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U.S. Geological Survey

Scientific Investigations Map 3306
Sheet 10 of 10
Pamphlet accompanies map

Onshore elevation data collected by Photoscience in 2005 for U.S. Geological Survey and County of San Mateo. Offshore shaded-relief bathymetry from map on sheet 2, this report. California's State Waters limit from NOAA Office of Coast Survey
Universal Transverse Mercator projection, Zone 10N

NOT INTENDED FOR NAVIGATIONAL USE

14° TRUE NORTH MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 2014

SCALE 1:24 000
1 MILE
7000 FEET
1 KILOMETER
BATHYMETRIC CONTOUR INTERVAL 10 METERS
ONE MILE = 0.869 NAUTICAL MILES

Offshore geology and geomorphology mapped by Janet T. Watt, H. Gary Greene, Stephen R. Hartwell, Charles A. Endris, Stephanie L. Ross, Eleyne L. Phillips, and Bryan E. Dieter, 2009-2012. Onshore geology compiled by Michael W. Manson from Brabb (1980), Weber and Lajoie (1980), California Geological Survey (1982, 2002b), Brabb and others (1998), and Witter and others (2006). Bathymetric contours by Peter Dartnell

GIS database and digital cartography by Janet T. Watt, Stephen R. Hartwell, and Eleyne L. Phillips

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Offshore and Onshore Geology and Geomorphology, Offshore of San Gregorio Map Area, California

By

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2014

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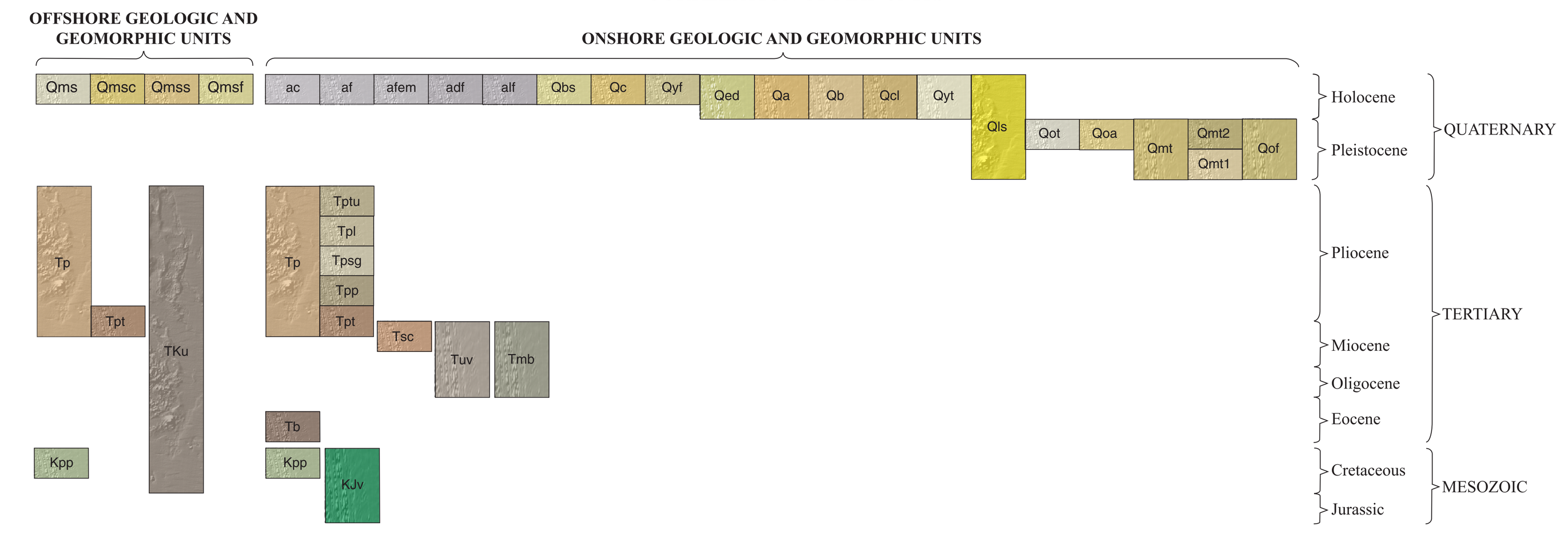
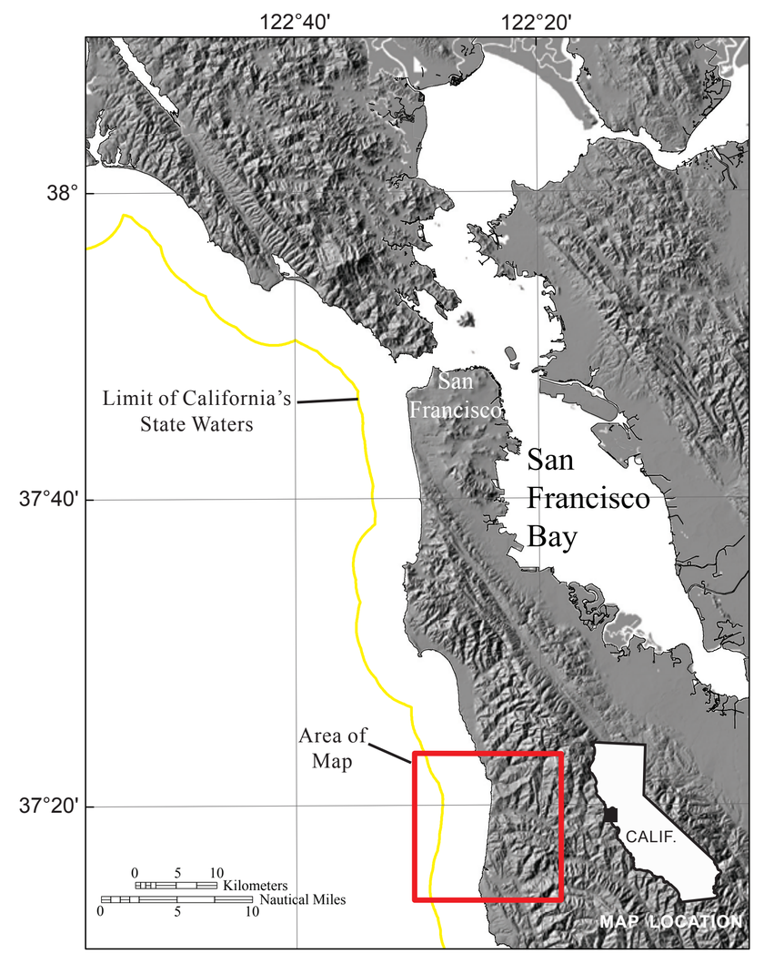
CORRELATION OF MAP UNITS





