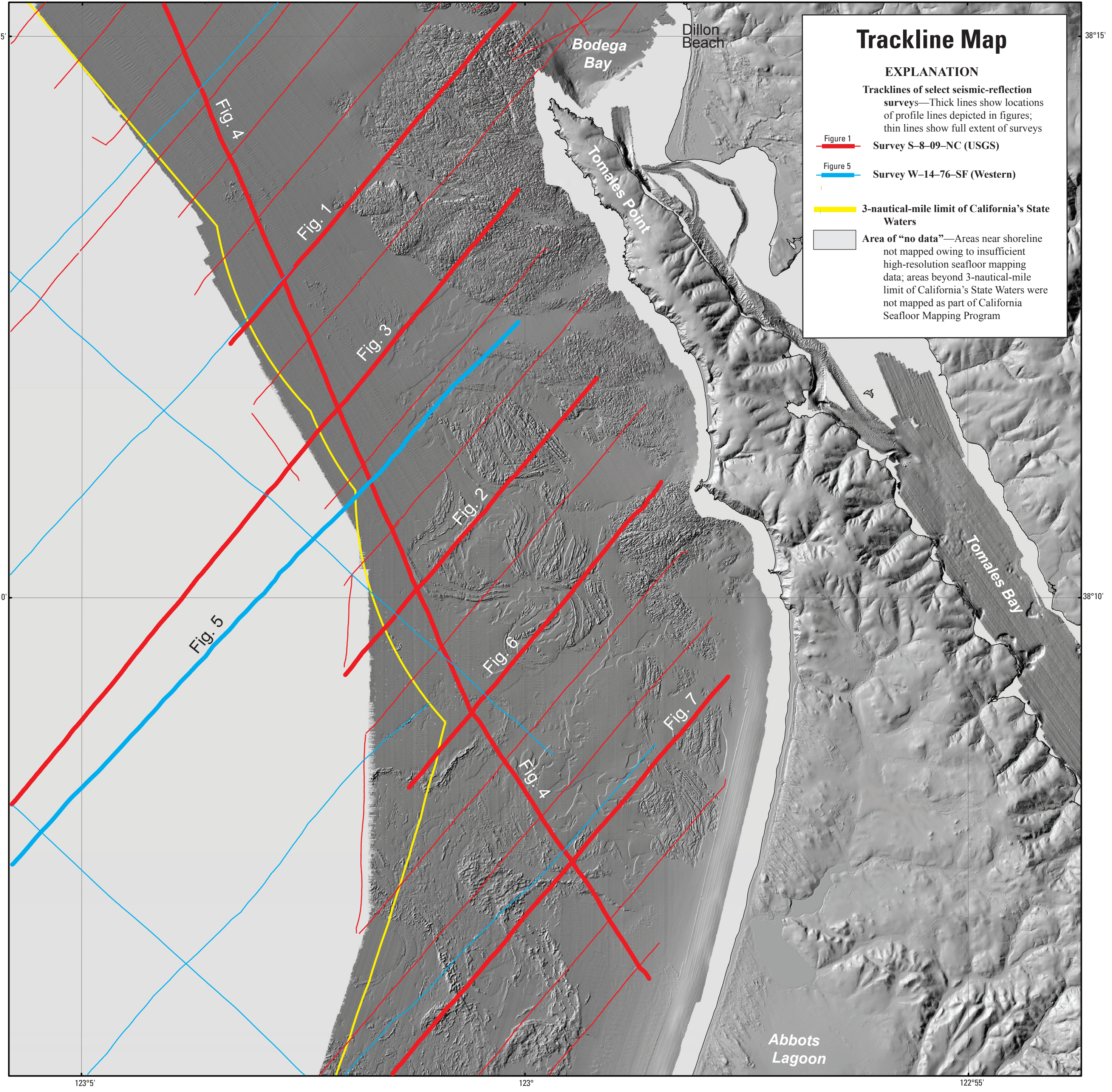
U.S. Department of the Interior
U.S. Geological Survey

Open-File Report 2015–1088
Sheet 8 of 10
Pamphlet accompanies map



Trackline Map

EXPLANATION

Tracklines of select seismic-reflection surveys—Thick lines show locations of profile lines depicted in figures; thin lines show full extent of surveys

Survey S–8–09–NC (USGS)

Survey W–14–76–SF (Western)

