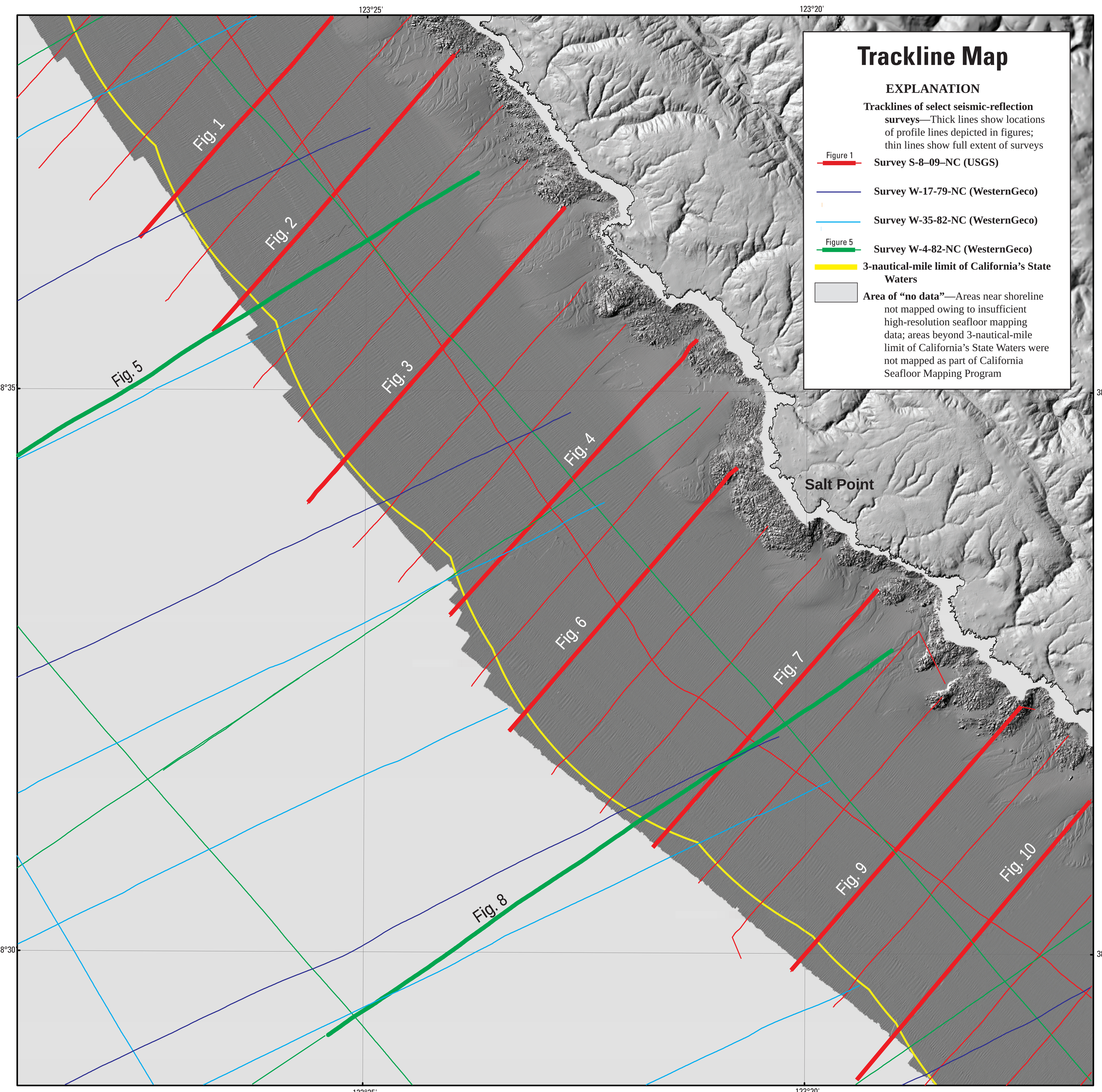
U.S. Department of the Interior
U.S. Geological Survey

Open-File Report 2015–1098
Sheet 8 of 10
Pamphlet accompanies map



Onshore elevation data from National Aeronautics and Space Administration and U.S. Geological Survey, available at http://www.opentopography.org/, and from U.S. Geological Survey, National Elevation Dataset, available at http://ned.usgs.gov/. 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 (14°; TRUE NORTH, MAGNETIC NORTH)

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 (CALIF.)

