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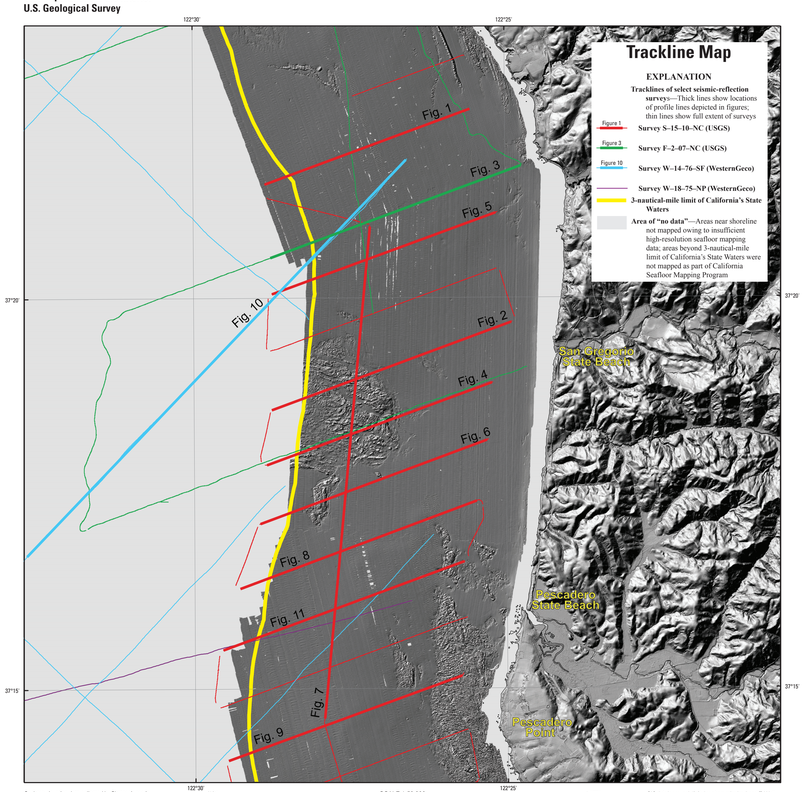
U.S. Department of the Interior
U.S. Geological Survey

Scientific Investigations Map 3306
Sheet 8 of 10
Pamphlet accompanies map



Onshore elevation data collected by Photoscience in 2005 for U.S. Geological Survey and County of San Mateo. 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, 2014

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

GIS database and digital cartography by Janet T. Watt, Elayne L. Phillips, and Florence L. Wong
Edited by Taryn A. Lindquist
Manuscript approved for publication June 30, 2014

MAP LOCATION

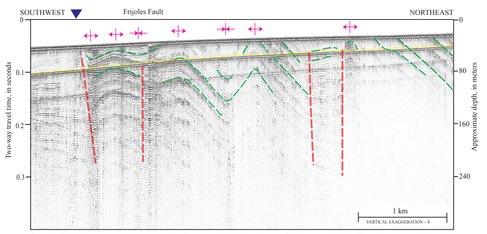


Figure 1. USGS high-resolution minisparker seismic-reflection profile P10–43 (collected in 2010 on survey S–15–10–NC), which crosses shelf northwest of San Gregorio State Beach, perpendicular to shoreline; see trackline map for location. Dashed red lines show faults. San Gregorio Fault Zone is imaged as multiple strands: of two faults in western part of fault zone (southwestern [left] side of profile), Frijoles Fault (on right) is more prominent strand; second steeply northeast-dipping reverse fault southwest (to left) of Frijoles Fault may link with Frijoles Fault at depth. Magenta symbols show fold axes (diverging arrows, antiforms; converging arrows, synforms). Dashed green lines highlight dipping and folded reflectors, probably within rocks of the upper Miocene and Pliocene Purisima Formation. Dashed yellow line is seafloor multiple (echo of seafloor reflector). Purple triangle shows location of California's State Waters limit (yellow line on trackline map).