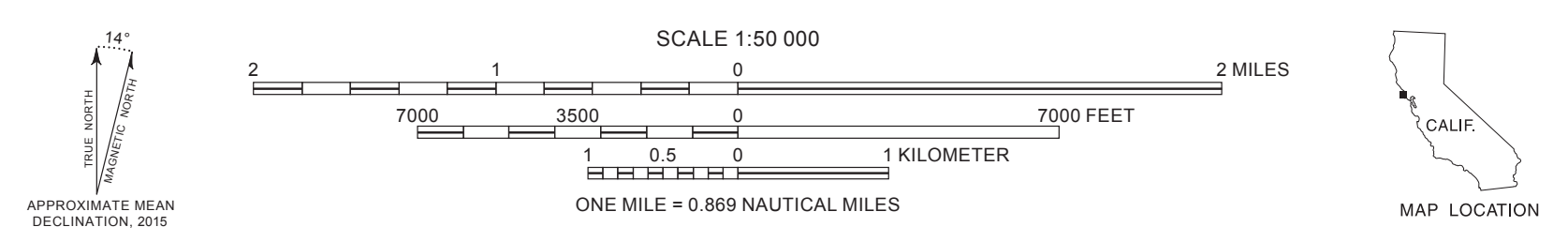
3-nautical-mile limit of California's State Waters

Area of "no data"—Areas near shoreline not mapped owing to insufficient high-resolution seafloor mapping data; areas beyond 3-nautical-mile limit of California's State Waters were not mapped as part of California Seafloor Mapping Program

Onshore elevation data from California Coastal Conservancy, available at http://www.csc.noaa.gov/digitalcoast/data/coastallidar/, 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



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

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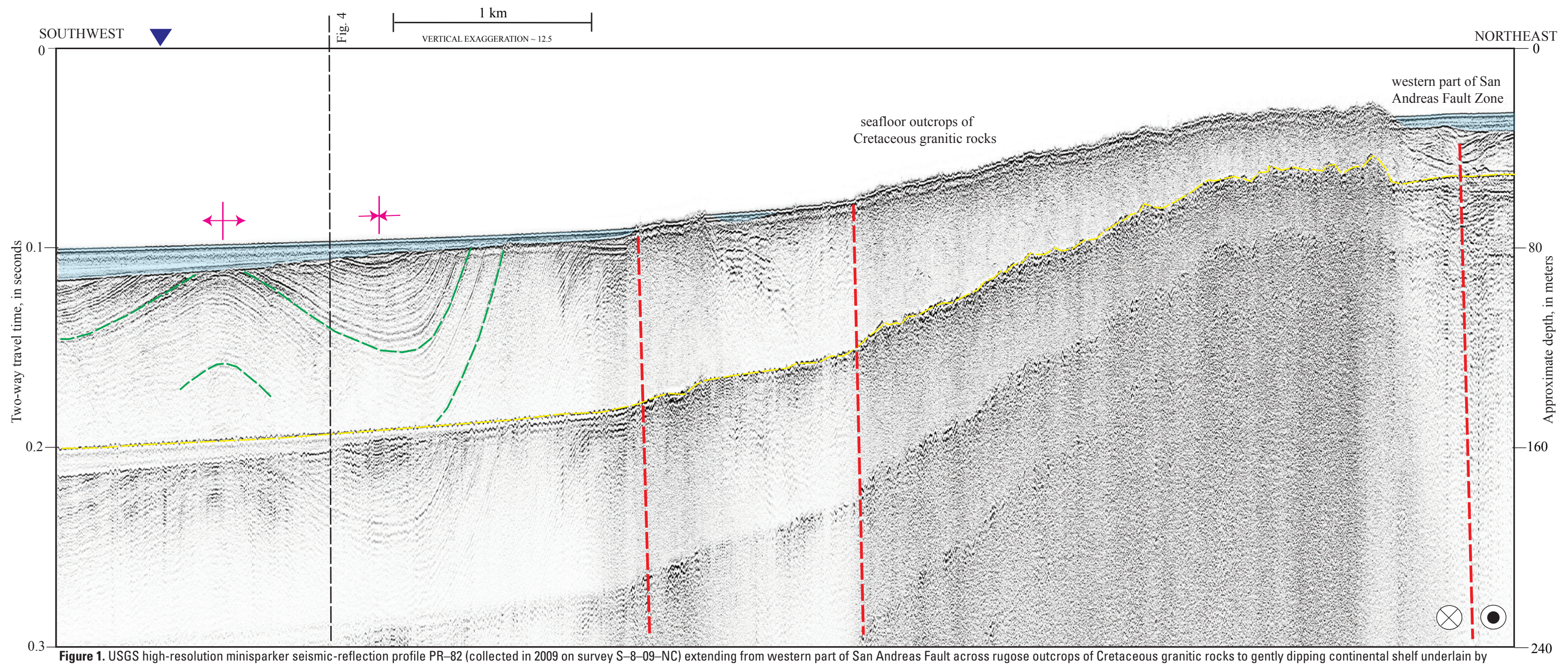


Figure 1. USGS high-resolution minisparker seismic-reflection profile PR–82 (collected in 2009 on survey S–8–09–NC) extending from western part of San Andreas Fault across rugose outcrops of Cretaceous granitic rocks to gently dipping continental shelf underlain by folded Neogene sedimentary rocks (see sheet 10); see trackline map for location. Dashed red lines show faults. On San Andreas Fault, circle with dot indicates strike-slip motion toward reader, and circle with "x" indicates motion away from reader. Pink symbols show fold axes (diverging arrows, anticline; converging arrows, syncline). Blue shading shows thin, inferred uppermost Pleistocene and Holocene strata, deposited since the last sea-level lowstand about 21,000 years ago. Dashed green lines highlight some continuous reflections that illustrate 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 trackline map).