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

Manuscript approved for publication May 12, 2015

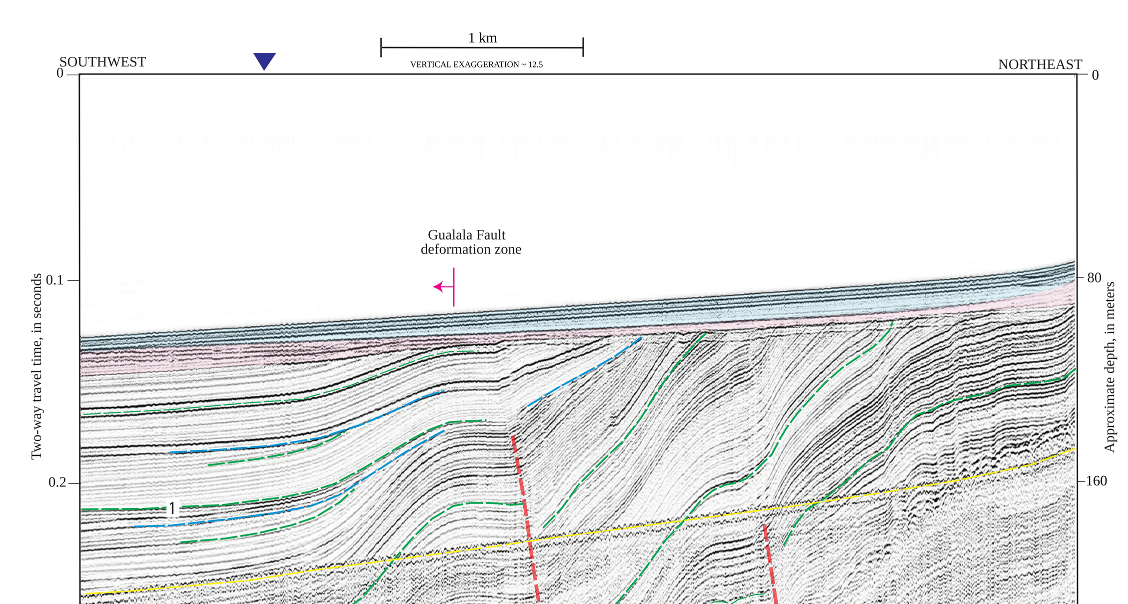


Figure 1. USGS high-resolution minisparker seismic-reflection profile PR-140 (collected in 2009 on survey S–8–09–NC), which crosses shelf northwest of Salt Point; see trackline map for location. Profile shows generally southwest-dipping folded strata beneath continental shelf. Dashed red lines show faults. Magenta symbol shows inflection point in folded strata. Blue shading shows inferred uppermost Pleistocene and Holocene strata, deposited since last sea-level lowstand about 21,000 years ago. Pink shading shows uppermost Pleistocene strata thought to have formed as sea level fell, between about 30,000 and 21,000 years ago. Underlying folded reflectors are of inferred Pleistocene age. Dashed green lines highlight continuous reflections that reveal structure (not distinctive stratigraphic markers). Narrowing between reflections labeled "1" and "2" reveals significant, west-to-east stratigraphic thinning across fold crest in Gualala deformation zone, indicating deposition during fold growth. Dashed blue lines show low-angle 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).

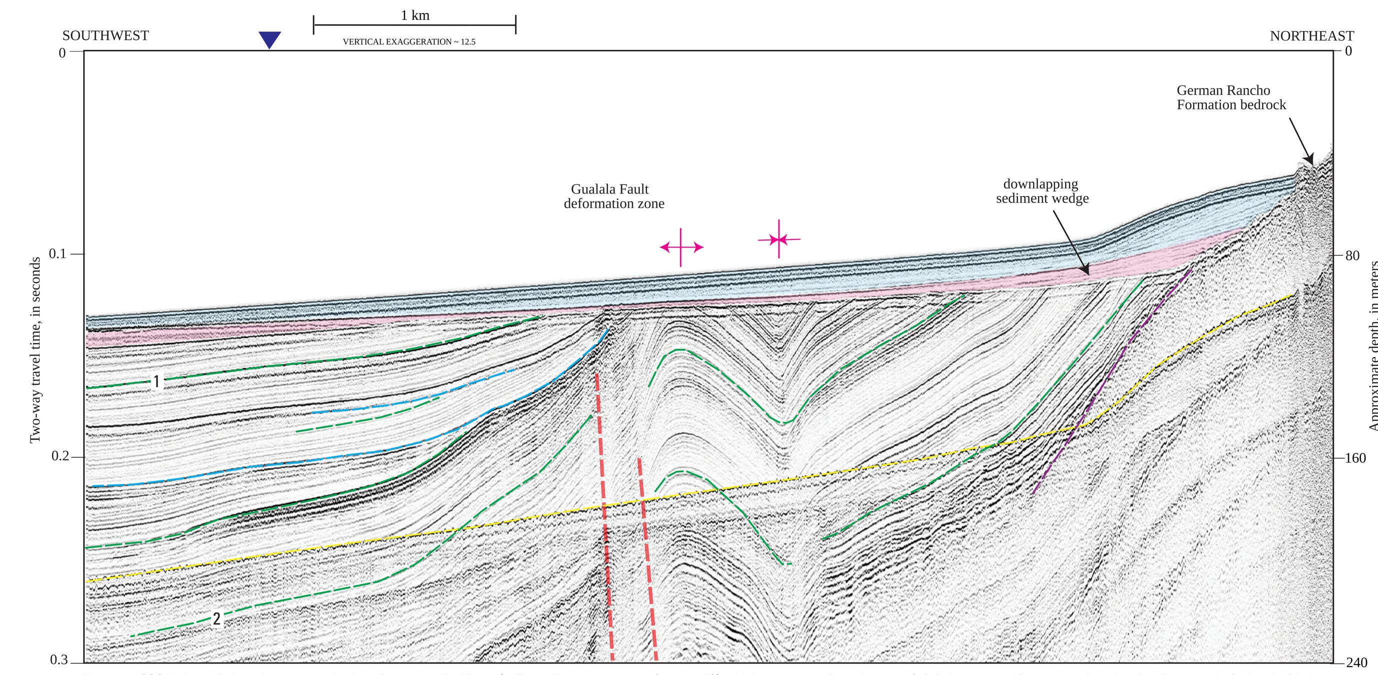


Figure 2. USGS high-resolution minisparker seismic-reflection profile PR-138 (collected in 2009 on survey S–8–09–NC), which crosses shelf northwest of Salt Point; see trackline map for location. Profile shows faulted and folded strata beneath continental shelf. Dashed red lines show faults. Magenta symbols show fold axes (diverging arrows, anticline; converging arrows, syncline). Blue shading shows inferred uppermost Pleistocene and Holocene strata, deposited since last sea-level lowstand about 21,000 years ago. Pink shading shows uppermost Pleistocene strata thought to have formed as sea level fell, between about 30,000 and 21,000 years ago. Underlying folded reflectors are of inferred Pleistocene age. Dashed green lines highlight continuous reflections that reveal structure (not distinctive stratigraphic markers). Narrowing between reflections labeled "1" and "2" reveals significant, west-to-east stratigraphic thinning associated with Gualala Fault deformation zone, indicating deposition during fold growth. Dashed blue lines show low-angle unconformities; dashed purple line is unconformity with Tertiary bedrock. 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).