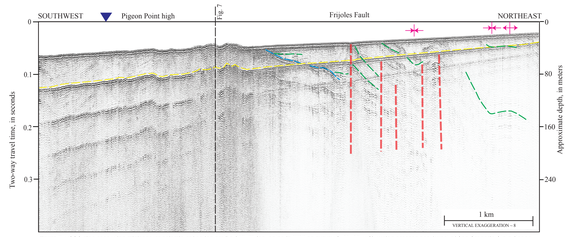


Figure 2. USGS high-resolution minisparker seismic-reflection profile P10–05 (collected in 2010 on survey S–15–10–NC), which crosses shelf west of San Gregorio State Beach, roughly perpendicular to shoreline; see trackline map for location. Dashed red lines show interpreted faults. San Gregorio Fault Zone is imaged as multiple strands, southwest-ermost of which is Frijoles Fault. Magenta symbols show fold axes (diverging arrows, antiform; converging arrows, synforms). Pigeon Point high (McCulloch, 1987; see also, fig. 12) is depicted here as relatively reflection-free basement rock southwest of Frijoles Fault that probably consists of rocks of the Upper Cretaceous Pigeon Point Formation; dashed blue line shows erosional unconformity on east flank of this basement high. Dashed green lines highlight continuous reflections: northeast of Frijoles Fault, reflections probably are within rocks of the upper Miocene and Pliocene Purisima Formation. Dashed yellow line is seafloor multiple (echo of seafloor reflector). Purple triangle shows location of California's State Waters limit (yellow line on trackline map).

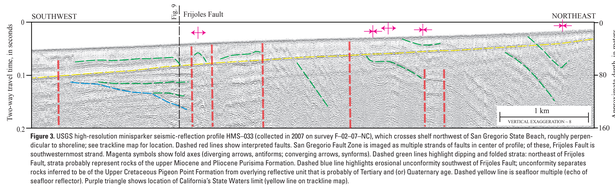


Figure 3. USGS high-resolution minisparker seismic-reflection profile HMS–033 (collected in 2007 on survey F–02–07–NC), which crosses shelf northwest of San Gregorio State Beach, roughly perpendicular to shoreline; see trackline map for location. Dashed red lines show interpreted faults. San Gregorio Fault Zone is imaged as multiple strands of faults in center of profile; of these, Frijoles Fault is southwesternmost strand. Magenta symbols show fold axes (diverging arrows, antiforms; converging arrows, synforms). Dashed green lines highlight dipping and folded strata: northeast of Frijoles Fault, strata probably represent rocks of the upper Miocene and Pliocene Purisima Formation. Dashed blue line highlights erosional unconformity southwest of Frijoles Fault; unconformity separates rocks inferred to be of the Upper Cretaceous Pigeon Point Formation from overlying reflective unit that is probably of Tertiary and (or) Quaternary age. Dashed yellow line is seafloor multiple (echo of seafloor reflector). Purple triangle shows location of California's State Waters limit (yellow line on trackline map).

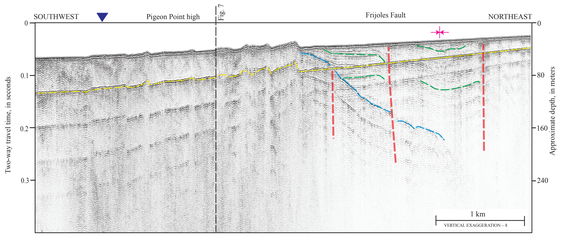


Figure 4. USGS high-resolution minisparker seismic-reflection profile P10–07 (collected in 2010 on survey S–15–10–NC), which crosses shelf west of San Gregorio State Beach, roughly perpendicular to shoreline; see trackline map for location. Dashed red lines show interpreted faults. Western part of San Gregorio Fault Zone is imaged as two strands, one of which is Frijoles Fault. Magenta symbol shows synform axis. Dashed green lines highlight dipping and mildly folded reflections from within rocks inferred to be of the upper Miocene and Pliocene Purisima Formation. Dashed blue line highlights erosional unconformity on east flank of Pigeon Point high (McCulloch, 1987; see also, fig. 12), which is depicted here as reflection-free basement rock (probably consisting of rocks of the Upper Cretaceous Pigeon Point Formation) southwest of Frijoles Fault. Dashed yellow line is seafloor multiple (echo of seafloor reflector). Purple triangle shows location of California's State Waters limit (yellow line on trackline map).