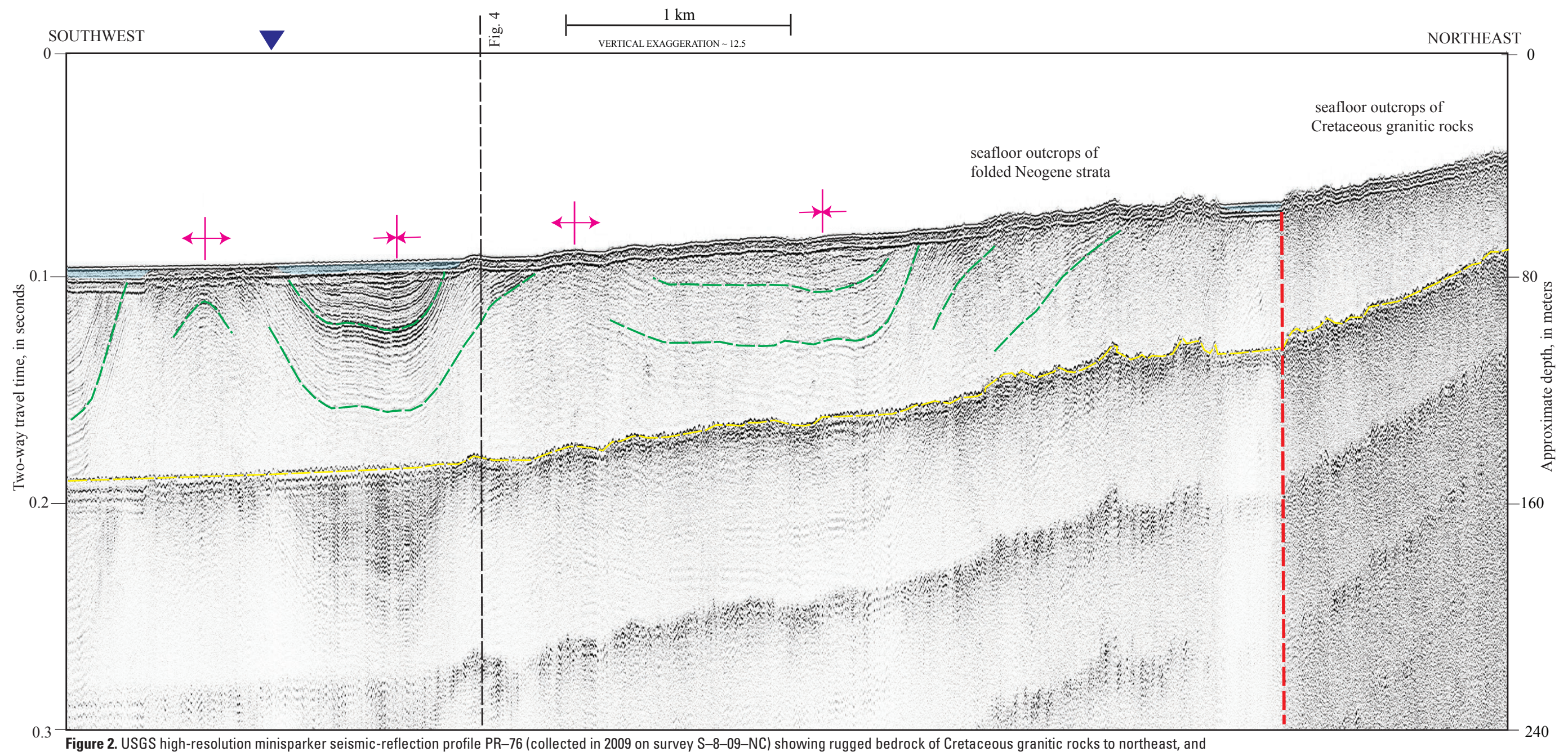


Figure 2. USGS high-resolution minisparker seismic-reflection profile PR–76 (collected in 2009 on survey S–8–09–NC) showing rugged bedrock of Cretaceous granitic rocks to northeast, and folded Neogene strata to southwest; see trackline map for location. Dashed red lines show faults. Pink symbols show fold axes (diverging arrows, anticlines; converging arrows, synclines). Blue shading shows very thin, inferred uppermost Pleistocene and Holocene strata, deposited since last sea-level lowstand about 21,000 years ago. Dashed green lines highlight some continuous reflections that illustrate 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 trackline map).