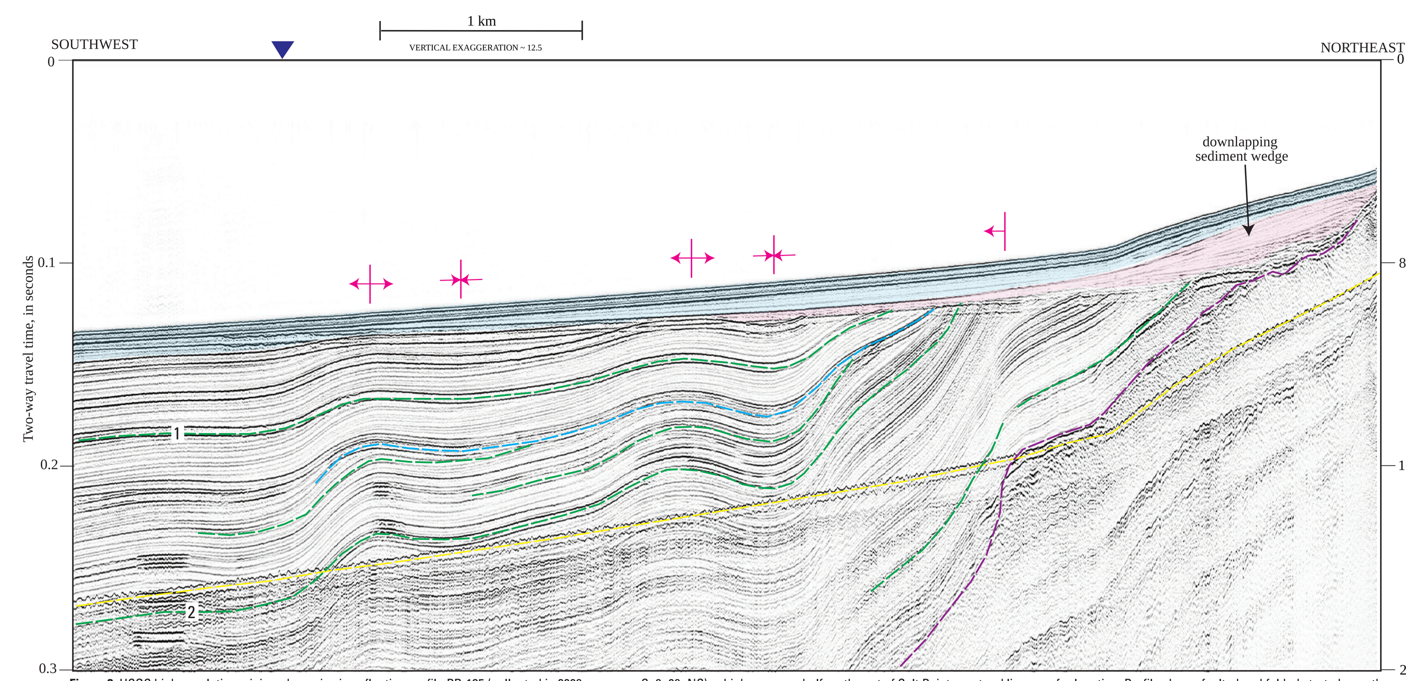


Figure 3. USGS high-resolution minisparker seismic-reflection profile PR-135 (collected in 2009 on survey S–8–09–NC), which crosses shelf northwest of Salt Point; see trackline map for location. Profile shows faulted and folded strata beneath continental shelf. Magenta symbols show fold axes (diverging arrows, anticlines; converging arrows, synclines) and sharp flexure (single arrow, showing direction of increased dip). Blue shading shows inferred uppermost Pleistocene and Holocene strata, deposited since last sea-level lowstand about 21,000 years ago. Pink shading shows uppermost Pleistocene strata thought to have formed as sea level fell, between about 30,000 and 21,000 years ago. Underlying reflectors are of inferred Pleistocene age. Dashed green lines highlight continuous reflections that reveal structure (not distinctive stratigraphic markers). Narrowing between reflections labeled "1" and "2" highlights significant southwest-to-northeast stratigraphic thinning. Dashed blue line shows low-angle unconformity; dashed purple line is unconformity with Tertiary bedrock. 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).

