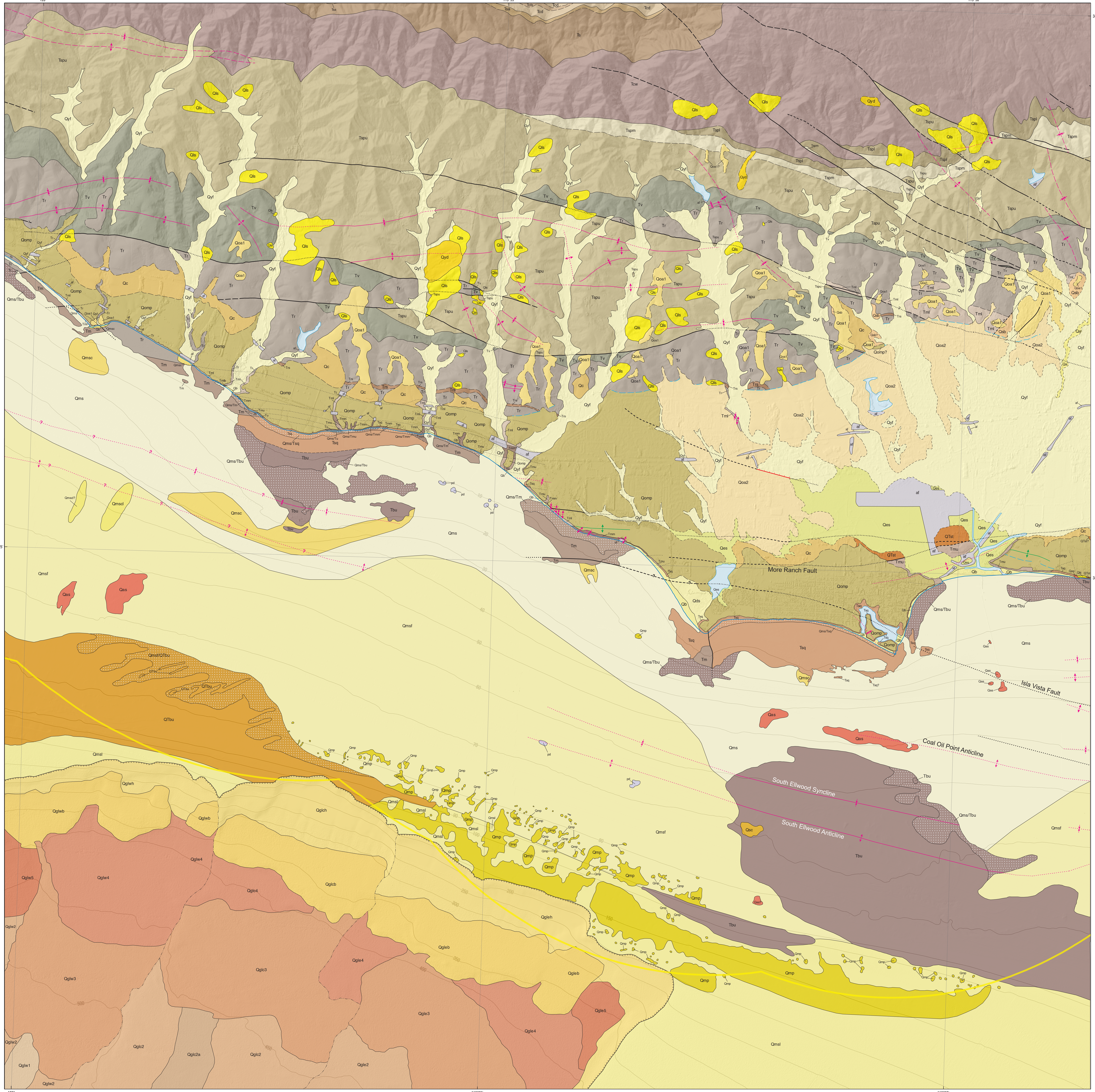

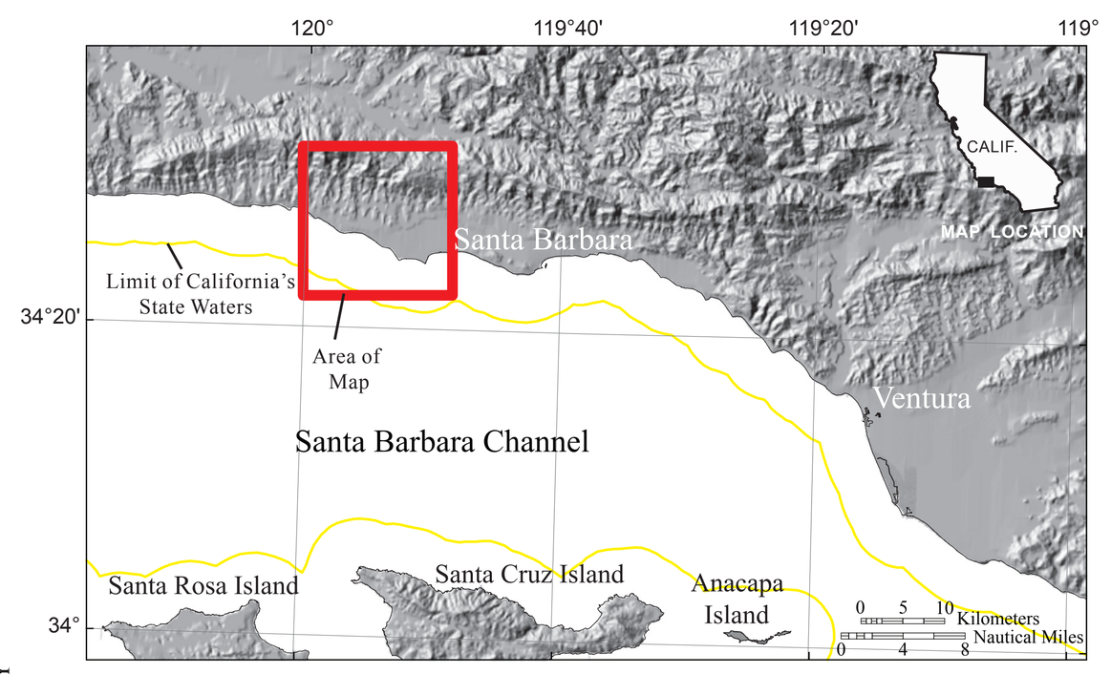

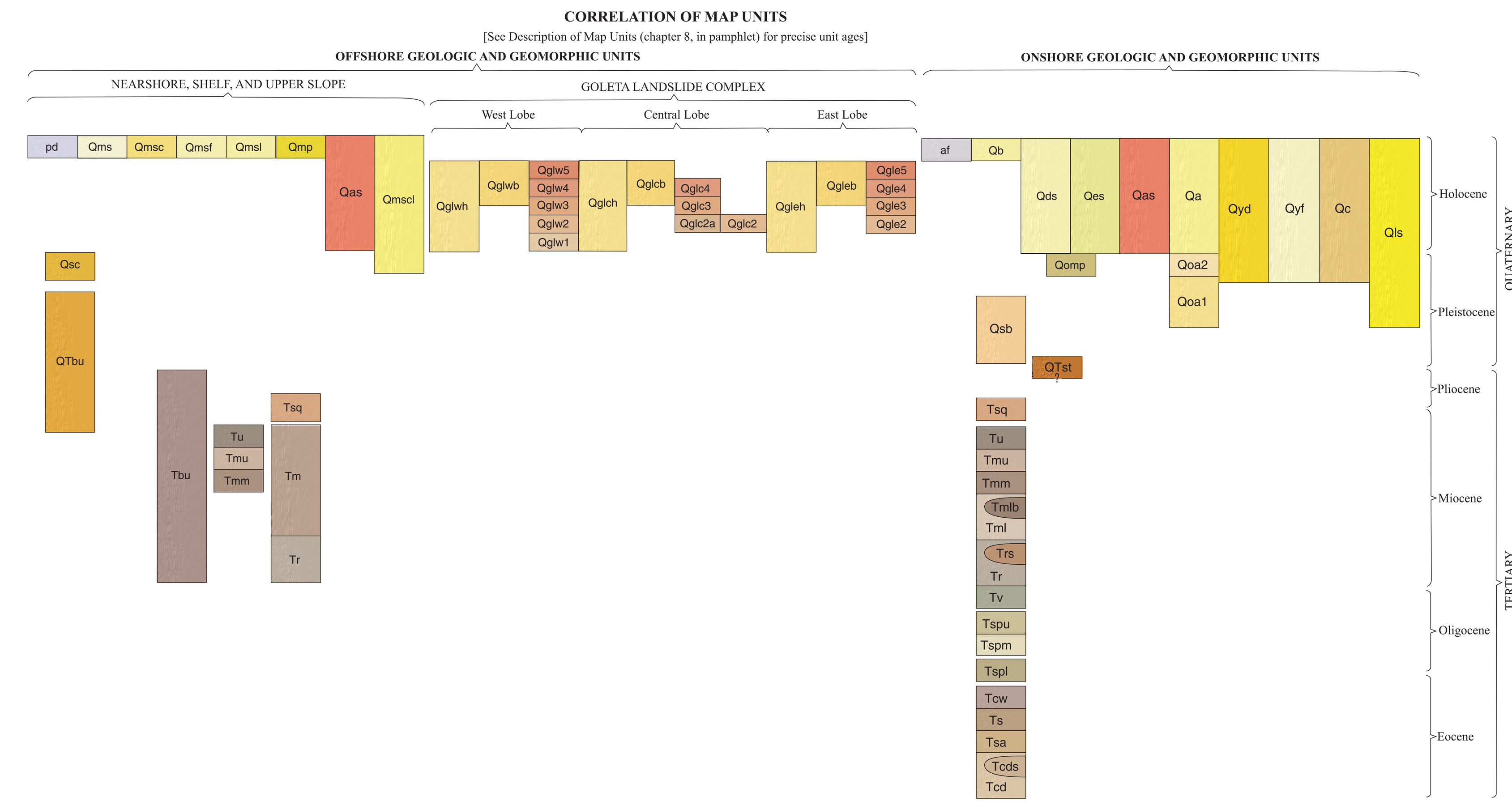

LIST OF MAP UNITS

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

OFFSHORE GEOLOGIC AND GEOMORPHIC UNITS

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

NEARHORE, SHELF, AND UPPER SLOPE

- pd — **Oil-platform debris (late Holocene)**—Mixed accumulations of construction material, coarse sediment, and shell debris associated with anthropogenic structures
- Qms — **Marine nearshore and shelf deposits (late Holocene)**—Mostly sand; ripples common
- Qmsc — **Coarse-grained marine nearshore and shelf deposits (late Holocene)**—Coarse sand and gravel to boulders
- Qmsf — **Fine-grained marine shelf deposits (late Holocene)**—Mostly clay, silt, and very fine sand
