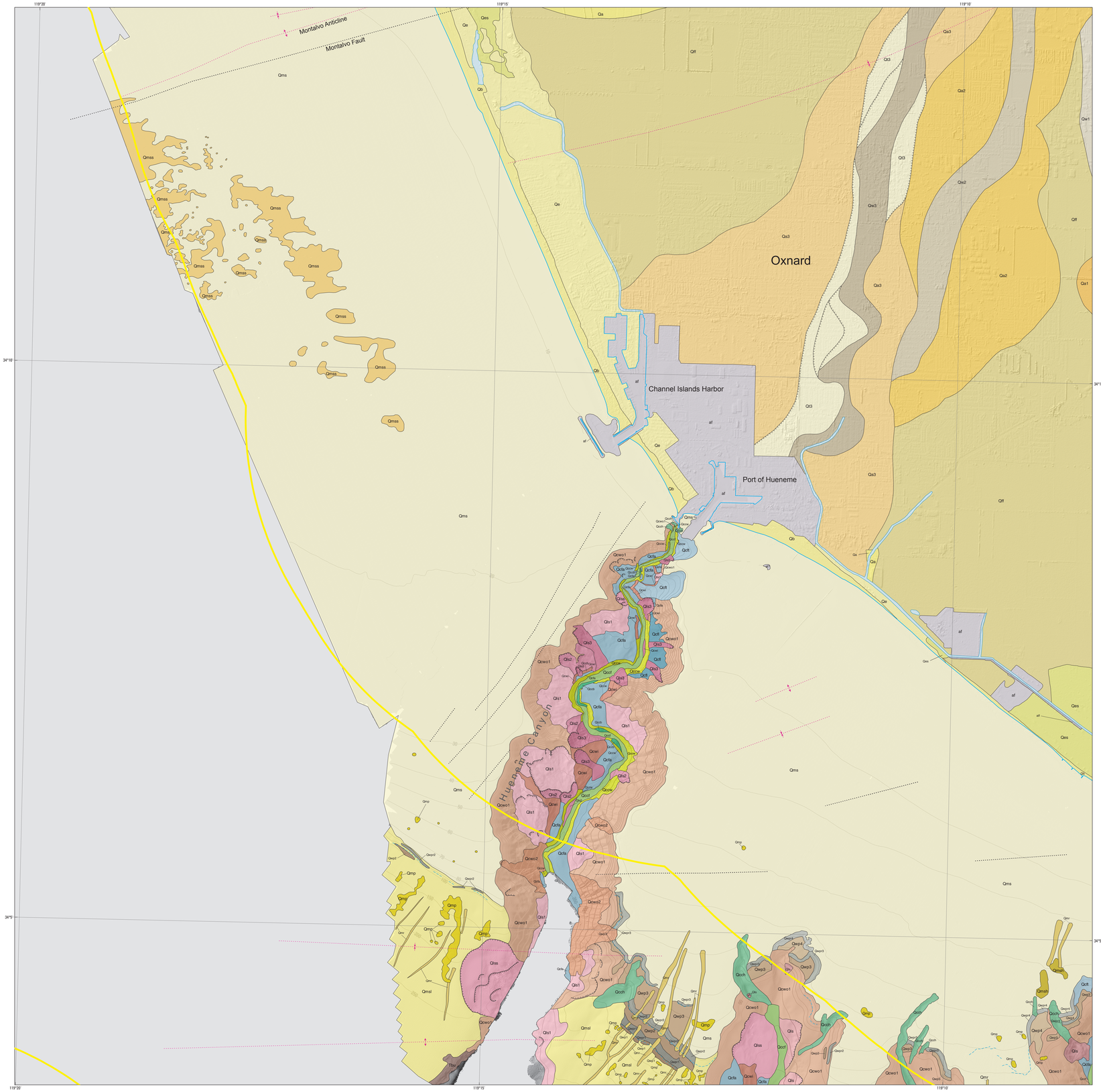
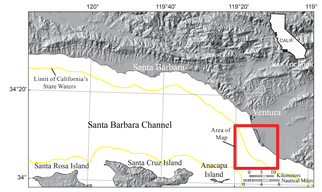
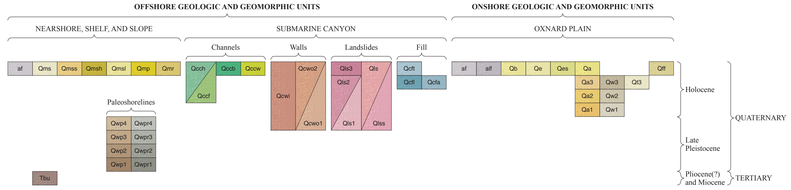
U.S. Department of the Interior
U.S. Geological Survey