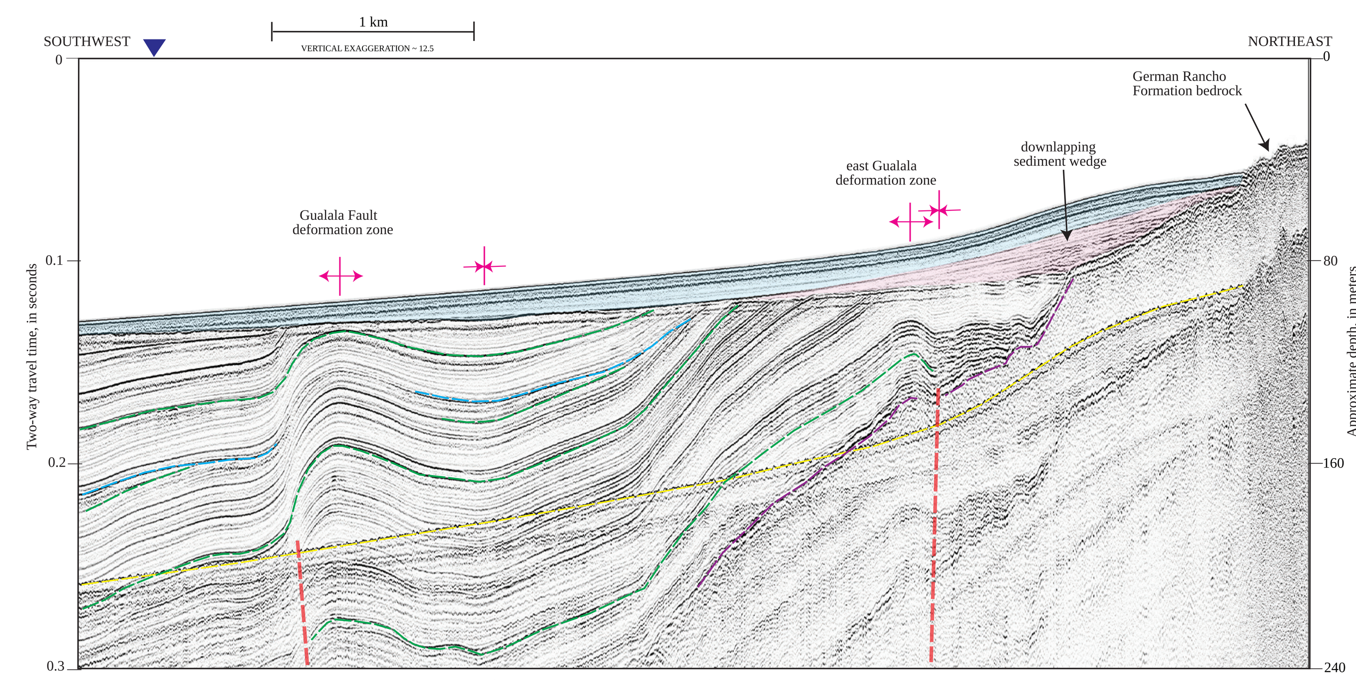


Figure 4. USGS high-resolution minisparker seismic-reflection profile PR-132 (collected in 2009 on survey S–8–09–NC), which crosses shelf west of Salt Point; see trackline map for location. Profile shows faulted and folded strata. Dashed red lines show faults. Magenta symbols show fold axes (diverging arrows, anticlines; converging arrows, synclines). Blue shading shows inferred uppermost Pleistocene and Holocene strata, deposited since last sea-level lowstand about 21,000 years ago. Pink shading shows uppermost Pleistocene strata thought to have formed as sea level fell, between about 30,000 and 21,000 years ago. Underlying folded reflections are of inferred Pleistocene age. Dashed green lines highlight continuous reflections that reveal structure (not distinctive stratigraphic markers). Dashed blue lines show low-angle unconformities; dashed purple line is unconformity with Tertiary bedrock. 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).

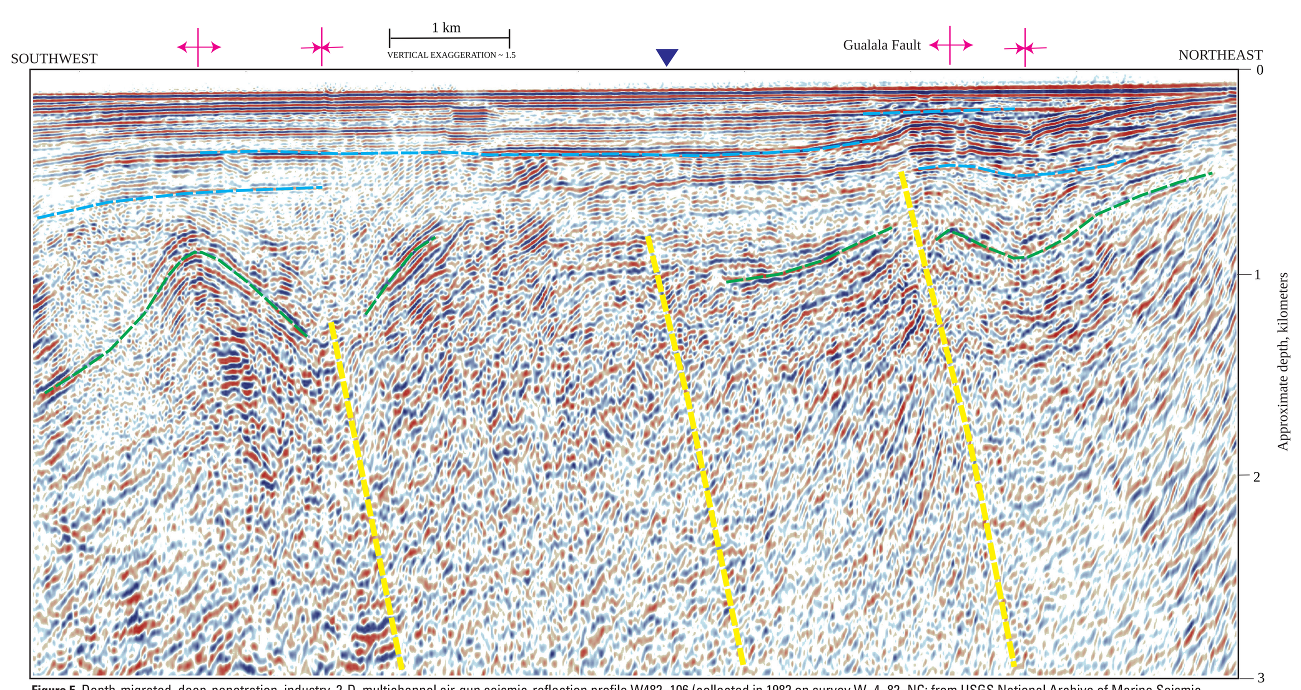


Figure 5. Depth-migrated, deep-penetration, industry, 2-D, multichannel air-gun seismic-reflection profile W482–106 (collected in 1982 on survey W–4–82–NC; from USGS National Archive of Marine Seismic Surveys [U.S. Geological Survey, 2009]), which crosses shelf northwest of Salt Point; see trackline map for location. Note that vertical scale and exaggeration are significantly different than for high-resolution profiles shown in figures 1, 2, 3, 4, 6, 7, 9, and 10. This profile highlights faults (dashed yellow lines), including the Gualala Fault, and folds (magenta symbols show fold axes—diverging arrows, anticlines; converging arrows, synclines) beneath the continental shelf. Dashed green lines highlight continuous reflections that reveal structure (not distinctive stratigraphic markers). Dashed blue lines show apparently discontinuous, low-angle, angular unconformities. Purple triangle shows location of California's State Waters limit (yellow line on trackline map).