- Qmsl — **Marine upper slope deposits (late Holocene)**—Mostly clay, silt, and very fine sand
- Qmp — **Marine pockmarks (late Holocene)**—Sand and mud, in circular to elliptical pockmarks
- Qas — **Asphalt deposits (Holocene)**—Black asphalt (tar) derived from nearby natural hydrocarbon seeps
- Qmscl — **Marine shelf-sediment lobes (Holocene or latest Pleistocene)**—Sand and gravel; lobate form
- Qsc — **Marine or nonmarine coarse-grained deposits (late Pleistocene?)**—Sedimentary strata, partly conglomeratic
- QTbu — **Bedrock, undivided (Pleistocene, Pliocene, and Miocene)**—Predominantly mudstone and siltstone
- Tbu — **Bedrock, undivided (Pliocene and Miocene)**—Undivided strata of the Pico, Sisquoc, and Monterey Formations
- Tsq — **Sisquoc Formation (early Pliocene and late Miocene)**—Mainly mudstone and shale
- Tu — **Unnamed mudstone (late Miocene)**—Marine mudstone, shale, and porcelanite, with subordinate dolomite and phosphatic pebble conglomerate. Shown only as composite unit Qms/Tu
- Tm — **Monterey Formation, undivided (Miocene)**—Mainly siliceous and calcareous mudstone and shale; may include strata of the unnamed mudstone unit (Tu), exposed in adjacent coastal (onshore) outcrops
- Tmu — **Upper siliceous unit (late Miocene)**—Mainly marine, diatomaceous and siliceous mudstone and shale, with subordinate dolomite and porcelanite. Shown only as composite unit Qms/Tmu
- Tmm — **Middle shale unit (late and middle Miocene)**—Mainly marine shale, mudstone, dolomite, porcelanite, phosphorite, and subordinate tuff
- Tr — **Rincon Shale (early Miocene)**—Mostly mudstone, with subordinate dolomite, shale, sandstone, and tuff

