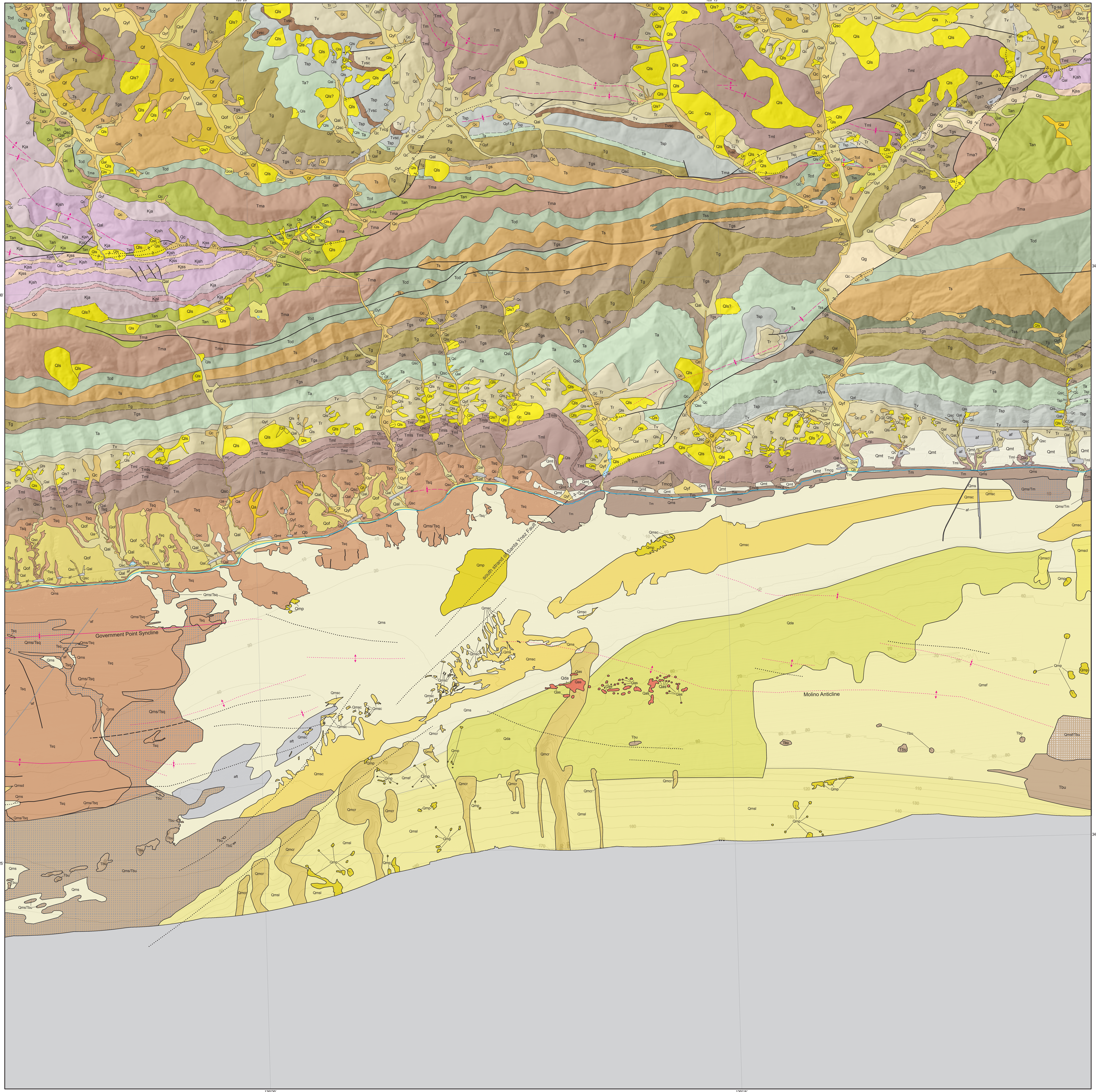


Onshore elevation data from National Oceanic and Atmospheric Administration (NOAA) Office for Coastal Management's Digital Coast (available at http://www.csc.noaa.gov/digitalcoast/data/coastallidar/) and from U.S. Geological Survey's National Elevation Dataset (available at http://ned.usgs.gov/). Offshore 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, 2018