LIST OF MAP UNITS

[See Description of Map Units (chapter 8, in pamphlet) for complete map-unit descriptions]

OFFSHORE GEOLOGIC AND GEOMORPHIC UNITS

[Note that composite units (gray-stippled areas) are designated on map by composite label indicating both overlying sediment cover and lower (older) unit, separated by slash (for example, Qms/Tp indicates that thin sheet of Qms overlies Tp)]

- Qms — **Marine nearshore and shelf deposits (late Holocene)**—Mostly sand; ripples common
- Qmsc — **Coarse-grained marine nearshore and shelf deposits (late Holocene)**—Predominantly coarse sand, gravel, cobbles, and boulders
- Qmss — **Marine shelf scour depressions (late Holocene)**—Inferred to be coarse sand and gravel
- Qmsf — **Fine-grained marine nearshore and shelf deposits (late Holocene)**—Mostly mud, very fine sand, and silt
- Tp — **Purisima Formation, undivided (Pliocene and late Miocene)**—Marine sandstone, siltstone, and mudstone
- Tpt — **Tahana Member (Pliocene and late Miocene)**—Medium-grained to very fine-grained lithic sandstone and siltstone, with some silty mudstone, tuffaceous sandstone, and pebble conglomerate
- TKu — **Bedrock, undivided (Tertiary and Cretaceous)**—May consist of rocks of the Purisima Formation, the unnamed Miocene and Oligocene sedimentary and volcanic rocks unit, or the Pigeon Point Formation
- Kpp — **Pigeon Point Formation (Late Cretaceous)**—Sandstone and conglomerate, interbedded with siltstone and mudstone

ONSHORE GEOLOGIC AND GEOMORPHIC UNITS

[Units are compiled from Brabb (1980), Weber and Lajoie (1980), Brabb and others (1998), and Witter and others (2006); unit ages, which are from these sources, reflect local stratigraphic relations. Locations of some faults are from California Geological Survey (1982, 2002b)]

