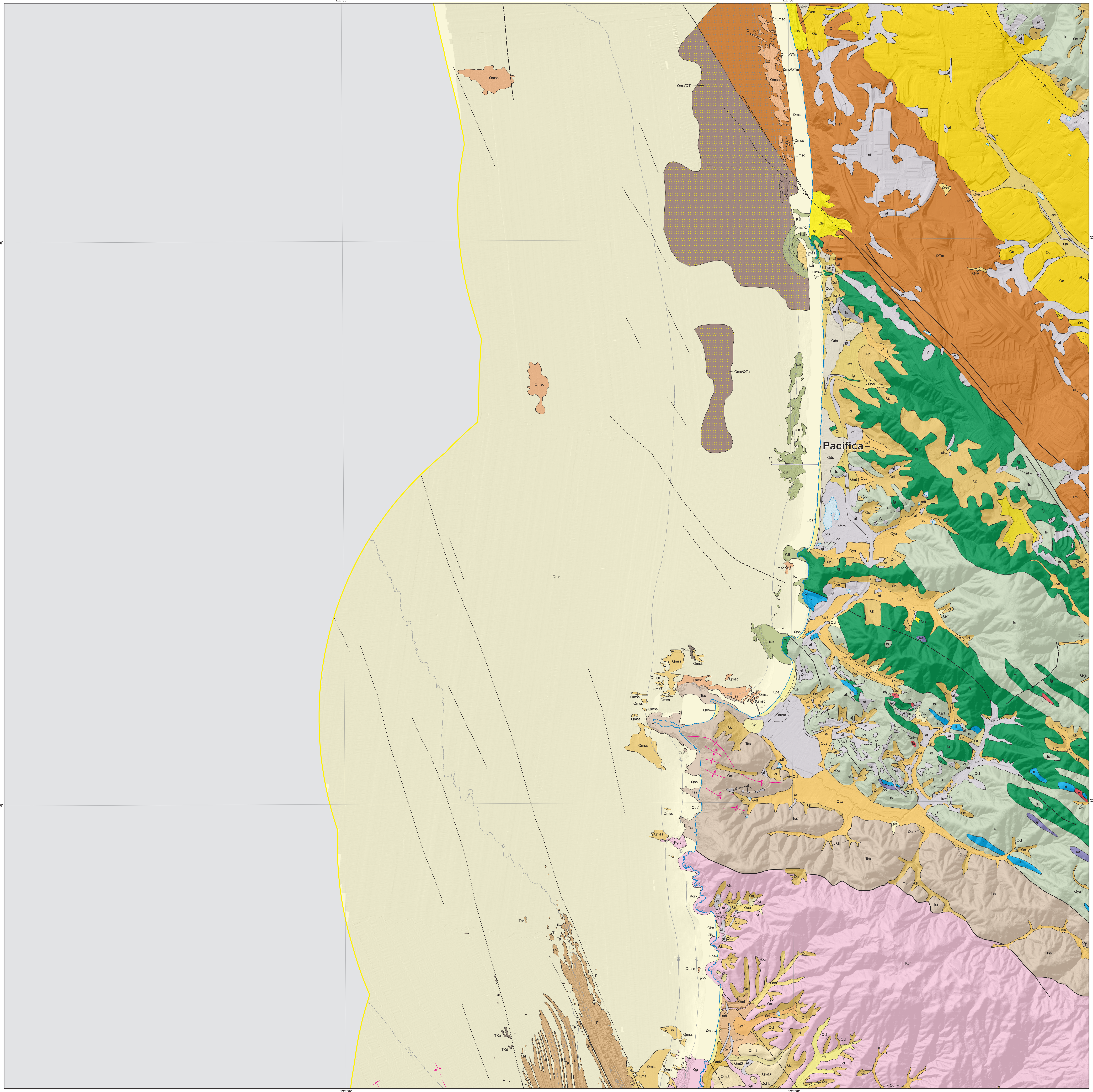
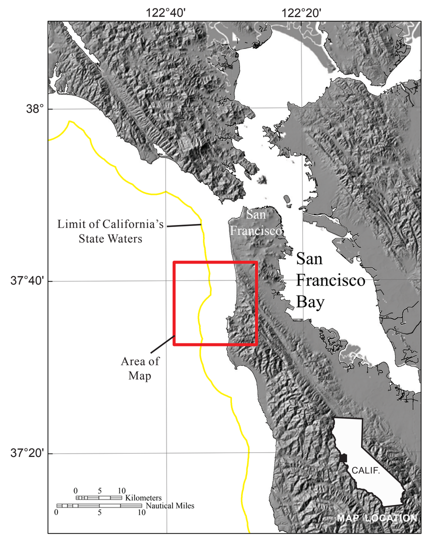
U.S. Department of the Interior
U.S. Geological Survey

