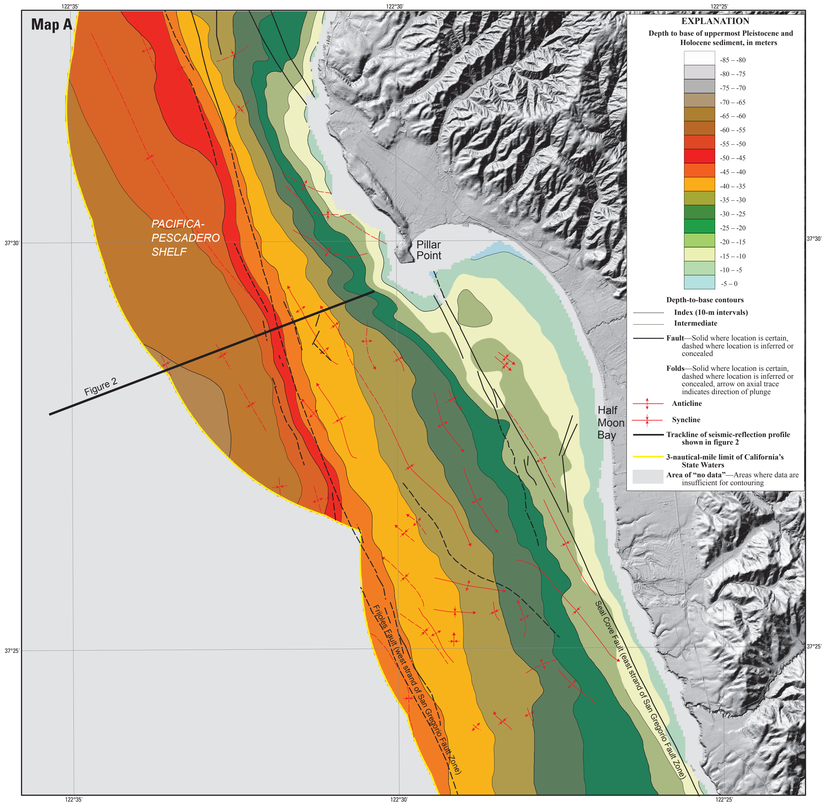
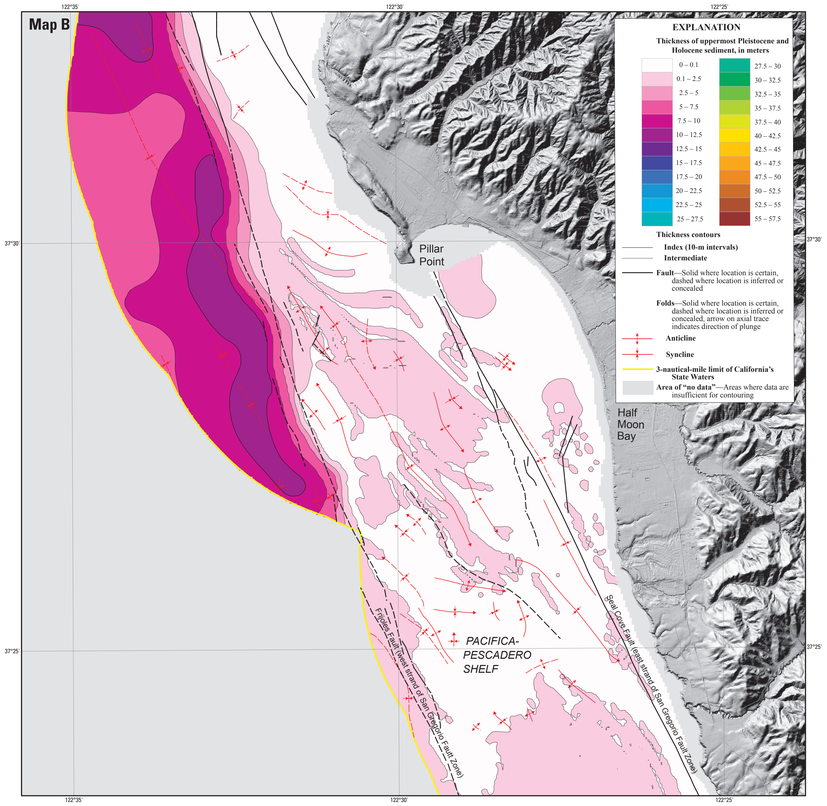
U.S. Department of the Interior
U.S. Geological Survey