- ac — **Artificial stream channel (late Holocene)**—Modified, realigned, or straightened stream channels
- af — **Artificial fill (late Holocene)**—Rock, sand, and mud, deposited by humans
- afem — **Artificial fill over estuarine mud (late Holocene)**—Material deposited by humans over estuarine sediment
- adf — **Artificial-dam fill (late Holocene)**—Earth- or rock-fill dams, embankments, and levees; constructed to impound land-locked water bodies
- alf — **Artificial-levee fill (late Holocene)**—Artificial levees bordering rivers, streams, salt ponds, and sloughs; constructed to contain floodwater or tidal waters
- Qbs — **Beach-sand deposits (late Holocene)**—Active beaches in coastal environment; may form veneer over bedrock platform
- Qc — **Stream-channel deposits (late Holocene)**—Fluvial deposits within active, natural stream channels
- Qyf — **Alluvial fan deposits (late Holocene)**—Alluvial fan deposits; judged to be late Holocene (<1,000 years) in age, on basis of records of historical inundation or presence of youthful braid bars and distributary channels. Internal contacts delineate individual alluvial fans
- Qed — **Estuarine-delta deposits (Holocene)**—Heterogeneous mixture of coarse and fine estuarine sediment; deposited in delta at mouths of tidally influenced coastal streams, where fresh water mixes with seawater
- Qa — **Alluvial deposits, undivided (Holocene)**—Alluvium; deposited in fan, terrace, or basin environments
- Qb — **Basin deposits (Holocene)**—Fine-grained sediment that accumulates from standing or slow-moving water in topographic basins
- Qcl — **Colluvium (Holocene)**—Loose to firm, unsorted sand, silt, clay, gravel, rock debris, and organic material, in varying proportions
- Qyf — **Stream-terrace deposits (Holocene)**—Relatively smooth, undissected terraces less than 8 to 10 m above active channel
- Qls — **Landslide deposits (Holocene and Pleistocene)**—Disintegrated bedrock; physically weathered; unit ranges from deep-seated landslides to active colluvium. Internal contacts delineate individual landslide masses
- Qot — **Older stream-terrace deposits (late Pleistocene)**—Relatively flat, slightly dissected stream terraces; late Pleistocene age is indicated by degree of soil development and by height of terrace above flood level
- Qoa — **Older alluvial deposits, undivided (late Pleistocene)**—Alluvial fan or terrace surfaces; late Pleistocene age is indicated by depth of stream incision, degree of soil development, and lack of historical flooding
- Qmt — **Marine-terrace deposits, undivided (Pleistocene)**—Sand and gravel, deposited on uplifted marine-abrasion platforms along coast. Local relative ages designated by numbers from youngest (Qmt2) to oldest (Qmt1)
- Qmt2 — **Younger marine-terrace deposits (Pleistocene)**—Younger sand and gravel, deposited on uplifted marine-abrasion platforms along coast
- Qmt1 — **Older marine-terrace deposits (Pleistocene)**—Older sand and gravel, deposited on uplifted marine-abrasion platforms along coast
- Qof — **Older alluvial fan deposits (late to early Pleistocene)**—Moderately well to deeply dissected alluvial deposits; in places, original fan-surface morphology is preserved
- Tp — **Purisima Formation, undivided (Pliocene and late Miocene)**—Medium-grained to very fine-grained, poorly indurated to friable sandstone, siltstone, and claystone, with conglomerate lenses and a few beds of white volcanic ash
- Tptu — **Tunitas Sandstone Member (Pliocene)**—Fine-grained sandstone, siltstone, and mudstone; some porcelaneous shale and mudstone, chert, silty mudstone, and volcanic ash
- Tpl — **Lobitos Mudstone Member (Pliocene)**—Unbedded silty mudstone
- Tpsg — **San Gregorio Sandstone Member (Pliocene)**—Fine- to coarse-grained sandstone that has calcareous concretions
- Tpp — **Pomponio Mudstone Member (Pliocene)**—Porcelaneous shale and mudstone; in places, rhythmically bedded with alternating layers of nonsiliceous mudstone
- Tpt — **Tahana Member (Pliocene and late Miocene)**—Medium-grained to very fine-grained lithic sandstone and siltstone, interbedded with some silty mudstone, tuffaceous sandstone, and pebble conglomerate
- Tsc — **Santa Cruz Mudstone (late Miocene)**—Siliceous mudstone, interbedded with nonsiliceous mudstone, siltstone, and minor sandstone
- Tuv — **Unnamed sedimentary and volcanic rocks (Miocene and Oligocene)**—Mainly pebbly, crossbedded, hard arkosic sandstone in Pescadero Point area; grades to hard mudstone in Año Nuevo area, 15 km south of map area
- Tmb — **Mindego Basalt and related volcanic rocks (Miocene and Oligocene)**—Basaltic volcanic rocks, both extrusive and intrusive
- Tb — **Butano Sandstone (middle and early Eocene)**—Very fine- to very coarse-grained arkosic sandstone, interbedded with mudstone and shale; conglomerate is present locally in lower part of section
- Kpp — **Pigeon Point Formation (Late Cretaceous)**—Sandstone and conglomerate, interbedded with siltstone and mudstone
- KJv — **Unnamed volcanic rocks (Cretaceous or Jurassic)**—Finely crystalline, felsic volcanic rock that contains quartz and albite phenocrysts

