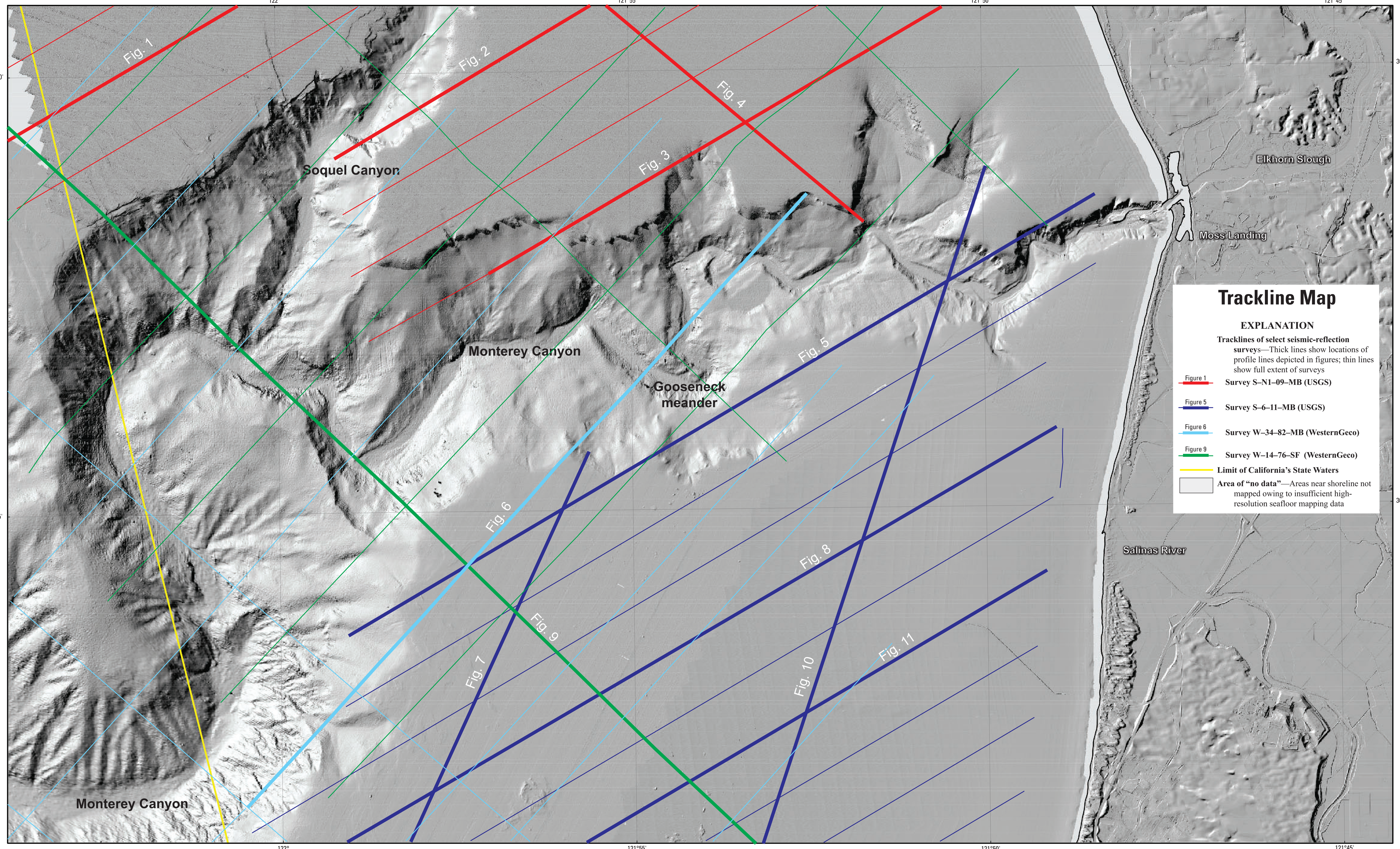
Open-File Report 2016–1072
Sheet 8 of 10
Pamphlet accompanies map



