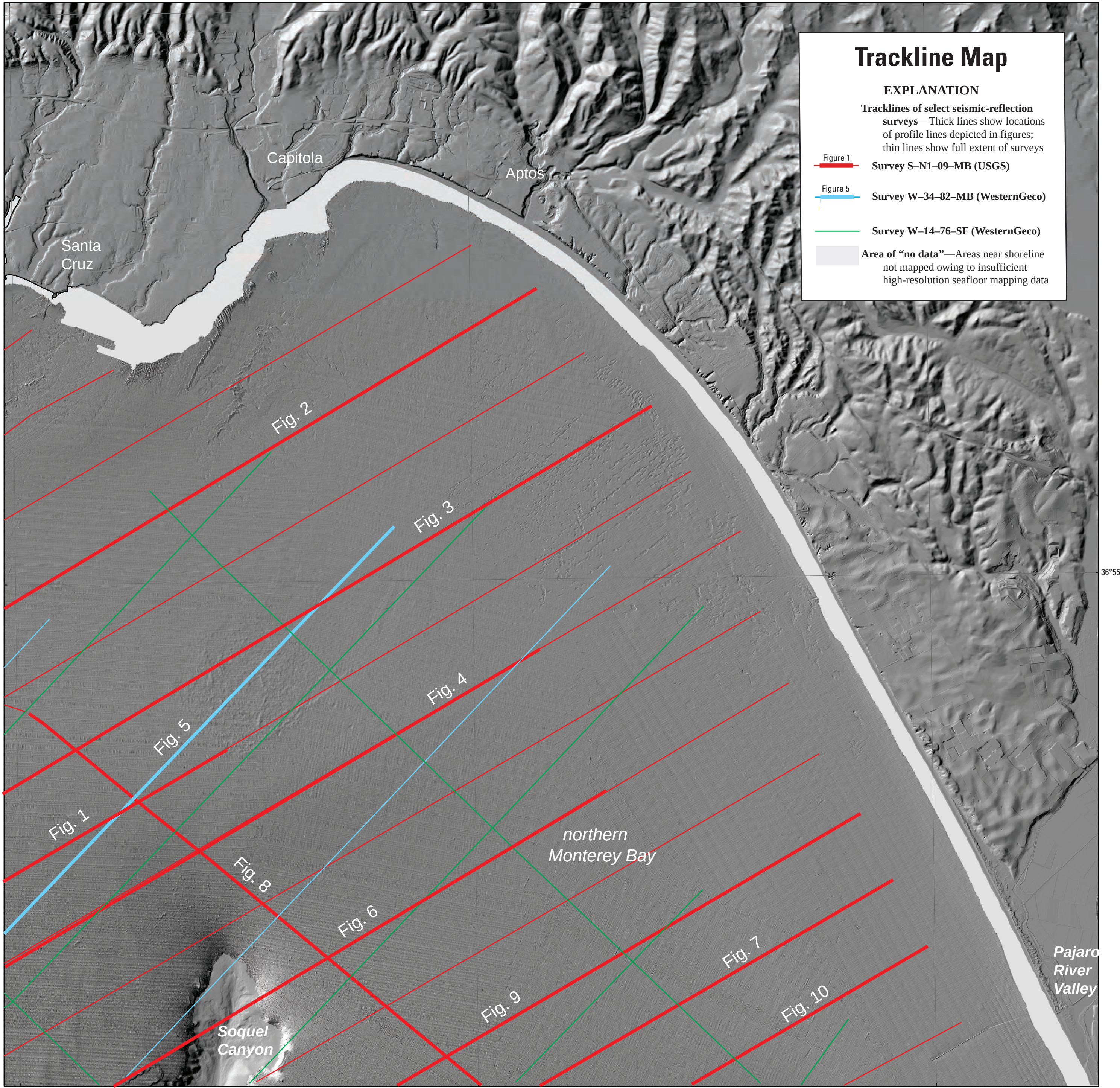
U.S. Department of the Interior
U.S. Geological Survey

Open-File Report 2016–1025
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

Figure 1 🟥	**Survey S–N1–09–MB (USGS)**
Figure 5 🟦	**Survey W–34–82–MB (WesternGeco)**
🟩	**Survey W–14–76–SF (WesternGeco)**
▨	**Area of "no data"**—Areas near shoreline not mapped owing to insufficient high-resolution seafloor mapping data

Onshore elevation data from National Oceanic and Atmospheric Administration (NOAA) Office for Coastal Management's Digital Coast (available at http://www.csc.noaa.gov/digitalcoast/data/coastallidar/) and from U.S. Geological Survey's National Elevation Dataset (available at http://ned.usgs.gov/). Offshore shaded-relief bathymetry from map on sheet 2, this report

Universal Transverse Mercator projection, Zone 10N

NOT INTENDED FOR NAVIGATIONAL USE

SCALE 1:50 000

ONE MILE = 0.869 NAUTICAL MILES

GIS database and digital cartography by Peter Dartnell and Stephen R. Hartwell, 2014