EXPLANATION OF MAP SYMBOLS

Contact

Fault—Solid where location is certain, long-dashed where location is approximate, short-dashed where location is inferred, dotted where location is concealed, queried where uncertain

Reverse fault—Solid where location is certain, dashed where location is approximate, dotted where location is concealed, queried where uncertain. Boxes on upthrown block

Folds—Solid where location is certain, long-dashed where location is approximate, short-dashed where location is inferred, dotted where location is concealed, queried where uncertain

Anticline

Syncline

Approximate modern shoreline—Defined as Mean High Water (MHW) (+1.46 m), North American Vertical Datum of 1988 (NAVD 88)

3-nautical-mile limit of California's State Waters

Area of "no data"—Areas beyond 3-nautical-mile limit of California's State Waters were not mapped as part of California Seafloor Mapping Program

DISCUSSION

Marine geology and geomorphology were mapped in the Offshore of San Gregorio map area from approximate Mean High Water (MHW) to the 3-nautical-mile limit of California's State Waters. MHW is defined at an elevation of 1.46 m above the North American Vertical Datum of 1988 (NAVD 88) (Weber and others, 2005). Offshore geologic units were delineated on the basis of integrated analyses of adjacent onshore geology with multibeam bathymetry and backscatter imagery (sheets 1, 2, 3), seafloor-sediment and rock samples (Reid and others, 2006), digital camera and video imagery (sheet 6), high-resolution seismic-reflection profiles (sheet 8), and aeromagnetic data (McCulloch and Chapman, 1977; U.S. Geological Survey, 2001).

Onshore geology was compiled from Brabb (1980), Weber and Lajoie (1980), California Geological Survey (1982, 2002b), Brabb and others (1998), and Witter and others (2006).

The continental shelf within California's State Waters in the Offshore of San Gregorio map area is shallow (less than about 55 m) and flat with a very gentle (less than 0.5°) offshore dip. Shelf morphology and evolution are the result of the interplay between local tectonics and sedimentation as sea level rose about 125 to 130 m over the last about 21,000 years (see, for example, Lambeck and Chappell, 2001; Gornitz, 2009), leading to the progressive eastward migration (a few tens of kilometers) of the shoreline and wave-cut platform and the associated transgressive erosion and deposition (see, for example, Catuneanu, 2006). The Offshore of San Gregorio map area is now an open-ocean shelf that is subjected to full, and sometimes severe, wave energy and strong currents. Shelf deposits are almost exclusively sand (unit Qms) at water depths less than 60 m, but, at greater depths in the southwestern part of the map area, they transition to the finer grained, muddy sediments of unit Qmsf. The boundary between units Qms and Qmsf is based on observations and extrapolation from sediment sampling (Reid and others, 2006) and camera ground-truth surveying (sheet 6). It is important to note that the boundary between units Qms and Qmsf should be considered transitional and approximate, as it likely shifts seaward or landward as a result of seasonal- to annual- to decadal-scale changes in sediment supply, sediment transport, and wave climate.