SCALE 1:50 000

NOT INTENDED FOR NAVIGATIONAL USE

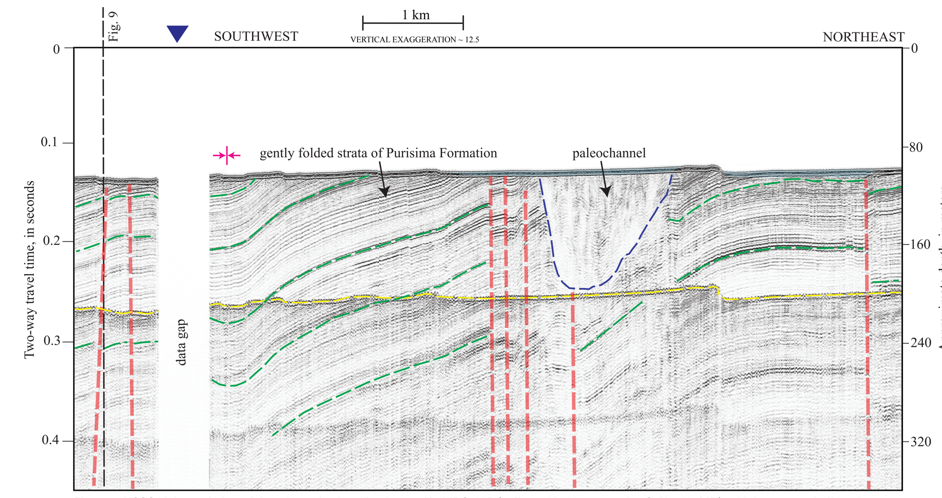


Figure 1. USGS high-resolution minisparker seismic-reflection profile MBS–36B (collected in 2009 on cruise S–N1–09–MB), which crosses shelf northwest of Soquel Canyon; see trackline map for location. Profile highlights 1,300-m-wide and 90-m-deep, sediment-filled paleochannel, inferred to be tributary of Soquel Canyon during sea-level lowstand of Last Glacial Maximum (LGM), about 21,000 years ago. Paleochannel eroded through gently folded and faulted strata of upper Miocene and Pliocene Purisima Formation. Bedrock was beveled during post-LGM transgression, and it is overlain locally by very thin, post-LGM sediment layer (blue shading; see also, sheet 9). Dashed red lines show faults. Magenta symbol shows syncline axis. Dashed green lines highlight some continuous reflections that reveal structure (not distinctive stratigraphic markers). Dashed purple line shows margin of paleochannel. Dashed yellow lines are seafloor multiples (echoes of seafloor reflector). Purple triangle shows approximate location of California's State Waters limit (yellow line on trackline map).

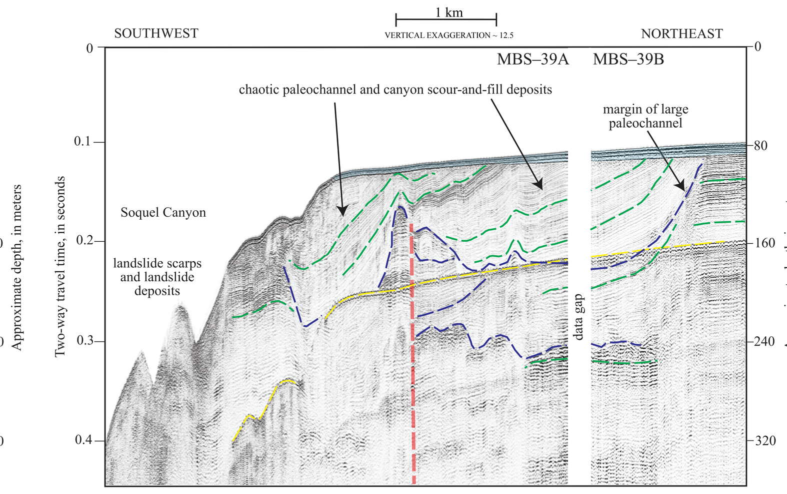


Figure 2. USGS high-resolution minisparker seismic-reflection profiles MBS–39A and MBS–39B (left and right sides of fig. 2, respectively; collected in 2009 on cruise S–N1–09–MB), which cross parts of east wall of Soquel Canyon and shelf east of canyon; see trackline map for location. Profile extends obliquely across complicated nested-paleochannel complex on east wall of Soquel Canyon. Channels are inferred to be cut in both subaerial and submarine environments during Pleistocene sea-level lowstands, and channel-fill deposits likely consist of mainly marine deposits, on basis of depth below sea-level-lowstand depths. Profile also cuts across landslide deposits along southeast wall of Soquel Canyon. Dashed red line shows fault. Blue shading at top of profile shows inferred uppermost Pleistocene and Holocene strata, deposited since last sea-level lowstand about 21,000 years ago. Dashed purple lines show erosional surfaces within paleochannel complex. Dashed green lines highlight some continuous reflections that reveal structure (not distinctive stratigraphic markers). Dashed yellow lines are seafloor multiples (echoes of seafloor reflector).

