Angeles County	<p>K–Ar age (Berry and others, 1976): 15.0 ± 1.0 Ma* on plagioclase</p> <p>Field relations: volcanic rocks are interstratified with sedimentary rocks of early and middle Miocene age, and are overlain by sedimentary rocks of middle and late Miocene age (Yerkes and Campbell, 1979)</p>
33.98	-119.73	BF	Inferred source of dacitic, andesitic, and basaltic volcanoclastic rocks and minor lava flows in Blanca Formation of Weaver and others (1969) and Beechers Bay Formation of Dibblee and Ehrenspeck (1998), Santa Rosa Island	<p>$^{40}\text{Ar}/^{39}\text{Ar}$ age (Weigand and others, 1998, p. 39): 15.8 ± 0.08 Ma on plagioclase in andesite clast</p> <p>K–Ar ages (McLean and others, 1976): 14.9 ± 0.8 Ma* on basalt flow; 13.3 ± 1.2 Ma* on dacite clast</p> <p>Field relations: volcanoclastic rocks are interstratified with fossiliferous sedimentary rocks of late early Miocene and middle Miocene age (McLean and others, 1976; Nuccio and Wooley, 1998)</p>

33.95	-117.89	WH	Unnamed diabasic rocks (mainly in subsurface) within and northeast of Whittier fault zone, Los Angeles and Orange Counties	Field relations: diabase intrudes fossiliferous sedimentary rocks of late early Miocene to middle Miocene (Relizian to early Mohnian) age (Eaton, 1958; Durham and Yerkes, 1964; Yerkes, 1972; T.H. McCulloh, oral and written communs., 1996); clasts of similar diabase occur in early Pliocene (Repettian) conglomerate (Durham and Yerkes, 1964; Yerkes, 1972)
33.95	-120.10	SRI	Santa Rosa Island Volcanics of Dibblee and Ehrenspeck (1998) (basalt and basaltic andesite)	⁴⁰ Ar/ ³⁹ Ar incremental heating ages (Luyendyk and others, 1998): 19.3 ± 1.1 Ma and 18.1 ± 0.34 Ma whole-rock on diabase intrusions Field relations: volcanic rocks are interstratified with fossiliferous sedimentary rocks of late early Miocene (Saucesian to early Relizian) age, and diabase intrudes sedimentary strata as young as late early Miocene (Dibblee and Ehrenspeck, 1998)
33.90	-117.98	WC	Volcanic rocks (basalt and andesite) in subsurface, West Coyote oil field and vicinity, Orange County	Field relations: volcanic rocks overlie and may be interstratified with sedimentary rocks of late early Miocene to middle Miocene (Relizian) age and are interstratified with sedimentary rocks of middle Miocene (Luisian) age (Yerkes and others, 1965; Yerkes, 1972; Blake, 1991; Wright, 1991, p. 86–87)
33.87	-118.24	DO	Unnamed volcanic rocks (andesite and basalt) in subsurface, Dominguez oil field, Los Angeles County	Field relations: volcanic rocks overlie sedimentary rocks of middle Miocene (Luisian) age and are interstratified with and overlain by sedimentary rocks of middle Miocene (lower Mohnian) age (Graves, 1954; Eaton, 1958; West and others, 1987, 1988; T.H. McCulloh, oral and written communs., 1996 and 2000)
33.82	-118.16	LO	Unnamed volcanic rocks in subsurface, Long Beach Airport oil field, Los Angeles County	Field relations: volcanic rocks are interstratified with sedimentary rocks that are possibly but not assuredly of middle Miocene (Luisian) age (Wright, 1991, p. 71; T.H. McCulloh, oral and written communs., 2000)

33.78	-117.79	EM	El Modeno Volcanics (basalt and andesite), Orange County	<p>$^{40}\text{Ar}/^{39}\text{Ar}$ incremental heating ages (Luyendyk and others, 1998): 11.2 ± 0.2 Ma and 10.7 ± 0.2 Ma, whole-rock on basaltic andesite</p> <p>K–Ar age (Turner, 1970, p. 109): 14.1 ± 1.6 Ma* on plagioclase from andesite</p> <p>Field relations: volcanic rocks overlie and are interstratified with fossiliferous sedimentary rocks of middle Miocene (Luisian) age and are overlain by fossiliferous sedimentary rocks of upper middle Miocene (lower Mohnian) age (Yerkes, 1957; Smith, 1960; Schoellhamer and others, 1981; T.H. McCulloh, written commun., 1998)</p>
33.75	-118.35	PVP	Rhyolitic tuffs and basaltic and andesitic rocks in Altamira Shale Member of Monterey Formation, Palos Verdes Peninsula, Los Angeles County	<p>K–Ar age (Turner, 1970): 14.9 ± 1.1 Ma* on plagioclase in Portuguese tuff bed of Woodring and others (1946)</p> <p>Field relations: tuffs and basaltic extrusive rocks are interstratified with fossiliferous sedimentary rocks of middle Miocene (Relizian and Luisian) age; dikes and sills of andesite and basalt intrude sedimentary rocks of middle Miocene (Relizian and Luisian) age (Woodring and others, 1946; Eaton, 1957; Yerkes and others, 1965; Conrad and Ehlig, 1987; Blake, 1991)</p> <p>[Note: Eaton (1957) believes that the basaltic and andesitic rocks represent an episode of igneous activity older than the episode that produced the rhyolitic tuffs]</p>
33.60	-117.80	SJ	Extrusive and intrusive rocks (andesite and basalt) in the San Joaquin Hills–Newport Bay–Laguna Beach area, Orange County	<p>K–Ar age (Turner, 1970): 15.8 ± 1.3 Ma* on plagioclase from andesite</p> <p>Field relations: andesitic volcanic rocks are interstratified with fossiliferous sedimentary rocks of late early Miocene to middle Miocene age (Relizian to Luisian), whereas basaltic and andesitic dikes and sills intrude sedimentary rocks of late early Miocene to middle Miocene (Relizian to lower Mohnian) age (Vedder and others, 1957; Eaton, 1957, 1958; Yerkes and others, 1965; Blake, 1991)</p>

