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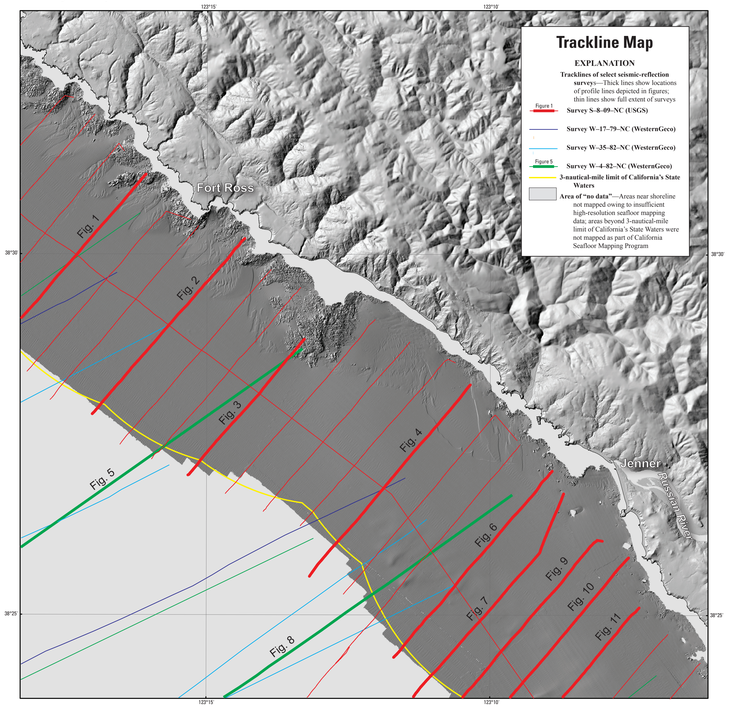
U.S. Department of the Interior
U.S. Geological Survey

Open-File Report 2015–1211
Sheet 8 of 10
*Pamphlet accompanies map*




Onshore elevation data from National Oceanic and Atmospheric Administration's (NOAA's) Digital Coast (available at http://coast.noaa.gov/digitalcoast/data/coastallidar), from OpenTopography (available at http://www.opentopography.org/), and from U.S. Geological Survey's National Elevation Dataset (available at http://ned.usgs.gov). Offshore bathymetry and nearshore 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, 2015

SCALE 1:50 000

2 MILES
7000 3500 0 7000 FEET
0.5 0 1 KILOMETER
1 NAUTICAL MILE = 0.869 NAUTICAL MILES

CALIFORNIA

MAP LOCATION

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

Manuscript approved for publication November 5, 2015

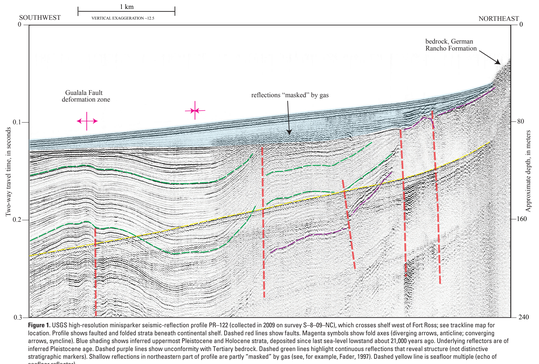



**Figure 1.** USGS high-resolution minisparker seismic-reflection profile PR–122 (collected in 2009 on survey S–8–09–NC), which crosses shelf west of Fort Ross; see trackline map for location. Profile shows faulted and folded strata beneath continental shelf. Dashed red lines show faults. Magenta symbols 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. Underlying reflectors are of inferred Pleistocene age. Dashed purple lines show unconformity with Tertiary bedrock. Dashed green lines highlight continuous reflections that reveal structure (not distinctive stratigraphic markers). Shallow reflections in northeastern part of profile are partly "masked" by gas (see, for example, Fader, 1997). Dashed yellow line is seafloor multiple (echo of seafloor reflector).