SCALE 1:24 000

BATHYMETRIC CONTOUR INTERVALS 10 METERS

ONE MILE = 0.869 NAUTICAL MILES

MAP LOCATION

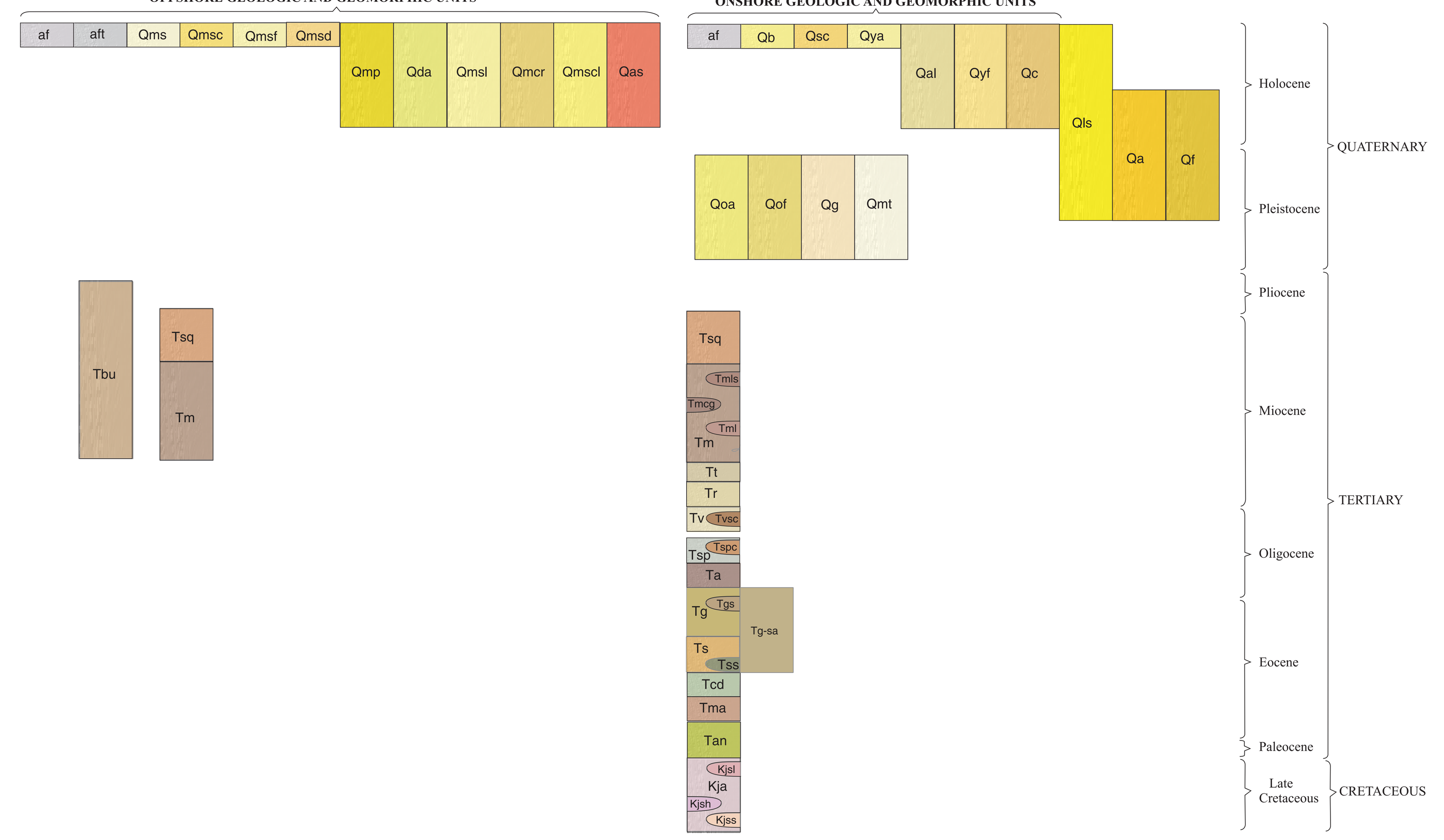
Offshore geology and geomorphology mapped by Samuel Y. Johnson and Stephen R. Hartwell, 2014. Onshore geology and geomorphology compiled by Clifton W. Davenport, 2014, from Dibblee (1988a,b). Bathymetric contours by Peter Dartnell, 2014