GOLETA LANDSLIDE COMPLEX

West Lobe

- Qglwh — **Goleta landslide headwall, west lobe (Holocene)**—Scarp exposing bedrock and overlying late Quaternary shelf and slope deposits
- Qglwb — **Goleta landslide head block, west lobe (Holocene)**—Mix of intact to semi-intact blocks of sediment and unconsolidated mud and sand, at base of headwall scarp
- Qglw5 — **Goleta landslide fifth-phase flow deposit, west lobe (Holocene)**—Landslide deposits consisting of mud and sand; derived from sidewall failure
- Qglw4 — **Goleta landslide fourth-phase flow deposit, west lobe (Holocene)**—Landslide deposits consisting of mud and sand
- Qglw3 — **Goleta landslide third-phase flow deposit, west lobe (Holocene)**—Landslide deposits consisting of mud and sand
- Qglw2 — **Goleta landslide second-phase flow deposit, west lobe (Holocene)**—Landslide deposits consisting of mud and sand
- Qglw1 — **Goleta landslide initial flow deposit, west lobe (Holocene)**—Landslide deposits consisting of mud and sand

Central Lobe

- Qglch — **Goleta landslide headwall, central lobe (Holocene)**—Scarp exposing bedrock and overlying late Quaternary shelf and slope deposits
- Qglcb — **Goleta landslide head block, central lobe (Holocene)**—Mix of intact to semi-intact blocks of sediment and unconsolidated mud and sand, at base of headwall scarp
- Qglc4 — **Goleta landslide fourth-phase flow deposit, central lobe (Holocene)**—Landslide deposits consisting of mud and sand
- Qglc3 — **Goleta landslide third-phase flow deposit, central lobe (Holocene)**—Landslide deposits consisting of mud and sand
- Qglc2a — **Goleta landslide, secondary failure of second-phase flow deposit, central lobe (Holocene)**—Landslide deposits consisting of mud and sand
- Qglc2 — **Goleta landslide second-phase flow deposit, central lobe (Holocene)**—Landslide deposits consisting of mud and sand

East Lobe

- Qgleh — **Goleta landslide headwall, east lobe (Holocene)**—Scarp exposing bedrock and overlying late Quaternary shelf and slope deposits
- Qgleb — **Goleta landslide head block, east lobe (Holocene)**—Mix of intact to semi-intact blocks of sediment and unconsolidated mud and sand, at base of headwall scarp
- Qgle5 — **Goleta landslide fifth-phase flow deposit, east lobe (Holocene)**—Landslide deposits consisting of mud and sand
- Qgle4 — **Goleta landslide fourth-phase flow deposit, east lobe (Holocene)**—Landslide deposits consisting of mud and sand
- Qgle3 — **Goleta landslide third-phase flow deposit, east lobe (Holocene)**—Landslide deposits consisting of mud and sand
- Qgle2 — **Goleta landslide second-phase flow deposit, east lobe (Holocene)**—Landslide deposits consisting of mud and sand

ONSHORE GEOLOGIC AND GEOMORPHOLOGIC UNITS

[Units are compiled from Dibblee (1981, 1987a,b) and Minor and others (2009). Unit ages, which are largely from Minor and others (2009), reflect local stratigraphic relations]