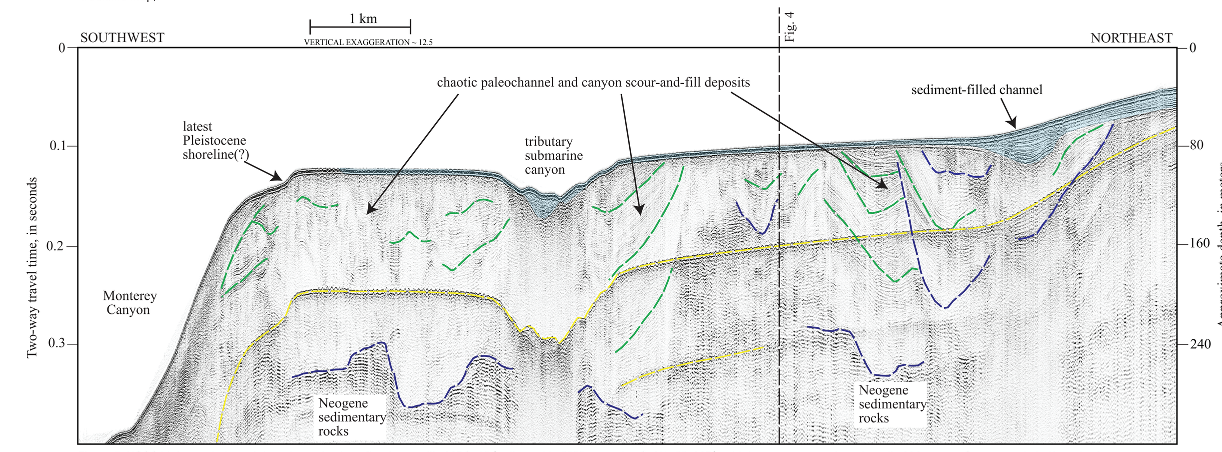


Figure 3. USGS high-resolution minisparker seismic-reflection profile MBS–42 (collected in 2009 on cruise S–N1–09–MB), which crosses part of north wall of Monterey Canyon and shelf north of canyon, roughly perpendicular to profile shown in figure 4; see trackline map for location. Profile highlights chaotic scour-and-fill deposits in the Pleistocene paleochannel and canyon-fill deposits north of Monterey Canyon. Paleochannels and canyons presumably were cut during multiple Quaternary sea-level lowstands and filled mainly during sea-level highstands. Blue shading at top of profile shows inferred uppermost Pleistocene and Holocene strata, deposited since last sea-level lowstand about 21,000 years ago. Dashed purple lines show erosional unconformities; lowest unconformities erode Neogene bedrock. Dashed green lines highlight some discontinuous reflections within paleochannel and canyon-fill deposits (not distinctive stratigraphic markers). Dashed yellow lines are seafloor multiples (echoes of seafloor reflector).

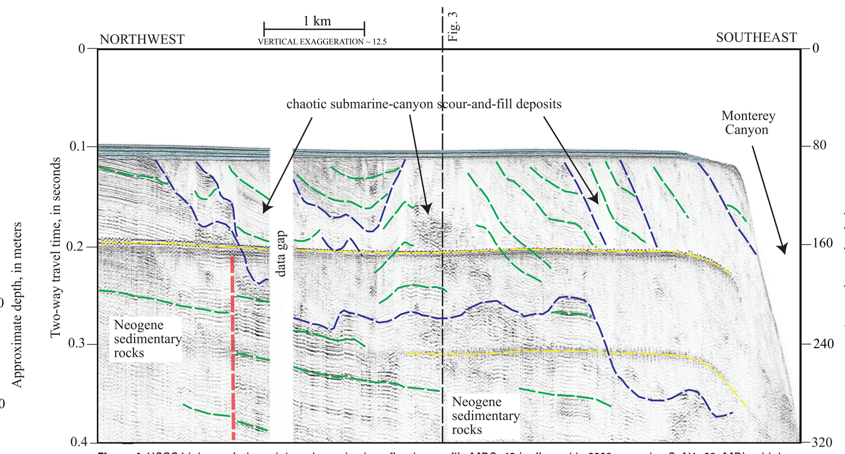


Figure 4. USGS high-resolution minisparker seismic-reflection profile MBS–43 (collected in 2009 on cruise S–N1–09–MB), which crosses shelf north of Monterey Canyon, roughly perpendicular to profile shown in figure 3; see trackline map for location. Profile highlights chaotic paleochannel and canyon scour-and-fill deposits. Paleochannel and canyons presumably were cut during multiple Quaternary sea-level lowstands and filled during mainly sea-level highstands. Blue shading at top of profile shows inferred uppermost Pleistocene and Holocene strata, deposited since last sea-level lowstand about 21,000 years ago. Dashed purple lines show erosional unconformities; lowest unconformities erode Neogene bedrock. Dashed green lines highlight some discontinuous reflections within channel-fill deposits (not distinctive stratigraphic markers). Dashed red line shows fault. Dashed yellow lines are seafloor multiples (echoes of seafloor reflector).