Coarser grained deposits (coarse sand and gravel) of units Qmss and Qmsc are recognized primarily on the basis of their high backscatter (see sheet 3). Unit Qmsc is mapped as a nearshore, shore-parallel bar at water depths typically between 5 and 10 m. Unit Qmss typically exists as erosional lags in scour depressions whose contacts with horizontal sand sheets of unit Qms usually are relatively sharp but, less commonly, also can be diffuse. These scour depressions, which generally form irregular to lenticular exposures that have abrupt landward contacts with bedrock, typically are a few tens of centimeters deep and range in size from a few tens of meters to more than 1 km². Such scour depressions are common along this stretch of the California coast (see, for example, Cacchione and others, 1984; Hallenbeck and others, 2012), where offshore sandy sediment is relatively thin (and, thus, is unable to fill the depressions) owing to low sediment supply and also to erosion and transport of sediment during large northwest winter swells.

Bedrock units mapped in the offshore include two units of the upper Miocene and Pliocene Purisima Formation (units Tp and Tpt). Rocks of the Purisima Formation are characterized by their high backscatter (sheet 3), as well as their distinct bedding style (caused by differential erosion), which is recognized in multibeam imagery and (or) seismic-reflection data (see sheets 1, 2, 8). These Tertiary rocks are underlain by, or in fault contact with, Upper Cretaceous basement rocks, including sedimentary rocks of the Pigeon Point Formation (unit Kpp). The Pigeon Point Formation is mapped on the basis of its high backscatter, its massive and (or) rugged texture on multibeam imagery (sheets 1, 2), and its reflection-free character on seismic-reflection profiles (sheet 8). Offshore outcrops of the Pigeon Point Formation expose part of the Pigeon Point high (McCulloch, 1987).

In areas where bedrock is exposed on the seafloor but where less certainty exists regarding age, the undivided Cretaceous and Tertiary bedrock unit (TKu) is mapped. This undivided bedrock unit may include rocks of the Upper Cretaceous Pigeon Point Formation, the Oligocene and Miocene unnamed sedimentary and volcanic rocks unit (Tuv) (mapped onland near the mouth of Pescadero Creek), or the upper Miocene and Pliocene Purisima Formation.

In areas where shelf sediments form thin (less than 2.5 m) veneers over low-relief rocks of the undivided Cretaceous and Tertiary bedrock unit or the upper Miocene and Pliocene Purisima Formation, composite units Qms/TKu and Qms/Tp are mapped. These composite units are recognized on the basis of the combination of flat relief, continuity with moderate- to high-relief bedrock outcrops, high-resolution seismic-reflection data (sheet 8), and (in some cases) moderate to high backscatter. Overlying sediment is interpreted as an ephemeral and dynamic sediment layer that may or may not be continuously present, depending on storms, seasonal and (or) annual patterns of sediment movement, or longer term climate cycles. Storlazzi and others (2011) described the seasonal burial and exhumation of submerged bedrock in a similar high-energy setting in northern Monterey Bay, about 40 km south of the map area.

The Offshore of San Gregorio map area lies about 15 to 25 km southwest of the San Andreas Fault, the dominant structure in the distributed transform boundary between the North American and Pacific plates. The map area straddles the right-lateral San Gregorio Fault system, a prominent structure west of the San Andreas Fault in the broader San Andreas Fault system. The San Gregorio Fault system extends for about 400 km from Point Conception on the south to Bolinas and Point Reyes on the north (Dickinson and others, 2005), predominantly in the offshore but also onshore at coastal promontories such as Pescadero Point in the map area and also at Pillar Point, 14 km north of the map area and a few kilometers north of Half Moon Bay (see sheet 9, Map E).

In the Offshore of San Gregorio map area, the San Gregorio Fault system forms a distributed shear zone about 2 to 4 km wide that includes two main diverging fault strands (fig. 1). The west strand (also known as the Frijoles Fault), which extends offshore from Pescadero Point, forms the boundary between rocks of the upper Miocene and Pliocene Purisima Formation on the east and the undivided Cretaceous and Tertiary rocks (Pigeon Point Formation?) on the west. The east strand (also known as the Coastways Fault or Seal Cove Fault) is mostly onshore in this map area. Seismic-reflection profiles (see sheet 8) reveal that the offshore exposures of the Purisima Formation between the east and west strands of the San Gregorio Fault Zone are highly deformed compared to those of the undivided Cretaceous and Tertiary rocks west of the Frijoles Fault.

Cumulative lateral slip on the San Gregorio Fault Zone is thought to range from 4 to 10 mm/yr in this area (U.S. Geological Survey and California Geological Survey, 2010). The entire map area lies along strike with the young, high topography of the Santa Cruz Mountains and Coast Ranges (see sheet 9). Rates of uplift of nearby marine terraces of as much as 0.44 mm/yr near Año Nuevo, 15 km south of the map area, confirms that regional uplift is ongoing and that it includes the coastal zone (Weber, 1990).