Open-File Report 2014–1214
Sheet 9 of 10
*Pamphlet accompanies map*




Onshore elevation data collected by Photoscience in 2005 for U.S. Geological Survey and County of San Mateo. California's State Waters limit from NOAA Office of Coast Survey
Universal Transverse Mercator projection, Zone 10N

APPROXIMATE MEAN DECLINATION, 2014

SCALE 1:50 000
2 1 0 2 MILES
7000 3500 0 7000 FEET
1 0.5 0 1 KILOMETER
ONE MILE = 0.869 NAUTICAL MILES

MAP LOCATION

Depth and thickness mapped by Samuel Y. Johnson and Stephen R. Hartwell, 2010-2011
GIS database and digital cartography by Stephen R. Hartwell, Eleyne L. Phillips, and Florence L. Wong

## DISCUSSION

This sheet includes maps that show the interpreted thickness and the depth to base of uppermost Pleistocene and Holocene deposits in California's State Waters for the Offshore of Half Moon Bay map area (Maps A, B), as well as for a larger area that extends about 91 km along the coast from Bolinas to Pescadero (Maps C, D) to establish a regional context. This uppermost stratigraphic unit (blue shading in seismic-reflection profile of fig. 1; see also, figs. 1, 2, 3, 4, 6, 7, 9, 10 on sheet 8) is inferred to have been deposited during the post–Last Glacial Maximum (LGM) sea-level rise in the last about 21,000 years (see, for example, Peltier and Fairbanks, 2006; Stanford and others, 2011). The unit commonly is characterized either by "acoustic transparency" or by parallel, low-amplitude, low- to high-frequency, continuous to moderately continuous, diffuse reflections (terminology from Mitchum and others, 1977). The acoustic transparency can be caused by extensive wave winnowing, which results in a uniform sediment grain size and the consequent lack of acoustic-impedance contrasts needed to produce seismic reflections. On the continental shelf, the contact with underlying units is a transgressive surface of erosion commonly marked by angularity, channeling, or a distinct upward change to lower amplitude, more diffuse reflections.

To make these maps, water bottom and depth to base of the post-LGM horizons were mapped from seismic-reflection profiles (fig. 1; see also, sheet 8). The difference in the two horizons was exported for every shot point as XY coordinates (UTM zone 10) and two-way travel time (TWT). The thickness of the post-LGM unit (Maps B, D) was determined by applying a sound velocity of 1,600 m/sec to the TWT. The thickness points were interpolated to a preliminary continuous surface, overlaid with zero-thickness bedrock outcrops (see sheet 10), and contoured, following the methodology of Wong and others (2012).

The thickness data points are dense along tracklines (about 1 m apart) and sparse between tracklines (1 km apart), resulting in minor contouring artifacts. To incorporate the effect of a few rapid thickness changes along faults, to remove irregularities from interpolation, and to reflect other geologic information and complexity, minor manual editing of the preliminary thickness contours was undertaken. Contour modifications and regridding were repeated several times to produce the final sediment-thickness maps. Information for the depth to base of the post-LGM unit (Maps A, C) was generated by adding the sediment-thickness data to water depths determined by multibeam bathymetry (see sheet 1).