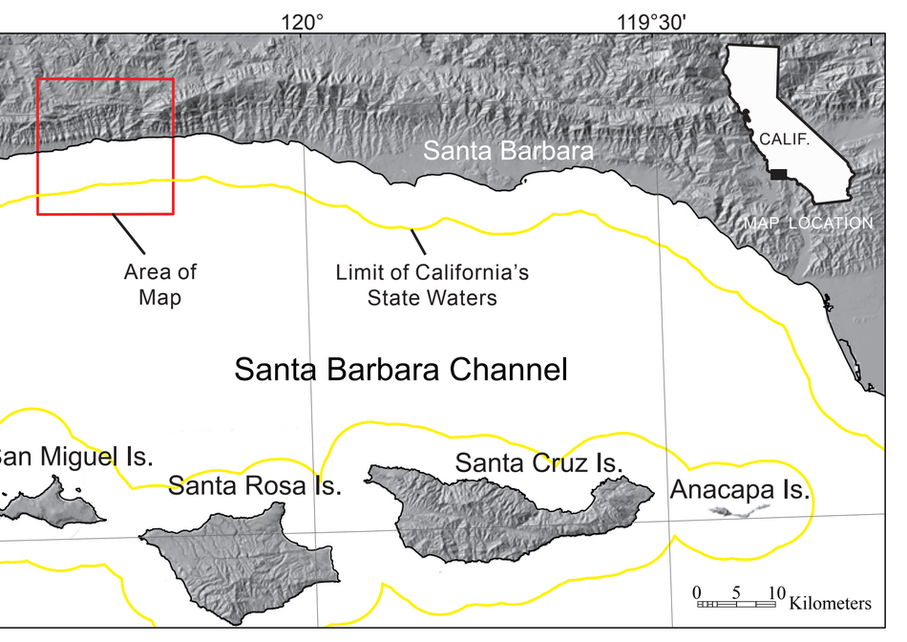
GIS database and digital cartography by Stephen R. Hartwell and Peter Dartnell

Manuscript approved for publication February 12, 2018

CORRELATION OF MAP UNITS

[See Description of Map Units (chapter 7, in pamphlet) for precise unit ages]





LIST OF MAP UNITS

[See Description of Map Units (chapter 7, 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/Tm indicates that thin sheet of Qms overlies Tm)]

- af — **Artificial seafloor (late Holocene)**—Pipelines on inner shelf, south of Gaviota marine terminal
- aft — **Artificially modified seafloor (late Holocene)**—Sandy seafloor crossed by very low relief (about 10 to 20 cm high), widely spaced (about 5 to 15 m apart), northeast-trending ridges, interpreted as trawling scars
- Qms — **Marine nearshore and shelf deposits (late Holocene)**—Mostly sand; ripples common. Found mainly on gently seaward-dipping shelf and on Gaviota sediment bar
- Qmsc — **Coarse-grained marine nearshore and shelf deposits (late Holocene)**—Ranges from coarse sand and gravel to boulders. Found mainly on Gaviota sediment bar
- Qmsf — **Fine-grained marine shelf deposits (late Holocene)**—Mostly clay, silt, and very fine sand. Found on gently seaward-dipping shelf, at depths of between about 50 to 70 m and about 90 m
- Qmsd — **Marine shelf scour depression (late Holocene)**—Inferred to be coarse sand and gravel, in low-relief scour depression
- Qmp — **Marine pockmarks (Holocene)**—Sand and mud, in circular to elliptical pockmarks
- Qda — **Marine shelf slump deposits (Holocene)**—Hummocky, sandy debris-flow deposits. Found on southeast flank of Gaviota sediment bar
- Qmsl — **Marine upper slope deposits (Holocene)**—Predominantly clay, silt, and very fine sand; commonly bioturbated. Found below shelf break on seaward-dipping (about 5°) slope
- Qmcr — **Marine canyons and rills (Holocene)**—Probably sand and mud; forms narrow, elongate, and shallow to deep channels or rills; cut into midshelf to outer shelf and slope and also upper part of Conception fan
- Qmscl — **Marine shelf-sediment lobes (Holocene)**—Predominantly sand to boulders(?). Found as two distinct, irregularly shaped lobes near east edge of map area, at water depths of 35 to 60 m
- Qas — **Asphalt deposits (Holocene)**—Asphalt (tar); weathered and biodegraded oil derived from underlying or nearby natural hydrocarbon seeps. Found along and near axis of Molino Anticline
- Tbu — **Bedrock, undivided (Pliocene and Miocene)**—Mainly mudstone and siltstone. Probably consists of the Pliocene Pico and Repetto Formations, the lower Pliocene and upper Miocene Sisquoc Formation, and the Miocene Monterey Formation
- Tsq — **Sisquoc Formation (early Pliocene and late Miocene)**—Marine, tan- to white-weathering, diatomaceous mudstone and shale, conglomerate, and subordinate dolomite
- Tm — **Monterey Formation (Miocene)**—Mainly siliceous and calcareous mudstone and shale

