U.S. Department of the Interior
U.S. Geological Survey

Scientific Investigations Map 3260
Sheet 1 of 2
Pamphlet accompanies map

Table 1. *Correlation of mapped units*

[ka, kilo-annum, 10^3 years; Ma, mega-annum, 10^6 years; OSL, optically stimulated luminescence (ages from S. Mahan, written commun., U.S. Geological Survey, 2012); --, no data]

Age	Terrace number	Geologic map unit name	Terrace elevation range (meters)	Arroyo Seco and Sierra de Salinas (west side of Salinas Valley): Terrace	Dominant alluvial soils	OSL age (years)	Alluvial fan or floodplain	Dominant alluvial soil	Bedrock terrace	Dominant residual soil	Terrace elevation range (meters)	Salinas River and Gabilan Mesa drainages (east side of Salinas Valley): Terrace	Dominant alluvial soil	Alluvial fan or floodplain	Dominant alluvial soil	Eolian	Soil	Bedrock	Dominant residual soil
latest Holocene (recent)		Qcb	--	--	--	--	cut bank	--	--	--	--	--	--	--	--	--	--	--	--
	20	Qfr2	60–200	active floodplain, includes gravel and sand bars	Psamments and Fluvents	--	active floodplain, includes gravel and sand bars	Psamments and Fluvents	--	--	60–90	--	--	active floodplain	Psamments and Fluvents	active sand dunes	Dune land (Df)	--	--
	19	Qfr1	70–200	terrace and floodplain	Psamments and Fluvents	--	floodplain	Tujunga	--	--	60–100	terrace	Psamments and Fluvents	--	--	--	--	--	--
late Holocene (recent–3 ka)	18	Qfy2	60–100	--	--	--	floodplain	Mocho, Metz, Pico	--	--	70–100	--	--	floodplain	Mocho, Metz, Pico	--	--	--	--
	17	Qfy1	70–380	terrace	Fluvents	1,030 ± 150 1,590 ± 190	alluvial fan	Fluvents	--	--	70–100	terrace	Salinas, Cropley	alluvial fan	Salinas, Cropley	--	--	--	--
middle to early Holocene (3–11.7 ka)	16	Qfay	70–180	terrace	Arroyo Seco, Lockwood	9,570 ± 680	alluvial fan	Arroyo Seco, Elder	--	--	70–190	--	--	alluvial fan	Gorgonio, Arroyo Seco	--	--	--	--
latest late Pleistocene (11.7–115 ka)	15	Qfai4	90–120	--	--	8,770 ± 350	alluvial fan	Rincon	--	--	90–120	terrace	Rincon	alluvial fan	Rincon	--	--	--	--
	14	Qfai3	140–300	terrace	Chualar, Lockwood	35,350 ± 3,680	alluvial fan	Chualar, Lockwood	terrace on Tertiary marine sediments (Tms)	Sheridan, Santa Lucia	--	--	--	--	--	--	--	--	--
	13	Qei	90–180	--	--	--	--	--	--	--	90–180	terrace	Garey	--	--	old sand dune	Garey	--	--
	12	Qfai2y	130–350	terrace	Lockwood	50,640 ± 2,980 45,960 ± 1,840	alluvial fan	Lockwood	terrace on Tms	Santa Lucia-Reliz assoc., Santa Lucia, Gazos	110–210	--	--	--	--	--	--	--	--
	11	Qfai2o	220–380	terrace	Lockwood	>65,000	alluvial fan	Lockwood	--	Santa Lucia, Gazos	--	--	--	--	--	--	--	--	--
early late Pleistocene (115–126 ka)	10	Qfai1	220–380	terrace	Placentia	>120,000	--	--	terrace on Tms and Paso Robles Formation	Santa Lucia, Chamise, Gazos	--	terrace	Placentia	--	--	--	--	--	--
	25	Qfai1	120–310	terrace on Paso Robles Formation	Chamise	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	30	Qfai1	180–390	--	--	--	--	--	terrace on Paso Robles Formation	Linne	--	terrace on Paso Robles Formation	Linne	--	--	--	--	terrace on Paso Robles Formation	Linne
late middle Pleistocene (126–300? ka)	9	Qao	240–300	terrace	Gloria	--	alluvial fan	Gloria	--	--	--	terrace	Gloria	--	--	--	--	--	--
middle to early Pleistocene (300?–781 ka)	8	Qfo8	280–420	terrace remnant	--	--	--	--	terrace on Tms	Santa Lucia, Lopez	--	--	--	--	--	--	--	--	--
	7	Qfo7	370–510	terrace remnant	--	--	--	--	terrace on Tms	Santa Lucia, Gazos	--	--	--	--	--	--	--	--	--
	6	Qfo6	420–570	terrace remnant	--	--	--	--	terrace on Tms	Santa Lucia, Gazos	--	--	--	--	--	--	--	--	--
	5	Qfo5	480–530	terrace remnant	--	--	--	--	terrace on Tms	Santa Lucia-Reliz assoc.	--	--	--	--	--	--	--	--	--
	4	Qfo4	490–580	terrace remnant	--	--	--	--	terrace on Tms	mixed	--	--	--	--	--	--	--	--	--
	3	Qfo3	560–660	terrace remnant	--	--	--	--	terrace on Tms	Santa Lucia-Reliz Ass, mixed	--	--	--	--	--	--	--	--	--
	2	Qfo2	610–670	terrace remnant	--	--	--	--	terrace on Tms	Santa Lucia-Reliz assoc.	--	--	--	--	--	--	--	--	--
	1	Qfo1	670–740	terrace remnant	--	--	--	--	terrace on Tms	Santa Lucia-Reliz assoc.	--	--	--	--	--	--	--	--	--
middle Pleistocene to Pliocene (450–4,000 ka)	35	QTpr	--	--	--	--	--	--	Paso Robles Formation (terrestrial alluvial sediments)	Linne	--	--	--	--	--	--	--	Paso Robles Formation	Linne, Shedd, and minor Nacimiento
Pliocene (2.6–5.33 Ma)	40	Tsa	--	--	--	--	--	--	Sandstone of San Ardo (shallow marine sediments)	Santa Lucia, Santa Lucia-Reliz assoc.	--	--	--	--	--	--	--	--	--
Pliocene to Miocene (2.6–23.0 Ma)	45	Tpr	--	--	--	--	--	--	Pancho Rico Formation (marine sediments)	Santa Lucia-Reliz assoc., Santa Lucia	--	--	--	--	--	--	--	--	--
Miocene to Paleocene (5.33–65.5 Ma)	50	Tms	--	--	--	--	--	--	Tertiary Marine Sediments (Tms) (primarily Monterey Formation)	Santa Lucia complex, Santa Lucia	--	--	--	--	--	--	--	--	--
Mesozoic to Paleozoic (older than 65.5 Ma)	55	MzPzub	--	--	--	--	--	--	Undifferentiated basement (MzPzub includes plutonic and meta-sedimentary rocks)	Cieneba, McCoy, Sheridan	--	--	--	--	--	--	--	undifferentiated basement (MzPzub), includes plutonic and meta-sedimentary rocks	McCoy, Sheridan, and Vista