The thickness of the post-LGM unit in the Offshore of Half Moon Bay map area ranges from 0 to 12 m (Map B), and the depth to base of the unit ranges from less than 5 to 56 m (Map A). This relatively thin sediment cover suggests a lack of sediment "accommodation space" (Catuneanu, 2006), consistent with regional uplift expressed by the young, high topography of the Santa Cruz Mountains and Coast Ranges, as well as nearby uplifted marine terraces (Weber, 1990; Lajoie and others, 1991; Brabb and others, 1998). This uplift has been attributed to the northwest-transpressional bend in the San Andreas Fault (see, for example; Zoback and others, 1999), which lies about 12 km northeast of the map area. The San Gregorio Fault Zone, which cuts through the Offshore of Half Moon Bay map area, consists of an east strand ("Seal Cove Fault" or "Coastways Fault"), a west strand ("Frijoles Fault"), and related splay faults (fig. 2). The thickest sediment (about 12 m) in the map area is west of of the Frijoles Fault, and it results from offset and (or) gentle downwarping associated with that structure (for example, fig. 1).

Five different "domains" of sediment thickness are recognized on the regional sediment-thickness map (Map D): (1) the Bolinas shelf, located west of the east strand of the San Gregorio Fault Zone, in the northwestern part of the regional map (Map D); (2) the San Andreas graben, located between the San Gregorio Fault Zone and the Golden Gate Fault, east-southeast of the Bolinas shelf and both southwest and southeast of the Marin shelf; (3) the Marin shelf, located both northeast and northwest of the San Andreas graben and north of the San Francisco ebb-tidal delta paleovalley; (4) the northeast-trending San Francisco ebb-tidal delta paleovalley, located outside the Golden Gate at the mouth of San Francisco Bay, between the Marin shelf and San Andreas graben on the north and the Pacifica-Pescadero shelf on the south; and (5) the Pacifica-Pescadero shelf, which is located south of the San Francisco ebb-tidal delta paleovalley and which extends south all the way to Pescadero Point (including all of the Offshore of Half Moon Bay map area).

The five sediment-thickness domains have distinct geologic controls. The Bolinas and Pacifica-Pescadero shelves are uplifting and are relatively sediment poor (mean sediment thickness of 0.8 and 3.6 m, respectively). Thicker sediment accumulations (as much as 20 m) on the western margins of the Pacifica-Pescadero shelf (within California's State Waters) are associated with west-side-down slip on the west strand of the San Gregorio Fault Zone and with deposition on the outboard, west-dipping Pigeon Point block (McCulloch, 1987; see also, fig. 2) farther south, offshore of Pescadero Point. The San Andreas graben is a rapidly subsiding, fault-controlled sedimentary basin (Cooper, 1973; Ryan and others, 2008) that has sediment thicknesses of as much as 57 m; the Marin shelf forms the uplifted northeastern and northwestern margins of this basin. The San Francisco ebb-tidal delta is filling a paleovalley that formed during the last sea-level lowstand, with sediment thicknesses of as much as 32 m along the trough axis. Although the southern part of the San Andreas graben may extend into the paleovalley, the north flank of the paleovalley is used here as the boundary when calculating sediment volumes for the five sediment-thickness domains (see table 7–1 in accompanying pamphlet). Subsidence in the San Francisco ebb-tidal delta paleovalley and the San Andreas graben can be partly attributed to the northward change in strike of both the San Andreas and San Gregorio Fault Zones offshore of San Francisco, which has resulted in the local change from contractional deformation to extensional deformation (Zoback and others, 1999).

Map E shows the regional pattern of major faults and of earthquakes occurring between 1967 and April 2014 that have inferred or measured magnitudes of 2.0 and greater. Fault locations, which have been simplified, are compiled from our mapping within California's State Waters (see sheet 10) and from the U.S. Geological Survey's Quaternary fault and fold database (U.S. Geological Survey and California Geological Survey, 2010). Earthquake epicenters are from the Northern California Earthquake Data Center (2014), which is maintained by the U.S. Geological Survey and the University of California, Berkeley, Seismological Laboratory. Map E also shows the inferred location of the devastating great 1906 California earthquake (M7.8, 4/18/1906), thought to have nucleated on the San Andreas Fault offshore of San Francisco (see, for example, Bolt, 1968; Lomax, 2005). Map E clearly shows that the largest number of earthquakes in the region occur within the broad San Andreas Fault Zone between Pacifica and Bolinas; events west of the east strand of the San Gregorio Fault Zone and east of the Golden Gate Fault are much less common. The Offshore of Half Moon Bay map area is notably devoid of seismicity during this time period.