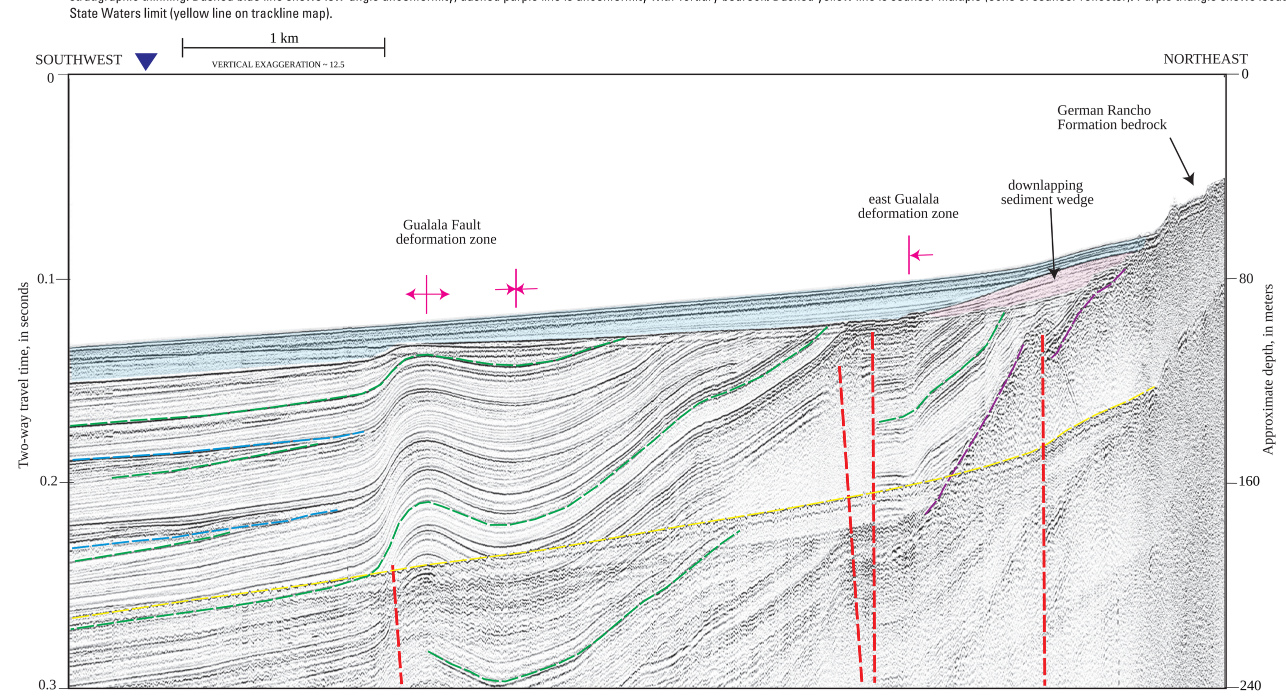


Figure 6. USGS high-resolution minisparker seismic-reflection profile PR-130 (collected in 2009 on survey S–8–09–NC), which crosses shelf west of Salt Point; see trackline map for location. Profile shows faulted and folded strata beneath continental shelf. Dashed red lines shows faults. Magenta symbols show fold axes (diverging arrows, anticline; converging arrows, syncline) and sharp flexure (single arrow, showing direction of increased dip). Blue shading shows inferred uppermost Pleistocene and Holocene strata, deposited since last sea-level lowstand about 21,000 years ago. Pink shading shows uppermost Pleistocene strata thought to have formed as sea level fell, between about 30,000 and 21,000 years ago. Underlying reflectors are of inferred Pleistocene age. Dashed green lines highlight continuous reflections that reveal structure (not distinctive stratigraphic markers). Dashed blue lines show low-angle unconformities; dashed purple line shows unconformity with Tertiary basement. 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).

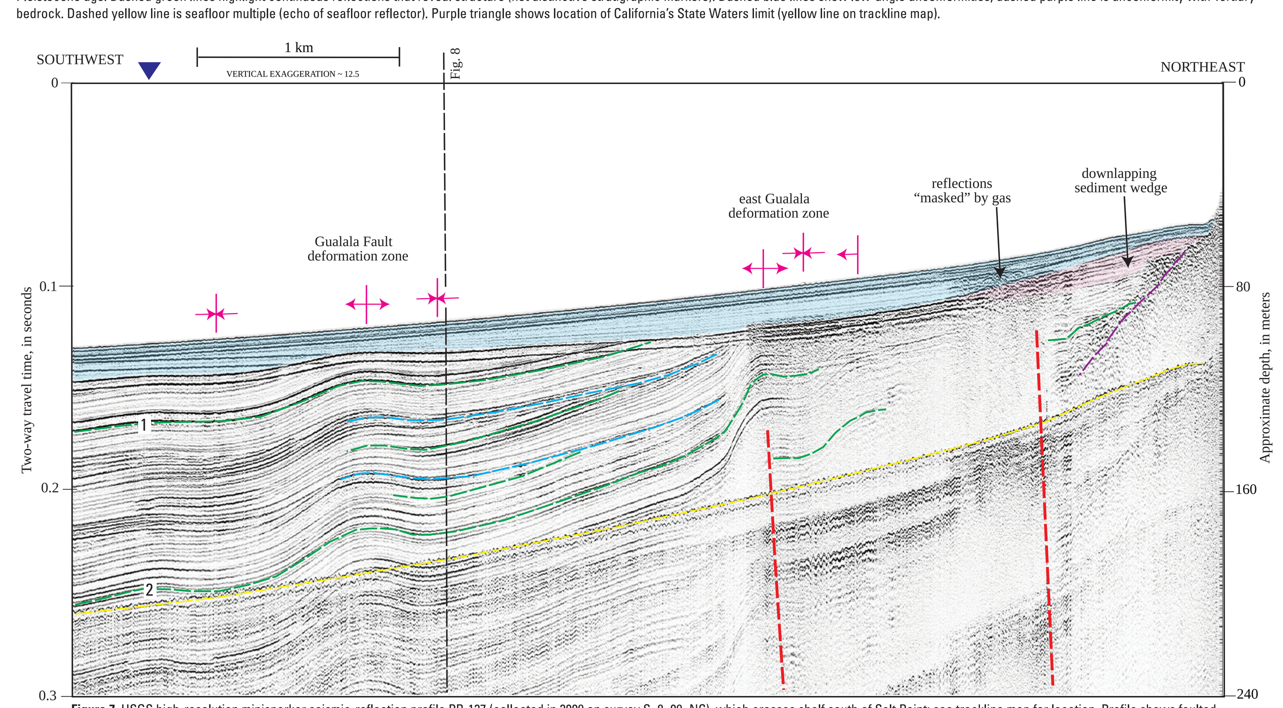


Figure 7. USGS high-resolution minisparker seismic-reflection profile PR-127 (collected in 2009 on survey S–8–09–NC), which crosses shelf south of Salt Point; see trackline map for location. Profile shows faulted and folded strata beneath continental shelf. Dashed red lines shows faults. Magenta symbols show fold axes (diverging arrows, anticlines; converging arrows, synclines) and sharp flexure (single arrow, showing direction of increased dip). Blue shading shows inferred uppermost Pleistocene and Holocene strata, deposited since last sea-level lowstand about 21,000 years ago. Pink shading shows uppermost Pleistocene strata thought to have formed as sea level fell, between about 30,000 and 21,000 years ago. Underlying reflectors are of inferred Pleistocene age. Dashed green lines highlight continuous reflections that reveal structure (not distinctive stratigraphic markers). Narrowing between reflections labeled "1" and "2" highlights significant, west-to-east stratigraphic thinning. Dashed blue lines show low-angle unconformities; dashed purple line shows unconformity with Tertiary basement. Shallow reflections in central part of section are partly "masked" by gas (see, for example, Fader, 1997). 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).