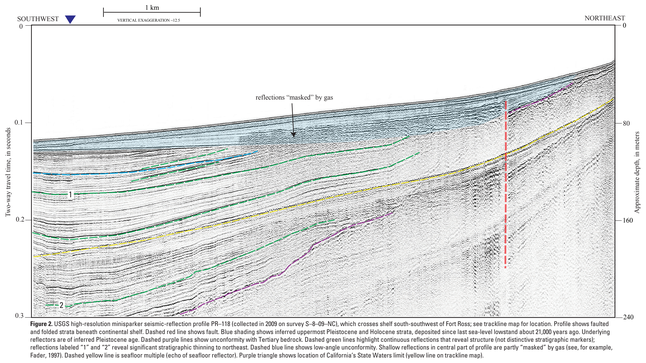



**Figure 2.** USGS high-resolution minisparker seismic-reflection profile PR–118 (collected in 2009 on survey S–8–09–NC), which crosses shelf south-southwest of Fort Ross; see trackline map for location. Profile shows faulted and folded strata beneath continental shelf. Dashed red line shows fault. Blue 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. Dashed purple lines show unconformity with Tertiary bedrock. Dashed green lines highlight continuous reflections that reveal structure (not distinctive stratigraphic markers); reflections labeled "1" and "2" reveal significant stratigraphic thinning to northeast. Dashed blue line shows low-angle unconformity. Shallow reflections in central part of profile 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).

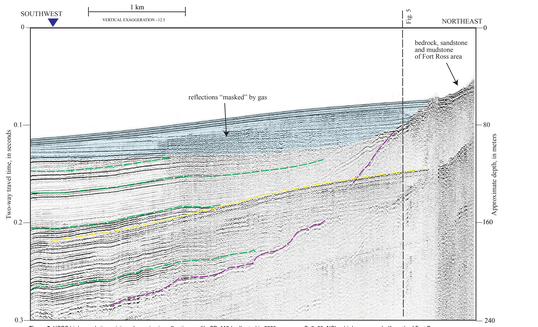



**Figure 3.** USGS high-resolution minisparker seismic-reflection profile PR–115 (collected in 2009 on survey S–8–09–NC), which crosses shelf south of Fort Ross; see trackline map for location. Profile shows gently dipping strata beneath inner shelf and midshelf areas. Blue shading shows inferred uppermost Pleistocene and Holocene strata, deposited since last sea-level lowstand about 21,000 years ago. Underlying reflectors are of inferred Pleistocene age. Dashed purple lines show unconformity with Tertiary bedrock. Dashed green lines highlight continuous reflections that reveal structure (not distinctive stratigraphic markers). Shallow reflections in central part of profile 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).

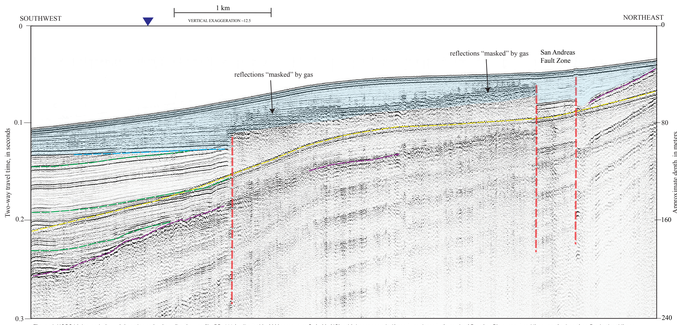



**Figure 4.** USGS high-resolution minisparker seismic-reflection profile PR–111 (collected in 2009 on survey S–8–09–NC), which crosses shelf west-northwest of mouth of Russian River; see trackline map for location. Dashed red lines show faults. Profile shows prominent asymmetric basin within San Andreas Fault Zone and gently dipping strata on its southwest flank. 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. Dashed purple lines show unconformity with Tertiary bedrock. Dashed green lines highlight continuous reflections that reveal structure (not distinctive stratigraphic markers). Dashed blue line shows low-angle unconformity. Shallow reflections in central part of profile 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).

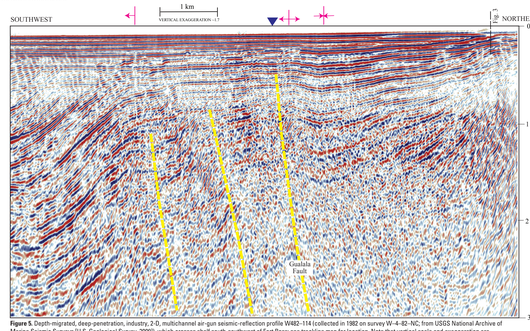



**Figure 5.** Depth-migrated, deep-penetration, industry, 2-D, multichannel air-gun seismic-reflection profile W482–114 (collected in 1982 on survey W–4–82–NC; from USGS National Archive of Marine Seismic Surveys) (U.S. Geological Survey, 2009), which crosses shelf south-southwest of Fort Ross; see trackline map for location. Note that vertical scale and exaggeration are significantly greater than that of high-resolution USGS profiles shown on this sheet. Dashed yellow lines show faults. Magenta symbols show fold axes (diverging arrows, anticline; converging arrows, syncline) and sharp flexure (single arrow shows direction of increasing dip). Profile shows faulted and folded strata beneath continental shelf west of nearby (inland) San Andreas Fault (see sheet 10). Gualala Fault is easternmost of three steeply northeast-dipping reverse faults. Purple triangle shows location of California's State Waters limit (yellow line on trackline map).