ONSHORE GEOLOGIC AND GEOMORPHIC UNITS

[Units compiled from Dibblee (1988a,b); unit ages, which are from these sources, reflect local stratigraphic relations. In addition, some Quaternary units modified by C.W. Davenport on basis of analysis of 2004 ifSAR and 2009 lidar imagery]

- af — **Artificial fill (late Holocene)**—Engineered and (or) nonengineered material deposited by humans
- Qb — **Beach deposits (late Holocene)**—Unconsolidated, fine- to coarse-grained sand, pebbles, and boulders. Mapped in coastal band from shoreline to highest elevation of swash zone
- Qsc — **Active stream-channel deposits (late Holocene)**—Active stream channels that contain unconsolidated sand, silt, and gravel deposits
- Qya — **Alluvium (late Holocene)**—Alluvial deposits adjacent to active stream channels
- Qal — **Alluvial deposits, undivided (Holocene)**—Sand, gravel, and silt deposits, adjacent to or near active stream channels
- Qyf — **Alluvial fan deposits (Holocene)**—Unconsolidated, heterogeneous layers of sand, silt, and gravel; relatively undissected. Internal contacts delineate individual alluvial fans
- Qc — **Colluvium (Holocene)**—Loose to firm, unsorted sand, silt, clay, gravel, rock debris, and organic material; includes slope wash and valley fill; may contain numerous small landslides and (or) coalesced alluvial fans
- Qls — **Landslide deposits (Holocene and Pleistocene)**—Deposits of diverse slope-movement processes; queried where identity is uncertain. Internal contacts delineate individual landslide bodies
- Qa — **Alluvial deposits, undivided (Holocene and Pleistocene)**—Sand, gravel, and silt deposits. Mapped on gently sloping to level surfaces near stream channels
- Qf — **Alluvial fan deposits (Holocene and Pleistocene)**—Poorly consolidated silt, sand, and gravel deposits. Mapped either where older age is indicated by greater degree of dissection or where elevations are higher than that of adjacent Holocene alluvial fans. Internal contacts delineate individual alluvial fans
- Qoa — **Alluvial deposits (Pleistocene)**—Sand, gravel, and silt deposits; includes remnants of stream terraces and alluvial fans
- Qof — **Alluvial fan deposits (Pleistocene)**—Discontinuous or highly dissected deposits of semiconsolidated, moderately to poorly sorted layers of silty clay, silt, sand, and gravel. Found adjacent to mountain fronts
- Qg — **Gravel, cobbles, and boulders (Pleistocene)**—Fan and fanglomerate deposits that consist of gravel, cobbles, and boulders
- Qmt — **Marine-terrace deposits, undivided (Pleistocene)**—Semiconsolidated sand and local gravel deposits, on uplifted marine-abrasion platforms along coast
- Tsq — **Sisquoc Formation (early Pliocene and late Miocene)**—Marine shale, claystone, and diatomite
- Tm — **Monterey Formation, undivided (Miocene)**—Marine, predominantly well-bedded, siliceous chert, mudstone, shale, diatomite, and conglomerate breccia. Locally divided into three subunits
  - Tmcg — **Conglomerate breccia (Miocene)**—Siliceous and cherty shale detritus in tar-soaked sandstone matrix
  - Tml — **Light-gray diatomite (Miocene)**
  - Tmls — **Semisiliceous shale (Miocene)**