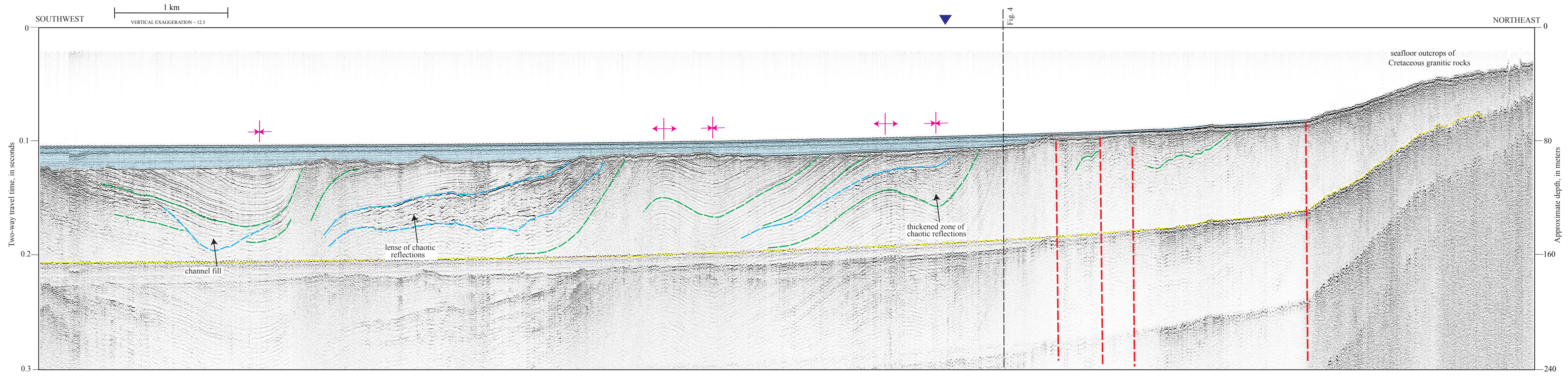


Figure 3. USGS high-resolution minisparker seismic-reflection profile PR–65 (collected in 2009 on survey S–8–09–NC) showing rugged Cretaceous granitic bedrock to northeast, and folded Neogene strata beneath gently dipping continental shelf to southwest; see trackline map for location. Dashed red lines show faults. Pink symbols show fold axes (diverging arrows, anticlines; converging arrows, synclines). Blue shading shows thin, inferred uppermost Pleistocene and Holocene strata, deposited since last sea-level lowstand about 21,000 years ago. Dashed green lines highlight some continuous reflections that illustrate structure (not distinctive stratigraphic markers). Blue dashed lines show intrastratal unconformities and (or) boundaries of zones of chaotic reflections. Dashed yellow line is seafloor multiple (echo of seafloor reflector). Dashed green lines highlight some continuous reflections that illustrate structure (not distinctive stratigraphic markers). Blue dashed lines show intrastratal unconformities and (or) boundaries of zones of chaotic reflections. Dashed yellow line is seafloor multiple (echo of seafloor reflector). Purple triangle shows location of the outer boundary of California's State Waters.

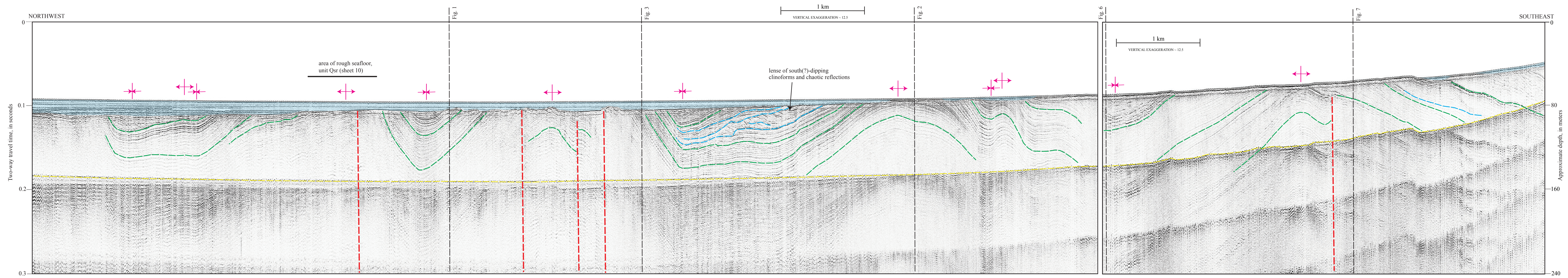


Figure 4. USGS high-resolution minisparker seismic-reflection profiles PR–71 (left) and 71A (right), (collected in 2009 on survey S–8–09–NC) showing folded and faulted Neogene strata beneath continental shelf; see trackline map for location. Dashed red lines show faults. Pink symbols show fold axes (diverging arrows, anticlines; converging arrows, synclines). Blue shading shows thin, inferred uppermost Pleistocene and Holocene strata, deposited since last sea-level lowstand about 21,000 years ago. Dashed green lines highlight some continuous reflections that illustrate structure (not distinctive stratigraphic markers). Blue dashed lines show intrastratal unconformities and boundaries of a lens comprising south(?)-dipping clinoforms and chaotic reflections. Dashed yellow line is seafloor multiple (echo of seafloor reflector).