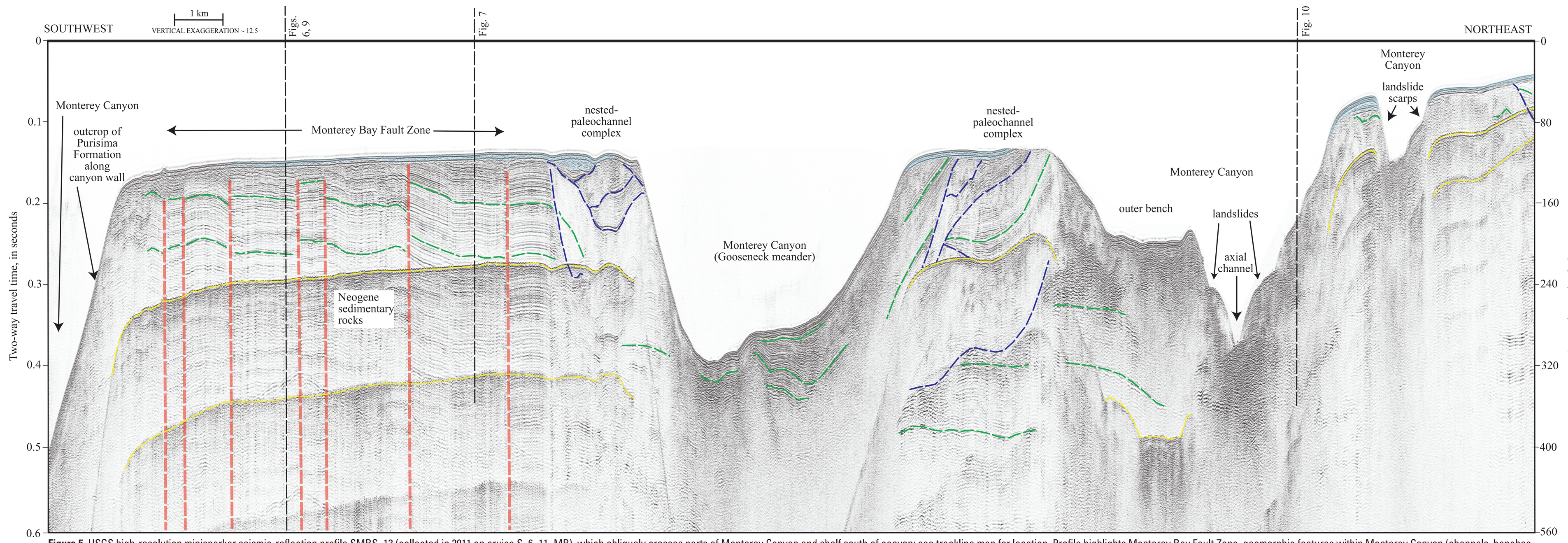


Figure 5. USGS high-resolution minisparker seismic-reflection profile SMBS–13 (collected in 2011 on cruise S–6–11–MB), which obliquely crosses parts of Monterey Canyon and shelf south of canyon; see trackline map for location. Profile highlights Monterey Bay Fault Zone, geomorphic features within Monterey Canyon (channels, benches, walls, landslides), and nested complexes of Pleistocene paleochannel and canyon-fill deposits. Dashed red lines show faults. Blue shading shows thin layer of inferred uppermost Pleistocene and Holocene strata, deposited since last sea-level lowstand about 21,000 years ago. Gently dipping reflectors beneath continental shelf in southwestern part (to left) of profile are Neogene sedimentary bedrock, primarily including strata of upper Miocene and Pliocene Purisima Formation. Dashed purple lines show erosional unconformities. Dashed green lines highlight some continuous reflections that reveal structure and stratigraphic architecture (not distinctive stratigraphic markers). Dashed yellow lines are seafloor multiples (echoes of seafloor reflector).

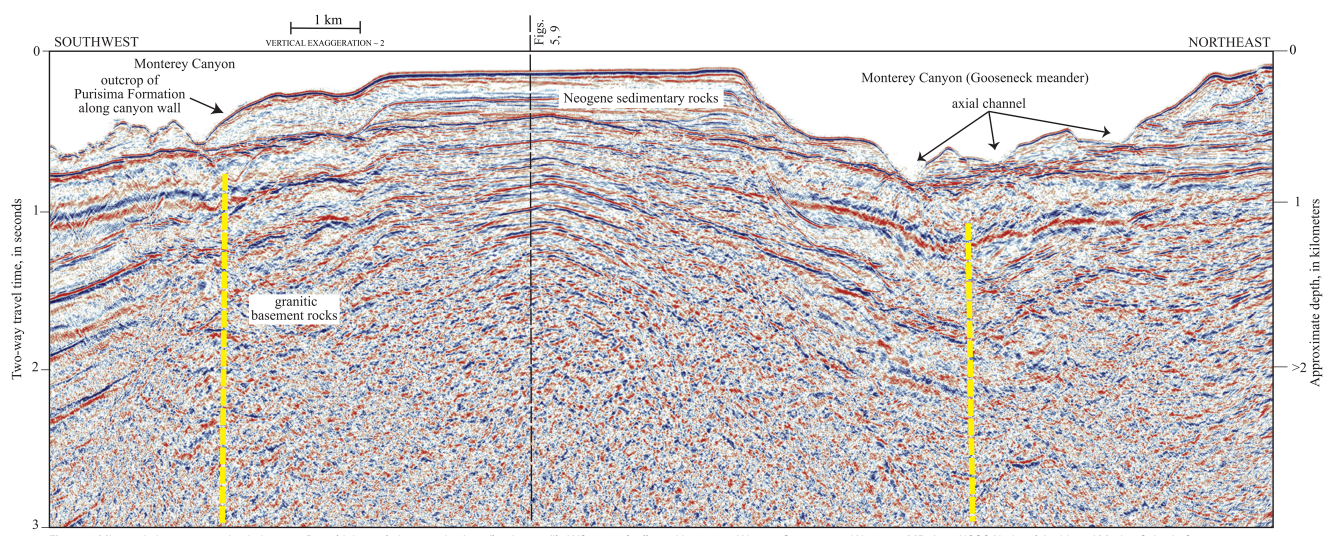


Figure 6. Migrated, deep-penetration industry, 2-D, multichannel air-gun seismic-reflection profile WS82–630 (collected in 1982 on WesternGeco survey W–34–82–MB; from USGS National Archive of Marine Seismic Surveys [Triezenberg and others, 2016]), which obliquely crosses parts of Monterey Canyon and shelf south of canyon; 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, 5, 7, 8, 10, and 11. Profile highlights gently folded Neogene sedimentary rocks (primarily the upper Miocene to Pliocene Purisima Formation and possibly older rocks) overlying granitic basement rocks, as well as large-scale Monterey Canyon geomorphic features. Dashed yellow lines show faults.