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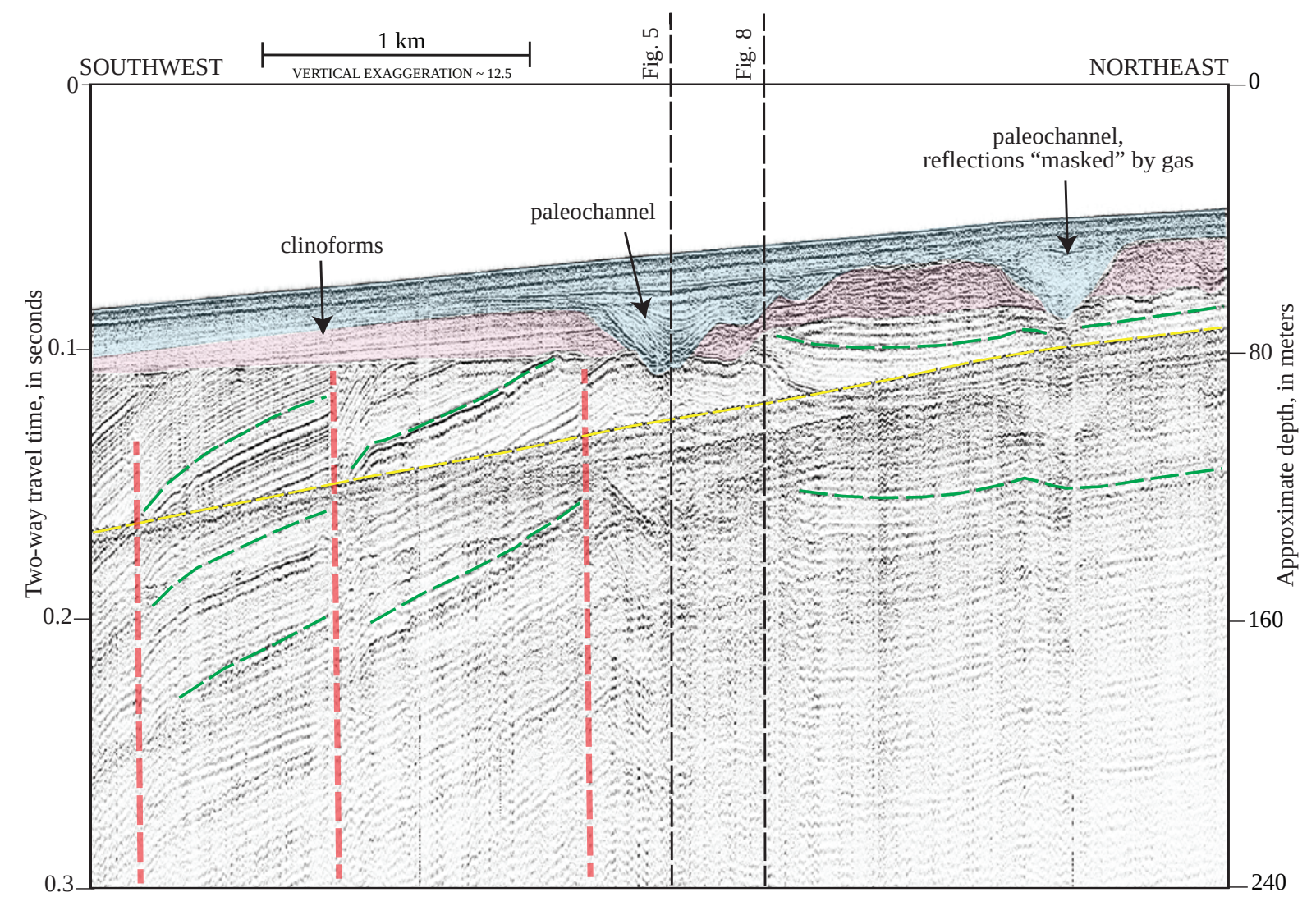


Figure 1. USGS high-resolution minisparker seismic-reflection profile MBS-17 (collected in 2009 on cruise S–N1–09–MB), which crosses shelf southwest of Aptos; see trackline map for location. Profile highlights paleochannels and faulted and folded strata beneath continental shelf in northern Monterey Bay. Dashed red lines show faults. Blue and pink shading shows inferred uppermost Pleistocene and Holocene strata, deposited since about 30,000 years ago during final stages of sea-level fall and subsequent sea-level rise. Underlying reflectors are of inferred Neogene age. Dashed green lines highlight some continuous reflections that reveal structure. Dashed yellow line is seafloor multiple (echo of seafloor reflector).

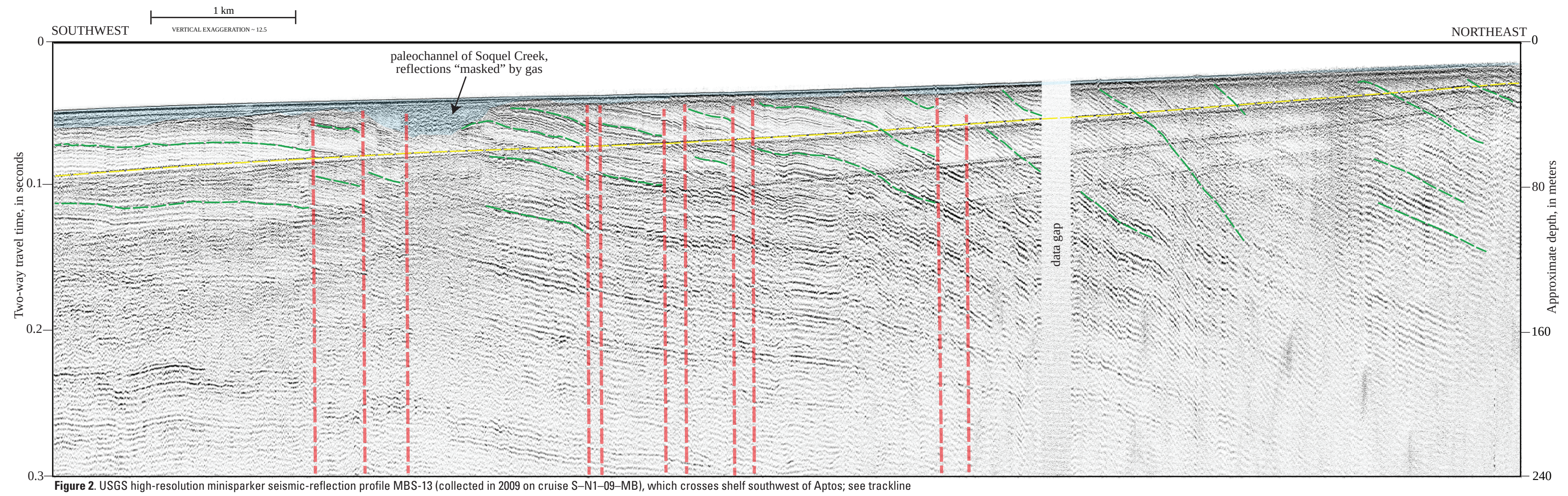


Figure 2. USGS high-resolution minisparker seismic-reflection profile MBS-13 (collected in 2009 on cruise S–N1–09–MB), which crosses shelf southwest of Aptos; see trackline map for location. Profile highlights faulted strata beneath continental shelf in northern Monterey Bay. Dashed red lines show faults. Blue shading shows inferred uppermost Pleistocene and Holocene strata, deposited since last sea-level lowstand about 21,000 years ago. Underlying reflectors image inferred Neogene strata. Dashed green lines highlight some continuous reflections that reveal structure (not distinctive stratigraphic markers). Dashed yellow line is seafloor multiple (echo of seafloor reflector).