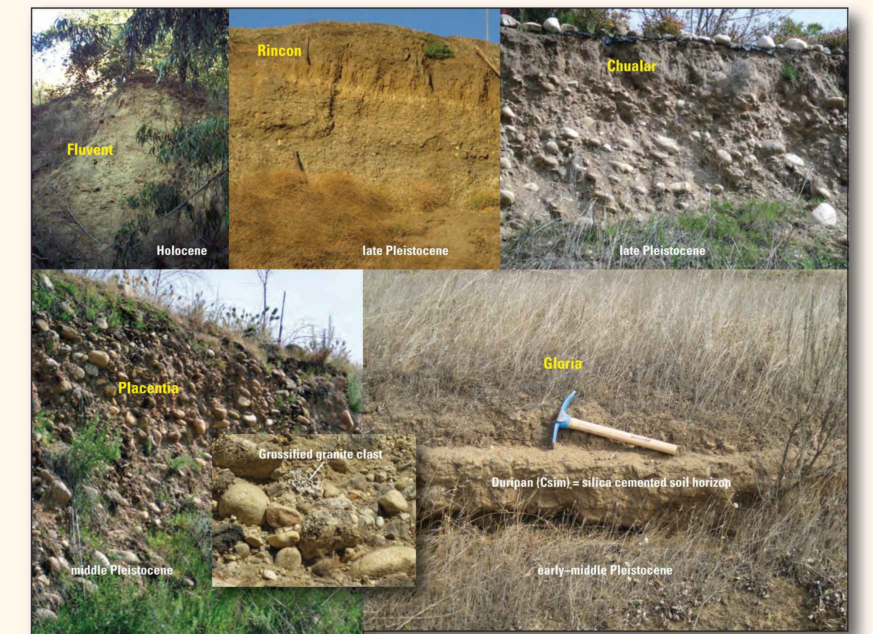


Figure 4. Unique soils are developed on the terrace surfaces. After deposition and fluvial abandonment, soils develop redder and thicker B horizons. These B horizons become increasingly cemented over time. Once intact gravel weathers to grus, only scattered and larger clasts are visible on the surface of the deposit. These photographs are typical common soils (names in yellow; table 2) developed on different-aged deposits (ages in white; table 1).