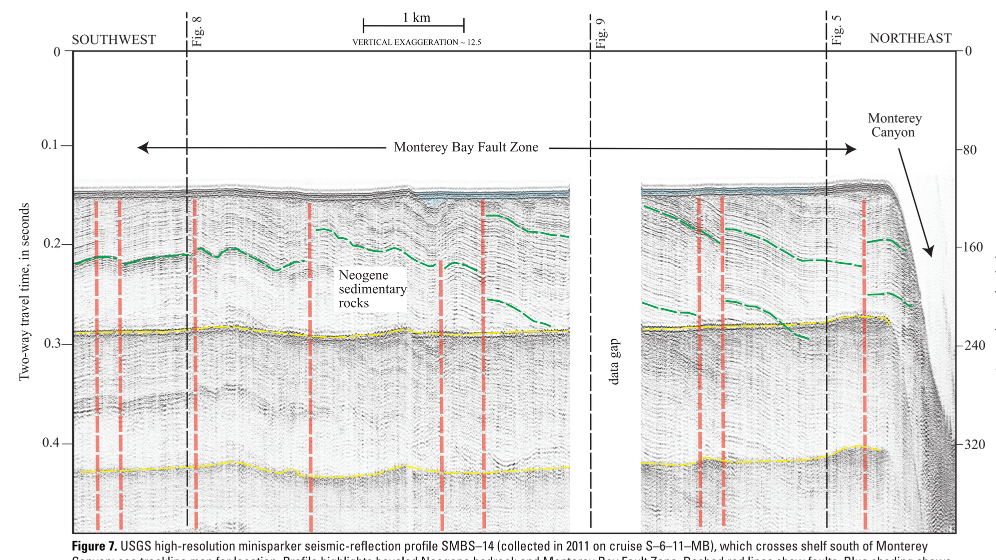


Figure 7. USGS high-resolution minisparker seismic-reflection profile SMBS–14 (collected in 2011 on cruise S–6–11–MB), which crosses shelf south of Monterey Canyon; see trackline map for location. Profile highlights beveled Neogene bedrock and Monterey Bay Fault Zone. Dashed red lines show faults. Blue shading shows thin layer of inferred uppermost Pleistocene and Holocene strata, deposited in last about 21,000 years. Underlying reflectors image gently folded Neogene strata, likely of the upper Miocene and Pliocene Purisima Formation. Dashed green lines highlight some continuous reflections that reveal structure (not distinctive stratigraphic markers). Dashed yellow lines are seafloor multiples (echoes of seafloor reflector).

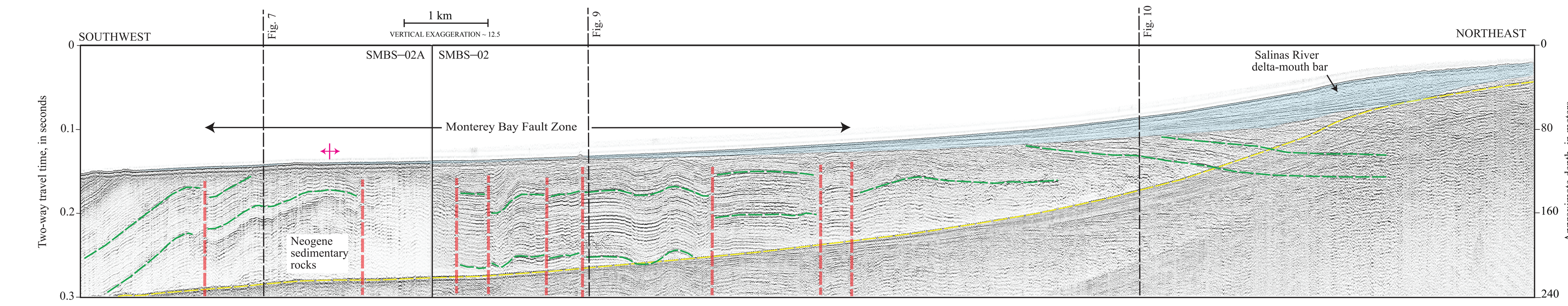


Figure 8. USGS high-resolution minisparker seismic-reflection profiles SMBS–02A and SMBS–02 (left and right sides of fig. 8, respectively; collected in 2011 on cruise S–6–11–MB), which cross shelf south of Monterey Canyon; see trackline map for location. Profile highlights Salinas River delta-mouth bar, Monterey Bay Fault Zone, and beveled bedrock that underlies continental shelf. Dashed red lines show faults. Magenta symbol shows anticline axis. Blue shading shows inferred uppermost Pleistocene and Holocene strata, deposited in last about 21,000 years. Underlying reflectors image gently folded Neogene strata, likely consisting of the upper Miocene and Pliocene Purisima Formation. Dashed green lines highlight some continuous reflections that reveal structure (not distinctive stratigraphic markers). Dashed yellow line is seafloor multiple (echo of seafloor reflector).

