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

Open-File Report 2016–1110
Sheet 4 of 10
*Pamphlet accompanies map*

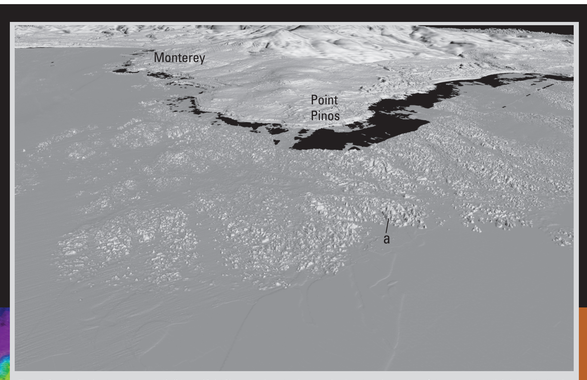



**Figure 1.** Perspective view to south over shelf offshore of Point Pinos, showing extensive area of rocky outcrop in nearshore. Outcrop has local relief of about 2 to 3 m; in places (a), relief is as high as 10 m. Outcrop, which extends approximately 1.5 km offshore, is mapped as the Cretaceous granitic rocks of Monterey (see sheet 10 of this report). Vertical exaggeration, 2x; distance across bottom of image, about 1.5 km.

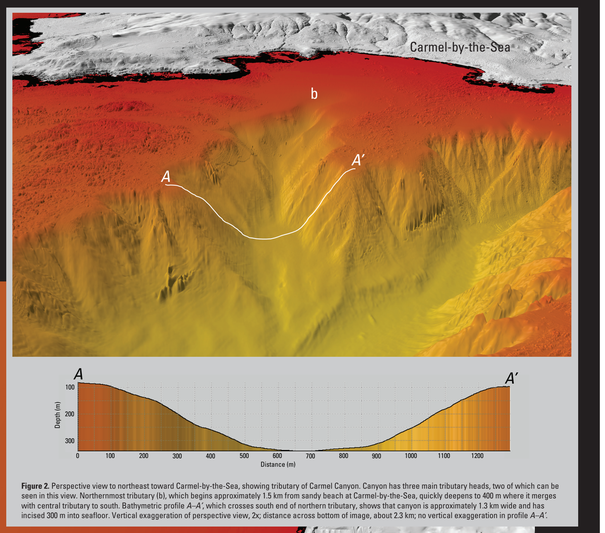



**Figure 2.** Perspective view to northeast toward Carmel-by-the-Sea, showing tributary of Carmel Canyon. Canyon has three main tributary heads, two of which can be seen in this view. Northernmost tributary (b), which begins approximately 1.5 km from sandy beach at Carmel-by-the-Sea, quickly deepens to 400 m where it merges with central tributary to south. Bathymetric profile *A–A′*, which crosses south end of northern tributary, shows that canyon is approximately 1.3 km wide and has incised 300 m into seafloor. Vertical exaggeration of perspective view, 2x; distance across bottom of image, about 2.3 km; no vertical exaggeration in profile *A–A′*.

## DISCUSSION

Mapping California's State Waters has produced a vast amount of acoustic and visual data, including bathymetry, acoustic backscatter, seismic-reflection profiles, and seafloor video and photography. These data are used by researchers to develop maps, reports, and other tools to assist in the coastal and marine spatial-planning capability of coastal-zone managers and other stakeholders. Seafloor-character, habitat, and geologic maps may be used for fisheries management, for designation of Marine Protected Areas, for monitoring of environmental change such as sea-level-rise impacts, for prediction of sediment and contaminant budgets and transport, and for assessment of earthquake and tsunami hazards. To achieve these goals, it is helpful to integrate the different datasets and then view the results in three-dimensional representations such as those displayed on this data integration and visualization sheet for the Offshore of Monterey Bay map area.

The map view in the center of the sheet is similar to the colored shaded-relief bathymetry map of the Offshore of Monterey map area (see sheet 1 of this report). Numbered arrows show viewing directions of the perspective views on this sheet; the numbers indicate the figure number of the perspective view.

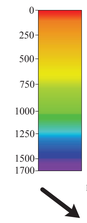
The perspective views and bathymetric profile in figures 1, 2, 3, 4, and 5 show the shaded-relief bathymetry of the Offshore of Monterey map area, as viewed from different directions. These views highlight the seafloor morphology of the map area, which includes complex patterns of scour depressions, areas of rocky outcrop, and the head of Carmel Canyon, a tributary of Monterey Canyon.