CORRELATION OF MAP UNITS

[Angled boxes represent estimated range of age uncertainty; Holocene and Pleistocene subdivisions and boundary ages are from Gibbard and others, 2010, p. 99]

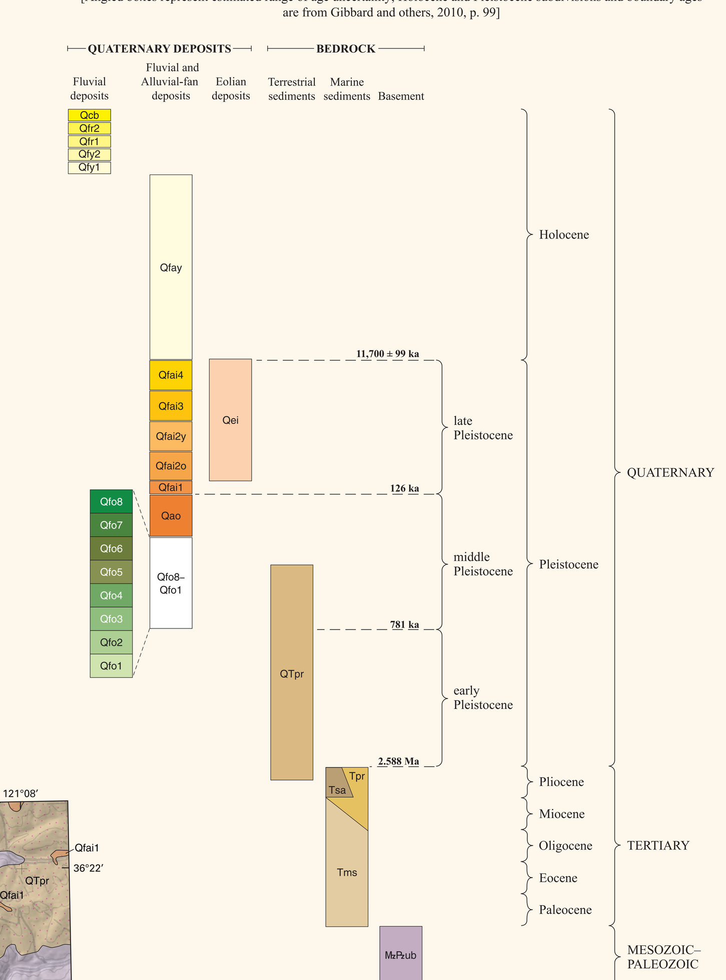


Table 2. *Summary of soil characteristics.*

[cm, centimeter; MaxClay, percent of clay in the maximally developed B horizon; %, percent; --, no data; NRCS, Natural Resources Conservation Service]