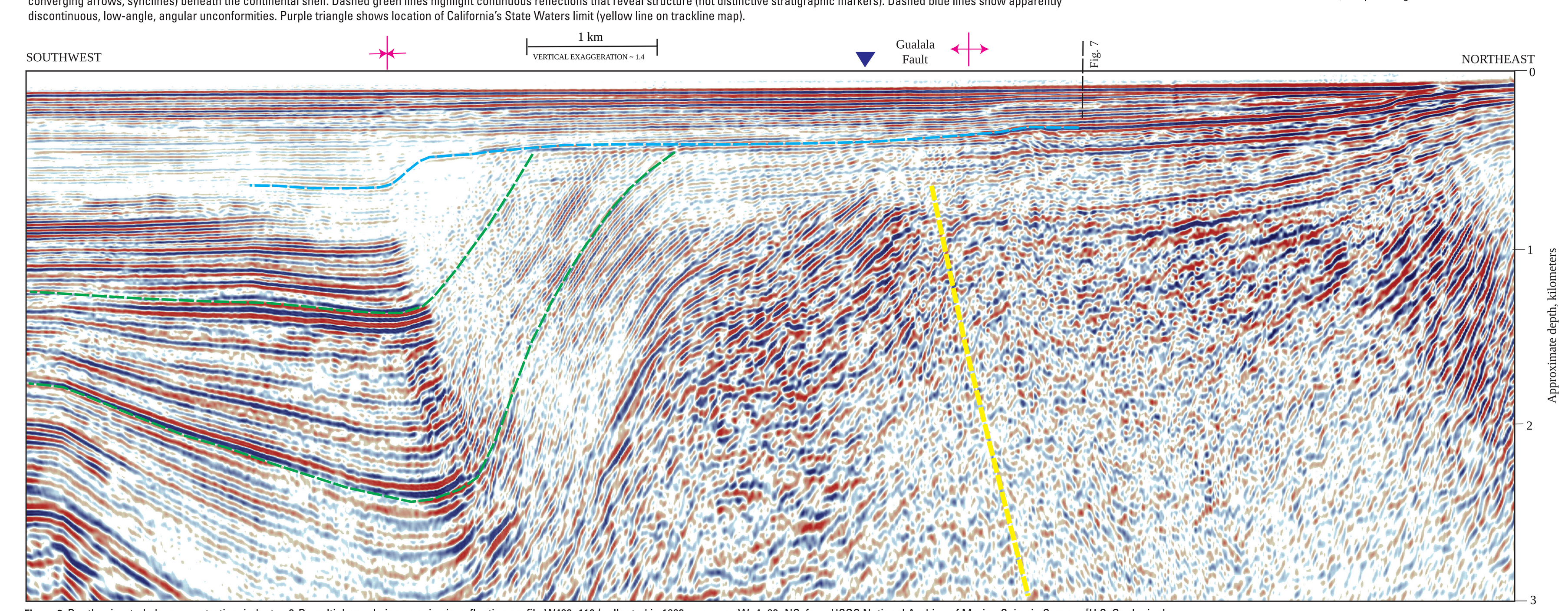


Figure 8. Depth-migrated, deep-penetration, industry, 2-D, multichannel air-gun seismic-reflection profile W482–110 (collected in 1982 on survey W–4–82–NC; from USGS National Archive of Marine Seismic Surveys [U.S. Geological Survey, 2009]), which crosses shelf south of Salt Point; see trackline map for location. Note that vertical scale and exaggeration are significantly different than for the high-resolution profiles shown in figures 1, 2, 3, 4, 6, 7, 9, and 10. This profile shows the Gualala Fault (dashed yellow line) and folds (pink symbols show fold axes—diverging arrows, anticline; converging arrows, syncline) beneath the continental shelf. Dashed green lines show continuous reflections in large asymmetric syncline; dashed blue line shows angular unconformity above the folded strata that transitions to a conformable contact at the southwest end of the profile. Purple triangle shows location of California's State Waters limit (yellow line on trackline map).