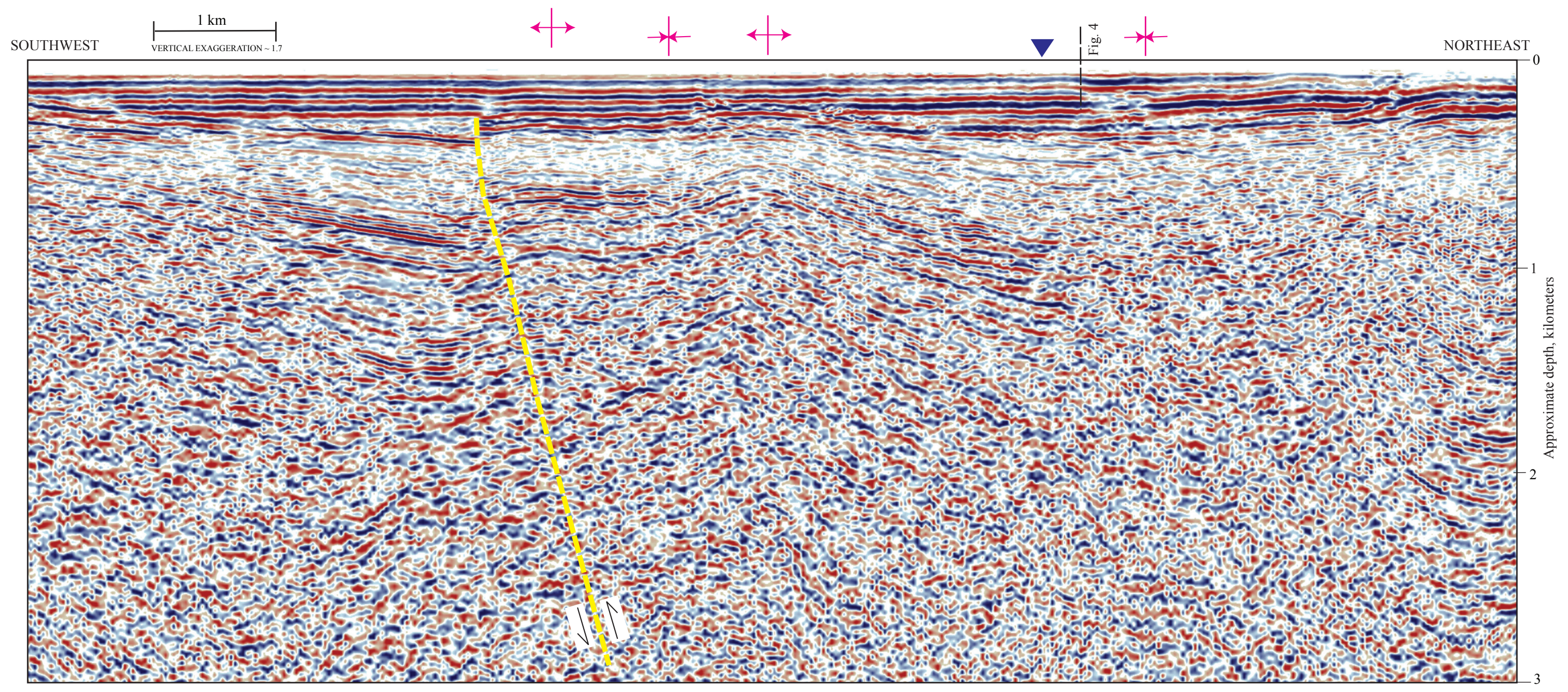


Figure 5. Deep-penetration industry, 2-D, multichannel air-gun seismic-reflection profile WSF–102 (collected in 1976 on survey W–14–76–SF) from USGS National Archive of Marine Seismic Surveys (USGS, 2009); see trackline map for location. Note that vertical scale and exaggeration are significantly different than for high-resolution profiles shown in figures 1, 2, 3, 4, 6, and 7. Dashed yellow line shows fault with arrows indicating sense of offset. Pink symbols show fold axes (diverging arrows, anticlines; converging arrows, synclines) beneath continental shelf west of Tomales Point. Purple triangle shows location of California's State Waters limit (yellow line on trackline map).

