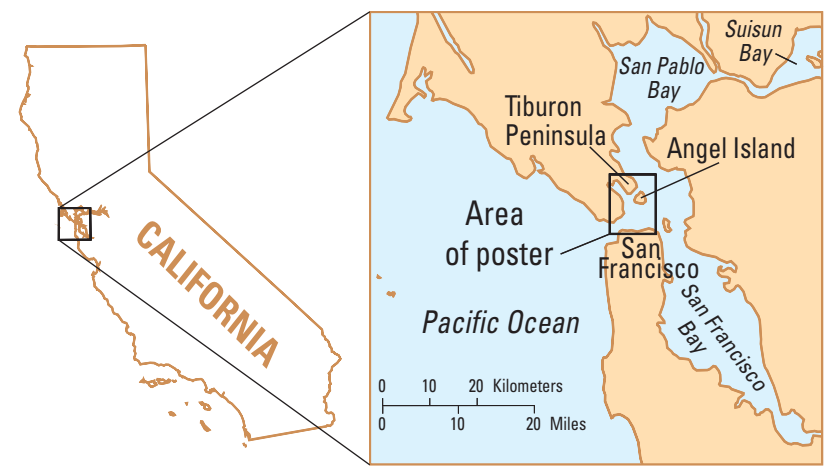


Under San Francisco Bay—A New View of the Floor of West-Central San Francisco Bay



This poster features a new view of the floor of west-central San Francisco Bay—the deep part of the bay, where ocean-going vessels traverse the shipping lanes and strong tidal currents sculpt the bay floor. The data used to create it provide the first look at such a large area of the bay floor in such detail.

This new view of the floor of San Francisco Bay was made from data gathered by the U.S. Geological Survey (USGS) and the National Oceanic and Atmospheric Administration (NOAA) using a state-of-the-art mapping system (see “High-Resolution Multibeam Mapping,” below).

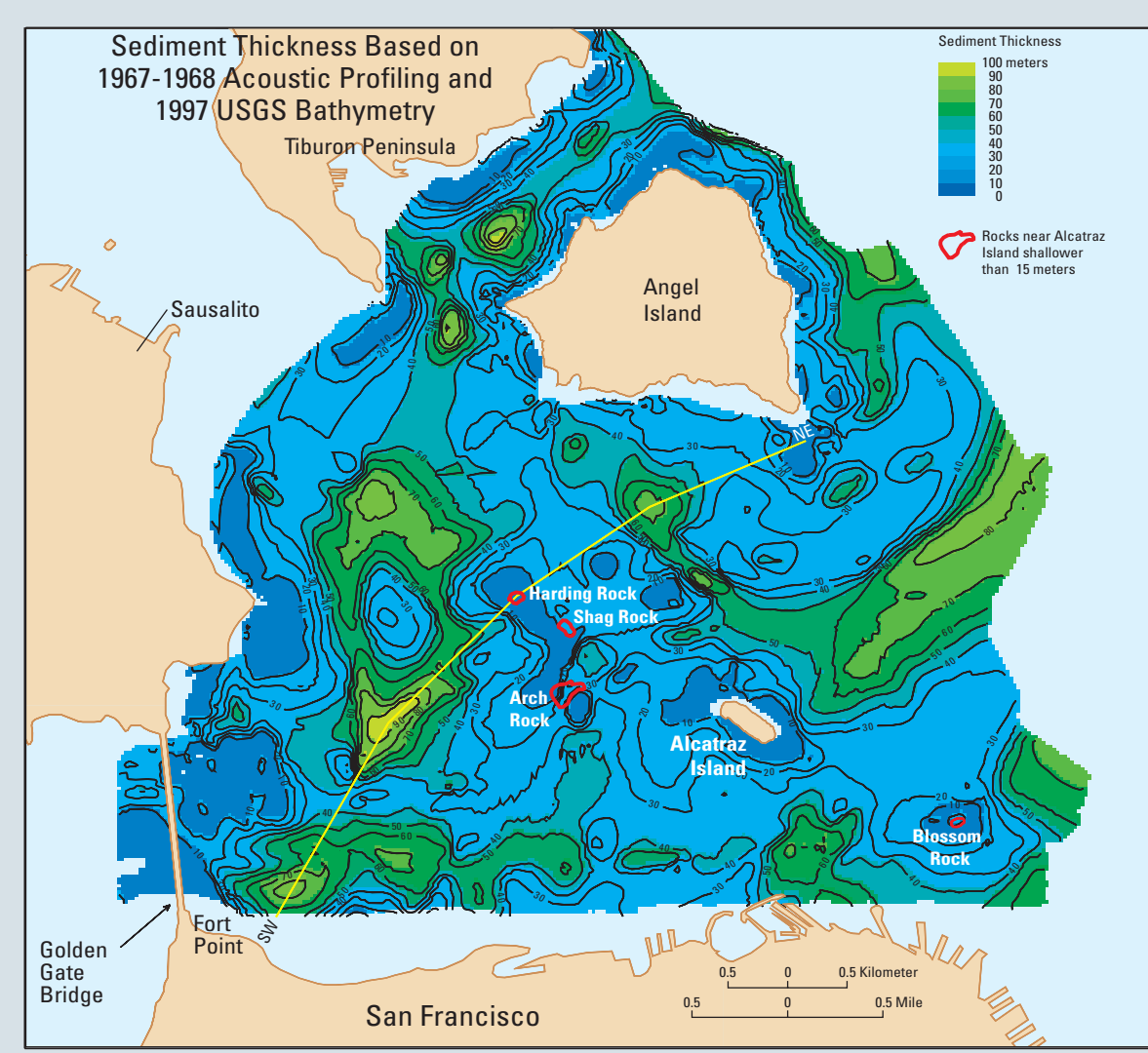
The new data from the floor of San Francisco Bay are helping to answer challenging questions, such as:

1. How much sediment is on the bay floor, and how do water currents move the sediment?
2. Where can sediment dredged from harbors and shipping channels be safely disposed of?
3. How much rock must be trimmed from pinnacles on the bay floor to ensure that ships do not run aground on them?