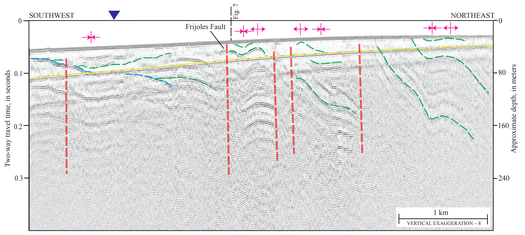


Figure 5. USGS high-resolution minisparker seismic-reflection profile P10–01 (collected in 2010 on survey S–15–10–NC), which crosses shelf northwest of San Gregorio State Beach, roughly perpendicular to shoreline; see trackline map for location. Dashed red lines show inferred faults. San Gregorio Fault Zone is imaged as zone of faults in center of profile: of these, Frijoles Fault is southwesternmost strand. Magenta symbols show fold axes (diverging arrows, antiforms; converging arrows, synforms). Dashed green lines highlight folded strata: northeast of Frijoles Fault, folded strata is inferred to be rocks of the upper Miocene and Pliocene Purisima Formation; southwest of Frijoles Fault, gently folded Tertiary and Quaternary strata unconformably overlie reflection-free bedrock that probably consists of rocks of the Upper Cretaceous Pigeon Point Formation. Dashed blue lines highlight erosional unconformities. Dashed yellow line is seafloor multiple (echo of seafloor reflector). Purple triangle shows location of California's State Waters limit (yellow line on trackline map).

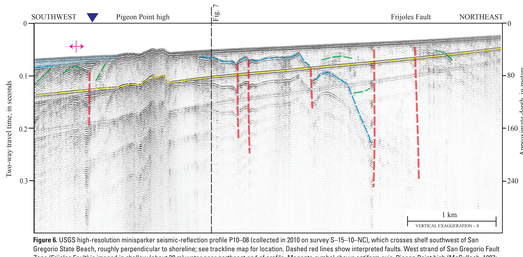
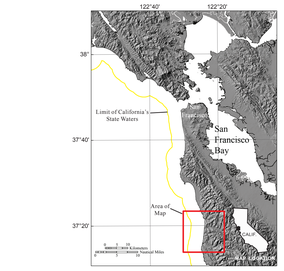


Figure 6. USGS high-resolution minisparker seismic-reflection profile P10–08 (collected in 2010 on survey S–15–10–NC), which crosses shelf southwest of San Gregorio State Beach, roughly perpendicular to shoreline; see trackline map for location. Dashed red lines show interpreted faults. West strand of San Gregorio Fault Zone (Frijoles Fault) is imaged in shallow (about 20 m) water near northeast end of profile. Magenta symbol shows antiform axis. Pigeon Point high (McCulloch, 1987; see also, fig. 12) is depicted here as reflection-free basement rock (inferred to be rocks of the Upper Cretaceous Pigeon Point Formation) southwest of Frijoles Fault; these basement rocks are unconformably overlain by undeformed to gently folded strata of presumed Tertiary and Quaternary age. At southwest end of profile, erosional unconformity separates these folded strata from overlying, westward-thickening (from 2 to 10 m) layer of shelf strata (blue shading), inferred to be of latest Pleistocene and Holocene age (that is, deposited since last sea-level lowstand about 21,000 years ago). Dashed green lines highlight continuous reflections (not distinctive stratigraphic markers). Dashed blue lines show erosional unconformities. Dashed yellow line is seafloor multiple (echo of seafloor reflector). Purple triangle shows location of California's State Waters limit (yellow line on trackline map).



DISCUSSION

This map sheet shows seismic-reflection profiles from four different surveys of the Offshore of San Gregorio map area, providing imagery of the subsurface geology. This map area is largely characterized by a shallow (less than 65 m) bedrock platform that is overlain locally by thin sediment cover. The seismic-reflection profiles provide the data for interpreting subbottom stratigraphy, sediment thickness, and geologic structure (see sheets 9, 10 of this report).