Scientific Investigations Map 3225
Sheet 10 of 12
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

NEARSHORE, SHELF, AND SLOPE

- af — **Artificial fill (Holocene)**—Rock, sand, and mud; placed and (or) dredged. Also includes seafloor significantly modified by human activity
- Qms — **Marine nearshore and shelf deposits (Holocene)**—Mostly sand; ripples common
- Qmss — **Marine shelf scour depressions (Holocene)**—Inferred to be coarse sand and gravel
- Qmsh — **Marine shelf hummocky deposits (Holocene)**—Sand forming hummocky surface relief
- Qmsl — **Marine slope deposits (Holocene)**—Sand and mud
- Qmp — **Marine pockmarks (Holocene)**—Sand and mud
- Qmr — **Marine rill (Holocene)**—Probably sand and mud
- Tbu — **Bedrock, undivided (Pliocene? and Miocene)**

Paleoshorelines

- Qwp4 — **Submerged wave-cut platform, about 65 m deep (latest Pleistocene)**—Inferred to be sand and gravel
- Qwpr4 — **Submerged wave-cut platform riser, base about 65 m deep (latest Pleistocene)**—Inferred to be sand and gravel
- Qwp3 — **Submerged wave-cut platform, about 75 to 85 m deep (latest Pleistocene)**—Inferred to be sand and gravel
- Qwpr3 — **Submerged wave-cut platform riser, base about 75 to 85 m deep (latest Pleistocene)**—Inferred to be sand and gravel
- Qwp2 — **Submerged wave-cut platform, about 95 to 100 m deep (latest Pleistocene)**—Inferred to be sand and gravel
- Qwpr2 — **Submerged wave-cut platform riser, base about 95 to 100 m deep (latest Pleistocene)**—Inferred to be sand and gravel
- Qwp1 — **Submerged wave-cut platform, about 120 to 125 m deep (latest Pleistocene)**—Inferred to be sand and gravel
- Qwpr1 — **Submerged wave-cut platform riser, base about 120 to 125 m deep (latest Pleistocene)**—Inferred to be sand and gravel

SUBMARINE CANYON

Channels

- Qcch — **Submarine-canyon channel-head deposits (Holocene)**—Probably sand and gravel(?)
- Qccf — **Submarine-canyon channel-floor deposits (Holocene)**—Inferred to be sand and gravel
- Qccb — **Submarine-canyon channel-flanking bar deposits (Holocene)**—Inferred to be sand, mud, and gravel
- Qccw — **Submarine-canyon channel-wall deposits (Holocene)**—Inferred to be sand, mud, and gravel

Walls

- Qcwi — **Inner submarine-canyon-wall deposits (Holocene and latest Pleistocene)**—Inferred to be sand, mud, and gravel; slopes mostly more than 12° and commonly more than 20°
- Qcwo2 — **Outer submarine-canyon-wall deposits (Holocene and latest Pleistocene)**—Inferred to be sand, mud, and gravel; slopes mostly more than 30°; erosional and deeply incised
- Qcwo1 — **Outer submarine-canyon-wall deposits (Holocene and latest Pleistocene)**—Inferred to be sand, mud, and gravel; slopes generally more than 18° but rarely more than 30°; relatively smooth, and commonly sediment draped

