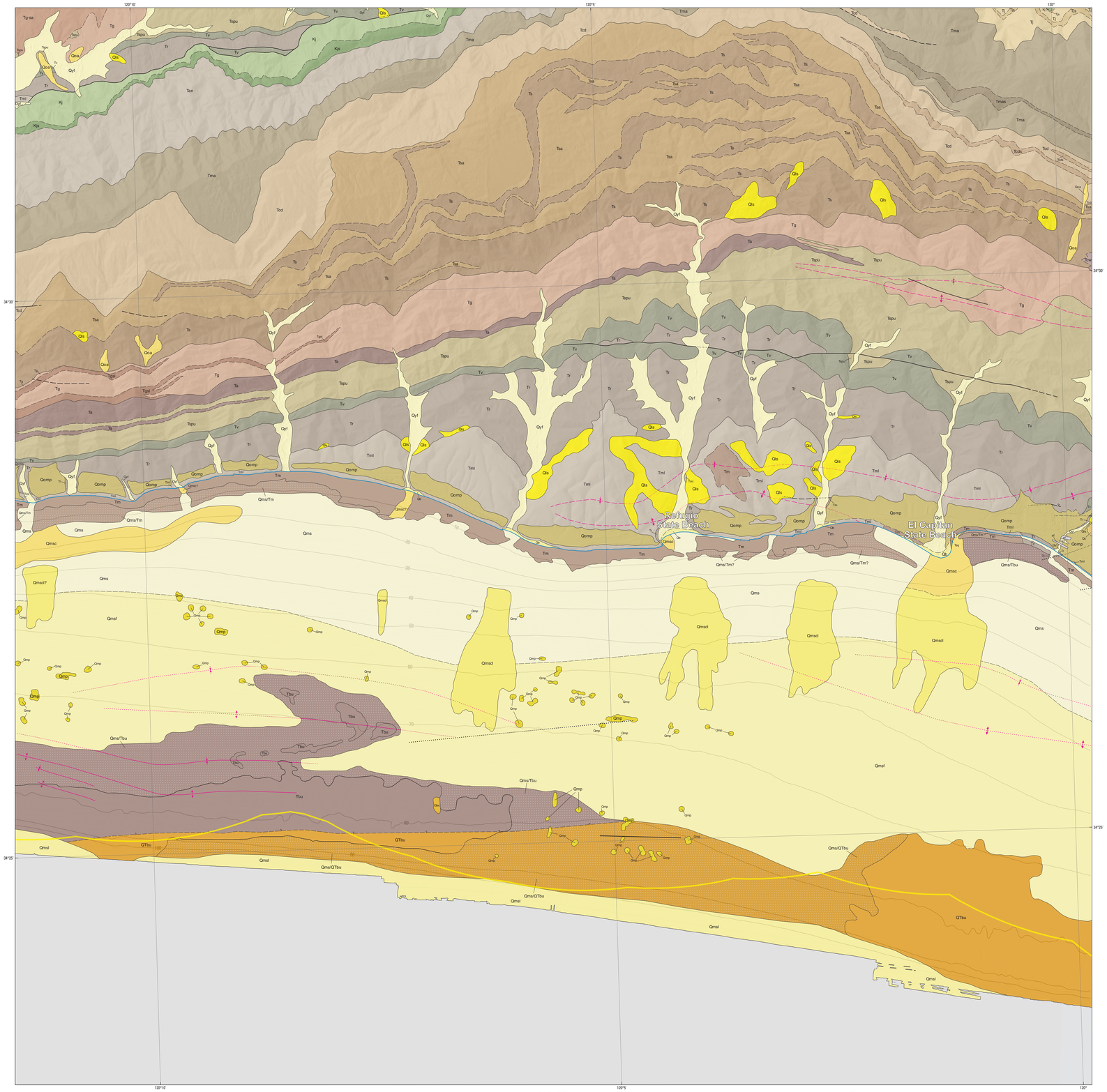
U.S. Department of the Interior
U.S. Geological Survey

Scientific Investigations Map 3319
Sheet 10 of 11
Pamphlet accompanies map



Onshore elevation data from NDAA 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 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, 2015

SCALE 1:24 000

1 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 0 1 KILOMETER

BATHYMETRIC CONTOUR INTERVAL 10 METERS
ONE MILE = 0.869 NAUTICAL MILES

MAP LOCATION

Offshore geology mapped by James E. Conrad, Andrew C. Ritchie, and Samuel Y. Johnson, 2010–2011. Onshore geology compiled by Gordon S. Seitz and Carlos I. Gutierrez from Dibblee (1981a,b,c,d) and Minor and others (2009). Bathymetric contour intervals by Andrew C. Ritchie, 2011

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

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Offshore and Onshore Geology and Geomorphlogy, Offshore of Refugio Beach Map Area, California