The Offshore of San Gregorio map area straddles the right-lateral San Gregorio Fault, an important structure in the distributed transform boundary between the North American and Pacific plates (see, for example, Dickinson and others, 2005). This fault is part of a predominantly offshore, regional fault system that extends for about 400 km, from Point Conception in the south (where it is known as the Hosgri Fault) to Bolinas and Point Reyes in the north. The fault continues onland at coastal promontories such as Pescadero Point (in this map area) and Pillar Point (14 km north of the map area, near Half Moon Bay) (see sheet 9; see also, Weber and Lajoie, 1980; Brabb and others, 1998). In the offshore, faults within this system are identified on seismic-reflection profiles by the abrupt truncation or warping of reflections and (or) the juxtaposition of reflection panels that have different seismic parameters such as reflection presence, amplitude, frequency, geometry, continuity, and vertical sequence.

In this map area, the San Gregorio Fault system forms a distributed, 2- to 5-km-wide shear zone that includes two main fault strands (see sheets 9, 10). The east strand (also known as the "Coastways Fault" or "Seal Cove Fault") is mostly onshore in this map area; where it does go offshore (see sheet 10), it is located too close to the shoreline to image with marine seismic-reflection profiles. The west strand (also known as the "Frijoles Fault;" see figs. 1, 2, 3, 4, 5, 6, 7, 8, 10) extends offshore from Pescadero Point. Seismic-reflection data do show extensive faulting and folding of Neogene bedrock along the inner shelf between the east (Coastways Fault) and west (Frijoles Fault) strands of the San Gregorio Fault Zone (figs. 1 through 5). Cumulative lateral slip on the San Gregorio Fault Zone is thought to range from 4 to 10 mm/yr in this area (U.S. Geological Survey and California Geological Survey, 2010).

The west strand of the San Gregorio Fault Zone (Frijoles Fault) forms the east boundary of the Pigeon Point high (McCulloch, 1987) (fig. 12; see also, figs. 2, 4, 6, 7, 8, 9, 10, 11), a bedrock ridge that extends offshore northwest from Pescadero Point. The Pigeon Point high is characterized by reflection-free (that is, massive and highly deformed) rocks of the Upper Cretaceous Pigeon Point Formation that are unconformably overlain by mildly to highly reflective Neogene strata (figs. 2, 4, 6, 7, 8, 9, 10, 11). Deeper penetrating, industry seismic-reflection profiles (fig. 10) show the Pigeon Point high as an area that has very high amplitude reflection(s) near the seafloor, underlain by a relatively reflection-free zone that is bounded on the northeast and southwest by faults.

Several high-resolution seismic profiles show an upper unit (blue shading in profiles; see figs. 6, 7, 8, 9, 11) that is inferred to have been deposited in the last about 21,000 years during the latest Pleistocene and Holocene, post–Last Glacial Maximum sea-level rise. These deposits typically are 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); this seismic "facies" is attributable to the inferred uniform grain size caused by wave winnowing, which results in the general lack of acoustic-impedance contrasts needed to yield seismic reflections. In much of the map area, this upper unit is very thin (less than 2.5 m; see sheet 9) and, hence, is difficult to map on seismic-reflection profiles. In contrast, offshore of Pescadero Point, the thickness of this unit reaches 20 m. The contact with underlying units is a commonly planar, transgressive surface of erosion that is marked by a distinct downward change to a section characterized by moderate- to high-amplitude, variably continuous, parallel to subparallel, folded and faulted reflections.