## REFERENCES CITED

Bolt, B.A., 1968, The focus of the 1906 California earthquake: Bulletin of the Seismological Society of America, v. 58, p. 457–471.

Brabb, E.E., Graymer, R.W., and Jones, D.L., 1998, Geology of the onshore part of San Mateo County, California—A digital database: U.S. Geological Survey Open-File Report 98–137, scale 1:62,500, available at http://pubs.usgs.gov/of/1998/of98-137/.

Catuneanu, O., 2006, Principles of sequence stratigraphy: Amsterdam, Elsevier, 375 p.

Cooper, A.K., 1973, Structure of the continental shelf west of San Francisco, California: U.S. Geological Survey Open-File Report 73–48, 65 p.

Lajoie, K.R., Ponti, D.J., Powell, C.L., II, Mathieson, S.A., and Sarna-Wojcicki, A.M., 1991, Emergent marine strandlines and associated sediments, coastal California—A record of Quaternary sea-level fluctuations, vertical tectonic movements, climatic changes, and coastal processes, *in* Morrison, R.B., ed., The Geology of North America, Quaternary nonglacial geology—Conterminous U.S.: Geological Society of America, Decade of North American Geology, v. K–2, p. 190–213.

Lomax, A., 2005, A reanalysis of the hypocentral location and related observations for the Great 1906 California earthquake: Bulletin of the Seismological Society of America, v. 95, p. 861–877, doi:10.1785/0120040141.

McCulloch, D.S., 1987, Regional geology and hydrocarbon potential of offshore central California, *in* Scholl, D.W., Grantz, A., and Vedder, J.G., eds., Geology and resource potential of the continental margin of western North America and adjacent ocean basins—Beaufort Sea to Baja California: Circum-Pacific Council for Energy and Mineral Resources, Earth Science Series, v. 6, p. 353–401.

Mitchum, R.M., Jr., Vail, P.R., and Sangree, J.B., 1977, Seismic stratigraphy and global changes of sea level, part 6—Stratigraphic interpretation of seismic reflection patterns in depositional sequences, *in* Payton, C.E., ed., Seismic stratigraphy—Applications to hydrocarbon exploration: Tulsa, Okla., American Association of Petroleum Geologists, p. 117–133.

Northern California Earthquake Data Center, 2014, Northern California earthquake catalog: Northern California Earthquake Data Center database, accessed April 5, 2014, at http://www.ncedc.org/ncsn/.

Peltier, W.R., and Fairbanks, R.G., 2006, Global glacial ice volume and Last Glacial Maximum duration from an extended Barbados sea level record: Quaternary Science Reviews, v. 25, p. 3,322–3,337, doi:10.1016/j.quascirev.2006.04.010.

Ryan, H.F., Parsons, T., and Sliter, R.W., 2008, Vertical tectonic deformation associated with the San Andreas Fault Zone offshore of San Francisco, California: Tectonophysics, v. 429, p. 209–224, doi:10.1016/j.tecto.2008.06.011.

Stanford, J.D., Hemingway, R., Rohling, E.J., Challenor, P.G., Medina-Elizalde, M., and Lester, A.J., 2011, Sea-level probability for the last deglaciation—A statistical analysis of far-field records: Global and Planetary Change, v. 79, p. 193–203, doi:10.1016/j.gloplacha.2010.11.002.

U.S. Geological Survey and California Geological Survey, 2010, Quaternary fault and fold database of the United States: U.S. Geological Survey database, accessed April 5, 2014, at http://earthquake.usgs.gov/hazards/qfaults/.

Weber, G.E., 1990, Late Pleistocene slip rates on the San Gregorio fault zone at Point Año Nuevo, San Mateo County, California, *in* Greene, H.G., Weber, G.E., Wright, T.L., and Garrison, R.E., eds., Geology and tectonics of the central California coast region—San Francisco to Monterey: American Association of Petroleum Geologists, Pacific Section, volume and guidebook, v. 67, p. 193–204.