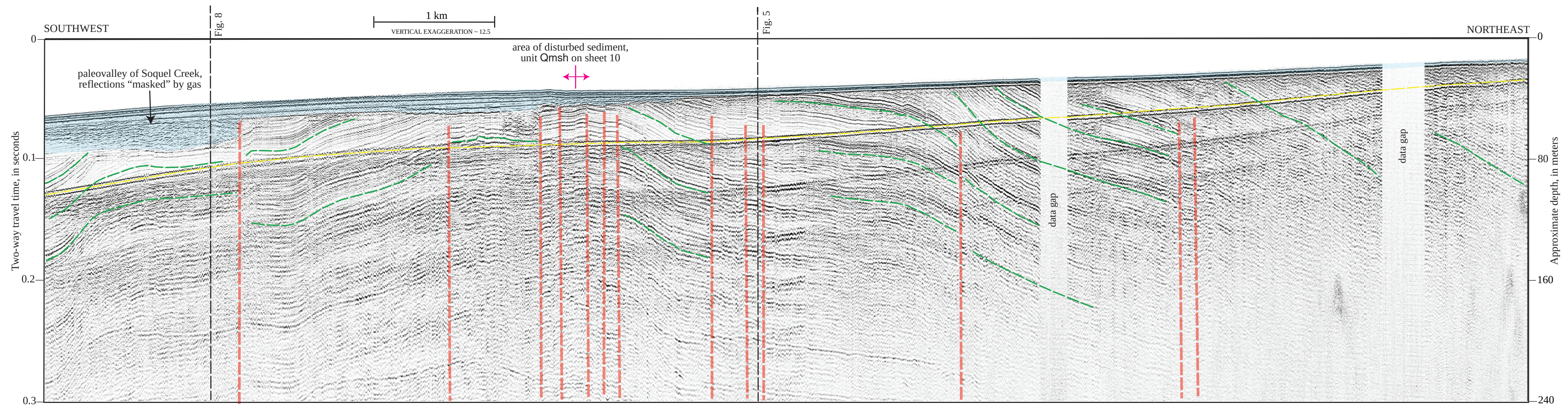


Figure 3. USGS high-resolution minisparker seismic-reflection profile MBS-16 (collected in 2009 on cruise S–N1–09–MB), which crosses shelf southwest of Aptos; see trackline map for location. Profile highlights faulted strata beneath continental shelf in northern Monterey Bay. Dashed red lines show faults. Magenta symbol shows fold axis (diverging arrows, anticline). Blue shading shows inferred uppermost Pleistocene and Holocene strata, deposited since last sea-level lowstand about 21,000 years ago. Underlying reflectors image deformed Neogene strata. Dashed green lines highlight some continuous reflections that reveal structure (not distinctive stratigraphic markers). Dashed yellow line is seafloor multiple (echo of seafloor reflector).

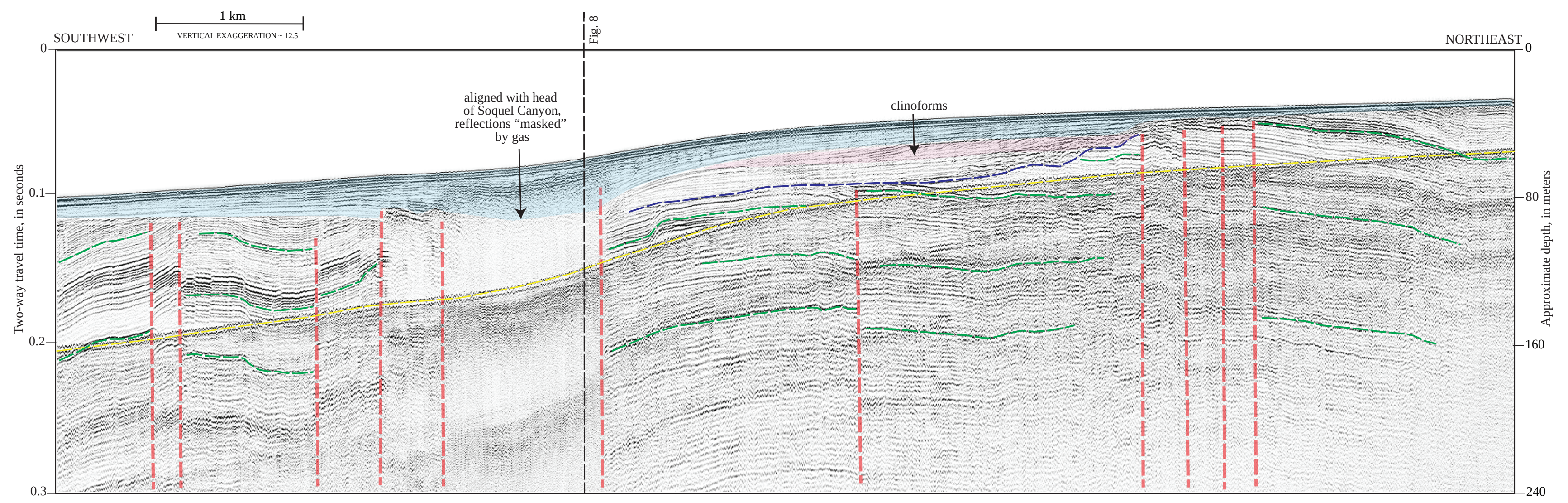


Figure 4. USGS high-resolution minisparker seismic-reflection profile MBS-18A (collected in 2009 on cruise S–N1–09–MB), which crosses shelf southwest of Aptos; see trackline map for location. Profile highlights faulted strata beneath continental shelf in northern Monterey Bay. Dashed red lines show faults. Blue and pink shading shows inferred uppermost Pleistocene and Holocene strata, deposited since about 30,000 years ago during final stages of sea-level fall and subsequent sea-level rise. Underlying reflectors image deformed Neogene strata. Dashed green lines highlight some continuous reflections that reveal structure (not distinctive stratigraphic markers). Dashed purple line shows unconformity. Dashed yellow line is seafloor multiple (echo of seafloor reflector).