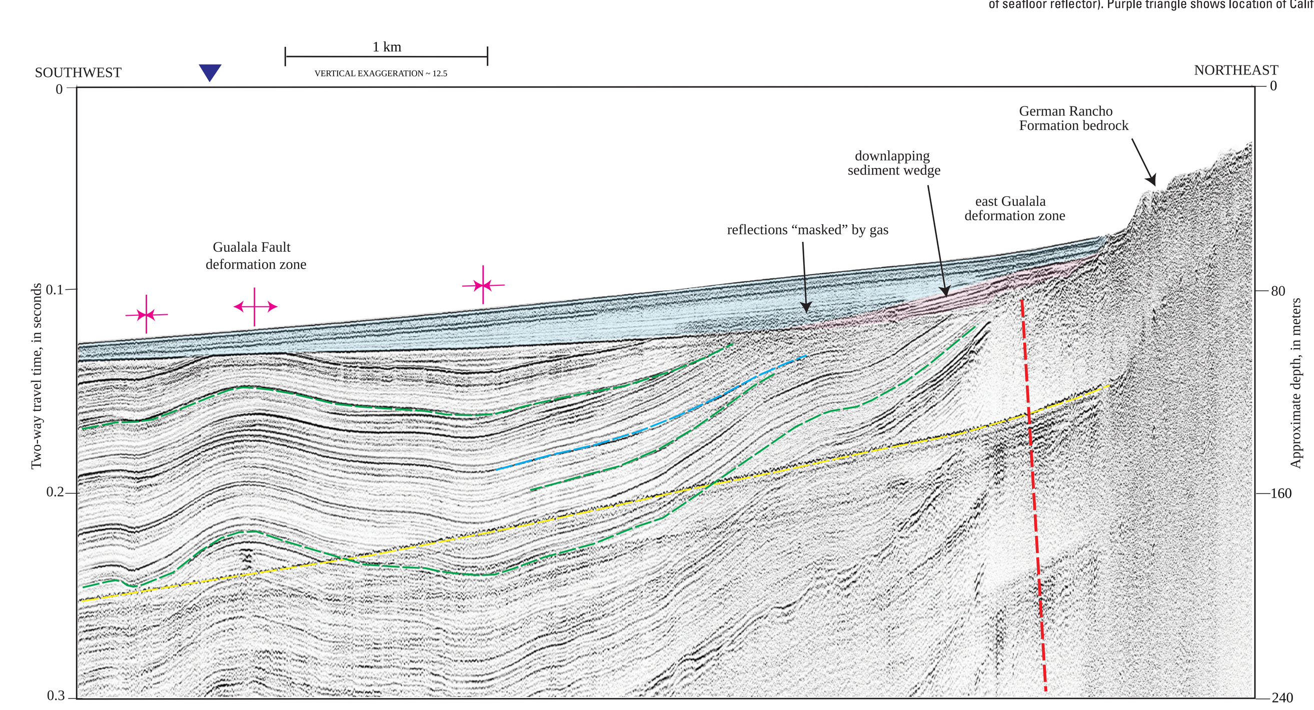


Figure 9. USGS high-resolution minisparker seismic-reflection profile PR-124 (collected in 2009 on survey S–8–09–NC), which crosses shelf south of Salt Point; see trackline map for location. Profile shows faulted and folded strata beneath continental shelf. Dashed red line shows fault. Magenta symbols show fold axes (diverging arrows, anticline; converging arrows, synclines). Blue shading shows inferred uppermost Pleistocene and Holocene strata, deposited since last sea-level lowstand about 21,000 years ago. Pink shading shows uppermost Pleistocene strata thought to have formed as sea level fell, between about 30,000 and 21,000 years ago. Underlying reflectors are of inferred Pleistocene age. Dashed green lines highlight continuous reflections that reveal structure (not distinctive stratigraphic markers). Dashed blue line shows low-angle unconformity. 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).

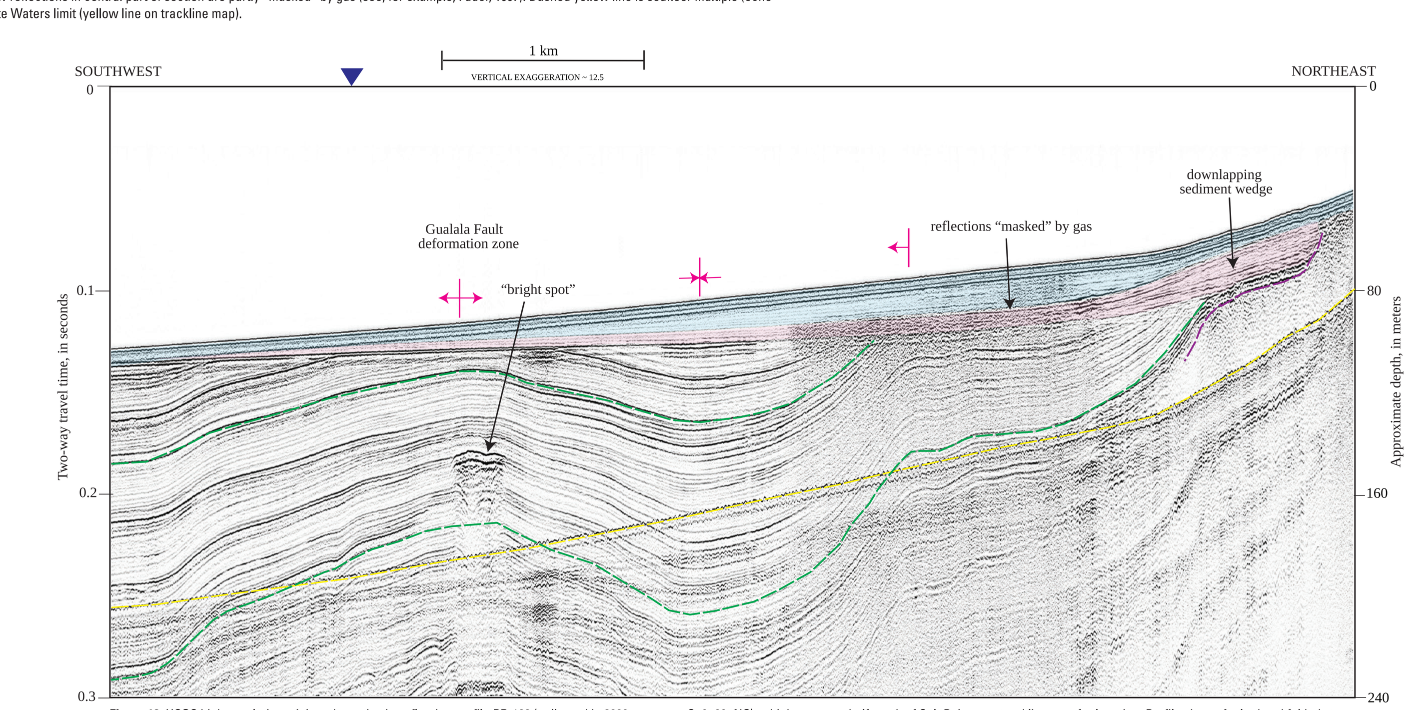
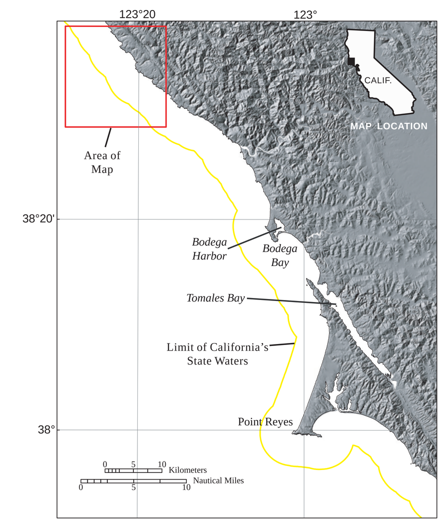