By

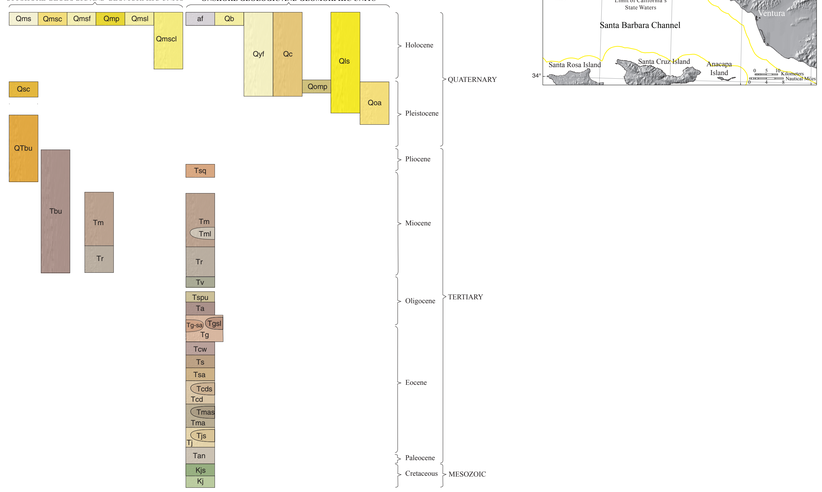
James E. Conrad,[1] Andrew C. Ritchie,[1] Samuel Y. Johnson,[1] Gordon G. Seitz,[2] and Carlos I. Gutierrez[2]

2015

[1]U.S. Geological Survey;
[2]California Geological Survey

CORRELATION OF MAP UNITS

[See Description of Map Units (chapter 8, in pamphlet) for precise unit ages]



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/Tm indicates that thin sheet of Qms overlies Tm)]

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

Qmp **Marine pockmarks (late Holocene)**—Sand and mud, in circular to elliptical pockmarks

Qmsl **Marine upper slope deposits (late Holocene)**—Mostly clay, silt, and very fine sand; occurs below shelf break at water depths more than 90 m

Qmscl **Marine shelf-sediment lobes (Holocene)**—Predominantly sand to boulders(?); lobate form

Qsc **Marine or nonmarine coarse-grained deposits (late Pleistocene?)**—Conglomerate

QTbu **Bedrock, undivided (Pleistocene to Miocene)**—Mainly mudstone and siltstone; includes conglomeratic sandstone. Consists of the Pico Formation and the Sisquoc Formation

Tbu **Bedrock, undivided (Pliocene and Miocene)**—Mainly mudstone and siltstone. Possibly consists of the Sisquoc Formation, the Monterey Formation, and the Rincon Shale

Tm **Monterey Formation (Miocene)**—Mainly siliceous and calcareous mudstone and shale

Tr **Rincon Shale (early Miocene)**—Mostly mudstone with subordinate dolomite, shale, sandstone, and tuff

ONSHORE GEOLOGIC AND GEOMORPHIC UNITS

[Units are compiled from Dibblee (1981a,b,c,d) and Minor and others (2009); unit ages, which are derived from these sources, reflect local stratigraphic relations]

af **Artificial fill (late Holocene)**—Engineered and (or) nonengineered

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

Qyf **Alluvium and colluvium, undivided (Holocene and late Pleistocene)**—Poorly consolidated silt, sand, and gravel deposits, in modern drainages and piedmont alluvial fans and floodplains

Qc **Colluvium (Holocene and late Pleistocene)**—Poorly consolidated, poorly stratified, and poorly sorted deposits chiefly derived from downslope movement of nearby bedrock

Qls **Landslide deposits (Holocene to middle Pleistocene)**—Deposits of slope processes; ranges from poorly sorted rock fragments and soil to relatively intact bedrock slump

Qomp **Marine-terrace deposits (late Pleistocene)**—Basal, about 1-m-thick, poorly consolidated, variably stratified gravel, sand, and silt; overlies nonmarine eolian, alluvial, and colluvial deposits

Qoa **Alluvial deposits (late and middle Pleistocene)**—Weakly consolidated, stratified silt, sand, gravel, conglomerate, breccia, and rare interbeds of clay, silt, and mudstone

Tsq **Sisquoc Formation (early Pliocene and late Miocene)**—Marine diatomaceous mudstone and shale, conglomerate, and subordinate dolomite

Tm **Monterey Formation, undivided (Miocene)**—Mainly siliceous and calcareous mudstone and shale

Tml **Lower calcareous unit (middle and early Miocene)**—Marine mudstone and shale, with subordinate dolomite, porcelanite, breccia, sandstone, and tuff

Tr **Rincon Shale (early Miocene)**—Marine, primarily massive and thick-bedded mudstone, with subordinate dolomite, siliceous shale, sandstone, or tuff

Tv **Vaqueros Formation (late Oligocene)**—Shallow-marine, massive, bioturbated, resistant sandstone

Tspu **Sespe Formation, upper sandstone and mudstone unit (Oligocene)**—Interbedded sandstone, siltstone, and mudstone

Ta **Alegria Formation (Oligocene)**—Shallow-marine, arkosic sandstone and greenish-gray siltstone; locally fossiliferous (Dibblee, 1981a)

Tg **Gaviota Formation (Oligocene and Eocene)**—Shallow-marine, thick-bedded arkosic sandstone and some gray siltstone; locally fossiliferous (Dibblee, 1981a)