	Soil parent material	Parent material source	Soil series name[1]	Soil[2]	Tinsley and Dohrenwend (1979) nomenclature	Soil age	Simplified soil profile[3]	Munsell Color (2009) Bt hue color, and thickness (cm)	Horizon top with MaxClay (cm)	% Clay	Soil taxonomic classification	Miscellaneous
Alluvial and Eolian Soils	eolian sand	--	Dune land	Df	--	recent	C	--	0	0	--	--
	sandy and gravelly alluvium	mixed	Psamments	Ps, Pr	stream channel	recent	C	--	0	10	Mixed, thermic Typic Xeropsamments	--
	sandy alluvium	mostly granitic rocks, mixed	Tujunga	Tb	stream channel	recent	C	--	0	5	Mixed, thermic Typic Xeropsamments	--
	fine-loamy alluvium	sandstone and shale	Mocho, Metz, Pico	Mn, Mo, Me, Mf, Mg, Pf	Metz and Salinas terraces, Salinas-Docas surface	late Holocene	A/C	--	0	35	Fluventic Haploxerolls, Typic Xerofluvents, Fluventic Haploxerolls	Includes minor amounts of Clear Lake (Cf) and Pacheco (Pa, Pb) soils
	fine-loamy alluvium	sandstone and shale	Salinas, Cropley	Sb, Cn	--	middle Holocene	A/C	--	0 0	35 60	Fine-loamy, mixed, superactive, thermic Pachic Haploxerolls; Aridic Haploxererts	Includes minor amounts of Docas (De) soil
	sandy and gravelly alluvium	mixed	Fluvents	Fa	--	late Holocene	A/C	--	0	5	Sandy-skeletal, mixed, thermic Typic Xerofluvents	--
	sandy and gravelly alluvium	granitic and sedimentary rocks	Arroyo Seco, Elder	As, Av, Ea, Eb, Ec	Arroyo Seco fan system, Salinas-Docas surface	late Holocene	A/C	--	0 0	18 18	Coarse-loamy, mixed, thermic Fluventic or Cumulic Haploxerolls	--
	coarse-loamy alluvium	granitic rocks (basement rocks)	Gorgonio	Gk	--	late Holocene	A/C	--	0	15	Sandy, mixed, thermic Fluventic Haploxerolls	Includes minor amounts of Danville (Da) (A/Bt/Btk) soils
	clayey alluvium	siliceous shale, sandstone and ashy rocks (fine-grained Monterey Formation)	Rincon	Ra	Chualar fan system, Chualar-Rincon terrace	late Pleistocene	A/Bt/Cca	10YR, 61	36	45	Fine, smectitic, thermic Mollic Haploxeralfs	--
	loamy alluvium	mostly granitic rocks, mixed	Chualar	Cb	Chualar fan system, Chualar-Rincon terrace	late-middle Pleistocene	A/Bt/C	7.5YR, 64	53	25	Fine-loamy, mixed, thermic Typic Argixerolls	--
	coarse-loamy eolian sand	eolian sand dune	Garey	Gb, Gc	eolian deposits	late-middle Pleistocene	A/Bt/C	10YR to 7.5YR, 51	76	15	Mixed, thermic Psammentic Haploxeralfs	--
	fine-loamy alluvium	siliceous shale, sandstone and ashy rocks (fine-grained Monterey Formation)	Lockwood	Ld, Le	--	middle Pleistocene	A/Bt/C	10YR, 127	102	35	Fine-loamy, mixed, thermic Pachic Argixerolls	--
	coarse-loamy alluvium	granitic rocks (basement rocks)	Placentia	Pn, Po	Placentia fan system, Placentia-Chamise terrace	middle Pleistocene	A/Bt/C	7.5YR to 5YR, 115	33	50	Fine, smectitic, thermic Typic Natrixeralfs	Includes minor amount of Pinnacles (Pg) (A/Bt/C) soils, clasts are decomposed in B horizon
	loamy alluvium	siliceous shale, sandstone and ashy rocks (fine-grained Paso Robles Formation)	Chamise	Ca	Placentia fan system, Placentia-Chamise terrace	middle Pleistocene	A/Bt/C	10YR, 48	48	55	Clayey-skeletal, mixed, thermic Ultic Palexerolls	Present as strath terraces on the Paso Robles Formation
	coarse-loamy alluvium	granitic rocks (basement rocks)	Gloria	Gh	Gloria fan system, Gloria-Pinnacles terraces	early-middle Pleistocene	A/Bt/Csim	7.5YR to 5YR, 51	41	60	Fine, illitic, thermic Abruptic Durixeralfs	Silica cemented duripan