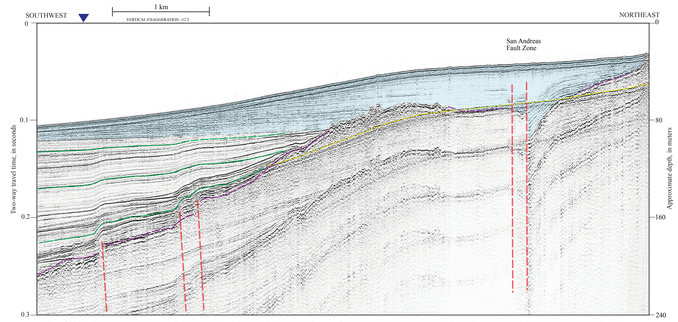



**Figure 6.** USGS high-resolution minisparker seismic-reflection profile PR–108 (collected in 2009 on survey S–8–09–NC), which crosses shelf west-southwest of mouth of Russian River; see trackline map for location. Dashed red lines show faults. Profile shows prominent asymmetric basin within San Andreas Fault Zone and gently dipping strata on its southwest flank. 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. Dashed purple lines show unconformity with Tertiary bedrock. Dashed green lines highlight continuous reflections that reveal 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).

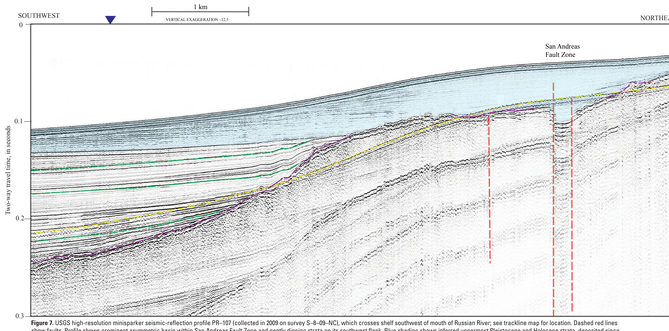



**Figure 7.** USGS high-resolution minisparker seismic-reflection profile PR–107 (collected in 2009 on survey S–8–09–NC), which crosses shelf southwest of mouth of Russian River; see trackline map for location. Dashed red lines show faults. Profile shows prominent asymmetric basin within San Andreas Fault Zone and gently dipping strata on its southwest flank. 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. Dashed purple lines show unconformity with Tertiary bedrock. Dashed green lines highlight continuous reflections that reveal 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).

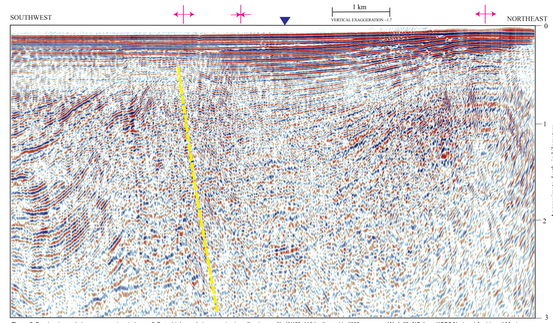



**Figure 8.** Depth-migrated, deep-penetration, industry, 2-D, multichannel air-gun seismic-reflection profile W482–116 (collected in 1982 on survey W–4–82–NC; from USGS National Archive of Marine Seismic Surveys) (U.S. Geological Survey, 2009), which crosses shelf west-southwest of mouth of Russian River. Note that vertical scale and exaggeration are significantly greater than that of high-resolution USGS profiles shown on this sheet. Dashed yellow line shows fault. Magenta symbols show fold axis (diverging arrows, anticline; converging arrows, syncline). Profile shows steeply northeast-dipping fault and folds beneath continental shelf west of nearby San Andreas Fault (see sheet 10). Purple triangle shows location of California's State Waters limit (yellow line on trackline map).