Landslides

- Qls3 — **Landslide deposits, third generation (Holocene)**—Inferred to be sand and gravel
- Qls2 — **Landslide deposits, second generation (Holocene and latest Pleistocene)**—Inferred to be sand and gravel
- Qls1 — **Landslide deposits, first generation (Holocene and latest Pleistocene)**—Inferred to be sand and gravel
- Qls — **Landslide deposits, undifferentiated (Holocene and latest Pleistocene; historical)**—Inferred to be sand and gravel; presently active
- Qlss — **Slump deposits on canyon walls (Holocene and latest Pleistocene)**—Probably sand

Fill

- Qcft — **Tributary-submarine-canyon fill (Holocene)**—Inferred to be sand and gravel
- Qcfl — **Lateral-submarine-canyon fill (Holocene)**—Inferred to be mud, sand, and gravel
- Qcfa — **Axial-submarine-canyon fill (Holocene)**—Inferred to be sand and gravel

ONSHORE GEOLOGIC AND GEOMORPHIC UNITS

OXNARD PLAIN

- af — **Artificial fill (Holocene)**—Engineered and (or) nonengineered
- alf — **Artificial-levee fill (Holocene)**—Engineered and (or) nonengineered
- Qb — **Beach deposits (Holocene)**—Unconsolidated, loose, fine- to coarse-grained sand; well sorted
- Qe — **Coastal eolian sand-dune deposits (Holocene)**—Well-sorted, loose sand and silt
- Qes — **Coastal-estuarine deposits (Holocene)**—Silty clay
- Qa — **Alluvial deposits (Holocene)**—Unconsolidated, poorly sorted, clayey sand and some gravel; deposited as overbank material associated with unit Qw3; recognized by scour and incised channels
- Qa3 — **Alluvial deposits (Holocene)**—Unconsolidated, poorly sorted, clayey sand and some gravel; deposited as overbank material associated with unit Qw3; recognized by scour and incised channels
- Qw3 — **Wash deposits (Holocene)**—Unconsolidated sand, silt, and gravel. Located in major abandoned river channels
- Qt3 — **Stream-terrace deposits (Holocene)**—Unconsolidated clayey sand, sandy clay, and gravel; deposited in point-bar and overbank settings associated with unit Qw3
- Qa2 — **Alluvial deposits (Holocene)**—Unconsolidated, poorly sorted, clayey sand and some gravel; deposited as overbank material associated with unit Qw2; recognized by scour and incised channels
- Qw2 — **Wash deposits (Holocene)**—Unconsolidated sand, silt, and gravel. Located in major abandoned river channels
- Qa1 — **Alluvial deposits (Holocene)**—Unconsolidated, sandy clay and some gravel; deposited as overbank material associated with unit Qw1; recognized by scour and incised channels
- Qw1 — **Wash deposits (Holocene)**—Unconsolidated sand, silt, and gravel. Located in major abandoned river channels
- Qff — **Alluvial fan deposits (Holocene)**—Fine-grained alluvial fan and floodplain overbank deposits. Fine facies; predominantly clay and interbedded lenses of coarser sand and gravel. Located on very gently sloping parts of valley floor

EXPLANATION OF MAP SYMBOLS

- **Contact**—Approximately located
- **Fluvial-terrace scarp**—Denotes fluvial terrace within unit Qt3; in places, also forms contact between unit Qt3 and units Qa2 and Qa3. Hachures point downscarp
- **Fault**—Solid where location is certain, dotted where location is concealed
- **Folds**—Solid where location is certain, dotted where location is concealed
  - **Antiform**
  - **Synform**
- **Head scarp of submarine landslide**—Sharp, distinct. In places, forms contact between landslide deposits or other units. Hachures point downscarp
- **Internal scarp in submarine landslide**—Sharp, distinct. Hachures point downscarp
- **Inferred former marine shoreline**
- **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**—Line in southwest corner of map area is limit surrounding Anacapa Island (outside of map area)
- **Area of "no data"**—Area not mapped owing to insufficient high-resolution seafloor-mapping data