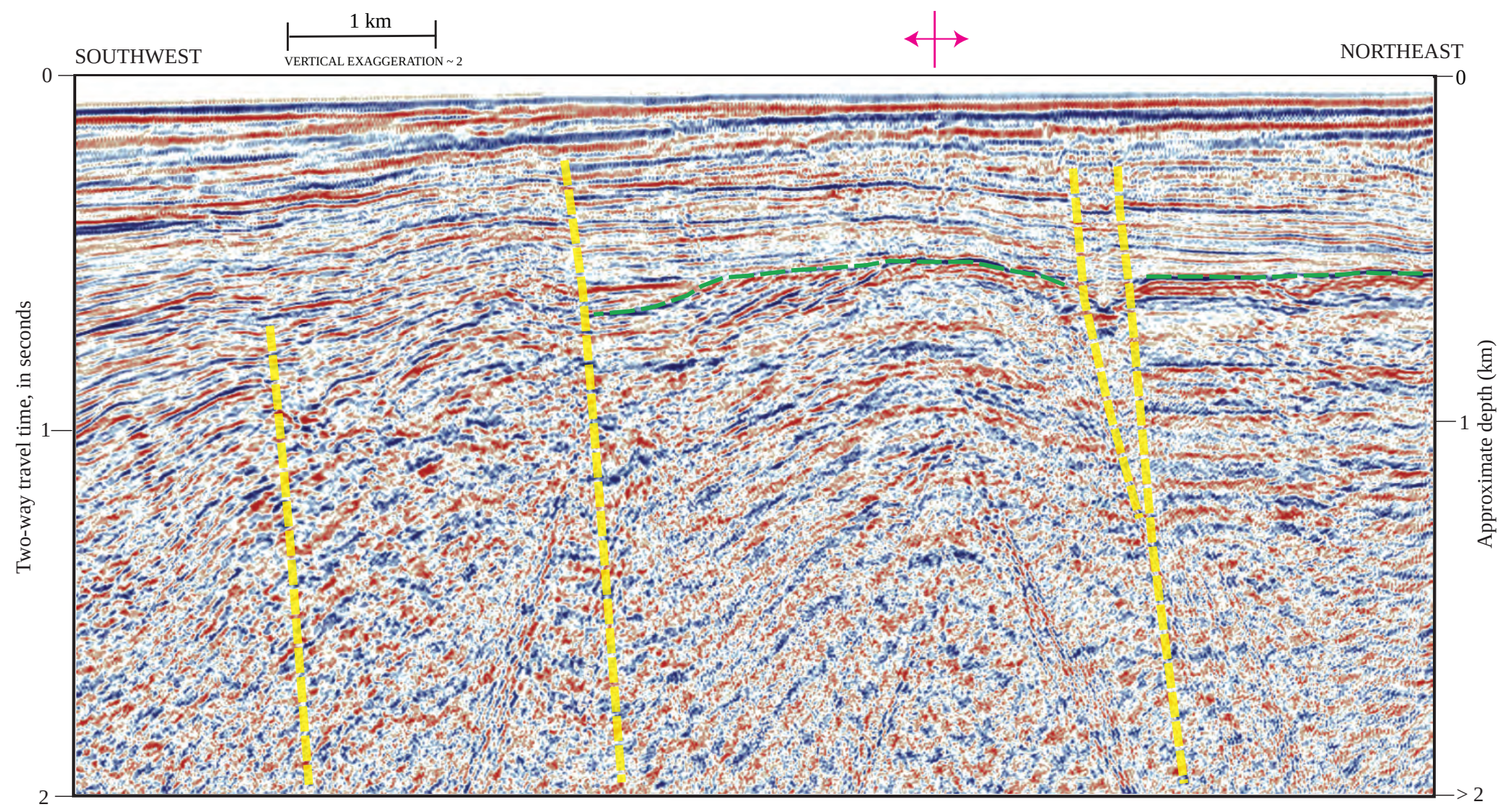


Figure 5. Migrated, deep-penetration industry, 2-D, multichannel air-gun seismic-reflection profile WSF–042 (collected in 1982 on survey W–34–82–MB; from USGS National Archive of Marine Seismic Surveys [U.S. Geological Survey, 2009]), which crosses shelf southwest of Aptos; see trackline map for location. Note that vertical scale and exaggeration are significantly different than that of high-resolution seismic-reflection profiles shown in figures 1, 2, 3, 4, 6, 7, 8, 9, and 10. Profile highlights faults (dashed yellow lines) and fold (magenta symbol; diverging arrows, anticline) beneath continental shelf in northern Monterey Bay. Dashed green line highlights stratigraphic surface that changes (from northeast to southwest [right to left]) from conformity to angular unconformity.

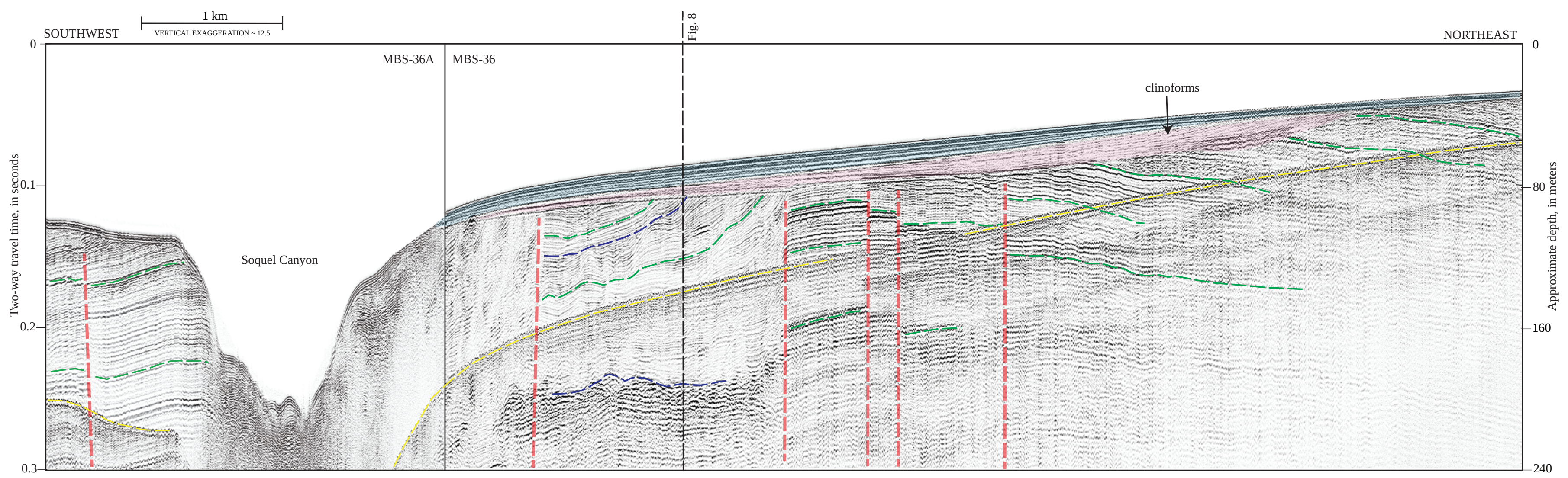


Figure 6. USGS high-resolution minisparker seismic-reflection profiles MBS-36A (left) and MBS-36 (right) (collected in 2009 on cruise S–N1–09–MB), which crosses shelf southwest of Aptos; see trackline map for location. Profile highlights head of Soquel Canyon and faulted strata beneath continental shelf in northern Monterey Bay. Dashed red lines show faults. Blue and pink shading shows inferred uppermost Pleistocene and Holocene strata, deposited since about 30,000 years ago during final stages of sea-level fall and subsequent sea-level rise. Underlying reflectors image deformed Neogene strata. Dashed purple lines shows unconformities in Neogene section. Dashed green lines highlight some continuous reflections that reveal structure (not distinctive stratigraphic markers). Dashed yellow line is seafloor multiple (echo of seafloor reflector).