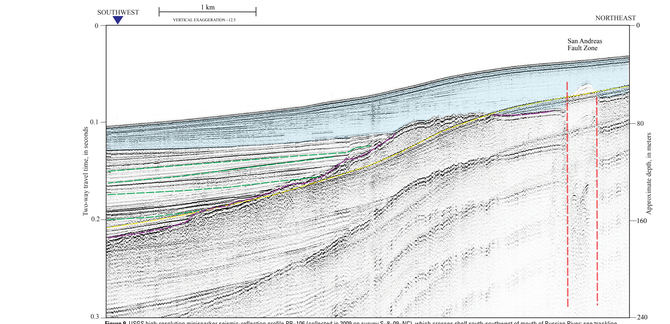



**Figure 9.** USGS high-resolution minisparker seismic-reflection profile PR–106 (collected in 2009 on survey S–8–09–NC), which crosses shelf south-southwest of mouth of Russian River; see trackline map for location. Dashed red lines show faults. Profile shows minor uplift between primary fault strands of San Andreas Fault Zone and gently dipping strata on its southwest flank. 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. Dashed purple lines show unconformity with Tertiary bedrock. Dashed green lines highlight continuous reflections that reveal 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).

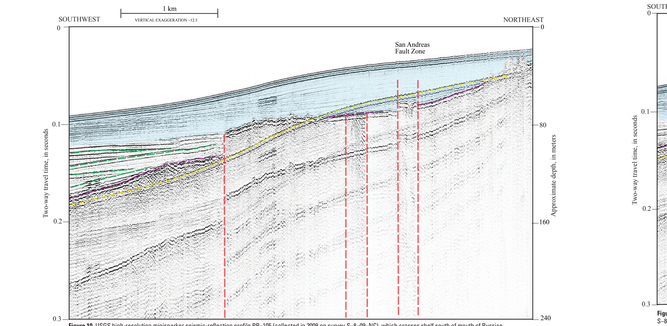



**Figure 10.** USGS high-resolution minisparker seismic-reflection profile PR–105 (collected in 2009 on survey S–8–09–NC), which crosses shelf south of mouth of Russian River; see trackline map for location. Dashed red lines show faults. Profile shows minor uplift between primary fault strands of San Andreas Fault Zone and gently dipping strata on its southwest flank. 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. Dashed purple lines show unconformity with Tertiary bedrock. Dashed green lines highlight continuous reflections that reveal structure (not distinctive stratigraphic markers). Dashed yellow line is seafloor multiple (echo of seafloor reflector).

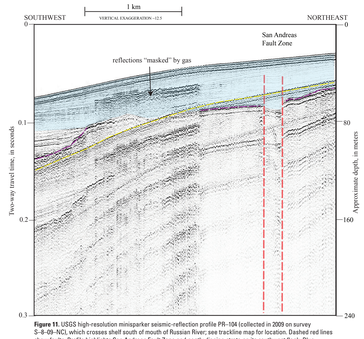
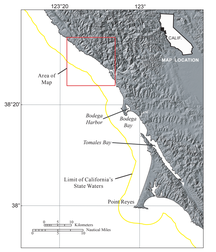



**Figure 11.** USGS high-resolution minisparker seismic-reflection profile PR–104 (collected in 2009 on survey S–8–09–NC), which crosses shelf south of mouth of Russian River; see trackline map for location. Dashed red lines show faults. Profile highlights San Andreas Fault Zone and gently dipping strata on its southwest flank. Blue shading shows inferred uppermost Pleistocene and Holocene strata, deposited since last sea-level lowstand about 21,000 years ago. Dashed purple lines show unconformity with Tertiary bedrock. Shallow reflections in central part of profile are partly "masked" by gas (see, for example, Fader, 1997). Dashed yellow line is seafloor multiple (echo of seafloor reflector).




## DISCUSSION

This map sheet shows seismic-reflection profiles from surveys of the Offshore of Fort Ross map area, providing imagery of the subsurface geology. The seismic-reflection profiles provide the data for interpreting subbottom stratigraphy, sediment thickness, and geologic structure (see sheets 9, 10 of this report).

