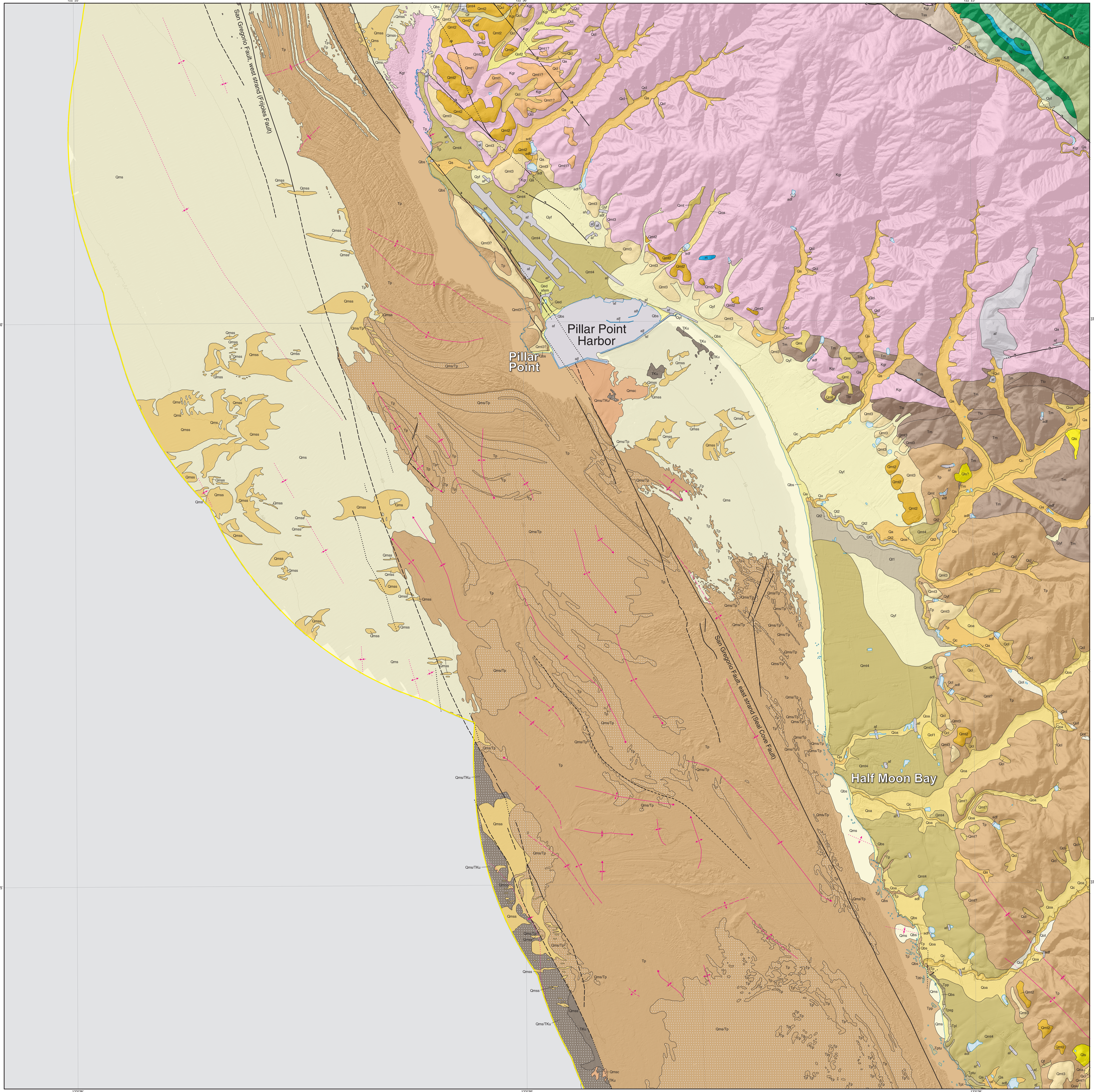
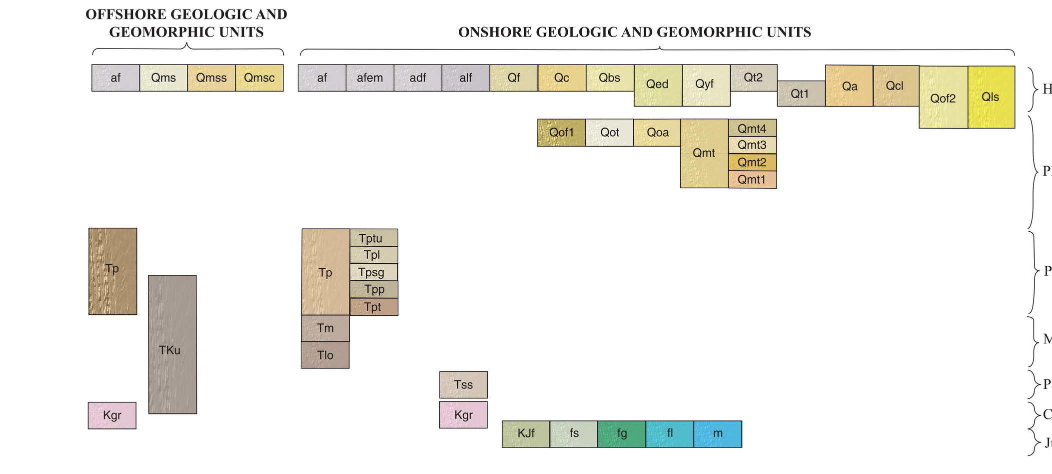
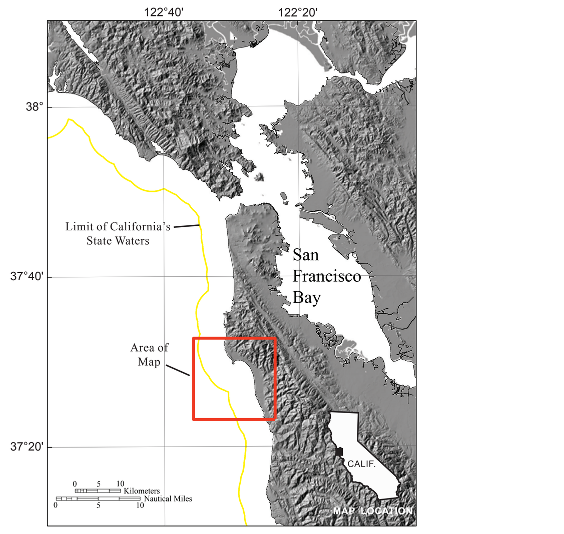
U.S. Department of the Interior
U.S. Geological Survey