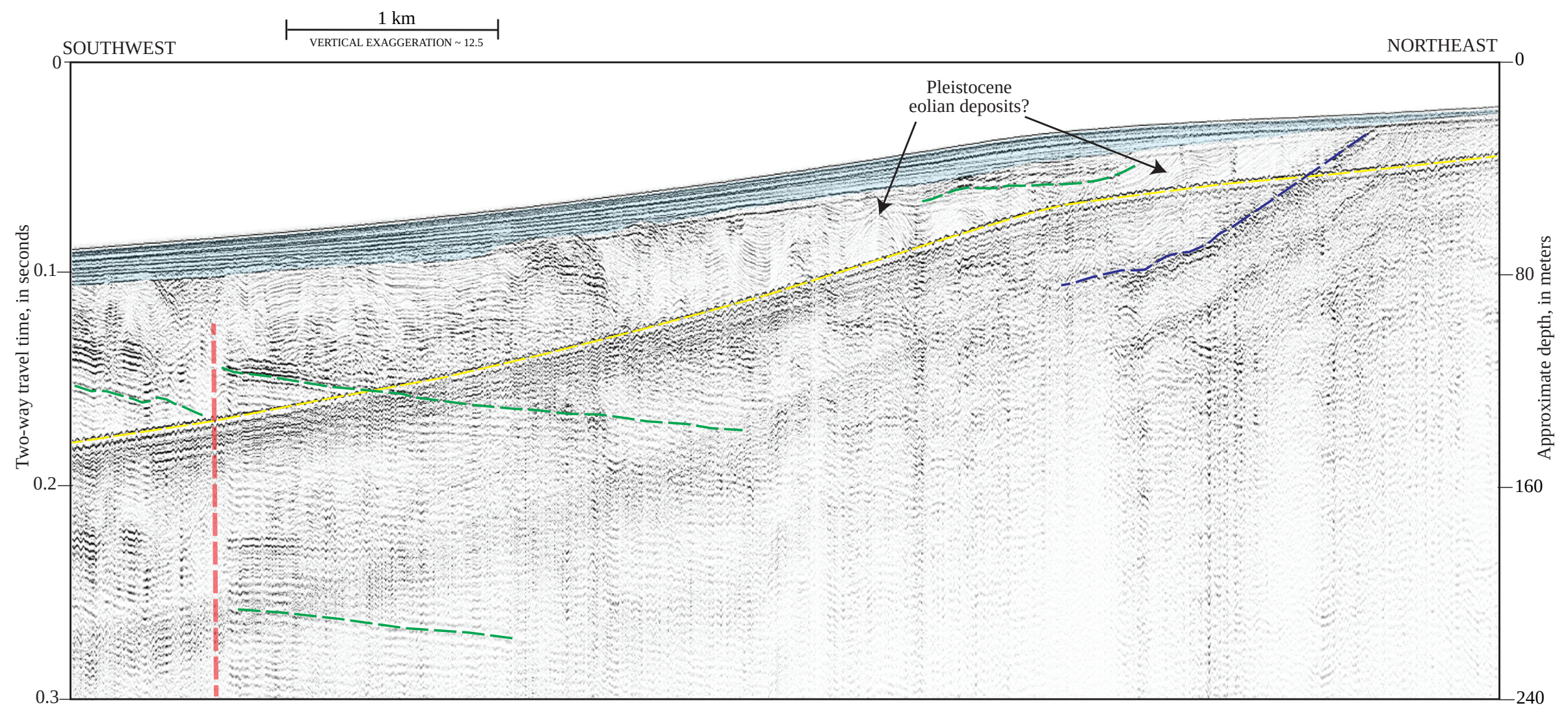


Figure 7. USGS high-resolution minisparker seismic-reflection profile MBS-40 (collected in 2009 on cruise S–N1–09–MB), which crosses shelf south of Aptos; see trackline map for location. Profile highlights subsurface geology in eastern Monterey Bay. Dashed red line shows fault. Blue shading shows inferred uppermost Pleistocene and Holocene strata, deposited since last sea-level lowstand about 21,000 years ago. Underlying reflectors are of inferred Pleistocene age, offshore extensions of eolian and fluvial deposits mapped in lower Pajaro River Valley (Brabb, 1997). Dashed purple line shows unconformity in Neogene strata. Dashed green lines highlight some continuous reflections that reveal structure (not distinctive stratigraphic markers). Dashed yellow line is seafloor multiple (echo of seafloor reflector).