- Tt — **Tranquillon Volcanics (Miocene)**—Rhyolitic tuff breccia
- Tr — **Rincon Shale (early Miocene)**—Marine shale or claystone
- Tv — **Vaqueros Formation (late Oligocene)**—Marine calcareous sandstone; queried where identity is uncertain. Includes one subunit
  - Tvsc — **Sandstone and pebble conglomerate (late Oligocene)**
- Tsp — **Sespe Formation, upper sandstone and mudstone unit (Oligocene)**—Nonmarine sandstone, siltstone, and mudstone. Includes one subunit
  - Tspc — **Sandstone and pebble conglomerate (Oligocene)**
- Ta — **Alegria Formation (Oligocene)**—Marine arkosic sandstone and silty claystone; queried where identity is uncertain
- Tg — **Gaviota Formation (Oligocene and Eocene)**—Marine arkosic sandstone, locally fossiliferous. Includes one subunit
  - Tgs — **Concretionary siltstone and claystone (Oligocene and Eocene)**—Queried where identity is uncertain
- Tg-sa — **Gaviota Formation and Sacate Formation, undivided (Oligocene and Eocene)**—Marine sandstone and siltstone
- Ts — **Sacate Formation (Eocene)**—Marine arkosic sandstone that contains interbeds of micaceous, clayey shale. Includes one subunit
  - Tss — **Predominantly shale (late Eocene)**
- Tcd — **Cozy Dell Shale (Eocene)**—Marine micaceous shale
- Tma — **Matilija Sandstone (Eocene)**—Marine arkosic sandstone; queried where identity is uncertain
- Tan — **Anita Shale (Eocene and Paleocene)**—Marine, micaceous, clayey shale; includes foraminiferal claystone (informally known as "Poppin shale")
- Kja — **Jalama Formation (Late Cretaceous)**—Marine arkosic sandstone; includes three subunits
  - Kjsl — **Siltstone (Late Cretaceous)**
  - Kjsh — **Micaceous shale and siltstone (Late Cretaceous)**
  - Kjss — **Arkosic sandstone with interbeds of micaceous shale (Late Cretaceous)**

EXPLANATION OF MAP SYMBOLS

Contact—Solid where location is certain or well located, dashed where location is approximate or inferred

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

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

Anticline

Syncline

Approximate modern shoreline—From National Oceanic and Atmospheric Administration's Shoreline Data Explorer (National Geodetic Survey, 2016)

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 Gaviota map area from the shoreline to the 3-nautical-mile limit of California's State Waters. The location of the shoreline, which is from the National Oceanic and Atmospheric Administration's (NOAA's) Shoreline Data Explorer, is based on their analysis of lidar imagery (National Geodetic Survey, 2016). 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 (Golden and Cochrane, 2013), and high-resolution seismic-reflection profiles (sheet 7). Bathymetric lidar and aerial photographs taken in multiple years were used to map the nearshore area (0 to 10 m water depth) and to link the offshore and onshore geology.

The onshore geology was compiled from Dibblee (1988a,b); unit ages, which are derived from these sources, reflect local stratigraphic relations. In addition, some Quaternary units were modified by C.W. Davenport on the basis of analysis of 2004 ifSAR and 2009 lidar imagery.

