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

Open-File Report 2015–1068
Sheet 4 of 10
Pamphlet accompanies map

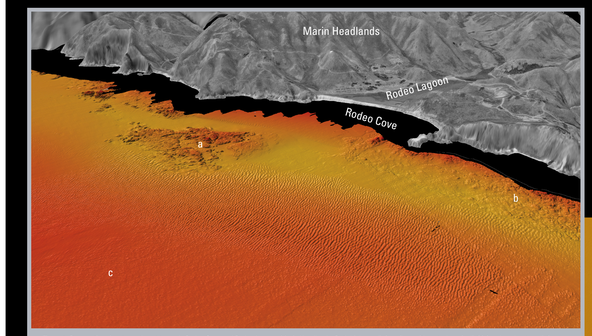


Figure 1. Perspective view to northeast towards Rodeo Cove and Rodeo Lagoon, Marin Headlands. Both higher-relief seafloor with up to 5 m of relief (a) and moderate-relief seafloor with up to 2 m of relief (b) are composed of Jurassic and Cretaceous Franciscan Complex bedrock (sheet 10, this report). Small bedforms (< 1 m of relief) offshore of outcrops are reworked sediment of San Francisco Bay ebb-tidal delta. Shallowest region within image (water depth, < 10 m) is located farther offshore (c) on area called Potato Patch, known for rough sea conditions during periods of large swell. Vertical exaggeration of perspective view, 2x; distance across bottom, about 1.4 km.

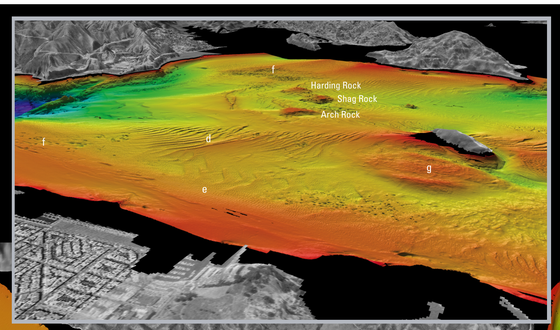


Figure 2. Perspective view to northwest over central San Francisco Bay, viewed from over downtown San Francisco. Both larger bedforms with up to 4 m of relief (d) and smaller bedforms with less than 1 m of relief (e) are found throughout Bay created by strong tidal currents. This part of Bay has experienced extensive human activity including sand mining for construction material (f) and dredge disposal (g). Arch, Harding, and Shag Rocks in center of Bay are bedrock highs that are navigational hazards to larger ships. General depth within Bay is 20–30 m, but drops quickly to about 115 m under Golden Gate Bridge. Vertical exaggeration of perspective view, 2x; distance across bottom, about 2.0 km.