The north half of the Offshore of Fort Ross map area is characterized by nearshore outcrops of Tertiary sedimentary rocks (see sheet 10 of this report). The nearshore zone and inner shelf area (to water depths of about 50 m) typically dip gently seaward (about 1.5° to 2.5°), whereas the midshelf area (about 50 to 85 m) is relatively flat (about 0.4°). In contrast, the nearshore to midshelf area in the south half of the map area has a more uniform dip: about 0.45° out to water depths of about 30 m and about 0.65° to 0.8° at water depths from 30 to 70 m. The south half of the map area lies directly offshore of the mouth of the Russian River, and this southward decrease in slope is caused by increased sedimentation and the resulting increase in sediment thickness (see Map B on sheet 9) in this wave-dominated, deltaic setting.

Shallow marine and shelf sediments were deposited in the last about 21,000 years during the sea-level rise that followed the last major lowstand associated with the Last Glacial Maximum (LGM) (Lambeck and Chappell, 2001). Sea level was about 125 m lower during the LGM, at which time the Offshore of Fort Ross map area was emergent, and the shoreline was about 20 km west of its present location. 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 (Stanford and others, 2011).

The sediments deposited during the post-LGM sea-level rise (the rapid transgression and highstand) are shaded blue in the high-resolution seismic-reflection profiles (figs. 1, 2, 3, 4, 6, 7, 9, 10, 11), and their thickness is shown on sheet 9 (Maps B, D). This post-LGM stratigraphic unit is characterized by relatively low-amplitude, low- to high-frequency, parallel to divergent reflections that are continuous to moderately continuous (terminology from Mitchum and others, 1977). The contact with underlying units is an abrupt transgressive surface of erosion commonly marked by minor channeling and a common upward change to lower amplitude, more diffuse reflections.

Strata beneath the post-LGM unit (which overlie the Tertiary basement rocks) are represented in seismic-reflection profiles (figs. 1, 2, 3, 4, 6, 7, 9, 10, 11) by low- to high-amplitude, high-frequency, parallel to subparallel, continuous reflections. Reflections commonly are flat to gently folded and typically have dips of 0° to 2° to a maximum (in the northern part of the map area) of about 5° (note that dips may appear steeper on the profiles because of the 12.5:1 vertical exaggeration). The upper contact with the post-LGM unit 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 they underlie post-LGM strata; in addition, their horizons can be traced continuously, along with other USGS data (from cruise S–8–09–NC), to the Quaternary section penetrated by Shell Oil Company offshore well P–027–1 (15 km south of the map area; Heck and others, 1990). Similar to the overlying post-LGM deposits, these inferred Pleistocene strata are wave-reworked deltaic and shelf sediments derived primarily from the Russian River. Reflections within this interval are locally obscured by interstitial gas within the sediment (see, for example, figs. 1, 2, 3, 4, 11). This effect has been referred to as "gas blanking," "acoustic turbidity," or "acoustic masking" (Fader, 1997). The gas scatters or attenuates the acoustic energy from the seismic-reflection-profiling system, inhibiting penetration of strata.

The map area is cut by the San Andreas Fault (figs. 4, 6, 7, 9, 10, 11; see also, sheet 10). West of the San Andreas Fault, bedrock exposed along the coast (onshore and offshore) consists of the Paleocene and Eocene German Rancho Formation (Elder, 1998) and the lower Miocene sandstone and mudstone of Fort Ross area (see sheet 10). East of the San Andreas Fault, coastal bedrock outcrops consist of diverse Jurassic, Cretaceous, Paleocene, and Eocene rocks of the Franciscan Complex. This bedrock appears massive and reflection-free on high-resolution seismic-reflection data (see, for example, figs. 2, 4, 6, 7, 9), and it forms the acoustic basement for overlying Quaternary sediments. On the higher energy, lower resolution seismic profiles (figs. 5, 8), bedrock west of the San Andreas Fault (inferred to be Tertiary sedimentary rocks) is characterized by low- to high-amplitude, parallel to divergent, continuous reflections.

The San Andreas Fault cuts through the Offshore of Fort Ross map area, crossing the shoreline a few kilometers south of Fort Ross (see sheet 10). North of Fort Ross, the San Andreas Fault forms a prominent topographic lineament in low coastal hills. Geologic studies in the onshore area suggest a slip rate of 17 to 24 mm/yr (U.S. Geological Survey and California Geological Survey, 2010). South of Fort Ross, the San Andreas Fault extends across the wave-dominated Russian River delta. The San Andreas Fault and other faults are identified on the 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 mapping reveals a 200- to 500-m-wide zone typically characterized by one or two primary fault strands (see sheet 10).