The offshore part of the map area largely consists of a narrow (4- to 5-km-wide), gently (about 1° to 1.5°) offshore-dipping shelf underlain by Neogene bedrock, as well as Holocene sediments that are derived primarily from Cañada de la Gaviota and smaller coastal watersheds that drain the Santa Ynez Mountains (see fig. 1–2, in pamphlet). Holocene nearshore and shelf deposits are primarily sand (unit Qms). Coarser grained sediments (unit Qmsc) are found mainly along the Gaviota sediment bar, a prominent bathymetric feature that extends southwestward for about 9 km from the mouth of Cañada de la Gaviota to the shelf break. The Gaviota sediment bar, which faces southeast, is as wide as 2 km and has a relatively flat (about 1.4°) top that extends to water depths of 60 m. The steep (as much as 5°) bar front, which formed by advancing clinoforms (see fig. 5 on sheet 7), is bounded by an apron of coalescing, hummocky debris-flow lobes (unit Qda). Coarser grained sediment also is present in the eastern part of a small scour depression (unit Qmsd) found along the west edge of the map area, at a water depth of about 35 m. Sandy seafloor (unit aft) that is crossed by very low relief (about 10 to 20 cm high), widely spaced (about 5 to 15 m apart), northeast-trending ridges is found in two areas (827,209 and 289,593 m^2) about 3.5 km south of the Gaviota shoreline, in water depths of about 40 to 55 m; the morphology of these ridges suggests that they were formed by fishing trawls.

Two subtle sediment lobes (unit Qmscl) are mapped near the east edge of the map area on the basis of their high backscatter and positive seafloor relief. These lobes, which occupy 257,490 and 92,932 m^2, are found about 1,080 to 2,100 m offshore, in water depths of 35 to 55 m. The lobes are located offshore of the mouths of steep coastal watersheds, and they have been interpreted as the deposits of debris flows or hyperpycnal flows, or a combination of these processes (Warrick and others, 2013; Steel and others, 2015). Preliminary ages (Steel and others, 2015) on similar features to the east indicate that they may have formed as early as 8,500 years ago when sea level was significantly lower (Steel and others, 2015).

Finer grained sediment—the very fine sand, silt, and clay of unit Qmsf—is mapped primarily in the eastern part of the map area, between depths of about 60 m and the shelf break. The boundary between units Qms and Qmsf is based on observations and extrapolation from sparse sediment sampling (for example, Reid and others, 2006) and camera ground-truth surveying (Golden and Cochrane, 2013). Thus, 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 similar to unit Qmsf also are found below the shelf break on the upper slope, at water depths greater than 90 m, where they are mapped as a separate unit (unit Qmsl) on the basis of their location and geomorphology. Both the shelf break and the distal part of the Gaviota sediment bar are incised by narrow rills and three large (150- to 300-m-wide) channels (collectively mapped as unit Qmcr) that have been referred to either as "the Gaviota Canyons" (Fischer and Cherven, 1998) or as "Drake Canyon," "Sacate Canyon," and "Alegria Canyon" (Eichhubl and others, 2002).

East of the south strand of the Santa Ynez Fault, bedrock exposures along the shoreline and on the inner shelf consist of siliceous and calcareous mudstone and shale of the Miocene Monterey Formation (unit Tm). West of this fault strand, bedrock outcrops in the nearshore and on the shelf consist primarily of marine shale, claystone, and diatomite of the upper Miocene and lower Pliocene Sisquoc Formation (unit Tsq). Seafloor outcrops of units Tm and Tsq both commonly have a "ribbed" appearance, reflecting the differential erosion of variably resistant interbeds. Because of the lack of sampling and their relative lack of distinctive seafloor morphology, some seafloor bedrock outcrops on the outer shelf cannot be confidently assigned to either unit Tm or unit Tsq; these areas are mapped as the undivided Tertiary bedrock unit (Tbu).