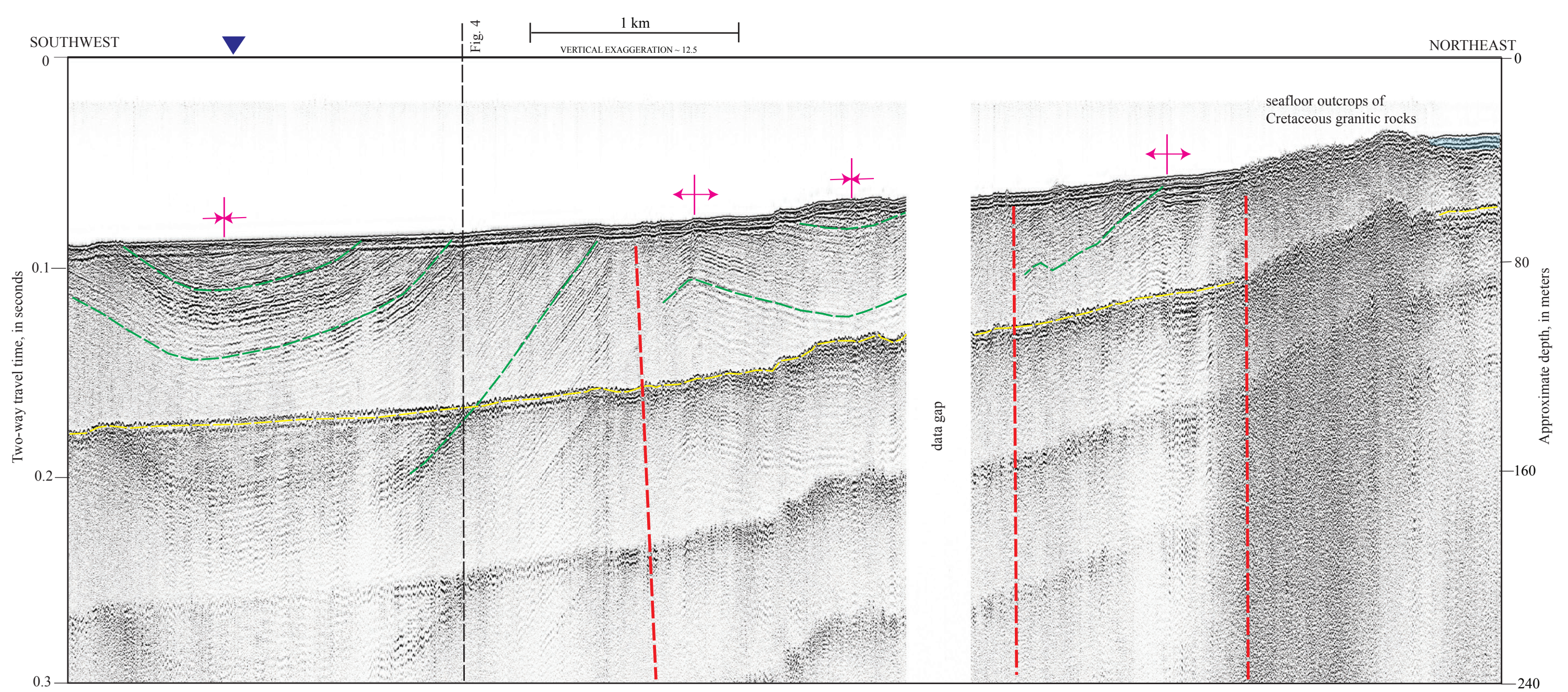


Figure 6. USGS high-resolution minisparker seismic-reflection profile PR–66 (collected in 2009 on survey S–8–09–NC) extending from rugose outcrops of Cretaceous granitic rocks to gently dipping continental shelf underlain by folded Neogene rocks (see sheet 10); see trackline map for location. Dashed red lines show faults. Pink symbols show fold axes (diverging arrows, anticlines; converging arrows, synclines). Blue shading (northeast end of profile) shows thin, inferred uppermost Pleistocene and Holocene strata, deposited since last sea-level lowstand about 21,000 years ago. Dashed green lines highlight some continuous reflections that illustrate 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 trackline map).