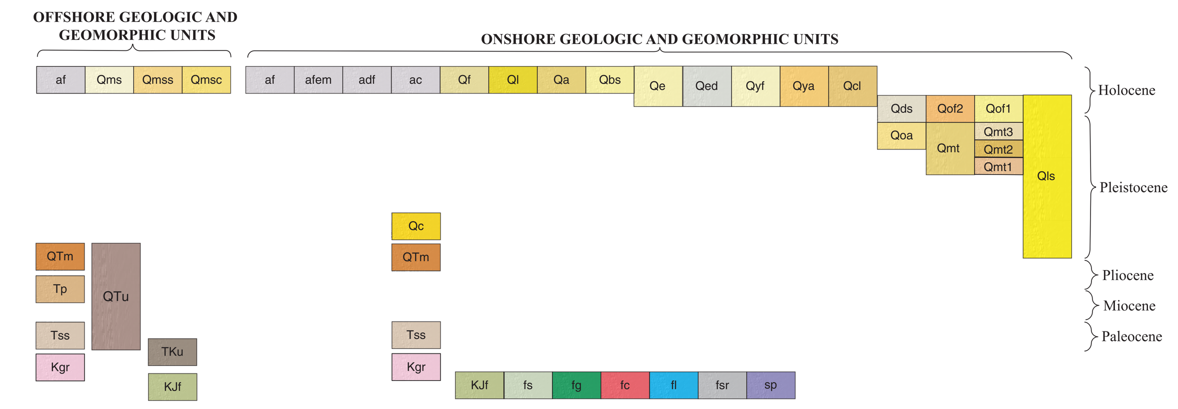
Open-File Report 2014–1260
Sheet 10 of 10
Pamphlet accompanies map





CORRELATION OF MAP UNITS

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



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

- 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)**—Coarse sand, gravel, cobbles, and boulders
- QTm — **Merced Formation (Pleistocene and Pliocene)**—Sandstone, siltstone and claystone, with some conglomerate lenses and minor volcanic ash
- QTu — **Sedimentary rocks, undivided (Pleistocene and Pliocene, Pliocene and Miocene, or Paleocene)**—May consist of rocks of the Merced Formation and (or) the Purisima Formation and (or) the unnamed Paleocene sedimentary unit
- Tp — **Purisima Formation (Pliocene and late Miocene)**—Marine sandstone, siltstone, and mudstone
- Tss — **Unnamed sandstone, shale, and conglomerate (Paleocene)**—Interbedded sandstone and shale, with minor boulder and cobble conglomerate
- TKu — **Bedrock, undivided (Tertiary and (or) Cretaceous)**—Possibly includes rocks of the Purisima Formation or Cretaceous granitic rocks
- Kgr — **Granitic rocks of Montara Mountain (Cretaceous)**—Medium-crystalline to coarsely crystalline, foliated granitic rock; largely quartz diorite with some granite
- KJf — **Franciscan Complex, undivided (Cretaceous and Jurassic)**

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]