Draping the acoustic-backscatter imagery (see sheet 3 of this report) over the bathymetry data (fig. 4) highlights the relations between the backscatter intensity and the seafloor morphology. It also aids in interpreting seafloor habitat and geology.

Video-mosaic images created from seafloor digital video (fig. 6) display the geologic (rock, sand, mud) and biologic complexity of the seafloor. Whereas photographs capture high-quality snapshots of a small area of the seafloor (see sheet 6 of this report), video mosaics can capture larger areas and, thus, can show transitional zones between different seafloor environments. Video-mosaic images that are draped over high-resolution digital terrain models (DTMs) can show very detailed views of the seafloor over small areas. These DTMs and mosaics are created using seafloor video along with Structure from Motion techniques. The technique generates three-dimensional surface models from overlapping two-dimensional images. The DTMs and mosaics can reveal individual boulders and rock that make up a larger rock outcrop and the organisms that inhabit the outcrop (fig. 6).

## EXPLANATION

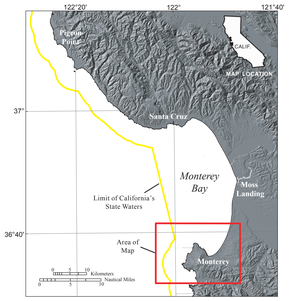
**Depth (in meters) and illumination (bright areas are illuminated, facing false sun; dark areas are in shadow, facing away from false sun)**




**Shallow**

**Deep**

**Direction of illumination from false sun**—Position of false sun is at 300° azimuth, 45° above horizon [arrow included in explanation for illustration purposes only; not shown on map]



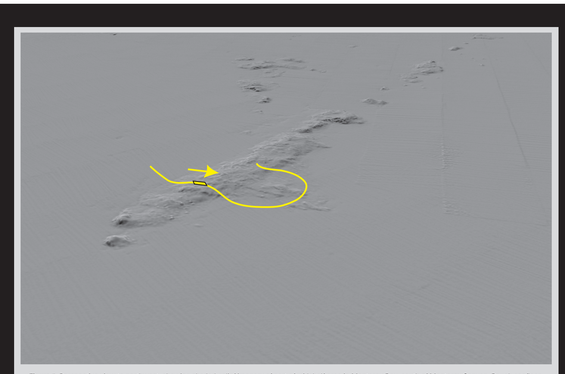
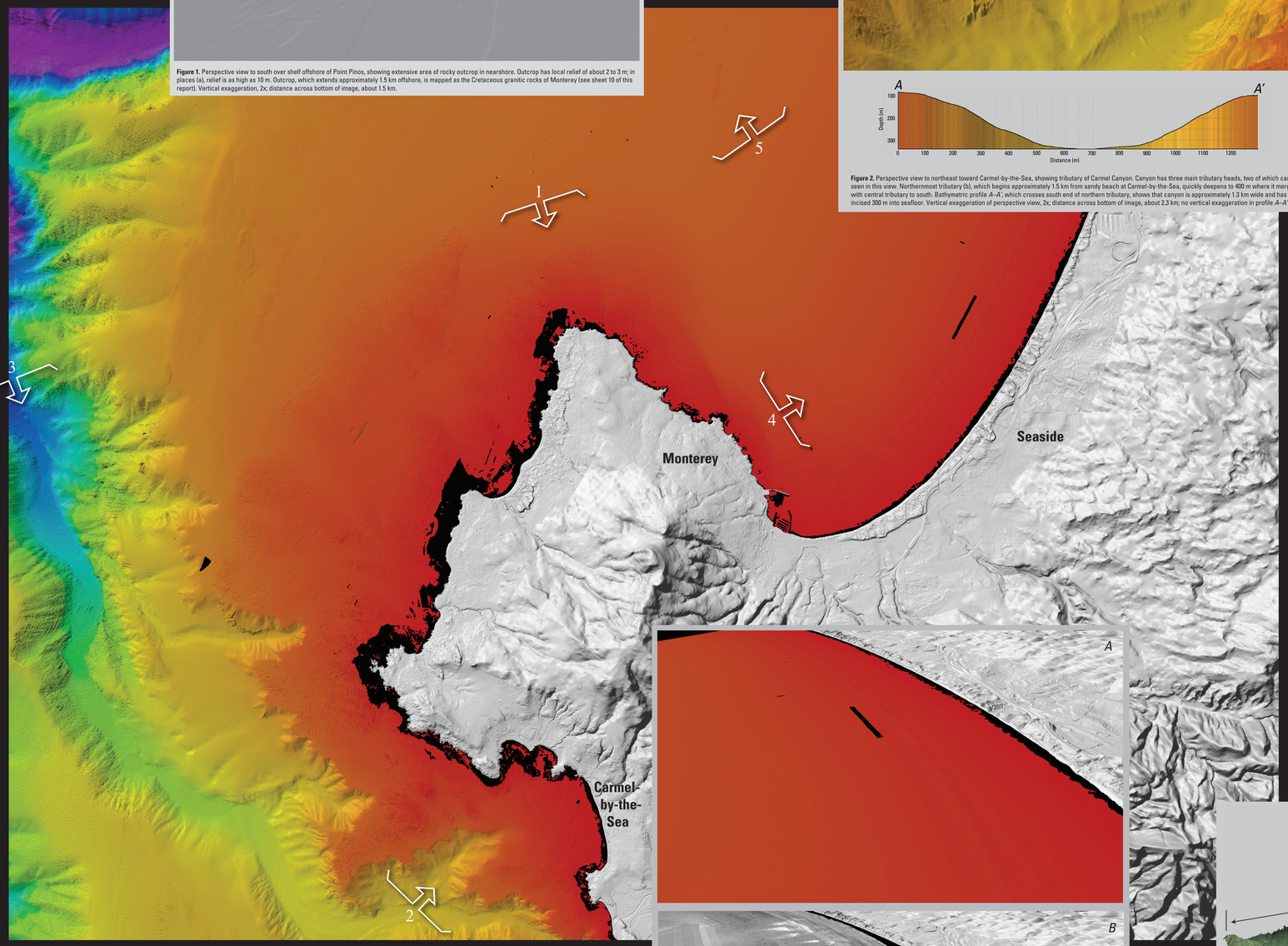