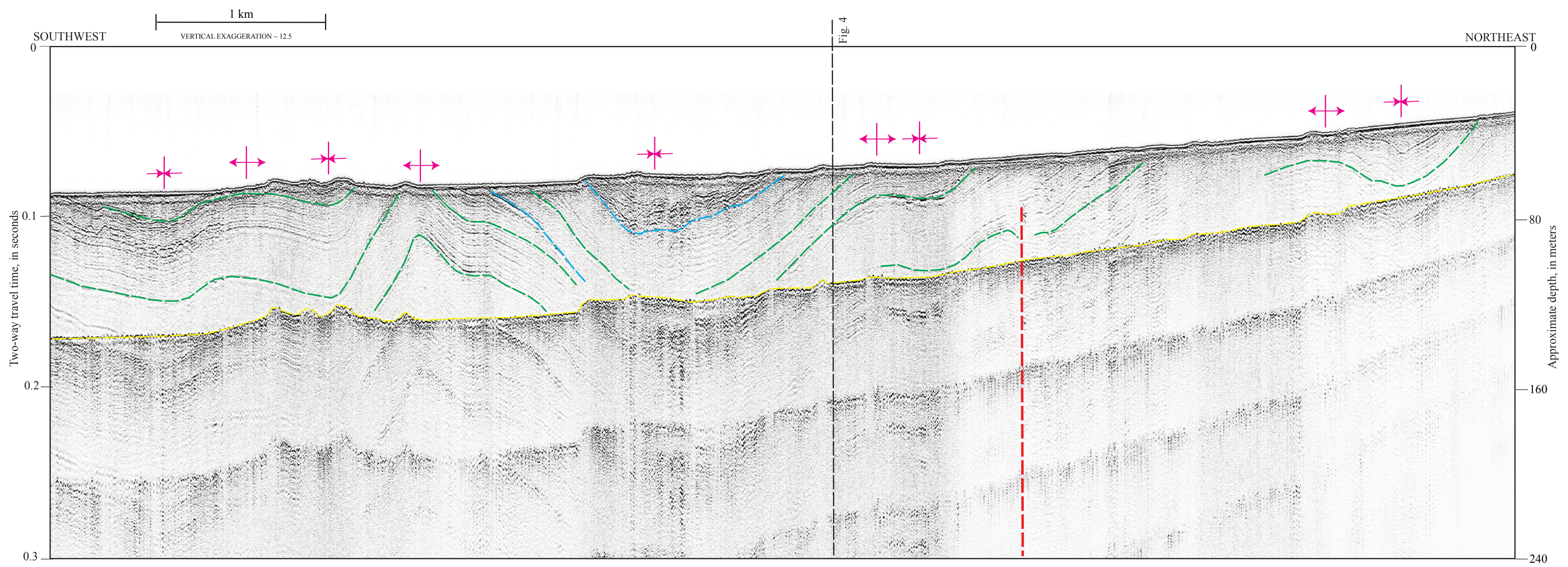
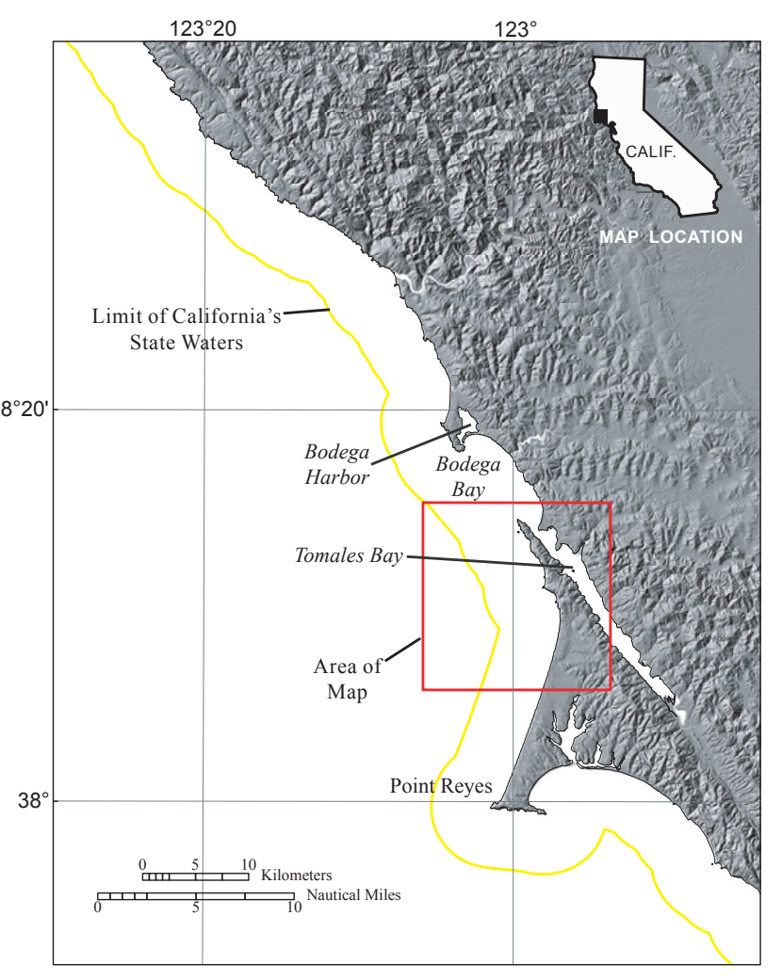


Figure 7. USGS high-resolution minisparker seismic-reflection profile PR–68 (collected in 2009 on survey S–8–09–NC) extending beneath continental shelf offshore of Tomales Point; see trackline map for location. Dashed red line shows fault. Pink symbols show fold axes (diverging arrows, anticlines; converging arrows, synclines) in inferred Neogene strata (see sheet 10). Dashed green lines highlight some continuous reflections that illustrate structure (not distinctive stratigraphic markers). Dashed blue lines show intrastratal unconformities. Dashed yellow line is seafloor multiple (echo of seafloor reflector).