Residual Soils	silty and clayey residuum	calcareous shale and sandstone (Paso Robles Formation)	Linne	La, Lb, Lc	--	late Pleistocene	A/C	--	0	35	Fine-loamy, mixed, thermic Calcic Pachic Haploxerolls	Present as residual soils on the Paso Robles Formation
	fine-loamy residuum	calcareous shale and sandstone (Paso Robles Formation)	Nacimiento	Na	--	late Pleistocene	A/Bk/Cr	--	0	35	Fine-loamy, mixed, superactive, thermic Calcic Haploxerolls	Present primarily as residual soils on the Paso Robles Formation
	silty and clayey residuum	siliceous shale, sandstone and ashy rocks (fine-grained Monterey Formation)	Shedd Santa Lucia,	SmG	--	late(?) Pleistocene	A/C	--	0	35	Fine-silty, mixed, superactive, calcareous, thermic Typic Xerorthents	Present primarily as residual soils on Paso Robles Formation, few exposures on Tms
	shaly clayey residuum	siliceous shale and ashy rocks (fine-grained Monterey Formation)	Reliz, Lopez complex	Sg	--	late Pleistocene	A/R	--	0 0 0	35 30 27	Complex	--
	sandy and gravelly residuum	granitic rocks (basement rocks)	Cieneba Sur,	Cc, Cd, Ce	--	late(?) Pleistocene	A/Cr	--	0	18	Loamy, mixed, nonacid, thermic, shallow Typic Xerorthents	--
	stony coarse-loamy residuum	granitic rocks (basement rocks)	Junipero complex	Ss	--	late Pleistocene	A/C/R	--	0 0	20 18	Complex	--
	shaly clayey residuum	siliceous shale, sandstone and ashy rocks (fine-grained Monterey Formation)	Santa Lucia	Sf	--	late Pleistocene	A/R	--	0	35	Clayey-skeletal, mixed, thermic Pachic Ultic Haploxerolls	Present primarily as residual soils on Paso Robles Formation and Tms
	coarse-loamy residuum	granitic rocks (basement rocks)	Sheridan	So	--	late Pleistocene	A/C	--	0	18	Coarse-loamy, mixed, superactive, thermic Pachic Haploxerolls	--
	coarse-loamy residuum	granitic rocks (basement rocks)	Vista	Va, Vb	--	late(?) Pleistocene	A/Bw/Cr	--	0	15	Coarse-loamy, mixed, superactive, thermic Typic Haploxerepts	--
	fine-loamy residuum	granitic rocks (basement rocks)	McCoy	Ma, Mb	--	middle Pleistocene	A/Bt/Cr	10YR, 23	46	35	Fine-loamy, mixed, superactive, thermic Pachic Argixerolls	--
Minor Residual Soils	silty and clayey residuum	shale or sandstone	Alo	Aa	--	late Pleistocene	A/Bk/Cr	10YR, 56	0	55	Fine, smectitic, thermic Aridic Haploxererts	--
	clayey residuum	siliceous shale, sandstone and ashy rocks (fine-grained Monterey Formation)	Diablo	Dd	--	late Pleistocene	A/Bk/C	--	0	60	Fine, smectitic, thermic Aridic Haploxererts	--
	coarse-loamy residuum	sandstone	Gaviota	Gd, Ge	--	late(?) Pleistocene	A/R	--	0	18	Loamy, mixed, superactive, nonacid, thermic Lithic Xerorthents	--
	fine-loamy residuum	shale and sandstone	Gazos	Gf	--	late Pleistocene	A/Bw/R	--	0	27	Fine-loamy, mixed, thermic Pachic Haploxerolls	--
	clayey residuum	shale and sandstone	Haire	Ha	--	late Pleistocene	A/Bt/C	10YR, 30	61	60	Clayey, mixed, thermic Typic Haploxerults	--
	fine-loamy residuum	diatomaceous shale	Lopez	Lh	--	late Pleistocene	A/R	--	0	27	Loamy-skeletal, mixed, thermic Lithic Ultic Haploxerolls	--
	fine-loamy residuum	sandstone and shale	Los Osos	Lm	--	middle Pleistocene	A/Bt/C	10YR, 46	28	50	Fine, smectitic, thermic Typic Argixerolls	--
Cut Bank	sandy and gravelly alluvium	mixed	Xerorthents	Xd	--	--	C	--	0	35	Xerorthents	--