The Santa Barbara Channel region is a mature hydrocarbon province that has a long history of petroleum exploration and production (Kunitomi and others, 1998). The Offshore of Gaviota map area includes the western part of the Molino offshore gas field, as well as the Gaviota and Caliente offshore gas fields and the Alegria and Cuarta offshore oil fields (Yerkes and others, 1969). Seafloor geomorphic features associated with petroleum seepage include fields of dense pockmarks (unit Qmp), asphalt mounds (unit Qas), carbonate mats, and mud volcanoes (see, for example, Keller and others, 2007). The pockmarks in the map area are predominantly grouped or, less commonly, solitary; are circular to elliptical; range in size from 50 to 150 m along their long axis; typically are 20 to 40 cm deep; and commonly have a central cone as much as 150 cm high. The largest field of pockmarks (709,384 m^2) is along the trace of the south strand of the Santa Ynez Fault, along which fractured bedrock may provide a conduit for seepage. Asphalt mounds in the map area are found along and near the crest of the Molino Anticline where they generally are less than 4 m high and less than 40 m in diameter (Lorenson and others, 2014); Draut and others (2009) noted that such mounds likely consist of a mixture of tar and sediment. Lorenson and others (2014) calculated a composite volume of asphalt in the Gaviota area of 4.5×10^5 m^3. Offshore pipelines, which are associated with offshore oil and gas development, are mapped as unit af.

Neogene strata are deformed in a fold belt that, on a regional scale, is located within a large, east-west-striking, south-dipping homocline that extends from the south flank of the Santa Ynez Mountains into the offshore. Nearby regional cross sections (Redin and others, 2005) and industry seismic-reflection profiles (see fig. 6 on sheet 7; see also, Sorlien and Nicholson, 2015) showed that the homocline formed above the blind Pitas Point–North Channel Fault system, which in the offshore extends westward for more than 100 km, from Pitas Point (10 km northwest of Ventura) to beyond Gaviota and Point Conception (see fig. 1–3, in pamphlet). South of Gaviota, the tip of the Pitas Point–North Channel Fault is inferred to be buried beneath the slope, about 10 km offshore, to a depth of about 2 to 3 km below sea level.

The southwest-striking south strand of the Santa Ynez Fault, as mapped onshore by Dibblee (1988b), is unique among Santa Barbara fold-belt structures in that it obliquely crosses the Santa Ynez Mountains and the dominant east-west-trending structural grain. In the offshore, the fault was difficult to map, despite our dense coverage of seismic-reflection data (see sheet 7), because (1) the pre-LGM section on the shelf includes massive, reflection-free zones, probably caused by either interstitial gas or steeply dipping strata, and (2) the adjacent slope is mainly underlain by the massive to chaotic seismic facies of the Conception fan. The location of the fault on our map coincides with the northwestern margin of the Gaviota sediment bar on the midshelf to outer shelf (see fig. 1–2, in pamphlet; see also, sheets 1, 2), suggesting that faulting may have been a control on bar development. In contrast to previously published offshore mapping of Fischer (1998), we map the Santa Ynez Fault as having a straighter strike (at about 224° azimuth) and being located as much as 900 m farther northwest on the midshelf to outer shelf. Both Fischer (1998) and Eichhubl and others (2002) inferred that the Santa Ynez Fault "captured" the heads of "Drake Canyon" and "Sacate Canyon" at the shelf break; indeed, the linearity of these canyon heads is striking, and it suggests left-lateral slip. Accordingly, our map shows a secondary, discontinuous strand of the fault that extends through these canyon heads; however, we cannot trace these strands to the northeast across the shelf using seismic-reflection profiles, and so their presence is based solely on bathymetry. South of the map area, the south strand of the Santa Ynez Fault appears to disperse into a diffuse zone of several shorter, more east-west-striking contractional faults on the outer shelf, and it cannot be traced across the slope into deeper water. This fanlike pattern of faults is characteristic of terminating strike-slip faults (Christie-Blick and Biddle, 1985; Mann, 2007).

In the offshore part of the map area, closely spaced seismic-reflection profiles (see sheet 7) image many shallow, west-northwest-striking folds that have variable geometries, lengths, amplitudes, degrees of continuity, and wavelengths. The two longest folds, the 17-km-long Molino Anticline and the 22-km-long Government Point Syncline, are truncated to the west and east, respectively, by the south strand of the Santa Ynez Fault. These regionally extensive folds, as well as many other shorter, east-west-striking structures, are probably rooted in blind thrust faults and back-thrust faults in the hanging wall above the Pitas Point–North Channel Fault system.

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Offshore and Onshore Geology and Geomorphology, Offshore of Gaviota Map Area, California

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2018

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