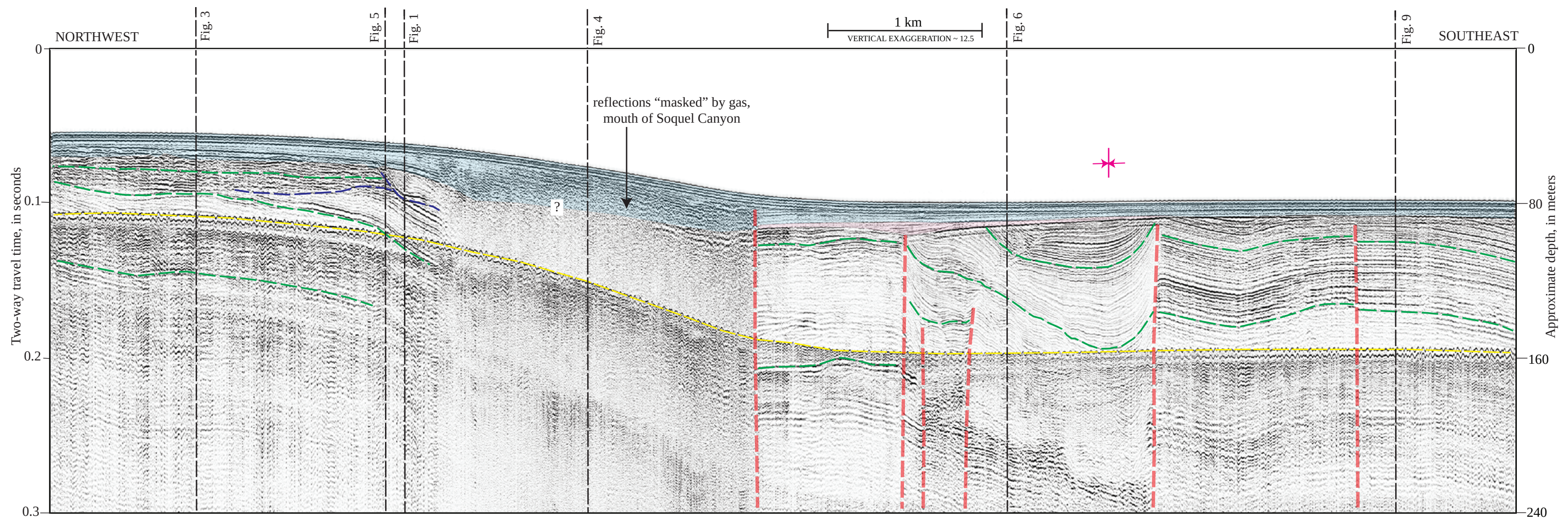


Figure 8. USGS high-resolution minisparker seismic-reflection profile MBS-43 (collected in 2009 on cruise S–N1–09–MB), which crosses shelf southwest of Aptos; see trackline map for location. Profile highlights faulted and folded strata beneath continental shelf in northern Monterey Bay, including oblique crossing of diffuse fault zone in eastern Monterey Bay. Dashed red lines show faults. Magenta symbol shows fold axis (converging arrows, syncline). Blue and pink shading shows inferred uppermost Pleistocene and Holocene strata, deposited about 30,000 years ago during final stages of sea-level fall and subsequent sea-level rise. Underlying reflectors are of inferred Neogene age. Dashed purple lines show unconformities. Dashed green lines highlight some continuous reflections that reveal structure (not distinctive stratigraphic markers). Dashed yellow line is seafloor multiple (echo of seafloor reflector).

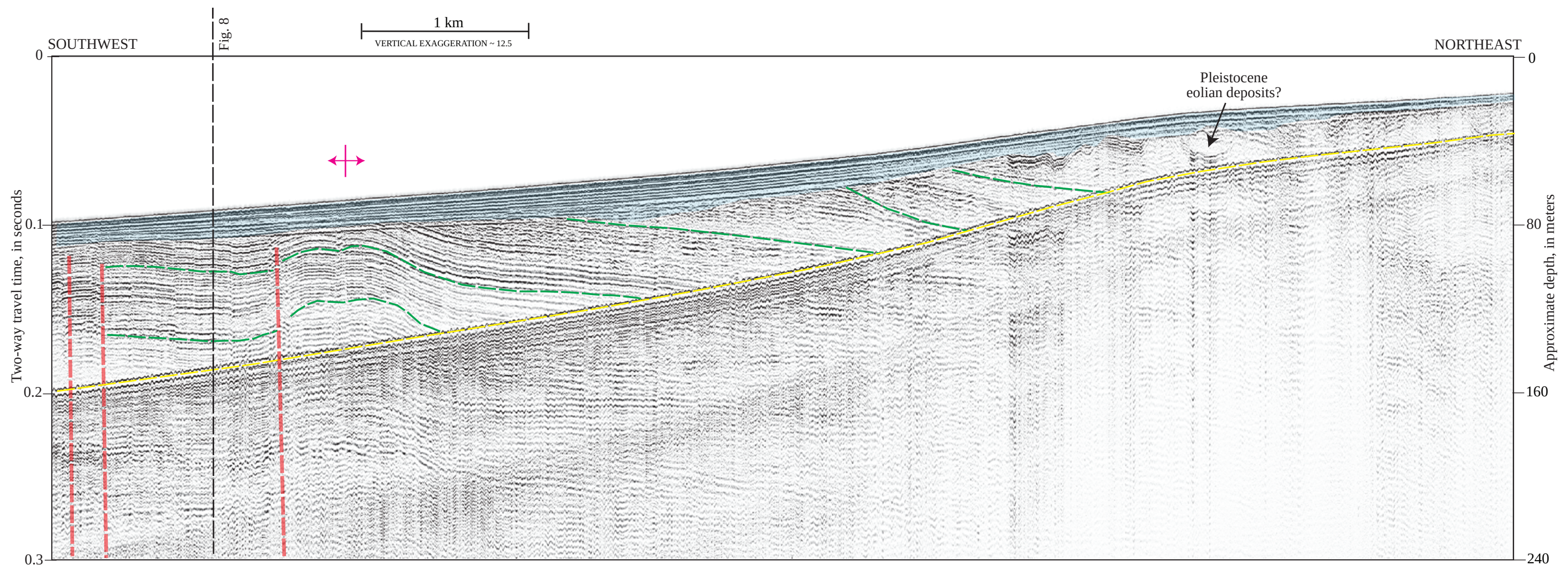


Figure 9. USGS high-resolution minisparker seismic-reflection profile MBS-39B (collected in 2009 on cruise S–N1–09–MB), which crosses shelf south of Aptos; see trackline map for location. Profile highlights faulted and folded strata beneath continental shelf, central Monterey Bay near head of Soquel Canyon. Dashed red lines show faults. Magenta symbol shows fold axis (diverging arrows, anticline). Blue shading shows inferred uppermost Pleistocene and Holocene strata, deposited since last sea-level lowstand about 21,000 years ago. Underlying reflectors in northeast part of profile image deformed Neogene strata and possibly Pleistocene eolian deposits (see figs. 7 and 10). Dashed green lines highlight some continuous reflections that reveal structure (not distinctive stratigraphic markers). Dashed yellow line is seafloor multiple (echo of seafloor reflector).