[1] NRCS soil classification from USDA (2009)
[2] NRCS abbreviation of soil name from USDA (2009)
[3] USDA (2009)

Figure 1. Photograph of the paleoerosional surface in the Tertiary marine sediments looking northwest to the bounding resistant basement rocks (MzPzub) (see map for location of photographic viewpoint). Nearly flat rolling topography lies in basin now isolated from fluvial erosion. The paleoerosional surface in the northwest corner of the mapped Tertiary marine sediment (Tms) records an ancestral drainage, prior to the major incision of Arroyo Seco. This surface is bound by a complex network of faults and is from 400 to 600 meters above the active drainage.

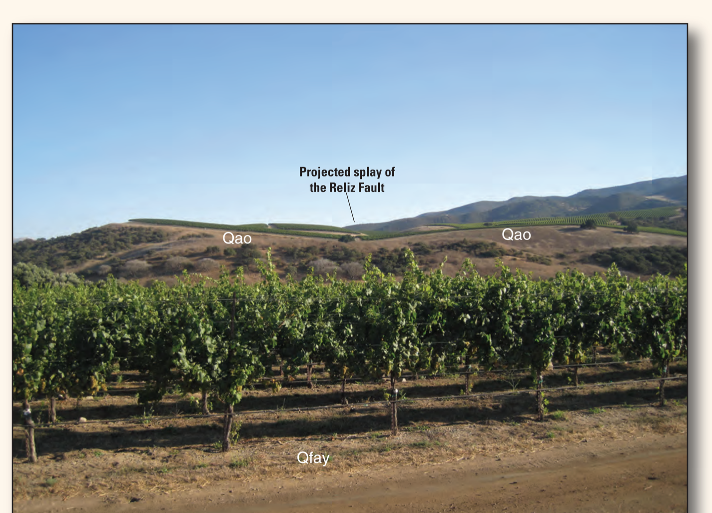


Figure 2. Where a splay of the Reliz fault crosses Qao, the topography appears warped. This view looking south (see map for location of photographic viewpoint) is one of very few possible locations where Quaternary offset is visible on the Reliz fault. The late middle Pleistocene unit, mapped at the surface, appears to be downwarped at the projected location of the fault.

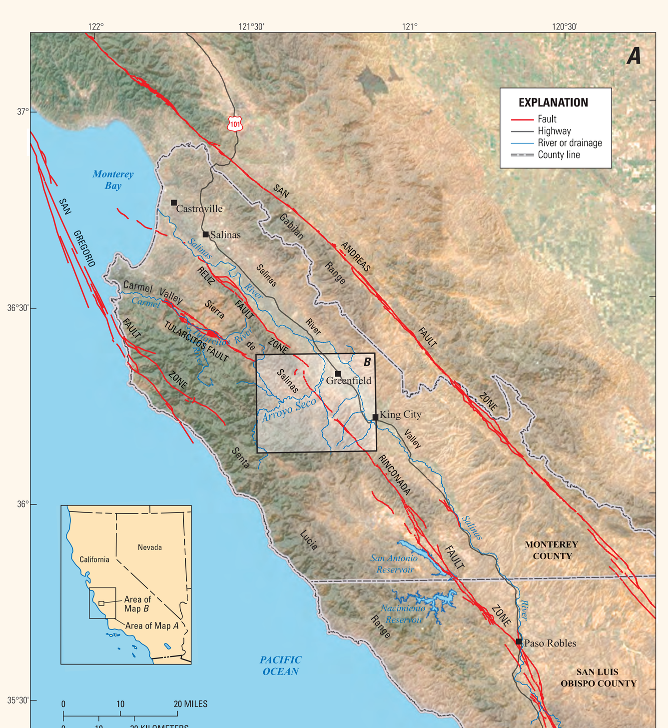
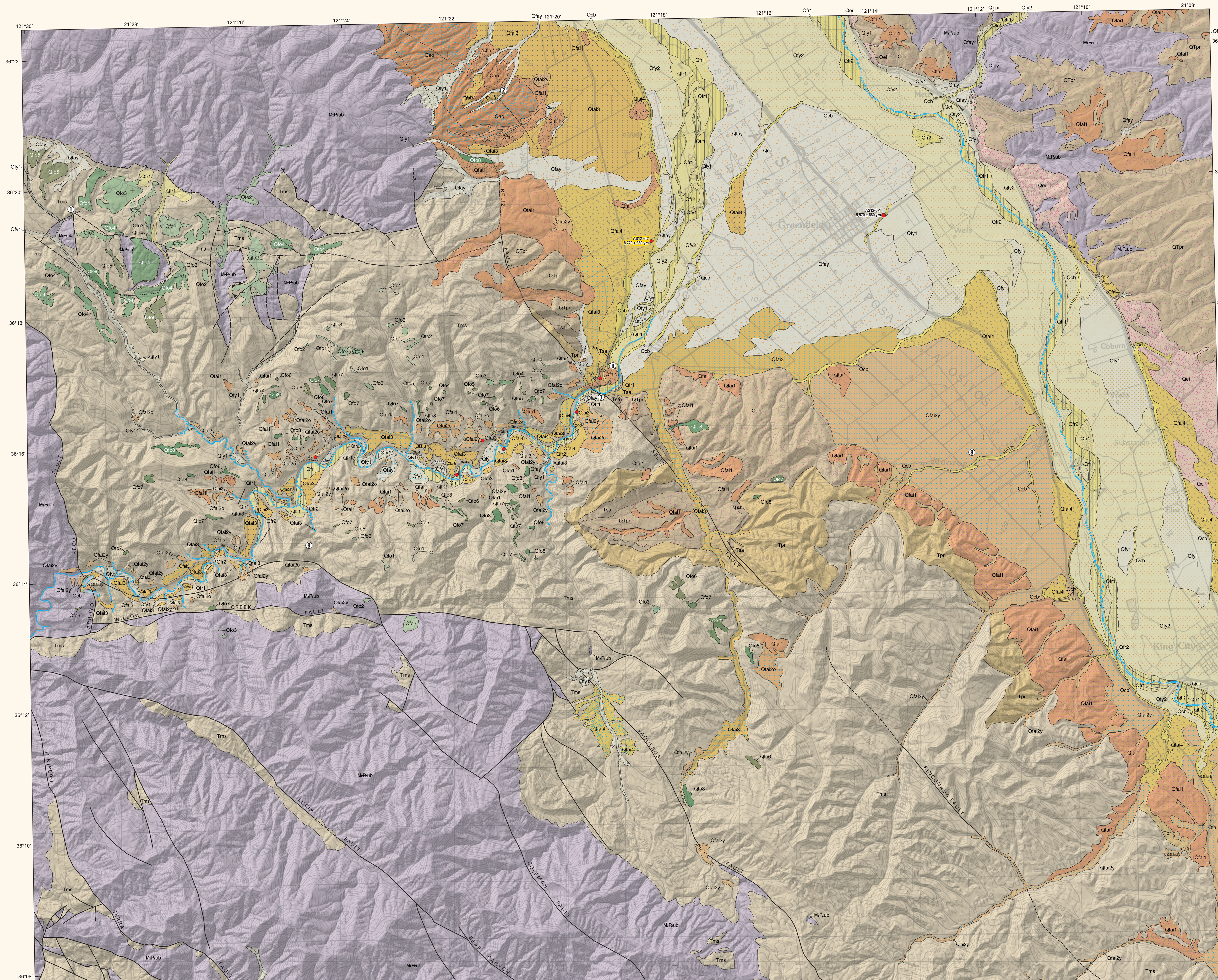