Open-File Report 2014–1214
Sheet 10 of 10
Pamphlet accompanies map



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)]

- af — **Artificial fill and anthropogenic material (late Holocene)**—Rock, sand, and mud. Placed, dredged, or substantially modified by human activity; includes pipelines
- Qms — **Marine nearshore and shelf deposits (late Holocene)**—Mostly sand; ripples common
- Qmss — **Marine shelf scour depressions (late Holocene)**—Inferred to be coarse sand and gravel
- Qmsc — **Coarse-grained marine nearshore and shelf deposits (late Holocene)**—Predominantly coarse sand, gravel, cobbles, and boulders
- Tp — **Purisima Formation (Pliocene and late Miocene)**—Marine sandstone, siltstone, and mudstone
- TKu — **Bedrock, undivided (Tertiary and (or) Cretaceous)**
- Kgr — **Granitic rocks of Montara Mountain (Cretaceous)**—Medium-crystalline to coarsely crystalline, foliated granitic rock; largely quartz diorite with some granite

ONSHORE GEOLOGIC AND GEOMORPHIC UNITS

[Units are compiled from 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 (1976, 1982, 2002b)]

- af — **Artificial fill (late Holocene)**—Rock, sand, and mud; material deposited by humans
- afem — **Artificial fill over estuarine mud (late Holocene)**—Material deposited by humans over estuarine sediments
- 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
- Qf — **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
- Qc — **Stream-channel deposits (late Holocene)**—Fluvial deposits within active, natural stream channels
- Qbs — **Beach-sand deposits (late Holocene)**—Active beaches in coastal environment; may form veneer over bedrock platform
- 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
- Qyf — **Alluvial fan deposits (Holocene)**—Sediment deposited by streams emanating from mountain canyons onto alluvial valley floors or alluvial plains
- Qt2 — **Stream-terrace deposits (Holocene)**—Relatively smooth, undissected terraces less than 8 to 10 m above active channel; younger than unit Qt1
- Qt1 — **Stream-terrace deposits (Holocene)**—Relatively smooth, undissected terraces less than 8 to 10 m above active channel; older than unit Qt2
- Qa — **Alluvial deposits, undivided (Holocene)**—Alluvium; deposited in fan, terrace, or basin environments
- Qcl — **Colluvium (Holocene)**—Loose to firm, unsorted sand, silt, clay, gravel, rock debris, and organic material, in varying proportions
- Qof2 — **Older alluvial fan deposits, undivided (Holocene and late Pleistocene)**—Mapped in small valleys where separate fan, basin, and terrace units could not be delineated at map scale
- Qls — **Landslide deposits (Holocene and Pleistocene)**—Disintegrated bedrock; physically weathered; ranges from deep-seated landslides to active colluvium
- Qof1 — **Older alluvial fan deposits (late Pleistocene)**—Alluvial fans; late Pleistocene age is indicated by degree of dissection or soil development greater than what is present on Holocene fans
- Qot — **Older stream-terrace deposits (late Pleistocene)**—Relatively flat, slightly dissected stream terraces; late Pleistocene age is indicated by degree of soil development and height of terrace above flood level
- Qoa — **Older alluvial deposits, undivided (late Pleistocene)**—Mapped on gently sloping to level alluvial fan or terrace surfaces or where separate units could not be delineated at map scale
- 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 (Qmt4) to oldest (Qmt1)
  - Qmt4 — **Marine-terrace deposits (Pleistocene)**—Sand and gravel, deposited on uplifted marine-abrasion platforms along coast
  - Qmt3 — **Marine-terrace deposits (Pleistocene)**—Sand and gravel, deposited on uplifted marine-abrasion platforms along coast
  - Qmt2 — **Marine-terrace deposits (Pleistocene)**—Sand and gravel, deposited on uplifted marine-abrasion platforms along coast
  - Qmt1 — **Marine-terrace deposits (Pleistocene)**—Sand and gravel, deposited on uplifted marine-abrasion platforms along coast
- Tp — **Purisima Formation, undivided (Pliocene and late Miocene)**—Medium-grained to very fine-grained 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)**—Massive 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
- Tm — **Monterey Formation (Miocene)**—Porcelaneous shale with chert, porcelaneous mudstone, impure diatomite, and calcareous claystone, as well as small amounts of siltstone and sandstone near base
- Tlo — **Lompico Formation (Miocene)**—Fine- to coarse-grained, well-cemented arkosic sandstone
- Tss — **Unnamed sandstone, shale, and conglomerate (Paleocene)**—Rhythmically alternating beds of sandstone and shale, with discontinuous boulder and cobble conglomerate lenses
- Kgr — **Granitic rocks of Montara Mountain (Cretaceous)**—Medium-crystalline to coarsely crystalline, foliated granitic rock; largely quartz diorite with some granite; highly fractured and deeply weathered
- KJf — **Franciscan Complex, undivided (Cretaceous and Jurassic)**—Mostly graywacke and shale. Locally divided into following subunits:
  - fs — **Sandstone**—Greenish-gray to buff, fine- to coarse-grained sandstone (graywacke), with interbedded siltstone and shale
  - fg — **Greenstone**—Dark-green to red, altered basaltic rocks, including flows, pillow lavas, breccias, tuff breccias, tuffs, and minor related intrusive rocks
  - fl — **Limestone**—Light-gray, finely to coarsely crystalline limestone in lenticular bodies; generally surrounded by Franciscan greenstone
  - m — **Marble and hornfels blocks (Paleozoic?)**—Finely crystalline marble, graphitic marble, and quartz-mica hornfels