All profiles displayed on this map sheet, except for line WSF–050 in figure 10, are single-channel seismic-reflection data acquired using the SIG 2Mille minisparker: figures 1, 2, 4, 5, 6, 7, 8, 9, and 11 show minisparker profiles collected in 2010 on USGS cruise S–15–10–NC, and figure 3 shows a minisparker profile collected in 2007 on USGS cruise F–02–07–NC. For these two USGS surveys, the SIG minisparker system used a 500-J high-voltage electrical discharge fired 1 to 4 times per second, which, at normal survey speeds of 4 to 4.5 nautical miles per hour, gives a data trace every 0.5 to 2.0 meters. The data were digitally recorded in standard SEG-Y 32-bit floating-point format, using Triton Subbottom Logger (SBL) software that merges seismic-reflection data with differential GPS-navigation data. After the survey, a short-window (20 ms) automatic gain control algorithm was applied to the data, along with a 160- to 1,200-Hz bandpass filter and a heave correction that uses an automatic seafloor-detection window (averaged over 30 m of lateral distance covered).

Figure 10 shows a deep-penetration, depth-converted, multichannel seismic-reflection profile collected in 1976 by WesternGeco on cruise W–14–76–SF. This profile and other similar data were collected in many areas offshore of California in the 1970s and 1980s when these areas were considered a frontier for oil and gas exploration. Much of these data have been publicly released and are now archived at the USGS National Archive of Marine Seismic Surveys (U.S. Geological Survey, 2009). These data were acquired with a large-volume air-gun source that has a frequency range of 3 to 40 Hz and recorded with a multichannel hydrophone streamer about 2 km long; shot spacing was about 30 m. These data can resolve geologic features that are 20 to 30 m thick, down to subbottom depths of about 4 km.

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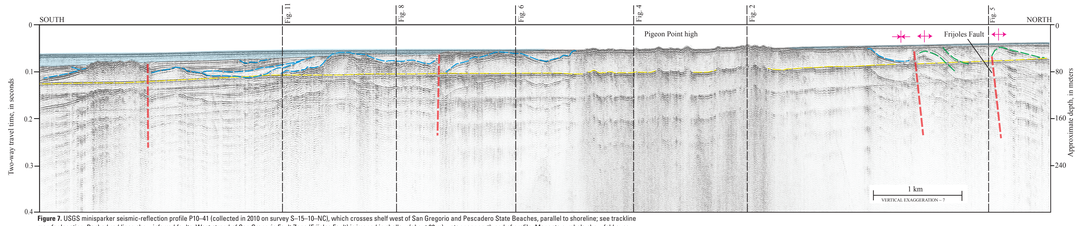

Figure 7. USGS minisparker seismic-reflection profile P10–41 (collected in 2010 on survey S–15–10–NC), which crosses shelf west of San Gregorio and Pescadero State Beaches, parallel to shoreline; see trackline map for location. Dashed red lines show inferred faults. West strand of San Gregorio Fault Zone (Frijoles Fault) is imaged in shallow (about 20 m) water near north end of profile. Magenta symbols show fold axes (diverging arrows, antiforms; converging arrows, synform). Pigeon Point high (McCulloch, 1987; see also, fig. 12), depicted here as reflection-free basement rock south of Frijoles Fault (as imaged within 100 m of seafloor), is inferred to consist of rocks of the Upper Cretaceous Pigeon Point Formation; these rocks are unconformably overlain by undeformed to mildly folded strata of presumed Tertiary and Pleistocene age. Along southern part of profile, erosional unconformity separates these folded strata from westward-thickening (to as much as 20 m) layer of shelf strata (blue shading), inferred to be of latest Pleistocene and Holocene age (that is, deposited since last sea-level lowstand about 21,000 years ago). Dashed green lines highlight continuous reflections in fault-bounded folds at north end of profile. Dashed blue lines show erosional unconformities. Dashed yellow line is seafloor multiple (echo of seafloor reflector).