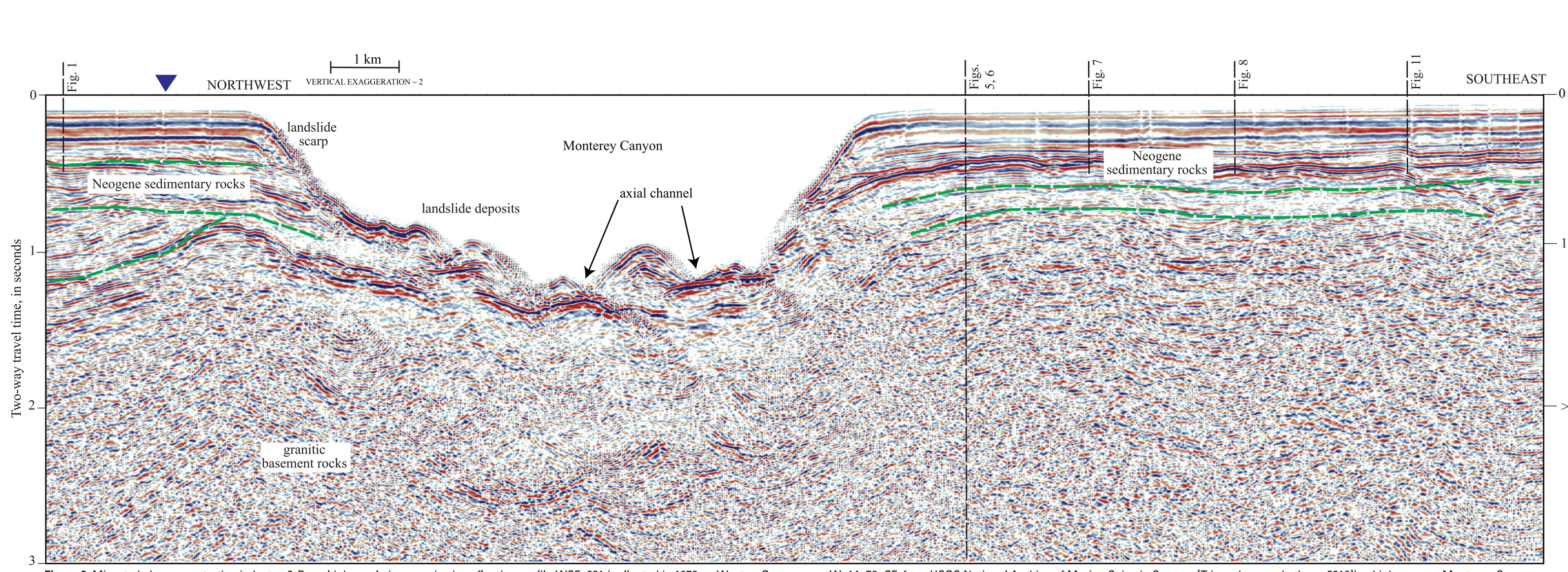


Figure 9. Migrated, deep-penetration industry, 2-D, multichannel air-gun seismic-reflection profile WSF–021 (collected in 1976 on WesternGeco survey W–14–76–SF; from USGS National Archive of Marine Seismic Surveys [Triezenberg and others, 2016]), which crosses Monterey Canyon and parts of shelf northwest and southeast of it; see trackline map for location. Profile, which is subparallel to Monterey Bay Fault Zone, highlights large landslide complex on northwest canyon wall. Flat-lying to gently folded Neogene sedimentary rocks include significant angular unconformity (shown by dashed green lines) at northwest (left) end of profile. Note that vertical scale and exaggeration are significantly different than that of high-resolution seismic-reflection profiles shown in figures 1, 2, 3, 4, 5, 7, 8, 10, and 11. Dashed green lines highlight some continuous reflections that reveal structure (not distinctive stratigraphic markers). Purple triangle shows approximate location of California's State Waters limit (yellow line on trackline map).

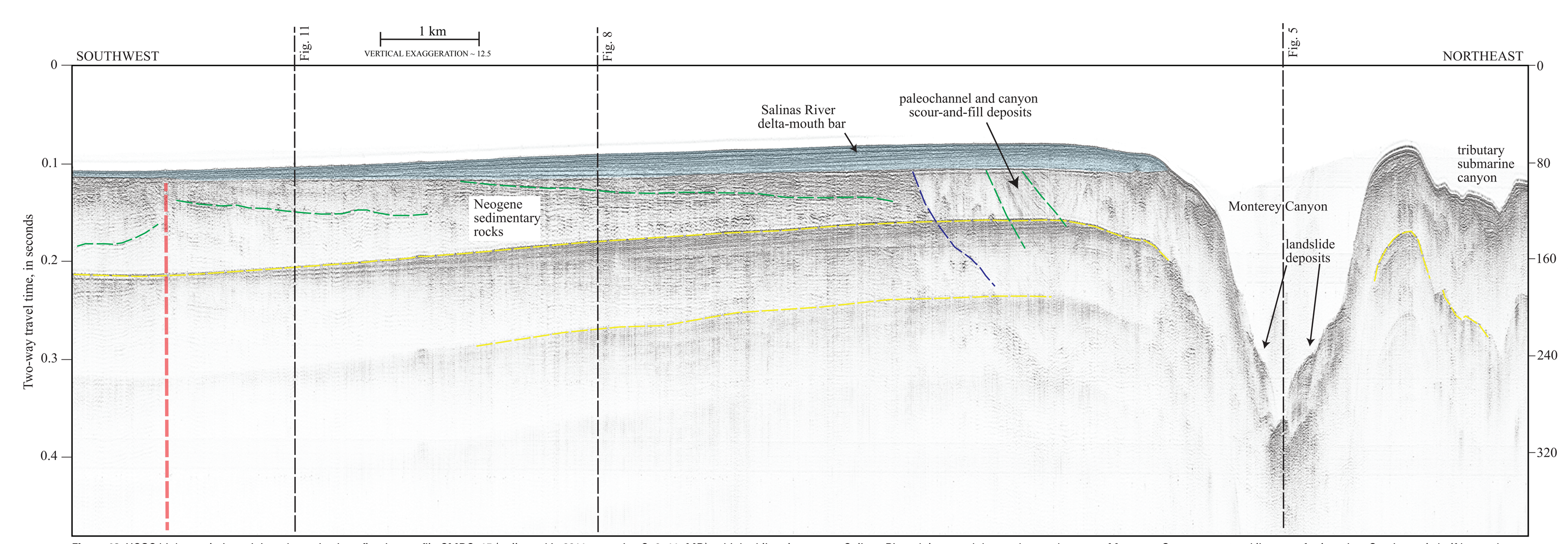


Figure 10. USGS high-resolution minisparker seismic-reflection profile SMBS–15 (collected in 2011 on cruise S–6–11–MB), which obliquely crosses Salinas River delta-mouth bar and extends across Monterey Canyon; see trackline map for location. Continental shelf beneath delta-mouth bar is underlain by Neogene bedrock, likely strata of the upper Miocene and Pliocene Purisima Formation, cut by large, erosional Pleistocene paleochannels and canyons. Blue shading shows inferred uppermost Pleistocene and Holocene strata, deposited in last about 21,000 years. Dashed red line shows fault. Dashed purple line highlights erosional unconformity. Dashed green lines highlight some continuous reflections that reveal structure and stratigraphic architecture (not distinctive stratigraphic markers). Dashed yellow lines are seafloor multiples (echoes of seafloor reflector).