EXPLANATION OF MAP SYMBOLS

- **Contact**—Approximately located
- **Fault**—Dashed where location is approximate, dotted where location is concealed, queried where uncertain
- **Folds**—Solid where location is certain, dashed where location is approximate, dotted where location is concealed, arrow on axial trace shows direction of plunge
  - **Anticline**
  - **Syncline**
- **Approximate modern shoreline**—Defined as Mean High Water (MHW) (+1.46 m), North American Vertical Datum of 1988 (NAVD 1988)
- **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 Half Moon Bay 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), and high-resolution seismic-reflection profiles (sheet 8).

Onshore geology was compiled from Brabb and others (1998) and Witter and others (2006).

The continental shelf within California's State Waters in the Offshore of Half Moon Bay 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 Half Moon Bay map area is now an open-ocean shelf that is subjected to full, and sometimes severe, wave energy and strong currents.

Given the relatively shallow depths and high energy, modern shelf deposits are mostly sand (unit Qms). Coarser grained sands and gravels (units Qmss and Qmsc) are recognized primarily on the basis of bathymetry and high backscatter (sheets 1, 2, 3). Unit Qmsc is mapped only as a nearshore bar (about 10 m water depth) just south of the Pillar Point Harbor jetty. Unit Qmss, which typically is mapped as erosional lags in scour depressions (see, for example, Cacchione and others, 1984), is more extensive and distributed, the largest concentrations found at water depths of 30 to 55 m offshore of Pillar Point, as well as in the nearshore (at depths of 5 to 15 m) south of Pillar Point Harbor and north-northwest of Pillar Point. Such scour depressions are common along this stretch of the California coast (see, for example, Cacchione and others, 1984; Hallenbeck and others, 2012; Davis and others, 2013) where offshore sandy sediment can be relatively thin (and, thus, is unable to fill the depressions) owing to lack of sediment supply from rivers and also to significant erosion and offshore transport of sediment during large northwest winter swells. Although the general areas in which both unit Qmss scour depressions and unit Qmsc nearshore bars are found are not likely to change substantially, the boundaries of the unit(s) likely are ephemeral, changing seasonally and during significant storm events.

Offshore bedrock outcrops are mapped as the upper Miocene and Pliocene Purisima Formation (unit Tp), the Cretaceous granitic rocks of Montara Mountain (unit Kgr), and undifferentiated sedimentary rocks of the undivided bedrock unit of Cretaceous and (or) Tertiary age (TKu). These units are delineated by extending outcrops and trends from mapped onshore geology and also by their distinctive surface textures as revealed by high-resolution bathymetry (see sheets 1, 2). Outcrops of the Purisima Formation form distinctive, straight to curved "ribs," caused by differential erosion of more and less resistant lithologies (for example, sandstone and mudstone). In contrast, granitic rocks have a densely cross-fractured surface texture. The Offshore of Half Moon Bay map area contains artificial fill (unit af) only inside Pillar Point Harbor.

Areas where shelf sediments form thin (2.5 m or less) veneers over low-relief rocks of the undivided Cretaceous and (or) Tertiary bedrock unit or the Purisima Formation (upper Miocene and Pliocene) are mapped as units Qms/TKu and Qms/Tp, respectively. 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 (see 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 at a specific location, 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 55 km south of the map area.

The Offshore of Half Moon Bay map area lies about 12 km southwest of the San Andreas Fault, the dominant structure in the distributed, right-lateral, 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 Pillar Point in the map area and also at Pescadero Point, about 15 km south of the map area (see Map E on sheet 9).