Figure 3. Location map of Arroyo Seco located in Monterey County in coastal, central California. Location map *A* shows the regional context of the mapping at Arroyo Seco. Location map *B* indicates the area of the 1:50,000-scale map shown on sheet 1. Arroyo Seco, in the Sierra de Salinas, is bound on the east by the Salinas River valley. Quaternary-age strath terraces were eroded into resistant basement rocks and Tertiary marine sediments in Arroyo Seco and the sediments were deposited in the Salinas River valley. The Salinas River also provides a source for fine-grained sediments on the valley floor producing terrace and floodplain deposits at and adjacent to the river.



SCALE 1:50 000
CONTOUR INTERVAL 10 METERS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

LIST OF MAP UNITS

- Qcb — Cut bank (latest Holocene)
- Qfr2 — Fluvial and minor eolian deposits (latest Holocene)
- Qfr1 — Fluvial deposits (latest Holocene)
- Qfy2 — Fluvial deposits (late Holocene)
- Qfy1 — Fluvial deposits (late Holocene)
- Qfay — Fluvial and alluvial deposits (middle to early Holocene)
- Qfai4 — Fluvial and alluvial deposits (latest late Pleistocene)
- Qfai3 — Fluvial and alluvial deposits (latest late Pleistocene)
- Qei — Eolian deposits (latest late Pleistocene)
- Qfai2y — Fluvial and alluvial deposits (latest late Pleistocene)
- Qfai2o — Fluvial and alluvial deposits (latest late Pleistocene)
- Qfai1 — Fluvial and alluvial deposits (early late Pleistocene)
- Qao — Alluvial deposits (late middle Pleistocene)
- Qfo8–1 (Qfo8, Qfo7, Qfo6, Qfo5, Qfo4, Qfo3, Qfo2, Qfo1) — Fluvial deposits (middle to early Pleistocene)
- QTpr — Paso Robles Formation (middle Pleistocene to Pliocene)
- Tsa — Shallow nearshore marine regressive sediments (Pliocene)
- Tpr — Pancho Rico Formation (Pliocene to Miocene)
- Tms — Tertiary marine sediments (Miocene to Paleocene)
- MzPzub — Undifferentiated basement rocks (Mesozoic to Paleozoic)

EXPLANATION OF MAP SYMBOLS

- **Contact**
- **Faults**—Solid where location is accurate; dashed where location is approximate or inferred; dotted where location is concealed
- **Thrust fault**—Sawteeth on upper plate
- **Major rivers and drainages**
- **Optically stimulated luminescence sample location and age**—Sample number and ages are labeled on sheet 1 only outside of Arroyo Seco; sample numbers and ages within Arroyo Seco are labeled on sheet 2 (AS10-9-8 1,590 ± 190 yrs)
- (9) **Location of photographic viewpoint**—Number indicates figure number on plate