The map sheet shows six profiles that transect the San Andreas Fault (figs. 4, 6, 7, 9, 10, 11), which illustrate the complex geology within the fault zone. The northernmost three of these six profiles (figs. 4, 6, 7) show prominent, asymmetric, intra–fault-zone basins (about 15 to 25 m deep) filled with post-LGM sediment, which probably represent subsidence and (or) erosion within the fault zone and which may have captured the Russian River channel during the LGM sea-level lowstand. In contrast, two profiles (figs. 9, 10), acquired 1 and 2 km south of the profile shown in figure 7, reveal gentle uplift between the two primary fault strands within the San Andreas Fault Zone. The fault zone has a gentle (about 2°), clockwise, extensional bend between the downdropped and uplifted parts of the zone, and this fault-zone bend is an inferred control on local intra–fault-zone morphology (see, for example, Johnson and Watt, 2012).

Geologic structure west of the San Andreas Fault in most of the Offshore of Fort Ross map area is relatively simple. The bedrock surface dips offshore about 1° to 2°, and it is overlain by an eastward- and southward-thinning wedge of flat-lying reflections of inferred late Pleistocene age.

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 meters. 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 over 30 m of lateral distance covered). These high-resolution data can resolve geologic features that are a few meters thick, 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. 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 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.

## REFERENCES CITED

Elder, W.P., ed., 1998, Geology and tectonics of the Gualala Block, northern California: Society of Economic Paleontologists and Mineralogists, Pacific Section, Book 84, 222 p.

Fader, G.B.J., 1997, The effects of shallow gas on seismic reflection profiles, *in* Davies, T.A., Bell, T., Cooper, A.K., Josenhans, H., Polyak, L., Solheim, A., Stoker, M.S., and Stravers, J.A., eds., Glaciated continental margins—An atlas of acoustic images: London, Chapman and Hall, p. 29–30.

Heck, R.G., Edwards, E.B., Kronen, J.D., Jr., and Willingham, C.R., 1990, Petroleum potential of the offshore outer Santa Cruz and Bodega basins, California, *in* Garrison, R.E., Greene, H.G., Hicks, K.R., Weber, G.E., and Wright, T.L., eds., Geology and tectonics of the central California coastal region, San Francisco to Monterey: American Association of Petroleum Geologists, Pacific Section, Bulletin GB67, p. 143–164.

Johnson, S.Y., and Watt, J.T., 2012, Influence of fault trend, bends, and convergence on shallow structure and geomorphology of the Hosgri strike-slip fault, offshore central California: Geosphere, v. 8, no. 6, 25 p., doi:10.1130/GES00830.1.

Lambeck, K., and Chappell, J., 2001, Sea level change through the last glacial cycle: Science, v. 292, p. 679–686, doi:10.1126/science.1059549.

Mitchum, R.M., Jr., Vail, P.R., and Sangree, J.B., 1977, Seismic stratigraphy and global changes of sea level, part 6—Stratigraphic interpretation of seismic reflection patterns in depositional sequences, *in* Payton, C.E., ed., Seismic stratigraphy—Applications to hydrocarbon exploration: Tulsa, Okla., American Association of Petroleum Geologists, p. 117–133.

Stanford, J.D., Hemingway, R., Rohling, E.J., Challenor, P.G., Medina-Elizalde, M., and Lester, A.J., 2011, Sea-level probability for the last deglaciation—A statistical analysis of far-field records: Global and Planetary Change, v. 79, p. 193–203, doi:10.1016/j.gloplacha.2010.11.002.

U.S. Geological Survey, 2009, National Archive of Marine Seismic Surveys: U.S. Geological Survey database, available at http://walrus.wr.usgs.gov/NAMSS/.

U.S. Geological Survey and California Geological Survey, 2010, Quaternary fault and fold database of the United States: U.S. Geological Survey database, accessed April 5, 2014, at http://earthquake.usgs.gov/hazards/qfaults/.

Waelbroeck, C., Labeyrie, L., Michel, E., Duplessy, J.C., McManus, J.F., Lambeck, K., Balbon, E., and Labracherie, M., 2002, Sea-level and deep water temperature changes derived from benthic foraminifera isotopic records: Quaternary Science Reviews, v. 21, p. 295–305.

# Seismic-Reflection Profiles, Offshore of Fort Ross Map Area, California

by

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2015

CALIFORNIA OCEAN PROTECTION COUNCIL

Coastal Conservancy

SEAFLOOR MAPPING LAB CSU MONTEREY BAY



Digital files available at http://dx.doi.org/10.3133/ofr20151211

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