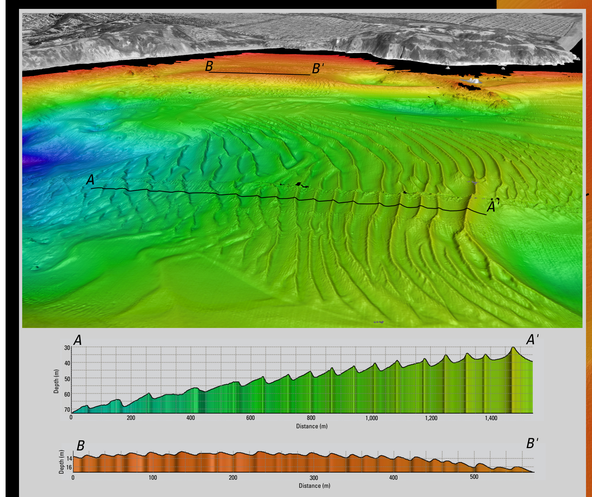
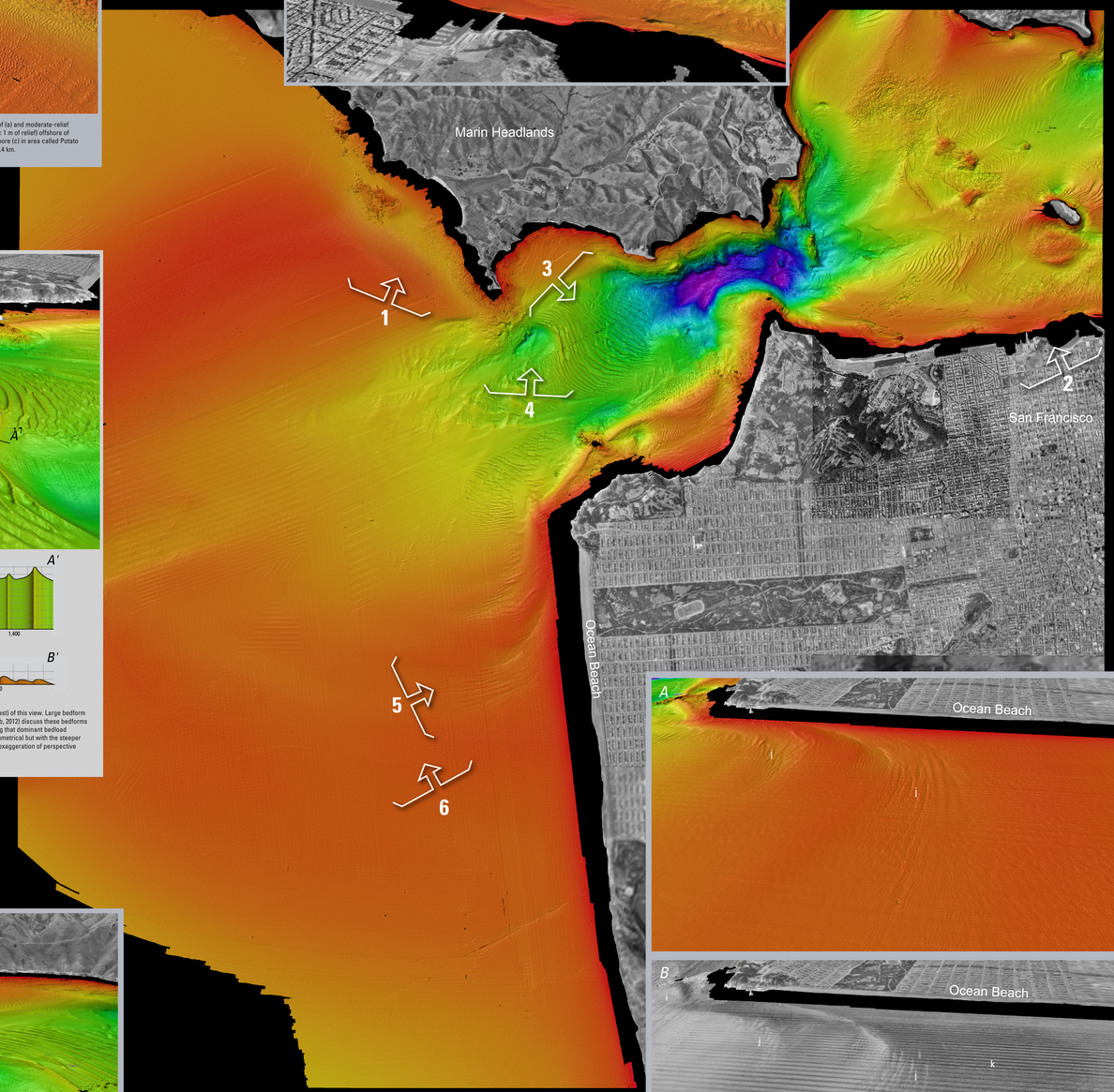


Figure 3. Perspective view to southeast over entrance to San Francisco Bay with bathymetric profiles *A–A′* and *B–B′*. Golden Gate Bridge is to left (east) of this view. Large bedform field lies within Golden Gate channel formed from sediment transported out of Bay and reworked by strong tidal currents. Barnard and others (2006a,b; 2012) discuss these bedforms in detail. Profile *A–A′* shows larger bedforms can reach heights of over 7 m and are asymmetrical with steeper sides towards the open coast, inferring that dominant bedload transport direction is from Bay to coast. Smaller bedform field lies to south near Baker Beach. Profile *B–B′* shows bedforms in this field are also asymmetrical but with the steeper sides towards Bay. Here, a large tidal eddy during ebb tides is forcing sediment northeast back towards the Bay (Barnard and others, 2012). Vertical exaggeration of perspective view, 2x; distance across bottom, about 1.3 km; vertical exaggeration of both bathymetric profiles, 5x.