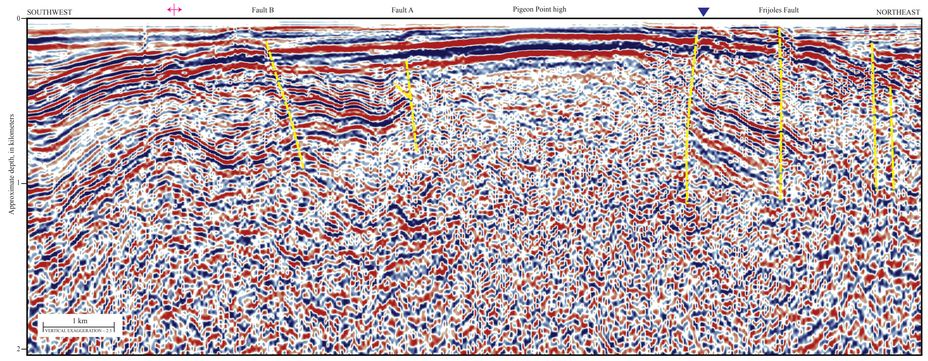

Figure 10. Deep-penetration, industry, 2-D, multichannel air-gun profile WSF–050 (collected in 1976 by WesternGeco on survey W–14–76–SF; from USGS National Archive of Marine Seismic Surveys [U.S. Geological Survey, 2009]), which extends southwest across shelf offshore of San Gregorio State Beach; see trackline map for location. Dashed yellow lines show faults. Magenta symbol shows antiform axis. Along this profile, Frijoles Fault (west strand of San Gregorio Fault Zone) is imaged as vertical structure. Pigeon Point high (McCulloch, 1987; see also, fig. 12) is depicted here with two unnamed faults (fault A, fault B) imaged along its southwest (left) edge: fault A appears to be northeast-dipping fault that has northeast-side-up motion; fault B is also northeast dipping, but sense of motion across fault is difficult to determine in this profile. Tertiary-age strata form relatively continuous and gently folded reflections southwest of Pigeon Point high. Purple triangle shows location of California's State Waters limit (yellow line on trackline map).

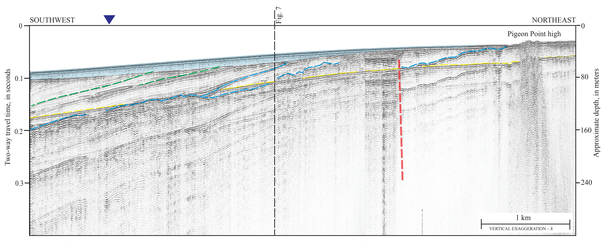

Figure 11. USGS high-resolution minisparker seismic-reflection profile P10–12 (collected in 2010 on survey S–15–10–NC), which crosses shelf west of Pescadero State Beach, roughly perpendicular to shoreline; see trackline map for location. Dashed red line shows interpreted fault. Pigeon Point high (McCulloch, 1987; see also, fig. 12) is depicted here as shallow, reflection-free basement rock, inferred to be rocks of the Upper Cretaceous Pigeon Point Formation. Southwest flank of Pigeon Point high is unconformably overlain by west-dipping strata (inferred to be of Neogene and Pleistocene age) that include internal unconformities; these strata are unconformably overlain by 2- to 10-m-thick layer of shelf strata (blue shading), inferred to be of latest Pleistocene and Holocene age (that is, deposited since last sea-level lowstand about 21,000 years ago). This uppermost unit thins to northeast and to southwest, suggesting deposition within shallow basin (see sheet 9). Dashed green lines highlight continuous, west-dipping reflections on west flank of Pigeon Point high (see fig. 12). Dashed blue lines show erosional unconformities. Dashed yellow line is seafloor multiple (echo of seafloor reflector). Purple triangle shows location of California's State Waters limit (yellow line on trackline map).

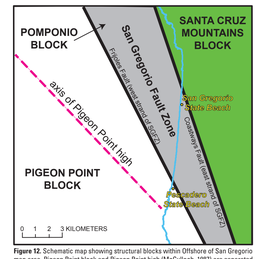

Figure 12. Schematic map showing structural blocks within Offshore of San Gregorio map area. Pigeon Point block and Pigeon Point high (McCulloch, 1987) are separated from Santa Cruz Mountains block by Pomponio block, which is bounded by Frijoles Fault (to west) and Coastways Fault (to east), two strands of San Gregorio Fault Zone (SGFZ). Blue line shows coastline. Modified from Weber (1990).

Seismic-Reflection Profiles, Offshore of San Gregorio Map Area, California

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2014

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