Tgsl **Lower unit (Oligocene and Eocene)**—Shallow-marine, gray, concretionary siltstone and claystone (Dibblee, 1981b)

Tg-sa **Gaviota Formation and Sacate Formation, undivided (Oligocene and Eocene)**—Marine sandstone and siltstone (Dibblee, 1981d)

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, 1981d)

Tsa **Sandstone subunit (Eocene)**—Marine, light-gray to tan arkosic sandstone (Dibblee, 1981d)

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

Tma **Matilija Sandstone (Eocene)**—Marine, thick-bedded arkosic sandstone

Tmas **Sandstone and shale subunit (Eocene)**—Interbedded sandstone and shale

Tj **Juncal Formation (Eocene)**—Marine shale

Tjs **Sandstone unit (Eocene)**—Marine sandstone

Tan **Anita Shale (Eocene and Paleocene)**—Marine, medium- to dark-gray micaceous shale, with thin sandstone layers (Dibblee, 1981c)

Jalama Formation (Late Cretaceous)—Marine sandstone and shale

Kjs **Sandstone unit (Late Cretaceous)**—Marine sandstone (Dibblee, 1981d)

Kj **Shale unit (Late Cretaceous)**—Marine shale (Dibblee, 1981d)

EXPLANATION OF MAP SYMBOLS

Contact—Solid where location is certain, dashed where location is approximate or inferred, dotted where location is concealed, queried where existence is questionable

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

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

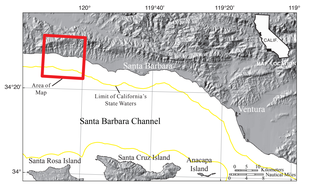
Antiform

Synform

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

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 Refugio Beach 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 (1981a,b,c,d) and Minor and others (2009). Unit ages, which are derived from these sources, 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. Nearshore and shelf deposits are primarily sand (unit Qms) at water depths less than about 45 m. More fine grained sediments (very fine sand, silt and clay) of unit Qmsf are mapped between depths of about 45 m and the shelf break, which is at 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 present at water depths greater than 90 m, below the shelf break on the upper slope; however, here they are mapped as a separate unit (unit Qmsl) on the basis of their location and geomorphology.

Coarser grained deposits of units Qmsc, Qmscl, and Qsc, which are recognized on the basis of their high backscatter, and in some cases, their moderate seafloor relief (sheets 1, 2, 3), are present in three modes of deposition. In the nearshore (10 to 30 m water depth), coarse-grained deposits of unit Qmsc underlie laterally coalescing and discontinuous bars at the mouths of steep coastal watersheds. Coarser grained deposits of unit Qmscl form several distinct lobes at water depths of 25 to 70 m, about 600 to 3,000 m offshore; these lobes, which range in size from about 0.1 km^2 to about 1.5 km^2, are mapped on the basis of their high backscatter and subtle positive seafloor relief. These coarse-grained strata clearly were derived from fluvial point sources in the adjacent, steep Santa Ynez Mountains. An isolated patch of clast-supported cobbles (unit Qsc), which rests on bedrock southwest of Refugio State Beach at a water depth of about 76 m, also may have been deposited at the mouth of a coastal watershed when sea level was lower during the Pleistocene.

Offshore bedrock exposures in the nearshore near El Capitan State Beach are mapped as either the early Miocene Rincon Shale (Tr) or the Monterey Formation (Tm) on the basis of their proximity to onshore coastal outcrops mapped by Dibblee (1981a,b). Much of the outer shelf (water depths of more than 70 m) is underlain by the undivided Tertiary bedrock unit (Tbu) and the undivided Tertiary and Quaternary bedrock unit (QTbu). On the basis of regional cross sections that are constrained by deep seismic-reflection data and borehole logs (Heck, 1998; Tennyson and Kropp, 1998; Forman and Redin, 2005; Redin, 2005), as well as on high-resolution seismic-reflection data (see sheet 8) coupled with proprietary oil-industry dartcore data (Ashley and others, 1977), these outer shelf outcrops consist of the late Miocene and early Pliocene Sisquoc Formation and the overlying Pliocene and Pleistocene Pico Formation (both of which are mapped here as the undivided QTbu unit). These undivided rocks have been uplifted in a large, warped, south-dipping regional homocline that formed above the blind, north-dipping North Channel Fault; the fault tip is inferred to be about 2 km deep (that is, at two-way travel time of about 1.5 sec) about 6 to 7 km offshore, beneath the slope and just outside the limit of California's State Waters (see sheet 8).

This area has a long history of petroleum production (Barnum, 1998), and pockmarks (unit Qmp) caused by gas seeps are common features in the Offshore of Refugio Beach map area. In 1962, Shell Oil Company discovered the Molino gas field (see fig. 1–2 in pamphlet), 4 km offshore, in the southwestern part of the map area. Natural gas production, achieved by onshore directional drilling of an offshore anticlinal trap, has been underway since the 1960s (Galloway, 1998).

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Coastal Conservancy

CALIFORNIA OCEAN PROTECTION COUNCIL

NOAA

CGS CALIFORNIA GEOLOGICAL SURVEY

US Army Corps of Engineers

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