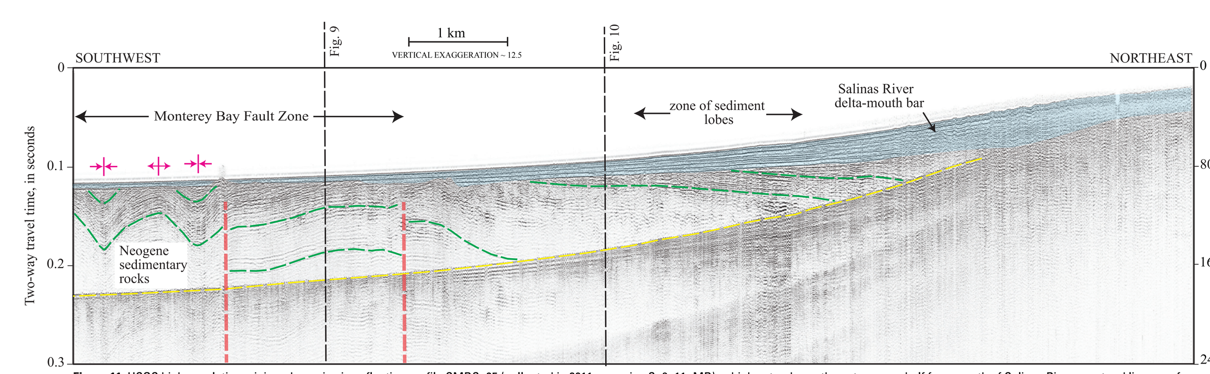
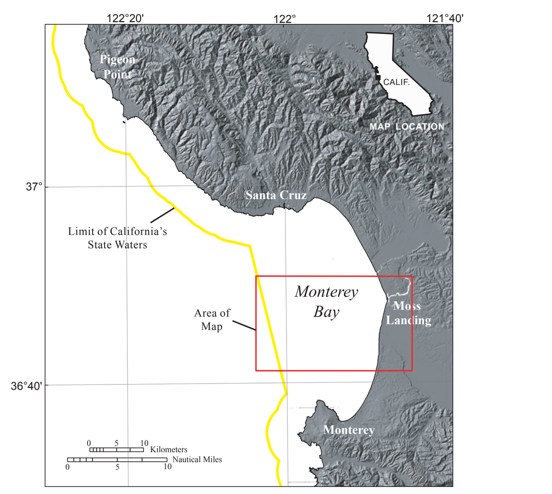


Figure 11. USGS high-resolution minisparker seismic-reflection profile SMBS–05 (collected in 2011 on cruise S–6–11–MB), which extends southwest across shelf from mouth of Salinas River; see trackline map for location. Profile highlights continental shelf in southern Monterey Bay, Salinas River delta-mouth bar, and Monterey Bay Fault Zone. Profile cuts through zone of sediment lobes mapped from bathymetry and acoustic-backscatter imagery (see sheet 3; see also, fig. 5 on sheet 4) as the marine shelf sediment lobes unit (Qmsl) on sheet 10. Dashed red lines show faults. Magenta symbols show fold axes (converging arrows, synclines; diverging arrows, anticline). Blue shading shows inferred uppermost Pleistocene and Holocene strata, deposited in last about 21,000 years. 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).



DISCUSSION

This map shows seismic-reflection profiles from four different surveys of the Monterey Canyon and Vicinity map area, providing imagery of the subsurface geology. The continental shelf in the map area is incised by Monterey Canyon and its tributaries, including Soquel Canyon. The shelf is underlain by Cretaceous granitic basement rocks, Neogene sedimentary rocks, Pleistocene paleochannel and canyon-fill deposits, and uppermost Pleistocene to Holocene sediments. Granitic basement rocks are characterized as massive, reflection-free zones on deeper penetration, industry seismic-reflection profiles (see, for example, figs. 6, 9). Neogene sedimentary rocks, predominantly consisting of the upper Miocene and Pliocene Purisima Formation, are characterized on both high-resolution and multichannel seismic-reflection profiles (see, for example, figs. 1, 5, 6, 7, 8, 9) by parallel to subparallel, continuous, variable-amplitude, high-frequency reflections (terminology from Mitchum and others, 1977). The seismic-reflection profiles reveal that these rocks typically are flat lying to gently folded and are cut by high-angle faults. These faults make up a diffuse zone of northwest-striking, steeply dipping to vertical faults of the Monterey Bay Fault Zone, originally mapped by Greene (1977, 1990). Fault strands within the Monterey Bay Fault Zone are mapped with 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, such as reflection presence, amplitude, frequency, geometry, continuity, and vertical sequence. The fault zone lacks a continuous "master fault" along which deformation is concentrated; fault strands are as long as about 20 kilometers (on the basis of mapping outside the map area), but most strands are only about 2 to 7 km long. Faults in this diffuse zone cut through Neogene bedrock and locally appear to disrupt the overlying inferred Quaternary sediments.