**Figure 5.** Perspective view to northwest, showing shaded-relief imagery of part of midshelf area in Monterey Bay, south of Monterey Canyon. Rough seafloor in center of view is rock outcrop, which rises about 6 m above surrounding seafloor; outcrop is mapped as the upper Miocene and Pliocene Purisima Formation (see sheet 10 of this report). Thin yellow line shows path of camera sled, towed 1 to 2 m above seafloor, that captured video and photographs; yellow arrow shows tow direction. Yellow rectangle shows location of video mosaic draped over Structure from Motion digital terrain model (see fig. 6) generated from video captured over rock outcrop. Vertical exaggeration, 2x; distance across bottom of image, about 750 m.




**Map view.** Colored shaded-relief bathymetry map of Offshore of Monterey map area, generated from multibeam-echosounder and bathymetric-sidescan data. Colors show depths: reds indicate shallower areas; purples, deeper regions. Illumination azimuth is 300°, from 45° above horizon. Ripple patterns and parallel lines that are apparent within map area are data-collection and -processing artifacts; these various artifacts are made obvious by hillshading process. Black areas are gaps in data collection. Numbered arrows show viewing directions of perspective views shown on this sheet; numbers correspond to figure numbers of views.

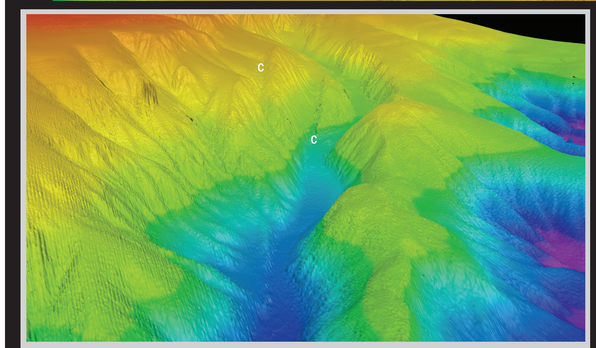



**Figure 3.** Perspective view to south-southeast along axis of Carmel Canyon, showing lineaments (c) associated with offset along San Gregorio Fault, which traverses parts of Carmel Canyon. To north-northwest (in opposite direction of view), canyon continues in relatively straight manner, roughly parallel to fault, until it merges with larger Monterey Canyon north of map area. Ripple patterns in left side of image are data-processing artifacts. Vertical exaggeration, 2x; distance across bottom of image, about 1.7 km.