Wong, F.L., Phillips, E.L., Johnson, S.Y., and Sliter, R.W., 2012, Modeling of depth to base of Last Glacial Maximum and seafloor sediment thickness for the California State Waters Map Series, eastern Santa Barbara Channel, California: U.S. Geological Survey Open-File Report 2012–1161, 16 p., available at http://pubs.usgs.gov/of/2012/1161/.

Zoback, M.L., Jachens, R.C., and Olson, J.A., 1999, Abrupt along-strike change in tectonic style—San Andreas Fault zone, San Francisco Peninsula: Journal of Geophysical Research, v. 104 (B5), p. 10,719–10,742.

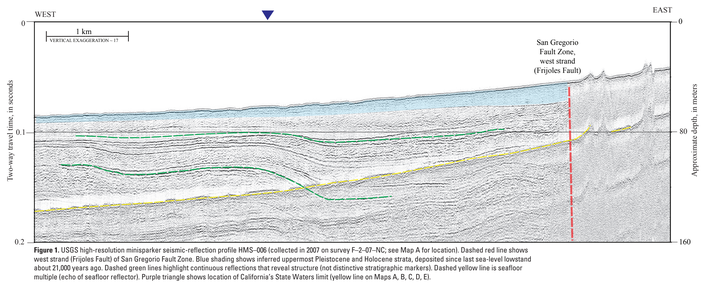



**Figure 1.** USGS high-resolution minisparker seismic-reflection profile HMS–006 (collected in 2007 on survey F–2–07–NC; see Map A for location). Dashed red line shows west strand (Frijoles Fault) of San Gregorio Fault Zone. Blue shading shows inferred uppermost Pleistocene and Holocene strata, deposited since last sea-level lowstand about 21,000 years ago. Dashed green lines highlight continuous reflections that reveal structure (not distinctive stratigraphic markers). Dashed yellow line is seafloor multiple (echo of seafloor reflector). Purple triangle shows location of California's State Waters limit (yellow line on Maps A, B, C, D, E).

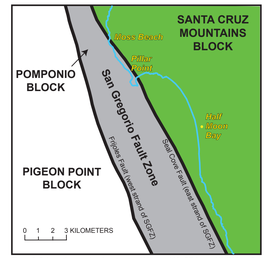
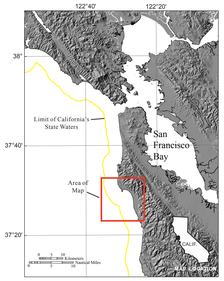
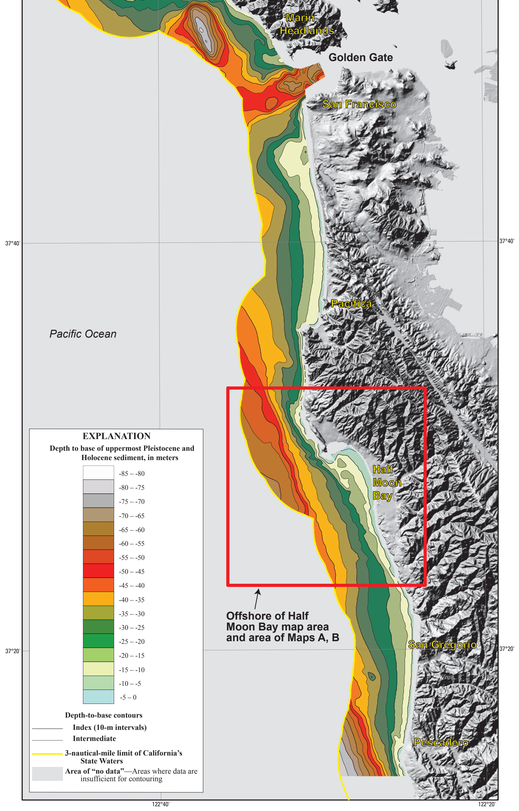