Map view. Colored shaded-relief bathymetry map of Offshore of San Francisco map area, generated from multibeam-echosounder data. Colors show depth: reds and oranges indicate shallower areas; purples, deeper areas. Illumination azimuth is 300°, from 45° above horizon. Numbered arrows show viewing directions of perspective views shown on this sheet; numbers correspond to figure numbers of views.

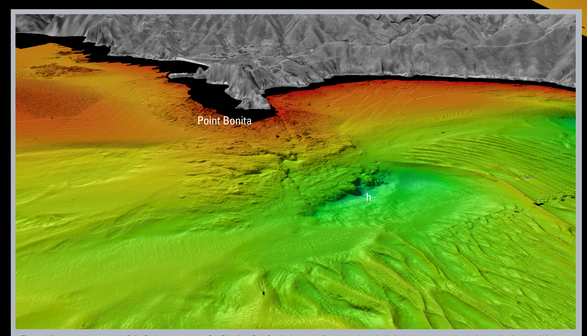


Figure 4. View to northeast towards Point Bonita at entrance to San Francisco Bay. South of point, seafloor drops dramatically from coast to water depth of about 60 m in about 800 m distance. Deep "hole" (h) surrounded by field of large bedforms (see fig. 3), is second deepest region within map area and is probably maintained by scouring from strong tidal currents flowing around Point Bonita. Vertical exaggeration of perspective view, 2x; distance across bottom, about 1.2 km.

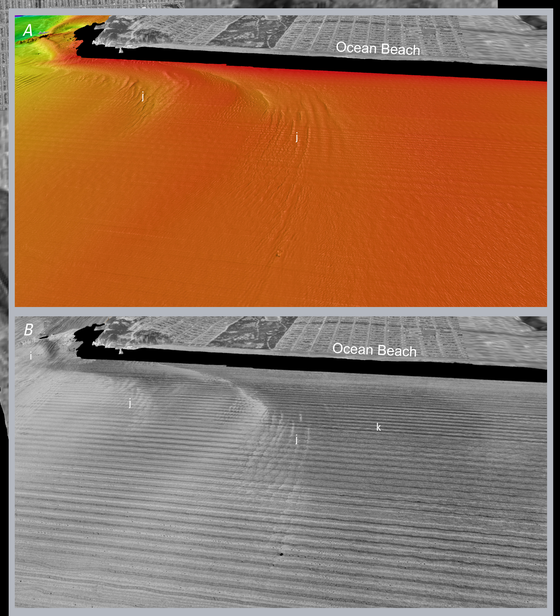


Figure 5. Perspective views to east of both colored shaded-relief bathymetry (*A*) and gray-scale acoustic backscatter (*B*). In backscatter imagery, lighter tones indicate stronger backscatter intensity suggesting rock or more coarse-grained sediment, whereas darker tones indicate weaker backscatter intensity suggesting more fine-grained sediment. Views look toward Ocean Beach and are near southern extent of San Francisco Bay ebb-tidal delta. Higher backscatter intensities are found in entrance to San Francisco Bay (i) as well as low-relief bedforms directly offshore Ocean Beach (j). These areas are likely coarser sands compared to finer-grained material towards the south (k). Horizontal lines in both bathymetry and backscatter views are data-collection artifacts. Vertical exaggeration of both perspective views, 2x; distance across bottom, about 2 km.

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 San Francisco map area.

The map view in the center of the sheet is similar to the colored shaded-relief bathymetry map of the Offshore of San Francisco map area (see sheet 1 of this report). Numbered arrows show viewing directions of the perspective views on this sheet (figs. 1, 2, 3, 4, 5, 6); the numbers indicate the figure number of the perspective view.

The perspective views and bathymetric profiles in figures 1, 2, 3, 4, 5, and 6 show the colored shaded-relief bathymetry within San Francisco Bay and offshore the Golden Gate as viewed from different directions. These views show a few examples of the complexity of the seafloor modified by tidal currents and human activity.