**Figure 4.** Perspective views to northeast along coastline north of Seaside, showing colored shaded-relief bathymetry (*A*) and acoustic-backscatter imagery (*B*). In acoustic-backscatter imagery, lighter tones indicate stronger backscatter intensity, suggesting rock or coarser grained sediment, whereas darker tones indicate weaker backscatter intensity, suggesting finer grained sediment. Although colored shaded-relief bathymetry (*A*) shows very little relief in nearshore environment, acoustic-backscatter imagery (*B*) reveals complex patterns of lower and higher backscatter. Higher backscatter intensities are found in low-relief scour depressions (see sheet 10) that are filled with coarser sands, which are common along California coast. Ripple patterns and parallel lines in acoustic-backscatter data roughly parallel to shoreline are data-processing artifacts. Black rectangle in both views is gap in data collection. Vertical exaggeration of perspective views, 2x; distance across bottom of both views, about 2.5 km.

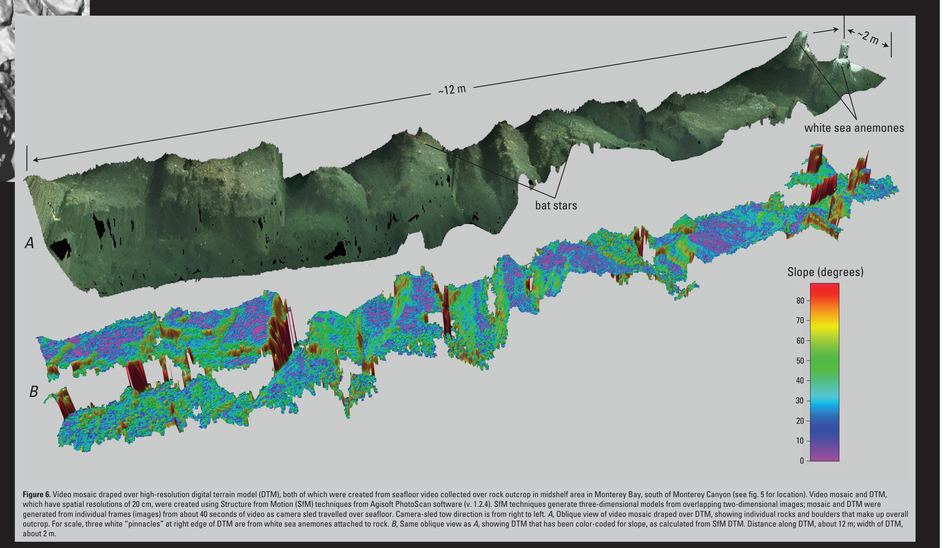



**Figure 6.** Video mosaic draped over high-resolution digital terrain model (DTM), both of which were created from seafloor video collected over rock outcrop in midshelf area in Monterey Bay, south of Monterey Canyon (see fig. 5 for location). Video mosaic and DTM, which have spatial resolutions of 20 cm, were created using Structure from Motion (SfM) techniques from Agisoft PhotoScan software (v. 1.2.4). SfM techniques generate three-dimensional models from overlapping two-dimensional images; mosaic and DTM were generated from individual frames (images) from about 40 seconds of video as camera sled travelled over seafloor. Camera-sled tow direction is from right to left. *A*, Oblique view of video mosaic draped over DTM, showing individual rocks and boulders that make up overall outcrop. For scale, three white "pinnacles" at right edge of DTM are from white sea anemones attached to rock. *B*, Same oblique view as *A*, showing DTM that has been color-coded for slope, as calculated from SfM DTM. Distance along DTM, about 12 m; width of DTM, about 2 m.

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 1, this report

Universal Transverse Mercator projection, Zone 10N

**NOT INTENDED FOR NAVIGATIONAL USE**


MAP LOCATION

# Data Integration and Visualization, Offshore of Monterey Map Area, California

By
Peter Dartnell

2016

Perspective views by Peter Dartnell, 2015. Bathymetric profile *A–A′* in figure 2 by Peter Dartnell, 2015. Acoustic-backscatter imagery in figure 4 from map on sheet 3, this report. Video-mosaic image and Structure from Motion DTM in figure 6 by Peter Dartnell, 2015

GIS database and digital cartography by Nadine E. Golden

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