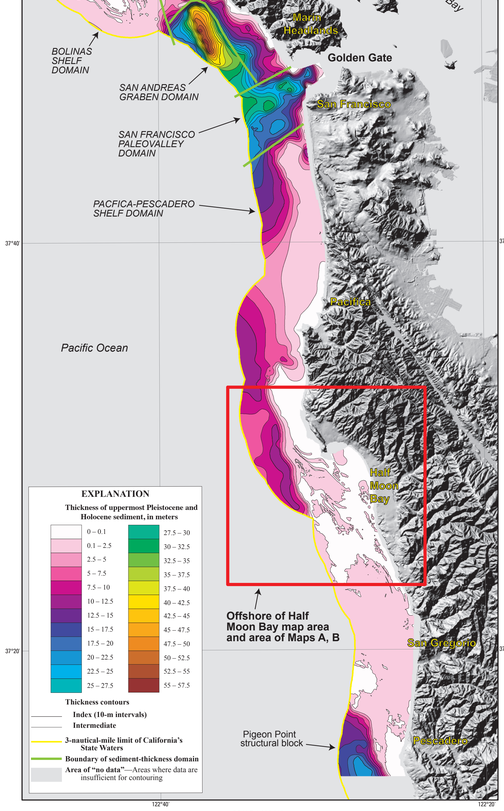

**Figure 2.** Schematic map showing structural blocks within Offshore of Half Moon Bay map area. Pigeon Point block is separated from Santa Cruz Mountains block by Pomponio block, which is bounded by Frijoles Fault (to west) and Seal Cove Fault (to east), two strands of San Gregorio Fault Zone (SGFZ). Blue line shows coastline. Modified from Weber (1990).




Onshore elevation data from U.S. Geological Survey (2013) National Elevation dataset; California's State Waters limit from NOAA Office of Coast Survey
Universal Transverse Mercator projection, Zone 10N

APPROXIMATE MEAN DECLINATION, 2014

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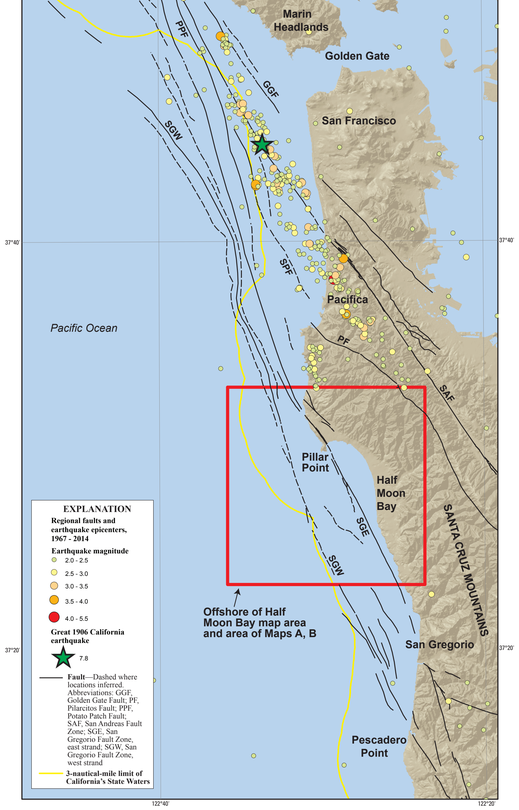
10 5 0 10 KILOMETERS
ONE MILE = 0.869 NAUTICAL MILES




MAP LOCATION

Depth and thickness mapped by Samuel Y. Johnson and Stephen R. Hartwell, 2011-2012
GIS database and digital cartography by Stephen R. Hartwell, Eleyne L. Phillips, and Florence L. Wong
Manuscript approved for publication October 2, 2014

# Local (Offshore of Half Moon Bay Map Area) and Regional (Offshore from Bolinas to Pescadero) Shallow-Subsurface Geology and Structure, California

By
Samuel Y. Johnson, Stephen R. Hartwell, Ray W. Sliter, Janet T. Watt, Eleyne L. Phillips, Stephanie L. Ross, and John L. Chin

2014



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