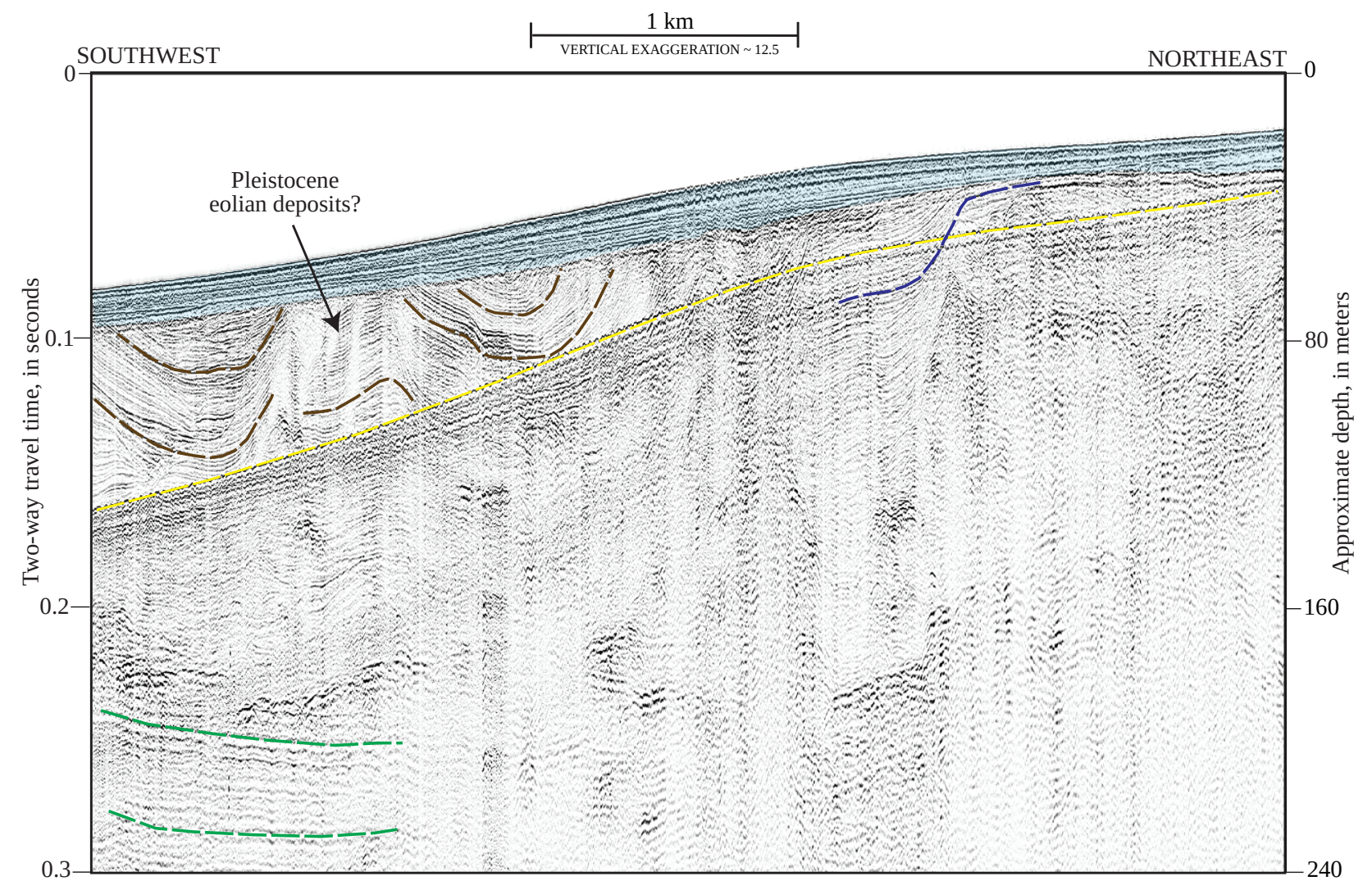
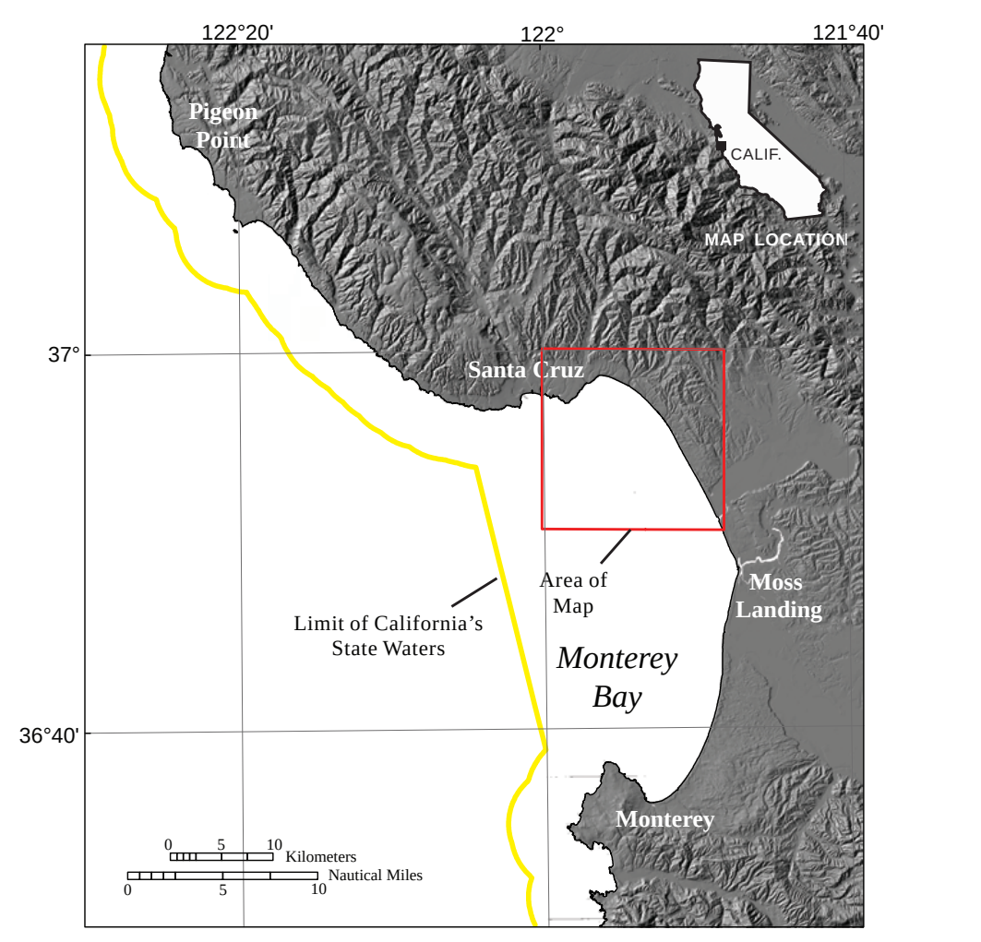


Figure 10. USGS high-resolution minisparker seismic-reflection profile MBS-41 (collected in 2009 on cruise S–N1–09–MB), which crosses shelf southeast of Aptos; see trackline map for location. Profile highlights subsurface geology in eastern Monterey Bay. Blue shading shows inferred uppermost Pleistocene and Holocene strata, deposited since last sea-level lowstand about 21,000 years ago. Underlying reflectors are of inferred Pleistocene age, including offshore extensions of eolian and fluvial deposits mapped in lower Pajaro River Valley (Brabb, 1997; Hanson, 2003). Dashed brown lines show inferred eolian bedding. Dashed green lines highlight some continuous reflections in inferred Neogene strata that reveal structure (not distinctive stratigraphic markers). Dashed purple line shows angular unconformity. 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 Aptos map area in northern Monterey Bay, providing imagery of the subsurface geology. The offshore part of this map area consists mainly of a gently (about 0.1° to 0.4°) offshore-dipping inner shelf and midshelf area, extending to water depths of about 90 m at the head and rim of north-south-trending submarine Soquel Canyon in the southwest corner of the map area. The map area includes the upper 2,300 m of Soquel Canyon, which extends to water depths of about 260 m at the southern boundary of the map. Most of the shelf is underlain by flat, sandy and muddy sediment; bedrock forms low- to moderate-relief outcrops that locally extend from the shoreline out to water depths of as much as 25 m (see sheet 10), most notably in the nearshore south of Santa Cruz and Capitola. The seismic-reflection profiles provide data for interpreting subbottom stratigraphy, sediment thickness, and geologic structure (see sheets 9, 10).