- af — **Artificial fill (late Holocene)**—Engineered and (or) nonengineered
- Qb — **Beach deposits (late Holocene)**—Unconsolidated sand along coastal beaches
- Qds — **Dune sand (Holocene)**—Unconsolidated wind-blown sand forming coastal dunes northwest of Coal Oil Point
- Qes — **Coastal-estuarine deposits (Holocene)**—Locally organic-rich clay, silt, and sand; deposited in low-lying, tidally influenced environments
- Qas — **Asphalt deposits (Holocene)**—Asphalt (tar); weathered and biodegraded oil derived from nearby natural hydrocarbon seeps
- Qa — **Channel alluvium (Holocene)**—Unconsolidated sediment, in modern stream channels
- Qyd — **Debris-flow deposits (Holocene and late Pleistocene)**—Massive, weakly consolidated rock-debris breccia; derived from upslope rock units
- Qyf — **Alluvium and colluvium (Holocene and late Pleistocene)**—Weakly consolidated silt, sand, and gravel deposits of modern drainages, piedmont alluvial fans, and floodplains
- Qc — **Colluvium (Holocene and late Pleistocene)**—Weakly consolidated, poorly stratified, and poorly sorted deposits; chiefly derived from downslope movement of nearby bedrock
- Qls — **Landslide deposits (Holocene to middle Pleistocene)**—Deposits that range from poorly sorted rock fragments and soil to relatively intact bedrock slump blocks
- Qomp — **Marine-terrace deposits (late Pleistocene)**—Basal, about 1-m-thick, weakly to moderately well consolidated, variably stratified gravel, sand, and silt overlying nonmarine eolian, alluvial, and colluvial deposits
- Qoa2 — **Intermediate-age alluvial deposits (late Pleistocene)**—Weakly consolidated silt, sand, and gravel that form terraces and piedmont fans above modern coastal piedmont surface
- Qoa1 — **Older alluvial deposits (late and middle Pleistocene)**—Moderately well consolidated, poorly sorted sand and sandstone, gravel, conglomerate, breccia, and rare interbeds of clay, silt, and mudstone
- Qsb — **Santa Barbara Formation (middle and early Pleistocene)**—Chiefly marine, friable, bioturbated, and massive sandstone; includes subordinate interbeds of shale, siltstone, and silty to clayey sandstone
- QTst — **Unnamed siltstone unit east of Goleta Pier (Pleistocene and Pliocene?)**—Massive and extensively bioturbated siltstone, mudstone, and silty sandstone. Contains marine fossils
- Tsq — **Sisquoc Formation (early Pliocene and late Miocene)**—Marine diatomaceous mudstone and shale, conglomerate, and subordinate dolomite
- Tu — **Unnamed mudstone (late Miocene)**—Marine mudstone, shale, and porcelanite, with subordinate dolomite and phosphatic pebble conglomerate
- **Monterey Formation (Miocene)**—Siliceous and calcareous mudstone and shale, with subordinate porcelanite and dolomite
  - Tmu — **Upper siliceous unit (late Miocene)**—Consists mainly of marine diatomaceous mudstone and shale, with subordinate dolomite and porcelanite
  - Tmm — **Middle shale unit (late and middle Miocene)**—Marine shale, mudstone, dolomite, porcelanite, phosphorite, and subordinate tuff
  - Tml — **Lower calcareous unit (middle and early Miocene)**—Marine mudstone and shale, with subordinate dolomite, porcelanite, breccia, sandstone, and tuff
  - Tmlb — **Breccia unit (middle? and early Miocene)**—Intraformational breccia exposed on sea cliff near mouth of Dos Pueblos Canyon. Contains clasts of calcareous mudstone and dolomite
- Tr — **Rincon Shale (early Miocene)**—Marine, primarily massive or thick-bedded mudstone, with subordinate dolomite, siliceous shale, sandstone, and tuff
  - Trs — **Siliceous shale interval (early Miocene)**—Marine, thin-bedded, white- to pale-gray-weathering siliceous shale
- Tv — **Vaqueros Formation (late Oligocene)**—Shallow-marine, massive and bioturbated sandstone
- **Sespe Formation (Oligocene and late Eocene)**—Nonmarine, fluvial, maroon, reddish-brown, and greenish- to pinkish-gray sandstone, mudstone, and conglomerate
  - Tspu — **Upper sandstone and mudstone unit (late Oligocene)**—Interbedded sandstone, siltstone, and mudstone
  - Tspm — **Middle conglomerate and sandstone unit (Oligocene)**—Interbedded conglomerate, sandstone, and mudstone
  - Tspl — **Lower conglomerate and sandstone unit (early Oligocene? and late Eocene)**—Interbedded conglomerate, conglomeratic sandstone, sandstone, mudstone, and minor shale
- Tcw — **Coldwater Sandstone (late? and middle Eocene)**—Shallow-marine, thin- to thick-bedded sandstone
- Ts — **Sacate Formation (Eocene)**—Marine, dark-gray micaceous siltstone and shale, with interbeds of hard arkosic sandstone (Dibblee, 1981)
  - Tsa — **Sandstone unit (Eocene)**—Marine, light-gray to tan arkosic sandstone
- Tcd — **Cozy Dell Shale (Eocene)**—Marine, dark-gray, argillaceous to silty micaceous shale, with minor light-gray to tan arkosic sandstone
  - Tcds — **Sandstone interval (Eocene)**—Marine, light-gray to tan arkosic sandstone, with minor interbeds of gray micaceous shale