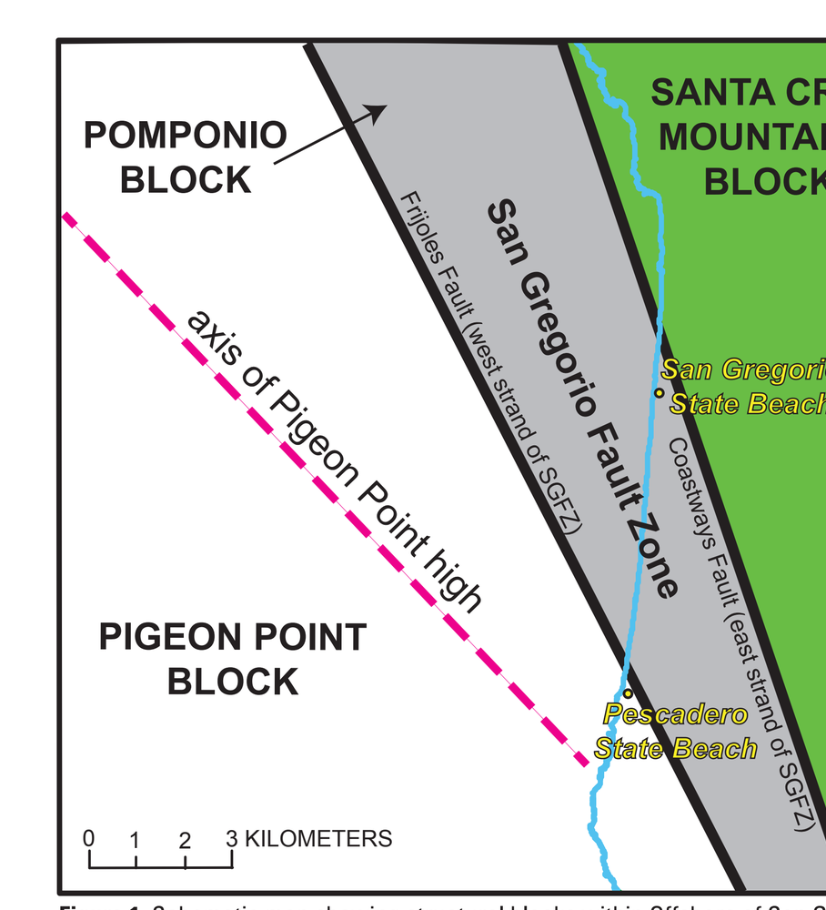


Figure 1. Schematic map showing structural blocks within Offshore of San Gregorio map area. Pigeon Point block and Pigeon Point high (McCulloch, 1987) are separated from Santa Cruz Mountains block by Pomponio block, which is bounded by Frijoles Fault (to west) and Coastways Fault (to east), two strands of San Gregorio Fault Zone (SGFZ). Blue line shows coastline. Modified from Weber (1990).

REFERENCES CITED

Brabb, E.E., 1980, Preliminary geologic map of the La Honda and San Gregorio quadrangles, San Mateo County, California: U.S. Geological Survey Open-File Report 80–245, scale 1:24,000.

Brabb, E.E., Graymer, R.W., and Jones, D.L., 1998, Geology of the onshore part of San Mateo County, California—A digital database: U.S. Geological Survey Open-File Report 98–137, scale 1:62,500, available at http://pubs.usgs.gov/of/1998/of98-137/.

Cacchione, D.A., Drake, D.E., Grant, W.D., and Tate, G.B., 1984, Rippled scour depressions of the inner continental shelf off central California: Journal of Sedimentary Petrology, v. 54, p. 1,280–1,291.

California Geological Survey, 1982, Alquist-Priolo earthquake fault zone map of Franklin Point quadrangle: California Geological Survey, State of California Special Studies Zone Map, scale 1:24,000, available at http://www.quake.ca.gov/gmaps/WH/regulatorymaps.htm.

California Geological Survey, 2002b, Fault evaluation reports prepared under the Alquist-Priolo Earthquake Fault Zoning Act, region 1, central California: California Geological Survey, CGS CD 2002–01, available at http://www.conservation.ca.gov/cgs/rghm/ap/ap_fer_cd/Pages/index.aspx.