33.46	-119.04	SB	Santa Barbara Island Volcanics of Weigand and others (1998) (basalt and andesite)	<p>$^{40}\text{Ar}/^{39}\text{Ar}$ incremental heating ages (Luyendyk and others, 1998): 15.5 ± 1.0 Ma whole-rock on basalt</p> <p>K–Ar ages (Howell, 1976): 16.8 ± 2.0 Ma* and 14.8 ± 1.8 Ma* on plagioclase from andesite</p> <p>Field relations: volcanic rocks are interstratified with fossiliferous sedimentary rocks of late early Miocene to middle Miocene (Relizian to Luisian) age (Vedder and Howell, 1976)</p>
33.38	-118.42	STC	Unnamed volcanic and igneous intrusive rocks (andesite, dacite, basalt, and rhyolite) of Santa Catalina Island	<p>$^{40}\text{Ar}/^{39}\text{Ar}$ incremental heating age (Luyendyk and others, 1998): 17.2 ± 0.6 Ma whole-rock on basalt</p> <p>K–Ar age (Forman, 1970): 19.6 ± 0.7 Ma* on hornblende from quartz diorite</p> <p>K–Ar age (Vedder and others, 1979): 19.0 ± 0.6 Ma on biotite from granodiorite</p> <p>K–Ar ages (Vedder and others, 1979): 14.5 ± 0.4 Ma and 14.2 ± 0.7 Ma on plagioclase from dacite; 14.7 ± 0.3 Ma and 14.6 ± 0.3 Ma whole-rock on dacite; 14.8 ± 0.3 Ma, 13.8 ± 0.3 Ma, 12.7 ± 1.1 Ma, and 12.4 ± 1.1 Ma whole-rock on andesite; 13.2 ± 2.3 Ma and 13.0 ± 2.2 Ma on plagioclase from andesite; 14.0 ± 2.7 Ma and 12.9 ± 2.7 Ma whole-rock on basalt</p> <p>K–Ar age (Hawkins and Divis, 1975): 15 Ma on biotite from dacite</p> <p>Field relations: volcanic rocks appear to be interstratified with fossiliferous sedimentary rocks of middle and late(?) Miocene age (Vedder and Howell, 1976; Vedder and others, 1979)</p>
33.36	-119.69	BR	Unnamed rhyolite of Begg Rock	Field relations: rhyolite of uncertain but probable Miocene age is bounded by seafloor outcrops of fossiliferous sedimentary rocks of late early Miocene to late(?) Miocene age (Vedder and Howell, 1976)
33.22	-119.46	SN	Basaltic and andesitic dikes of San Nicolas Island	Field relations: dikes of uncertain but probable Miocene age (Vedder and Howell, 1976) intrude Eocene sedimentary strata but not Pleistocene deposits (Vedder and Norris, 1963)

32.92	-118.5	SCL	Unnamed volcanic rocks (andesite, dacite, rhyolite and basalt) of San Clemente Island	$^{40}\text{Ar}/^{39}\text{Ar}$ incremental heating ages (Luyendyk and others, 1998): 15.95 ± 0.15 Ma, 15.32 ± 0.04 Ma, 15.15 ± 0.15 Ma, and 14.48 ± 0.15 Ma whole-rock on basaltic andesite K–Ar ages (Turner, 1970): 15.4 ± 1 Ma* on plagioclase from andesite; 13.6 ± 0.4 Ma* on plagioclase from rhyolite K–Ar ages (Merifield and others, 1971): 16.1 ± 0.8 Ma* and 15.9 ± 0.7 Ma* whole-rock on andesite Field relations: volcanic rocks are interbedded with and overlain by fossiliferous sedimentary rocks of late early Miocene to middle Miocene (Relizian to Luisian) age (Vedder and Howell, 1976; Vedder and Moore, 1976)
32.75	-116.09	JV	Volcanic rocks (basalt and andesite) in Jacumba–Vallecitos area, San Diego and Imperial Counties	K–Ar ages (Gastil and others, 1979): 20.5 ± 2.0 Ma*, 19.2 ± 1.3 Ma*, and 16.4 ± 1.0 Ma* whole-rock on andesite and basalt; 19.0 ± 1.3 Ma* on plagioclase from andesite; 19.1 ± 1.2 Ma* on hornblende from andesite
32.48	-117.10	RB	Andesitic and basaltic volcanic rocks of the Rosarito Beach Formation of Minch (1967), Tijuana–Ensenada area, Mexico	$^{40}\text{Ar}/^{39}\text{Ar}$ incremental heating ages (Luyendyk and others, 1998): 16.2 ± 0.3 Ma, 16.14 ± 0.06 Ma, 15.9 ± 0.6 Ma, and 15.51 ± 0.14 Ma whole-rock on basalt K–Ar ages (Hawkins, 1970): 15.1 ± 1.3 Ma* and (or) 14.7 ± 2.6 whole-rock on basalt K–Ar age (Gastil and others, 1975): 16.5 ± 2.1 Ma on plagioclase from basaltic andesite Field relations: basaltic volcanic rocks are interstratified with sparsely fossiliferous sedimentary rocks of Miocene age (Minch, 1967; Gastil and others, 1975)

* Isotopic age from original reference has been corrected for changes in decay constants using the method of Dalrymple (1979).

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