EXPLANATION OF MAP SYMBOLS

- **Contact**—Solid where location is certain, long-dashed where location is approximate, short-dashed where location is inferred, dotted where location is concealed
- **Contact between lobes of Goleta landslide complex**—Delineates east, central, and west lobes of landslide complex
- **Headscarp in Goleta landslide complex**—Hachures point downscarp
- **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
- **Fault scarp**—Inferred from aerial photographs; hachures point downscarp
- **Folds**—Solid where location is certain, long-dashed where location is approximate, short-dashed where location is inferred, dotted where location is concealed
  - **Antiform**
  - **Synform**
- **Anticlinal upwarp axis in Quaternary deposits**
- **Former shoreline or marine limit**
- **Approximate modern shoreline**—Defined as Mean High Water (MHW) (+1.33 m), North American Vertical Datum of 1988 (NAVD 1988)
- **3-nautical-mile limit of California's State Waters**

DISCUSSION

Marine geology and geomorphology were mapped in the Offshore of Coal Oil Point 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 1.33 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).

The onshore geology was compiled from Dibblee (1981, 1987a,b) and Minor and others (2009). Unit ages, which are largely from Minor and others (2009), reflect local stratigraphic relations.

The offshore part of the map area largely consists of a gently offshore-dipping (less than 1°) shelf underlain by sediments derived primarily from relatively small coastal watersheds that drain the Santa Ynez Mountains. Shelf deposits are primarily sand (Qms) at depths less than about 35 to 50 m, and they are finer grained sediment such as very fine sand, silt, and clay (Qmsf) from depths of 35 to 50 m southward to the shelf break at a depth of about 90 m. The boundary between units Qms and Qmsf is based on observations and extrapolation from sediment sampling (see, for example, Reid and others, 2006) and camera ground-truth surveying (see sheet 6). It is important to note that the boundary between units Qms and Qmsf should be considered transitional and approximate and is expected to shift as a result of seasonal- to annual- to decadal-scale cycles in wave climate, sediment supply, and sediment transport.

Fine-grained deposits that are similar to unit Qmsf also are mapped at water depths greater than 90 m, below the shelf break on the upper slope; however, here they are identified as a separate unit (unit Qmsl) because of their location below the distinct shelf-slope geomorphologic break.

Coarser grained, marine deposits (coarse sand to boulders) of units Qmsc, Qmscl, and Qsc are recognized on the basis of their high acoustic backscatter (sheet 3), their ground-truth-survey imagery (sheet 6), and, in some cases, their moderate seafloor relief (sheets 1, 2). This coarse-grained facies is linked either to the mouths of steep coastal watersheds or to adjacent seafloor bedrock outcrops, and the deposits generally represent wave-winnowed lags of deltaic sediment. Two distinct lobes of coarse-grained sediment (unit Qmscl), present in deeper water (about 50 m) near the west edge of the map area, may similarly represent winnowed deltaic deposits that formed at lower sea levels during the latest Pleistocene or early Holocene. An isolated patch of clast-supported cobbles (unit Qsc), which rests on bedrock south of Coal Oil Point at a water depth of 70 m, also may have been deposited at lower sea levels during the late Pleistocene.

Offshore bedrock exposures are mapped as either the Miocene Monterey Formation (Tm, Tmu, Tmm), the upper Miocene and lower Pliocene Sisquoc Formation (Tsq), or the undivided Quaternary and Tertiary bedrock (QTbu) or undivided Tertiary bedrock (Tbu) units on the basis of the confidence in extending the onshore mapping of Minor and others (2009) offshore. Midshelf to outer shelf bedrock exposures are all mapped as undivided units; however, offshore sampling data (see, for example, Kunitomi and others, 1998), as well as regional cross sections that are constrained by petroleum exploration data and sampling (Redin, 2005; Redin and others, 2005), have suggested that these seafloor outcrops predominantly are upper Miocene and Pliocene strata. These rocks have been uplifted in a large, regional, internally warped, south-dipping homocline that formed above the blind, north-dipping Pitas Point–North Channel Fault system; the fault tip is inferred to lie beneath the continental slope, about 6 to 7 km offshore.