Draping the acoustic-backscatter imagery (see sheet 3 of this report) over the bathymetry data (fig. 5) highlights the relations between the backscatter intensity and the seafloor morphology, and often reveals sediment transport patterns not seen in the bathymetry data alone.

Block diagrams (fig. 6), which combine the bathymetry with seismic-reflection-profile data (see sheet 8 of this report), help reveal the stratigraphic and structural relations between the surface and subsurface.

REFERENCES CITED

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Barnard, P.L., Hanes, D.M., Kvitek, R.G., and Iampietro, P.J., 2006a, Sand waves at the mouth of San Francisco Bay, California: U.S. Geological Survey Scientific Investigations Map 2944, 5 sheets, available at http://pubs.usgs.gov/sim/2006/2944/.

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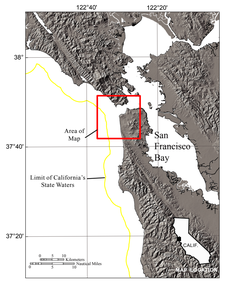
EXPLANATION

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

Shallow
20
40
60
80
100
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]



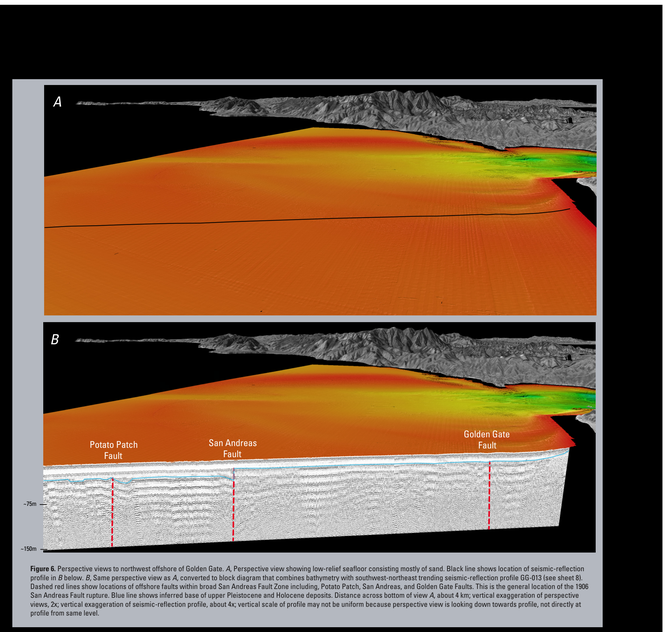


Figure 6. Perspective views to northwest offshore of Golden Gate. *A*, Perspective view showing low-relief seafloor consisting mostly of sand. Black line shows location of seismic-reflection profile in *B* below. *B*, Same perspective view as *A*, converted to block diagram that combines bathymetry with southwest-northeast trending seismic-reflection profile GG-013 (see sheet 8). Dashed red lines show locations of offshore faults within broad San Andreas Fault Zone including, Potato Patch, San Andreas, and Golden Gate Faults. This is the general location of the 1906 San Andreas Fault rupture. Blue line shows inferred base of upper Pleistocene and Holocene deposits. Distance across bottom of view *A*, about 4 km; vertical exaggeration of perspective views, 2x; vertical exaggeration of seismic-reflection profile, about 4x; vertical scale of profile may not be uniform because perspective view is looking down towards profile, not directly at profile from same level.

Onshore imagery from digital ortho-photographs available at Cal-Atlas Geospatial Clearinghouse, http://atlas.ca.gov/ (last accessed January 2013). Offshore shaded-relief bathymetry from map on sheet 2, this report

Universal Transverse Mercator projection, Zone 10N

NOT INTENDED FOR NAVIGATIONAL USE

MAP LOCATION

Perspective views by Peter Dartnell, 2012. Bathymetric profiles in figure 3 by Peter Dartnell, 2012. Acoustic-backscatter imagery in figure 5 from map on sheet 3, this report. Seismic-reflection profile in figure 6 from sheet 8, this report
GIS database and digital cartography by Nadine E. Golden and Florence L. Wong
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Data Integration and Visualization, Offshore of San Francisco Map Area, California

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