DISCUSSION

GEOLOGIC AND GEOMORPHIC SUMMARY—OFFSHORE

Marine geology and geomorphology was mapped in the Hueneme Canyon and vicinity map area from Mean High Water (MHW) to the 3-nautical-mile limit of California's State Waters and even farther offshore on the east and west flanks of Hueneme Canyon. MHW is defined at an elevation of 1.33 m above the North American Vertical Datum of 1988 (NAVD 88) (Weber and others, 2005).

The offshore map area is characterized by two major physiographic features: (1) the nearshore, the inner and outer continental shelf, and the upper slope, and (2) Hueneme Canyon and parts of three smaller, unnamed submarine canyons incised into the shelf southeast of Hueneme Canyon. The nearshore, shelf, and slope, which are underlain by recent sediments, are characterized by active sediment transport. Nearshore and inner shelf deposits are predominantly sand (unit Qms), which locally exhibits scour depressions (unit Qmss) and hummocky relief (unit Qmsh). Outer shelf and slope deposits consist of mixed sand and mud (unit Qmsl), which locally contains solitary or groups of pockmarks (unit Qmp) or is incised by narrow rills (unit Qmr).

The morphology and evolution of shelf and slope result from drainage incision into deltaic sediments of the Oxnard Plain during sea-level lowstand, followed by sedimentation as sea level rose about 125 to 130 m over the last approximately 18,000 to 20,000 years (Lambeck and Chappell, 2001). Sea-level rise (controlled by both eustasy and tectonic land-level change) was apparently not steady during this period, leading to development of shorelines during periods of relative sea-level stability. These paleoshorelines, which are characterized by shoreline angles and adjacent submerged wave-cut platforms and risers (Kern, 1977), commonly are buried by shelf sediment. However, their original morphology is at least partly preserved on the outer shelf and upper slope on the east flank of Hueneme Canyon. Four wave-cut platforms (units Qwp1, Qwp2, Qwp3, Qwp4) and risers (units Qwpr1, Qwpr2, Qwpr3, Qwpr4) are mapped here, separated by shoreline angles at depths of approximately 65 m, 75 to 85 m, 95 to 100 m, and 120 to 125 m.

Hueneme Canyon extends about 15 km offshore from its nearshore canyon head. The canyon is relatively deep (about 150 m deep at the California's State Waters limit) and steep (canyon walls as steep as 25° to 30°). The heads of the three smaller unnamed canyons southeast of Hueneme Canyon are not connected to the nearshore; however, during the last sea-level lowstand, these smaller canyons were connected to coastal watersheds that fed coarse-grained sediment directly to the Hueneme submarine fan (Normark and others, 2009). In the ensuing transgression, Hueneme Canyon maintained its connection with the shoreline as it eroded headward, whereas these smaller canyons became isolated and, thus, were abandoned.

Outer canyon walls, which extend upward to the shelf edge, in both Hueneme Canyon and the smaller canyons vary from smooth (sediment draped) (unit Qcwo1) to deeply incised (unit Qcwo2). Inner canyon walls (unit Qcwi) occupy an intermediate position between the shelf edge and canyon floor.

Both outer and inner canyon walls were formed primarily by landsliding. Three different landslide-deposit units are mapped in Hueneme Canyon on the basis of their morphology and relative age, inferred from crosscutting and (or) dinging relations: unit Qls1 (oldest), unit Qls2, and unit Qls3 (youngest). A fourth undifferentiated landslide-deposit unit (Qls) is mapped where morphology and relative-age indicators are not distinct. The landslide map units commonly include steep erosional scarps paired with hummocky landslide deposits; this genetic pairing (scarps and landslide deposits) distinguishes the internal scarps within landslide units from the head scarps within canyon-wall units. Lower relief, sediment-draped, deep-seated slumps are mapped as a fifth landslide-deposit unit (Qlss).