In the Offshore of Half Moon Bay map area, the San Gregorio Fault system forms a distributed shear zone about 2 to 4.5 km wide that includes two primary diverging fault strands (fig. 1). The east strand (also known as the Seal Cove Fault or Coastways Fault), which roughly parallels the shoreline, extends onshore for about 3 km at Pillar Point, locally forming the boundary between outcrops of Cretaceous granitic rocks to the east and the Purisima Formation to the west. The west strand (also known as the Frijoles Fault), which lies entirely offshore, forms a boundary between the Purisima Formation on the east and undivided Cretaceous and (or) Tertiary rocks of the Pigeon Point block (McCulloch, 1987) (fig. 1) on the west. The Pigeon Point block is a northwest-trending bedrock ridge that extends offshore of Pescadero for about 30 km and forms the northwest boundary of the outer Santa Cruz Basin.

Bathymetric data (see sheets 1, 2) and 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 have been spectacularly folded, faulted, and rotated by strike-slip motion and drag along the faults. Cumulative lateral slip on the San Gregorio Fault system 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). This regional uplift has been linked to a northwest-transpressive bend in the San Andreas Fault (see, for example, Zoback and others, 1999). Rates of uplift of marine terraces of as much as 0.44 mm/yr near Año Nuevo, 30 km south of the map area, confirms that regional uplift is ongoing and that it includes the coastal zone (Weber, 1990).

REFERENCES CITED

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, 1976, Alquist-Priolo earthquake fault zone map of Half Moon Bay 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, 1982, Alquist-Priolo earthquake fault zone map of Montara Mountain 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.

Davis, A.C.D., Kvitek, R.G., Mueller, C.B.A., Young, M.A., Storlazzi, C.D., and Phillips, E.L., 2013, Distribution and abundance of rippled scour depressions along the California coast: Continental Shelf Research, v. 69, p. 88–100, doi:10.1016/j.csr.2013.09.010.

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, doi:10.3354/meps09948.

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.

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, doi:10.1016/j.margeo.2011.09.010.

U.S. Geological Survey and California Geological Survey, 2010, Quaternary fault and fold database of 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, 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/.

Zoback, M.L., Jachens, R.C., and Olson, J.A., 1999, Abrupt along-strike change in tectonic style—San Andreas fault zone, San Francisco Peninsula: Journal of Geophysical Research, v. 104 (B5), p. 10,719–10,742.

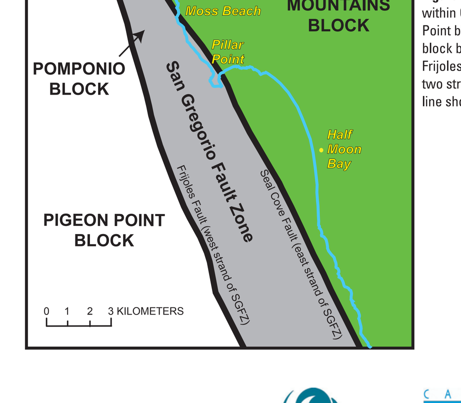


Figure 1. Schematic map showing structural blocks within Offshore of Half Moon Bay map area. Pigeon Point block is separated from Santa Cruz Mountains block by Pomponio block, which is bounded by Frijoles Fault (to west) and Seal Cove Fault (to east), two strands of San Gregorio Fault Zone (SGFZ). Blue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

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

APPROXIMATE MEAN DECLINATION, 2014

SCALE 1:24 000

BATHYMETRIC CONTOUR INTERVAL 10 METERS

ONE MILE = 0.869 NAUTICAL MILES

MAP LOCATION

Offshore geology and geomorphology mapped by H. Gary Greene, Bryan E. Dieter, Stephanie L. Ross, Stephen R. Hartwell, Samuel Y. Johnson, and Janet T. Watt. Onshore geology compiled by Michael W. Manson from Brabb and others (1998) and Witter and others (2006). Bathymetric contours by Carrie K. Bretz, 2008

GIS database and digital cartography by Stephen R. Hartwell, Eleyne L. Phillips, and Florence L. Wong

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Offshore and Onshore Geology and Geomorphology, Offshore of Half Moon Bay Map Area, California

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2014

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