- 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
- ac — **Artificial stream channels (late Holocene)**—Modified stream channels; includes straightened or realigned channels, flood-control channels, and concrete canals
- 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 youthful braid bars and distributary channels
- Ql — **Alluvial-fan levee deposits (late Holocene)**—Natural levee deposits of alluvial fans; age estimate (<1,000 years) made on basis of records of historical inundation or youthful braid bars and distributary channels
- Qa — **Alluvial deposits, undivided (late Holocene)**—Fluvial sediment; judged to be late Holocene (<1,000 years) in age, on basis of records of historical inundation and also identification of geomorphic features
- Qbs — **Beach-sand deposits (late Holocene)**—Active beaches in coastal environment; may form veneer over bedrock platform
- Qe — **Dune sand (Holocene)**—Active and recently stabilized dunes in coastal environments
- 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
- Qya — **Alluvial deposits, undivided (Holocene)**—Alluvium; deposited in fan, terrace, or basin environmentss
- Qcl — **Colluvium (Holocene)**—Loose to firm, unsorted sand, silt, clay, gravel, rock debris, and organic material, in varying proportions
- Qds — **Dune sand (Holocene and late Pleistocene)**—Very well sorted, fine- to medium-grained eolian sand
- Qof2 — **Older alluvial fan deposits (Holocene and late Pleistocene)**—Sand, gravel, silt, and clay on gently sloping, fan-shaped, relatively undissected alluvial surfaces
- Qof1 — **Older alluvial fan deposits, undivided (Holocene and late Pleistocene)**—Mapped in small valleys where separate fan, basin, and terrace deposits 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
- 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 (Qmt3) to oldest (Qmt1)
  - 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
- Qc — **Colma Formation (Pleistocene)**—Fine- to medium-grained arkosic sand, with subordinate gravel, silt, and clay. Total thickness unknown, but may be as much as 60 m
- QTm — **Merced Formation (Pleistocene and Pliocene)**—Sandstone, siltstone, and claystone, with some conglomerate lenses and minor volcanic ash
- Tss — **Unnamed sandstone, shale, and conglomerate (Paleocene)**—Sandstone and shale, with discontinuous pebble, boulder, and cobble conglomerate
- 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 and shale**—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
  - fc — **Chert**—White, green, red, and orange chert; in places, interbedded with reddish-brown shale
  - fl — **Limestone**—Light-gray, finely to coarsely crystalline limestone, in lenticular bodies; commonly surrounded by Franciscan greenstone
  - fsr — **Sheared rock (mélange)**—Predominantly graywacke, siltstone, and shale, substantial portions of which have been sheared; also includes hard blocks of all other rock types of the Franciscan Complex
  - sp — **Serpentinite**—Greenish-gray to bluish-green, sheared serpentinite; encloses variably abundant blocks of unsheared rock

EXPLANATION OF MAP SYMBOLS

Contact—Solid where location is certain, dashed where location is approximate

Fault—Solid where location is certain, dashed where location is approximate, dotted where location is concealed, queried where uncertain

Folds—Solid where location is certain, dotted where location is concealed

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 Pacifica 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 Pacifica map area is shallow (less than about 40 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, sea-level rise, sedimentary processes, and oceanography. Tectonic influences are related to local faulting and uplift. Sea level has risen about 125 to 130 m over the last about 21,000 years (see, for example, Lambeck and Chappell, 2001), 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 Pacifica map area is now mainly an open-ocean shelf that is subjected to the full, and sometimes severe, wave energy and strong currents of the Pacific Ocean (Storlazzi and Wingfield, 2005; Barnard and others, 2007). Most of the offshore is covered by marine sediments; artificial fill (unit af) is mapped only at the Pacifica Municipal Pier and at the south end of Pacifica State Beach.