The Offshore of Coal Oil Point map area includes the upper part of the large (130 km^2), well-documented submarine Goleta landslide complex (Eichhubl and others, 2002; Fisher and others, 2005; Greene and others, 2006). Greene and others (2006) reported that the complex, which measures 14.6 km long and 10.5 km wide and extends from water depths of 90 to 574 m, has displaced about 1.75 km^3 of landslide debris during the Holocene; they described it as a compound, multiphase submarine landslide that contains both surficial slump blocks and mud flows, in three distinct segments (west, central, and east lobes). Each segment consists of a distinct headwall scarp (units Qglwh, Qglch, Qgleh), a downdropped head block (units Qglwb, Qglcb, Qgleb), and several composite slide-debris lobes (units Qglw5, Qfglw4, Qglw3, Qglw2, Qglw1, Qglc4, Qglc3, Qglc2a, Qglc2, Qfle5, Qgle4, Qgle3, Qgle2). This map shows the upper approximately 3 km of this landslide complex. The landslide source is inferred to be Pleistocene-age, shelf-edge deltaic sediments, and Fisher and others (2005) suggested that the youngest landslides formed about 8,000 to 10,000 years ago.

The Santa Barbara Channel region, including the map area, has a long history of hydrocarbon production (Barnum, 1998) that began in 1928 with discovery of the Ellwood oil field (see sheet 11). Subsequent discoveries in the offshore part of the map area include the South Ellwood offshore oil field, the Coal Oil Point oil field, and the Naples oil and gas field (see sheet 11). Oil and gas are mainly sourced by the Miocene Monterey Formation; the reservoirs are in the Vaqueros Formation, the Rincon Shale, and the Monterey Formation. Development of the South Ellwood offshore oil field began in 1966 from platform "Holly" (see sheet 11), which was the last platform to be installed in California's State Waters. Debris and infrastructure associated with platform "Holly," as well as with seep containment devices ("seep tents"), are mapped as unit pd. Areas of grouped to solitary pockmarks (unit Qmp) caused by gas seeps are common features. In addition, numerous asphalt (tar) deposits (unit Qas) associated with hydrocarbon seeps and gas vents are mapped both onshore and offshore. The offshore deposits, which have been confirmed with seafloor video observations (see sheet 11), often are localized along bedrock structures such as faults or the crests of anticlines, forming bathymetric features that are morphologically similar to bedrock outcrops but are distinguished from them on the basis of their low acoustic backscatter. Although many such asphalt deposits are too small to be shown on the map, the larger deposits can cover as much as several hundred square meters.

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Onshore elevation data from NOAA Coastal Services Center (data collected by EarthData International in 2002-2003) and from U.S. Army Corps of Engineers (data collected by Fugro Pelagos in 2009). Offshore shaded-relief bathymetry within California's State Waters from map on sheet 2, this report. Offshore shaded-relief bathymetry outside California's State Waters from Monterey Bay Aquarium Research Institute (2001). California's State Waters limit from NOAA Office of Coast Survey

Universal Transverse Mercator projection, Zone 11N

NOT INTENDED FOR NAVIGATIONAL USE

APPROXIMATE MEAN DECLINATION, 2014 (12½°; TRUE NORTH, MAGNETIC NORTH)

SCALE 1:24 000

BATHYMETRIC CONTOUR INTERVALS 10 AND 50 METERS

ONE MILE = 0.869 NAUTICAL MILES

MAP LOCATION (CALIF.)

Offshore geology mapped by James E. Conrad, Andrew C. Ritchie, Samuel Y. Johnson, H. Gary Greene, and Peter Dartnell, 2010-2011. Onshore geology compiled by Gordon G. Seitz and Carlos I. Gutierrez from Dibblee (1981, 1987a,b) and Minor and others (2009). Bathymetric contours by Andrew C. Ritchie

GIS database and digital cartography by Andrew C. Ritchie and Eleyne L. Phillips

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Offshore and Onshore Geology and Geomorphology, Offshore of Coal Oil Point Map Area, California

By

James E. Conrad,[1] Andrew C. Ritchie,[1] Samuel Y. Johnson,[1] H. Gary Greene,[2] Peter Dartnell,[1] Gordon G. Seitz,[3] and Carlos I. Gutierrez[3]

[1]U.S. Geological Survey;
[2]Moss Landing Marine Lab, Center for Habitat Studies;
[3]California Geological Survey

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