Seismic-reflection profiles near the head of Monterey Canyon and at the mouths of the Salinas River (south of Monterey Canyon) and the Pajaro River (north of Monterey Canyon, about 700 m north of the map area) reveal nested, sediment-filled channel complexes (see, for example, figs. 2, 3, 4, 5). Erosional relief can be 200 m or more, and the depth of erosion can exceed 300 m below sea level; in addition, channel-fill deposits include numerous undulatory, internal-erosion surfaces. Reflections within the Pleistocene paleochannel and canyon-fill deposits typically are parallel to subparallel, low-amplitude, high-frequency, continuous, and mounded. The evolution of these channel complexes and the head of Monterey Canyon is linked to the Quaternary history of sea-level fluctuations (see, for example, Wadbrook and others, 2002), and the channel-fill deposits are interpreted to include interstratified marine, eolian, and fluvial deposits that accumulated during both sea-level highstands and lowstands.

Eustasy also was an important control on latest Pleistocene to Holocene shelf deposition in the Monterey Canyon and Vicinity map area. Surficial and shallow sediments were deposited on the shelf in the last about 21,000 years during the sea-level rise that followed the last major lowstand and the Last Glacial Maximum (LGM, Stanford and others, 2011). Global sea level was about 125 m lower during the LGM, at which time the shelf surrounding Monterey Canyon was emergent. The 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 (Peltier and Fairbanks, 2006; Stanford and others, 2011). The sediments deposited on the shelf during the post-LGM sea-level rise (above a transgressive surface of erosion) are shaded blue in the high-resolution seismic-reflection profiles (figs. 1, 2, 3, 4, 5, 7, 8, 10, 11); and their thicknesses are shown on sheet 9.

Post-LGM shelf sediments, which unconformably overlie both bedrock and the Pleistocene paleochannel and canyon-fill deposits in the Monterey Canyon and Vicinity map area, are characterized by subparallel, low- to moderate-amplitude, locally diffuse, laterally continuous reflections. Over much of the map area, these sediments form a thin layer over bedrock that was beveled during the post-LGM transgression (sheet 9). The thickest sediments are found in a prominent, shore-parallel, elongate (about 4 km long and 2 km wide) bar, located offshore of the mouth of the Salinas River (figs. 8, 10, 11). The geometry of reflections within the mound indicates both vertical aggradation and low-angle, seaward progradation.

Monterey Canyon and its tributaries, including Soquel Canyon, incise bedrock and sediments through the continental shelf in the Monterey Canyon and Vicinity map area, creating as much as several hundreds of meters of relief on the seafloor. Only a few of the available high-resolution seismic-reflection profiles cross Monterey Canyon, and the quality and resolution of these profiles is less than that of adjacent seismic-reflection data on the shelf. Side-echoes and diffractions are abundant, and they obscure subsurface reflectivity in the canyons, especially in the canyon walls. A few deep-penetration, multichannel seismic-reflection profiles cross Monterey Canyon (figs. 6, 9); however, these profiles image reflections at larger scales and lower resolutions than that of the high-resolution seismic-reflection profiles.

Major geologic and geomorphic features within Monterey and Soquel Canyons that are imaged in seismic-reflection profiles include steep canyon walls, bedrock outcrops, landslides, and axial channels. The proximal Monterey Canyon walls primarily are covered by muddy Quaternary sediments (Paull and others, 2005a, 2010), imaged (where they are thick) as continuous to semicontinuous, parallel to subparallel reflections (fig. 5). Canyon walls contain small areas of decreased slope that accumulate muddy sediments (Paull and others, 2005a, 2010), potentially including marine, hemipelagic, turbidite, and landslide deposits. These areas, which are termed "benches" (terminology from Paull and others, 2005a, 2010; Maier and others, 2012), are imaged in seismic-reflection profiles as relatively flat sections that are draped by moderate-amplitude, continuous, parallel to subparallel reflections (fig. 5). Canyon walls contain both landslide scarps, which are imaged in seismic-reflection profiles as truncated reflections below the seafloor, and landslide deposits, which are imaged as mounded deposits that have chaotic to continuous, low- to moderate-amplitude reflections (see figs. 2, 5, 9, 10). Canyon walls in the distal (within the map area) part of the canyon also contain bedrock outcrops. In deep-penetration, multichannel seismic-reflection profiles, the Monterey Canyon axial channel incises into high-amplitude, continuous to semicontinuous, parallel to subparallel reflections that are interpreted to be older canyon sediments and bedrock (figs. 6, 9). The high-resolution seismic-reflection profiles image moderate- to high-amplitude, discontinuous to chaotic reflections below the axial channel (figs. 5, 10).

Most seismic-reflection profiles displayed on this sheet (figs. 1, 2, 3, 4, 5, 7, 8, 10, 11) were collected in 2009 and 2011 on U.S. Geological Survey (USGS) cruises S–N1–09–MB and S–6–11–MB, respectively (Sliter and others, 2013), 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 speeds of 4 to 4.5 nautical miles/hour, gives a data trace every 0.5 to 2.0 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 over 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 as much as 400 m.

Figures 6 and 9 show migrated, deep-penetration, industry seismic-reflection profiles collected in 1976 and 1982 by WesternGeco on cruises W–14–76–SF and W–34–82–MB, respectively. 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. Much of these data have been publicly released and are now archived at the USGS National Archive of Marine Seismic Surveys (Triezenberg and others, 2016). 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, Monterey Canyon and Vicinity Map Area, California

by
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2016