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 as nearshore bars (less than 12 m water depth) for about 2 km along the coast north of Mussel Rock and in a few local places just offshore of the southern part of Pacifica, as well as in two isolated patches farther offshore, at about 25 m water depth. Unit Qmss forms erosional lags in scour depressions (see, for example, Cacchione and others, 1984) at water depths of about 15 to 25 m, in contact with offshore bedrock uplifts and unit Qms. 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 and scattered patches 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 undivided Jurassic and Cretaceous Franciscan Complex (unit KJf); the Cretaceous granitic rocks of Montara Mountain (unit Kgr); undivided Cretaceous and (or) Tertiary bedrock (unit TKu); the unnamed sandstone, shale, and conglomerate unit of Paleocene age (Tss); the Miocene and Pliocene Purisima Formation (unit Tp); undivided sedimentary rocks of Paleocene, Miocene and Pliocene, or Pliocene and Pleistocene age (unit QTu); and Pliocene and Pleistocene strata of the Merced Formation (unit QTm). These units are delineated by extending outcrops and trends from mapped onshore geology; by their distinctive surface textures as revealed by high-resolution bathymetry (see sheets 1, 2); and also by seismic-reflection profiles, which allow distinction of layered, relatively undeformed sedimentary bedrock from more massive and deformed basement rocks. For example, 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, and rocks of both the Franciscan Complex and the Paleocene unnamed sandstone, shale, and conglomerate unit have a more massive, more irregular, and smoother surface texture. Outcrops of the Purisima Formation are mapped in water as deep as 35 m, whereas other bedrock units are mapped in shallower (less than 20 m) water depths, most commonly adjacent to coastal promontories underlain by bedrock (for example, Mussel Rock, Mori Point, Point San Pedro, and south of Montara State Beach).

Areas where shelf sediments form thin (less than 2 m) veneers over low-relief rocks of the Franciscan Complex, the undivided Tertiary and Quaternary sedimentary rocks unit, or the Merced Formation are mapped as units Qms/KJf, Qms/QTu, and Qms/QTm, 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 80 km south of the map area.

The Offshore of Pacifica map area, which straddles the right-lateral transform boundary between the North American and Pacific plates, is cut by several active northwest-striking faults; these include the San Andreas Fault and the San Gregorio Fault Zone (Bruns and others, 2002; Ryan and others, 2008). The offshore parts of these faults, which are buried in the offshore by sediment and, thus, have no surface expression, have been mapped on the basis of seismic-reflection data (see sheet 8). The San Andreas Fault, which is the dominant plate-boundary structure, extends offshore near Mussel Rock. The San Andreas Fault in the map area has an estimated slip rate of 17 to 24 mm/yr (U.S. Geological Survey and California Geological Survey, 2010), and the devastating great 1906 California earthquake (M7.8) is thought to have nucleated on the San Andreas Fault a few kilometers north of the map area, offshore of San Francisco (see, for example, Bolt, 1968; Lomax, 2005).

The San Gregorio Fault, another major strike-slip fault system within the transform plate boundary, extends predominantly in the offshore for about 400 km from Point Conception in the south (where it is known as the Hosgri Fault) to Bolinas and Point Reyes in the north (McCulloch, 1987; Dickinson and others, 2005). Cumulated lateral slip is estimated to be about 4 to 10 mm/yr (U.S. Geological Survey and California Geological Survey, 2010). In the Offshore of Pacifica map area, the San Gregorio Fault forms a distributed, 2- to 3-km-wide shear zone in the offshore that includes two main faults, an east strand and a west strand, that are known to the south as the Seal Cove Fault and the Frijoles Fault, respectively (Weber and Lajoie, 1980; Brabb and others, 1998). The east strand juxtaposes Cretaceous granitic rocks to the east and rocks of the Purisima Formation to the west; the west strand is inferred to juxtapose the Purisima Formation to the east and undivided Cretaceous and (or) Tertiary bedrock to the west.

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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

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

Offshore geology and geomorphology mapped by H. Gary Greene, Stephen R. Hartwell, Michael W. Manson, Samuel Y. Johnson, Bryan E. Dieter, Eleyne L. Phillips, 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, 2009
GIS database and digital cartography by Stephen R. Hartwell, Bryan E. Dieter, Eleyne L. Phillips, and Florence L. Wong
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Offshore and Onshore Geology and Geomorphology, Offshore of Pacifica Map Area, California

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