Most profiles displayed on this sheet (figs. 1, 2, 3, 4, 6, 7, 8, 9, 10) were collected in 2009 on U.S. Geological Survey (USGS) cruise S–N1–09–MB. The single-channel seismic-reflection data were acquired using a SIG 2Mille minisparker system that used a 500-J high-voltage electrical discharge fired 2 times per second, which, at normal survey speeds of 4 to 4.5 nautical miles/hour, gives a data trace every 1.0 to 1.5 m of lateral distance covered. 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 across 30 m of lateral distance covered). These data can resolve geologic features a few meters thick (and, hence, are considered "high-resolution"), down to subbottom depths of about 400 m.

Figure 5 shows a migrated, deep-penetration, multichannel seismic-reflection profile collected in 1982 by WesternGeco on cruise W–34–82–MB. This profile and other similar data were collected in many areas offshore of California in the 1970s and 1980s when the 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.

The high-resolution seismic-reflection profiles (figs. 1, 2, 3, 4, 6, 7, 8, 9, 10) image a lower unit made up of deformed Neogene bedrock, Pleistocene eolian and alluvial deposits near the mouth of the Pajaro Valley, and one or two upper units (blue and pink shading) consisting of upper Quaternary sediments. Neogene bedrock is characterized by folded and faulted, moderate- to high-amplitude, variably continuous, parallel to subparallel reflections (terminology from Mitchum and others, 1977). Shallow bedrock imaged in seismic-reflection profiles is inferred to consist of the upper Miocene and Pliocene Purisima Formation (Powell and others, 2007), continuous with coastal outcrops that extend from northern Aptos to Santa Cruz (Brabb, 1997; Wagner and others, 2002; see sheet 10). The deeper seismic-reflection profile (fig. 5) images an unconformity that may represent the contact between the upper Miocene Santa Cruz Mudstone and the middle and upper Miocene Monterey Formation.

The Pleistocene deposits that overlie Neogene rocks near the mouth of the Pajaro River are imaged by a mix of reflection types (figs. 7, 10), inferred to represent different sedimentary facies. Inferred eolian deposits are characterized by low- to moderate-amplitude, continuous, high-frequency, subparallel to parallel reflections with dips as steep as 10° (note that dips appear steeper in seismic-reflection profiles because of vertical exaggeration and superficially resemble tectonic folds); variably gentle to steep reflections image primary bedding surfaces on paleo sand dunes. Reflections in inferred interstratified fluvial deposits have similar low to moderate amplitudes, but are discontinuous, horizontal to subhorizontal, and have variable frequency. This mixed eolian-fluvial unit has been mapped onshore along the coast in the surface and subsurface as the Pleistocene Aromas Sand (Brabb, 1997; Hanson, 2003). It forms an important local aquifer, as much as 180 m thick, and extends to depths as much as 240 m below sea level.

Elsewhere (away from the mouth of the Pajaro River), in most of the map area, one or two marine sedimentary units unconformably overlie Neogene bedrock. The lower unit (pink shading) of the two units is present in profiles near the head of Soquel Canyon (figs. 1, 4, 6, 8). This lower unit notably includes low-amplitude, low-angle (1° to 3°), offshore-dipping, clinoforms (Catuneanu, 2006) that are as thick as 13 m. The upper unit (blue shading) of the two units typically is characterized by low- to moderate-amplitude, continuous to moderately continuous, diffuse, subparallel reflections, and has a maximum thickness of about 32 m. The upper unit includes sediment-filled channels aligned with Soquel Canyon (figs. 1, 2, 3, 4). Reflections within channel fills are locally obscured by interstitial gas. This effect has been referred to as "gas blanking," "acoustic turbidity," or "acoustic masking" (Hovland and Judd, 1988; Fader, 1997). The gas scatters or attenuates the acoustic energy of the seismic-profiling system, preventing penetration.

Our preferred hypothesis is that the clinoforms in the lower unit (pink) represent a progradational shoreface and deltaic sequence that formed between about 30,000 and 21,000 years ago during the sea-level regression before the Last Glacial Maximum (Waelbroeck and others, 2002). The upper unit (blue) represents shelf sediments and paleochannel fill that were deposited during the sea-level transgression of the last about 21,000 years (Stanford and others, 2011). In this interpretation, the contact between the upper and lower units is a transgressive surface of erosion that formed as the shoreline migrated landward. Alternatively, Grossman and others (2006) suggested that both units were deposited in the last about 21,000 years, during the latest Pleistocene and Holocene sea-level rise. Because these two upper Quaternary units each consist of unconsolidated sediments, we have combined their thicknesses on the thickness maps (Maps B, D) on sheet 9.

The shelf in the Offshore of Aptos map area is cut by a diffuse zone of northwest-striking, steeply dipping to vertical faults identified in high-resolution seismic-reflection profiles on the basis of the abrupt truncation or warping of reflections and (or) the juxtaposition of reflection panels that have differing seismic parameters. Seismic-reflection profiles traverse as many as 13 faults over a distance of 8 km (fig. 3). Mapped fault lengths in this diffuse zone are typically 2 to 7 km, and the strike of these offshore faults ranges from about 325° to 350° from southwest to northeast. Faults in this diffuse zone cut through Neogene bedrock and locally appear to disrupt overlying upper Quaternary sediments (fig. 3), and the presence of warped reflections along some fault strands suggests there may be both vertical and strike-slip offsets. This broad, distributed zone of deformation resembles the northwest-trending Monterey Bay Fault Zone (Greene, 1977, 1990), which occurs about 10 km farther west in outer Monterey Bay and similarly lacks a lengthy (>20 km), continuous "master fault." Deformation in both the Monterey Bay Fault Zone and the diffuse zone of faults in the Offshore of Aptos map area is attributable to its location in the 40-km-wide, northward-narrowing structural zone between two major right-lateral strike-slip fault zones—the San Andreas Fault Zone to the east and the San Gregorio Fault Zone to the west (Greene, 1990; Wagner and others, 2002).

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Seismic-Reflection Profiles, Offshore of Aptos Map Area, California

By

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

2016

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