Catuneanu, O., 2006, Principles of sequence stratigraphy: Amsterdam, Elsevier, 375 p.

Dickinson, W.R., Ducea, M., Rosenberg, L.I., Greene, H.G., Graham, S.A., Clark, J.C., Weber, G.E., Kidder, S., Ernst, W.G., and Brabb, E.E., 2005, Net dextral slip, Neogene San Gregorio–Hosgri fault zone, coastal California—Geologic evidence and tectonic implications: Geological Society of America Special Paper 391, 43 p.

Gornitz, V., 2009, Sea level change, post-glacial, *in* Gornitz, V., ed., Encyclopedia of paleoclimatology and ancient environments: Springer, Encyclopedia of Earth Sciences Series, p. 887–893.

Hallenbeck, T.R., Kvitek, R.G., and Lindholm, J., 2012, Rippled scour depressions add ecologically significant heterogeneity to soft-bottom habitats on the continental shelf: Marine Ecology Progress Series, v. 468, p. 119–133.

Lambeck, K., and Chappell, J., 2001, Sea level change through the last glacial cycle: Science, v. 292, p. 679–686, doi: 10.1126/science.1059549.

McCulloch, D.S., 1987, Regional geology and hydrocarbon potential of offshore Central California, *in* Scholl, D.W., Grantz, A., and Vedder, J.G., eds., Geology and resource potential of the continental margin of western North America and adjacent ocean basins—Beaufort Sea to Baja California: Circum-Pacific Council for Energy and Mineral Resources, Earth Science Series, v. 6, p. 353–401.

McCulloch, D.S., and Chapman, R.H., 1977, Map showing residual magnetic intensity along the California coast, latitude 37 degrees 30 minutes N. to latitude 34 degrees 30 minutes N.: U.S. Geological Survey Open-File Report 77–79, 14 plates, scale 1:25,000.

Reid, J.A., Reid, J.M., Jenkins, C.J., Zimmerman, M., Williams, S.J., and Field, M.E., 2006, usSEABED—Pacific Coast (California, Oregon, Washington) offshore surficial-sediment data release: U.S. Geological Survey Data Series 182, available at http://pubs.usgs.gov/ds/2006/182/.

Storlazzi, C.D., Fregoso, T.A., Golden, N.E., and Finlayson, D.P., 2011, Sediment dynamics and the burial and exhumation of bedrock reefs along on emergent coastline as elucidated by repetitive sonar surveys, northern Monterey Bay, CA: Marine Geology, v. 289, p. 46–59.

U.S. Geological Survey, 2001, Six aeromagnetic surveys in Nevada and California—A web site for distribution of data: U.S. Geological Survey Open-File Report 2001–0145, available at http://pubs.usgs.gov/of/2001/ofr-01-0145/.

U.S. Geological Survey and California Geological Survey, 2010, Quaternary fault and fold database for the United States: U.S. Geological Survey database, accessed April 5, 2014, at http://earthquake.usgs.gov/hazards/qfaults/.

Weber, G.E., 1990, Late Pleistocene slip rates on the San Gregorio fault zone at Point Año Nuevo, San Mateo County, California, *in* Greene, H.G., Weber, G.E., Wright, T.L., and Garrison, R.E., eds., Geology and tectonics of the central California coast region—San Francisco to Monterey: American Association of Petroleum Geologists, Pacific Section, volume and guidebook, v. 67, p. 193–204.

Weber, G.E., and Lajoie, K.R., 1980, Map of Quaternary faulting along the San Gregorio Fault Zone, San Mateo and Santa Cruz Counties, California: U.S. Geological Survey Open-File Report 80–907, scale 1:24,000.

Weber, K.M., List, J.H., and Morgan, K.L.M., 2005, An operational mean high water datum for determination of shoreline position from topographic lidar data: U.S. Geological Survey Open-File Report 2005–1027, available at http://pubs.usgs.gov/of/2005/1027/.

Witter, R.C., Knudsen, K.L., Sowers, J.M., Wentworth, C.M., Koehler, R.D., Randolph, C.E., Brooks, S.K., and Gans, K.D., 2006, Maps of Quaternary deposits and liquefaction susceptibility in the central San Francisco Bay region, California: U.S. Geological Survey Open-File Report 2006–1037, scale 1:24,000, available at http://pubs.usgs.gov/of/2006/1037/.

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