Figure 10. USGS high-resolution minisparker seismic-reflection profile PR-122 (collected in 2009 on survey S–8–09–NC), which crosses shelf south of Salt Point; see trackline map for location. Profile shows faulted and folded strata beneath the continental shelf. Magenta symbols show fold axes (diverging arrows, anticline; converging arrows, syncline) and sharp flexure (single arrow, showing direction of increased dip). Blue shading shows inferred uppermost Pleistocene and Holocene strata, deposited since last sea-level lowstand about 21,000 years ago. Pink shading shows uppermost Pleistocene strata thought to have formed as sea level fell, between about 30,000 and 21,000 years ago. Underlying reflectors are of inferred Pleistocene age. Dashed green lines highlight some continuous reflections that reveal structure (not distinctive stratigraphic markers). Dashed purple line shows unconformity with Tertiary basement. Shallow reflections in the northeastern part of the section are partly "masked" by gas (see, for example, Fader, 1997) and the "bright spot" in the crest of the anticline in the southwestern profile of the profile is also likely related to a gas accumulation. 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 surveys of the Offshore of Salt Point map area, providing imagery of the subsurface geology. The seafloor in this area extends from the shoreline to water depths of about 90 to 100 m. The nearshore to inner shelf area (to water depths of about 50 to 60 m) typically dips seaward about 1.0° to 1.5°, and is underlain by rocky outcrops of the Paleocene and Eocene German Rancho Formation (Elder, 1998) and sand-sized to coarser grained sediment (sheet 10). The midshelf, underlain predominantly by muddy sediments, slopes more gently (less than 0.5°). The Russian River and small coastal watersheds are the primary sediment sources for this area (Drake and Cacchione, 1985).

Surficial and shallow sediments imaged in the upper portions of the high-resolution seismic-reflection profiles (figs. 1, 2, 3, 4, 6, 7, 9, 10) consist of two units (shaded pink and blue) of inferred latest Pleistocene to Holocene age. These two units each consist of unconsolidated sediment and their combined thickness is shown on Sheet 9. The contact between these unconsolidated strata and underlying units is a sharp erosional surface marked by minor channeling, and a common upward change to lower amplitude, more diffuse reflections. The lower unit (pink shading) typically consists of or includes a downlapping sediment wedge that formed adjacent to and on the southwest flank of nearshore bedrock outcrops. The upper unit (blue shading) comprises gently-offshore-dipping, continuous, parallel reflections that onlap and (or) drape the lowstand wedge. These reflection characteristics and geometries suggest deposition during a regression (lower pink unit) and subsequent transgression (upper blue unit), with the units separated by a transgressive surface of erosion (Mitchum and others, 1977; Catuneanu, 2006). The lower unit is inferred to have formed between about 30,000 and 21,000 years ago (marine isotope stage 2), as sea level fell from about 60 m to the Last Glacial Maximum (LGM, about 21,000 years ago), approximately 125 to 130 m lower than present (Waelbroeck and others, 2002). During the LGM, time the Offshore of Salt Point map area was emergent and the shoreline was about 20 km west of its present location. The upper unit is inferred to have formed during the post-LGM transgression. Post–LGM sea-level rise was rapid (about 9 to 11 meters per thousand years) until about 7,000 years ago, when it slowed considerably to about 1 meter per thousand years (Stanford and others, 2011).

Strata that occur beneath the shallow, latest Pleistocene (marine isotope stages 1 and 2) units (and overlie the German Rancho Formation to the east) are represented on sheet 8 (figs. 1, 2, 3, 4, 6, 7, 9, 10) by low-to-high amplitude, high-frequency, parallel to subparallel, continuous reflections.. Reflections are commonly flat to gently folded with dips less than 10° (though they appear much steeper because of the 12.5:1 vertical exaggeration). The upper contact between these strata and the two upper units ranges from angular (where the lower unit has been folded) to parallel or subparallel. These strata are inferred to be Pleistocene in age (marine isotope stage 3 and older; Waelbroeck and others, 2002) because (1) they underlie post–LGM strata, and (2) because their horizon can be traced continuously with other data from USGS cruise S–8–09–NC to the Quaternary section penetrated in Shell borehole P-027-1 (Heck and others, 1990), located 15 km south of the map area. Similar to the overlying post–LGM deposits, these underlying strata represent wave-reworked deltaic and shelf sediments derived primarily from the Russian River.

Bedrock of the German Rancho Formation is exposed onland and in the nearshore along the coast across the entire Offshore of Salt Point map area (sheet 10). Nearshore bedrock is cut by numerous faults and has moderate to steep dips. The unit appears massive and "reflection-free" on high-resolution seismic-reflection data (see, for example, figs. 2, 4, 6, 7, 9) forming an "acoustic basement" for overlying Quaternary sediments. On higher-energy, industry seismic profiles (figs. 5, 8), basement rocks of likely Tertiary age are characterized by low- to high-amplitude, parallel to divergent, continuous reflections.

Seismic-reflection profiles show shallow faulting and folding in a southwest-trending zone above the Gualala Fault ("Gualala Fault deformation zone") and in a more nearshore zone ("east Gualala deformation zone"). Faults cut and (or) are aligned with many fold axes and faulting is a clear control on fold development. Both faults and folds trend northwest, parallel to the shoreline (sheet 10, this report). There is notable stratigraphic thinning between synclinal troughs and anticlinal crests indicating that deposition occurred during fold growth. This pervasive deformation of Pleistocene strata and the overall pattern of faulting and folding (sheet 10, this report) suggests active northwest shortening above a northeast-dipping fault zone that may include one or more blind splays.

Except for the profiles in figures 5 and 8, all profiles displayed on this map sheet were collected in 2009 on U.S. Geological Survey (USGS) cruise S–8–09–NC. The single-channel seismic-reflection data were acquired using the SIG 2Mille minisparker, which 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 m. The data were digitally recorded in standard SEG-Y 32-bit floating-point format, using PC-based 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 across 30 m of lateral distance covered). These data can resolve geologic features a few meters thick (considered "high-resolution"), down to subbottom depths of about 400 m

Figures 5 and 8 show deep-penetration, depth-migrated, multichannel seismic-reflection profiles collected in 1982 by WesternGeco on cruise W–4–82–NC. These profiles 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. Most 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 using 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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Seismic-Reflection Profiles, Offshore of Salt Point Map Area, California

by
Samuel Y. Johnson, Ray W. Sliter, Stephen R. Hartwell, and John L. Chin
2015

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