SOIL TYPES

[Soil types were identified using the soil map of Monterey County (Cook, 1978), in digital format [United States Department of Agriculture (USDA), 2009]

- **Arroyo Seco gravelly sandy loam, Elder sandy loam**
- **Chamise loam**
- **Chualar loam**
- **Cropley silty clay, Salinas**
- **Dune**
- **Fluvents stony**
- **Garey sandy loam**
- **Gloria sandy loam**
- **Gorgonio sandy loam**
- **Linne silty clay loam**
- **Lockwood loam**
- **Metz loamy sand, Moncho silty loam, Pico sandy loam**
- **Placentia sandy loam**
- **Psamments, Fluvents**
- **Rincon clay loam**
- **Tujunga sand**

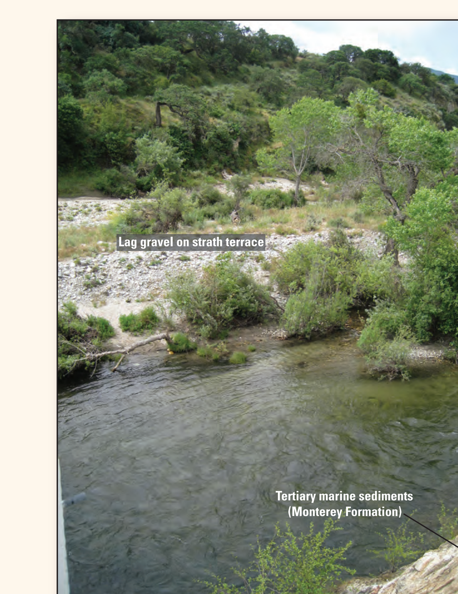


Figure 5. Strath terrace formation can be observed today in the active channel of Arroyo Seco. As the floodplain erodes the bedrock, lag gravel remains at the surface. Once the floodplain is abandoned, these gravels serve as markers for the tops of the strath terraces.

Figure 6. Lag gravel and a secondary fine-grained component compose a typical soil profile (see map for location of photographic viewpoint). The fine-grained component is largely eolian in origin.

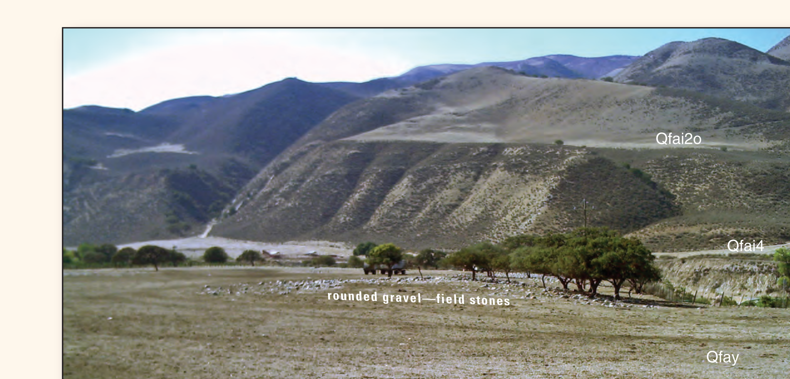


Figure 7. Rounded gravel derived from the resistant basement rocks (MzPzub) often occur at the eroded edges of strath terraces. These gravel deposits serve as useful field evidence for recording tops of strath terrace surfaces. The terrace in the foreground (see map for location of photographic viewpoint) is capped with rounded gravel, often referred to as field stones.

Figure 8. Strath terraces eroded into the Paso Robles (QTpr) and the Pancho Rico (Tpr) Formations are well preserved in the foothills that define the mouth of Arroyo Seco (see map for location of photographic viewpoint). This erosional surface can be projected to the east side of the Salinas River valley suggesting a floodplain of the Salinas River at least 70 to 100 m above the modern floodplain.

Figure 9. View looking northeast across Arroyo Seco (see map for location of photographic viewpoint). Middle to late Pleistocene strath terraces can be observed. Arroyo Seco is at about 160–170 meters in this reach and the visible terraces range from about 30 to 250 meters above the drainage. Dashed yellow lines are terrace surfaces.

Quaternary Geologic Map of the North-Central Part of the Salinas River Valley and Arroyo Seco, Monterey County, California

By
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2014

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