DISCUSSION

This map sheet shows seismic-reflection profiles from two different surveys of the Offshore of Tomales Point map area, providing imagery of the subsurface geology. The northeast part of the map area is cut by the San Andreas Fault (pamphlet, fig. 1–1), which forms a right-lateral transform boundary between the North American and Pacific tectonic plates. Fault slip along the San Andreas Fault has uplifted Cretaceous granitic rock and overlying Neogene, folded, marine sedimentary rock forming Tomales Point and much of the rugged, rocky, continental shelf on its west flank. These two different rock types are mapped (sheet 10) on the seafloor based on their distinctive morphology and seismic character. Granitic seafloor outcrops are characterized by a massive hackly texture and are cut by dense networks of crosscutting fractures and small faults. In contrast, folded Neogene sedimentary rocks are characterized by a "ribbed" seafloor morphology which results from dipping beds (lithologies) having variable resistance to erosion. In the southern part of the map area offshore of Abbots Lagoon, the sedimentary rocks are less "ribbed," owing to shallower dips and more uniform sandstone lithology (sheet 10). Seafloor underlain by granitic rocks typically slopes more than 1°, whereas seafloor underlain by sedimentary rocks slopes about 0.5°.

On seismic-reflection data, granitic rocks are notably "reflection-free," (see, for example, figs. 1, 2, 3, 5) whereas sedimentary rocks are characterized by continuous, parallel to subparallel, variable amplitude, high-frequency reflections (terminology after Mitchum and others, 1977). Within the sedimentary rocks, intrastratal low-angle unconformities and broad (as wide as about 1 km) channels are common (figs. 3, 4, 6). Lenses of chaotic reflections (figs. 3, 4) are inferred to represent smaller-scale channels and (locally) zones of prograding clinoforms.

Surficial and shallow sediments in the Offshore of Tomales Point map area were deposited on the bedrock in the last about 21,000 years during the sea-level rise that followed the Last Glacial Maximum (LGM) and the last major lowstand (Lambeck and Chappell, 2001). Sea level was about 125 m lower during the LGM, at which time the map area was emergent and the shoreline was about 30 km west of its present location. Post-LGM sea-level rise was rapid (about 9 to 11 m per thousand years) until about 7,000 years ago, when it slowed considerably to about 1 m per thousand years (Stanford and others, 2011). Sea-level rise lead to broadening of the continental shelf, progressive eastward migration of the shoreline and wave-cut platform, and associated transgressive erosion and deposition.

Sediments deposited during post-LGM sea-level rise (the rapid transgression and highstand after slowing at about 7 ka) are shaded blue in the high-resolution seismic-reflection profiles (figs. 1, 2, 3, 4, 6); their thickness is shown on Sheet 9 of this report (Maps B, D). The contact between underlying granitic and sedimentary rocks and post-LGM sediment is an abrupt transgressive surface of erosion commonly marked by minor channeling, and a common upward change to lower amplitude, more diffuse reflections.

Faults in the offshore part of the map area are identified on seismic-reflection profiles on the basis of abrupt truncation or warping of reflections and (or) the juxtaposition of reflection panels that have differing seismic parameters, such as reflection presence, amplitude, frequency, geometry, continuity, and vertical sequence. Only the western part of the San Andreas Fault is imaged on one seismic-reflection profile in the map area (fig. 1); the profile shows a down-dropped sedimentary basin, bounded to the west by uplifted granitic rocks. Nearby, onland geologic studies along this section of the San Andreas Fault suggest a slip rate of 17 to 30 mm/yr (Bryant and Lundberg, 2002; Grove and Niemi, 2005).

Both the high-resolution bathymetry (sheets 1, 2) and the seismic-reflection data (sheet 8) reveal complex structure beneath the bedrock shelf west of Tomales Point. Numerous northwest-striking faults and folds cut both granitic and sedimentary rocks, and their depositional contact (figs. 1, 6; sheet 10). Folds axes trend west to northwest and folds have common wavelengths of 0.5 to 2 kilometers. The folding occurred during the late Pliocene or Pleistocene; it does not obviously involve post-LGM sediments, and the upper Pliocene to upper Miocene Purisima Formation is apparently the youngest folded unit (Clark and Brabb, 1997). Folding may be synchronous with activity on the northwest-trending Point Reyes Thrust Fault located about 16 km offshore of the map area (McCulloch, 1987; Heck and others, 1990).

All but one of the profiles displayed on this map sheet (figs. 1, 2, 3, 4, 6, 7) were collected in 2009 on U.S. Geological Survey (USGS) cruise S–8–09–NC using the SIG 2Mille minisparker system. This system used a 500-J high-voltage electrical discharge fired 1 to 4 times per second, which, at normal survey speed 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 and a 160- to 1,200-Hz bandpass filter were applied to the minisparker data, followed by a heave correction that uses an automatic seafloor-detection window (averaged over 30 m of lateral distance covered). These data can resolve geologic features a few meters thick (hence considered "high-resolution"), down to subbottom depths of about 400 m.

Figure 5 shows a deep-penetration, migrated, 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 using a large-volume air-gun source that has a frequency range of 3 to 40 Hz and recorded using 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 Tomales Point Map Area, California

By

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

2015

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