Submarine-canyon channel heads (unit Qcch) are delineated on the basis of their incision into the nearshore (Hueneme Canyon) or outer shelf (three smaller canyons southeast of Hueneme Canyon), as well as their relatively steep gradients and their V-shaped profiles. These channel heads merge into lower gradient and more flat-bottomed canyon-floor channel deposits (unit Qccf). The Hueneme Canyon channel floor is a zone of active sediment transport characterized by large, asymmetric bedforms bounded by steep channel walls (unit Qccw). Narrow, elongate channel-flanking bars (unit Qccb) are elevated above, and are morphologically distinct from, the channel floors and, thus, are broken out as separate map units.

In addition to landslide and canyon-channel deposits, three additional canyon-fill map units are recognized. Axial-submarine-canyon-fill deposits (unit Qcfa), which form elevated surfaces 20 to 50 m above the floors of Hueneme Canyon and the smaller submarine canyons and which dip gently downcanyon, are composed of well-stratified sediment (sand, mud, gravel?), recognized on the basis of its seismic-reflection data (high frequency, moderate amplitude, and parallel reflections). Lateral-submarine-canyon-fill deposits (unit Qcfl), located on the east flank of Hueneme Canyon near its head, consist of west-dipping, stratified sediment (recognized on the basis of its seismic-reflection facies) that probably formed as distributed fluvial input into the canyon in the middle to late Holocene. Tributary-submarine-canyon-fill deposits (unit Qcft) are inferred to have formed as direct fluvial entrants into the canyons in the middle to late Holocene and, subsequently, were partly filled by nearshore and shelf sediment during sea-level rise.

One area of undifferentiated bedrock (unit Tbu) is recognized in the map area, on the slope on the west flank of Hueneme Canyon channel, at a depth of about 300 to 350 m. This unit is recognized on the basis of its high backscatter (see sheet 3) and its massive character on seismic-reflection data (Sliter and others, 2008; profiles HC–14, HC–15). Greene and others (1978; their plate 2) previously mapped this bedrock as the Miocene Monterey Formation.

GEOLOGIC AND GEOMORPHIC SUMMARY—ONSHORE

The onshore geology and geomorphology of the Hueneme Canyon and vicinity map area was compiled from Clahan (2003). The onshore part of the map area is in the southern part of the Western Transverse Ranges province, north of the California Continental Borderland (Fisher and others, 2009). Onshore deltaic and offshore shelf deposits are deformed in the northernmost part of the map area by the west-trending Montalvo Fault and Anticline (Fisher and others, 2005). The Montalvo structures are part of a band of active deformation that includes the west-trending Oak Ridge Fault (Fisher and others, 2005), which extends offshore just a few kilometers north of the map area. The zone of faulting that contains the Oak Ridge and Montalvo Faults, which forms the southern boundary of the Ventura Basin, is considered an earthquake hazard because it extends along strike for about 130 km, and it appears to be the westward continuation of the fault system responsible for the 1994 M6.7 Northridge earthquake.

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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 from map on sheet 2, this report. 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, 2012

SCALE 1:24 000

1 0 1/2 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 0 1 KILOMETER

BATHYMETRIC CONTOUR INTERVAL 10 METERS AND 50 METERS
ONE MILE = 0.869 NAUTICAL MILES

MAP LOCATION

Offshore geology and geomorphology mapped by Andrew C. Ritchie and Samuel Y. Johnson, 2010-2011. Onshore geology and geomorphology compiled by Kevin B. Clahan, 2003 (Clahan, 2003). Bathymetric contours by Andrew C. Ritchie, 2011

GIS database and digital cartography by Andrew C. Ritchie, Eleyne L. Phillips, and Marina T. Mascorro

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Offshore and Onshore Geology and Geomorphology, Hueneme Canyon and Vicinity, California

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