This poster describes the ways in which the USGS has started answering these questions.

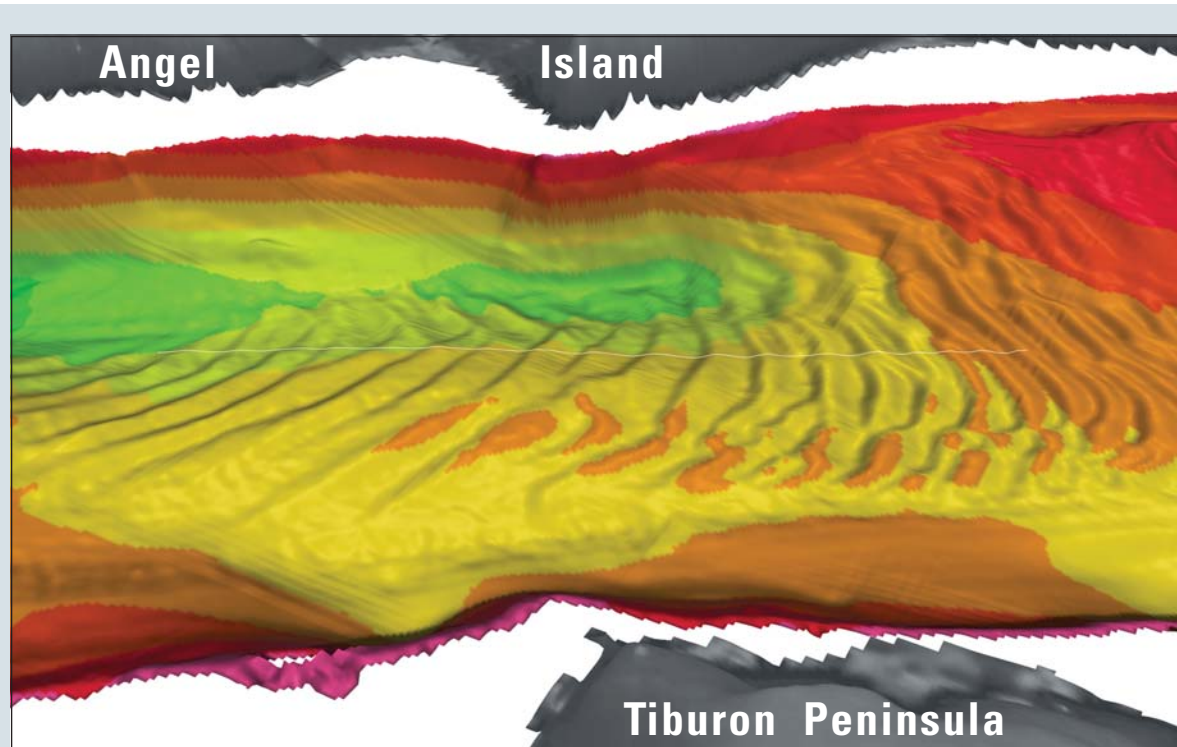
1. Sediment on the Floor of San Francisco Bay: Where is it and how does it move?

Understanding sediment on the floor of San Francisco Bay—how much is present and where and how fast it is moved by currents—is central to understanding virtually every other issue affecting the bay. USGS scientists have combined new water-depth data from the west-central bay with data used to measure depth to bedrock in the bay during the 1960’s. The result is the sediment-thickness map shown below. Most maps of the bay floor are bathymetric maps—they show the depth from the water surface to the bay floor. This sediment-thickness map shows the depth from the bay floor to bedrock, also called “basement.” The map shows that more than 90 meters (295 feet) of sediment underlies some parts of the bay floor. In other areas, sediment is absent and bedrock is exposed.



Map showing thickness of sediment on the floor of west-central San Francisco Bay (see text). Most of the sediment in the bay is sand, silt, or mud. It rests on solid rock, called “bedrock” or “basement.” Vertical profile below map runs from Fort Point through Harding Rock to Angel Island, along arc shown on map.

Currents have shaped much of the sediment on the bay floor into sand waves, which are underwater sand dunes. Some of the largest sand waves—for example, east of Tiburon Peninsula (see Area 1 on 3-dimensional image at right)—are up to 3 meters (10 feet) high and 30 to 40 meters (100 to 130 feet) from crest to crest. Strong tidal currents form and move these sand waves. The waves’ asymmetric shapes reveal the direction of sand movement—currents sweep sand up the gently sloping side of a sand wave, and the sand tumbles down the steep side.



Oblique view of sand waves between Angel Island and Tiburon Peninsula (from Area 2 on 3-dimensional image at right). The most recent movement of the sand waves was from right to left, or to the northeast, as shown by the asymmetry of the waves.

2. Dredged Sediment: Where to put it?

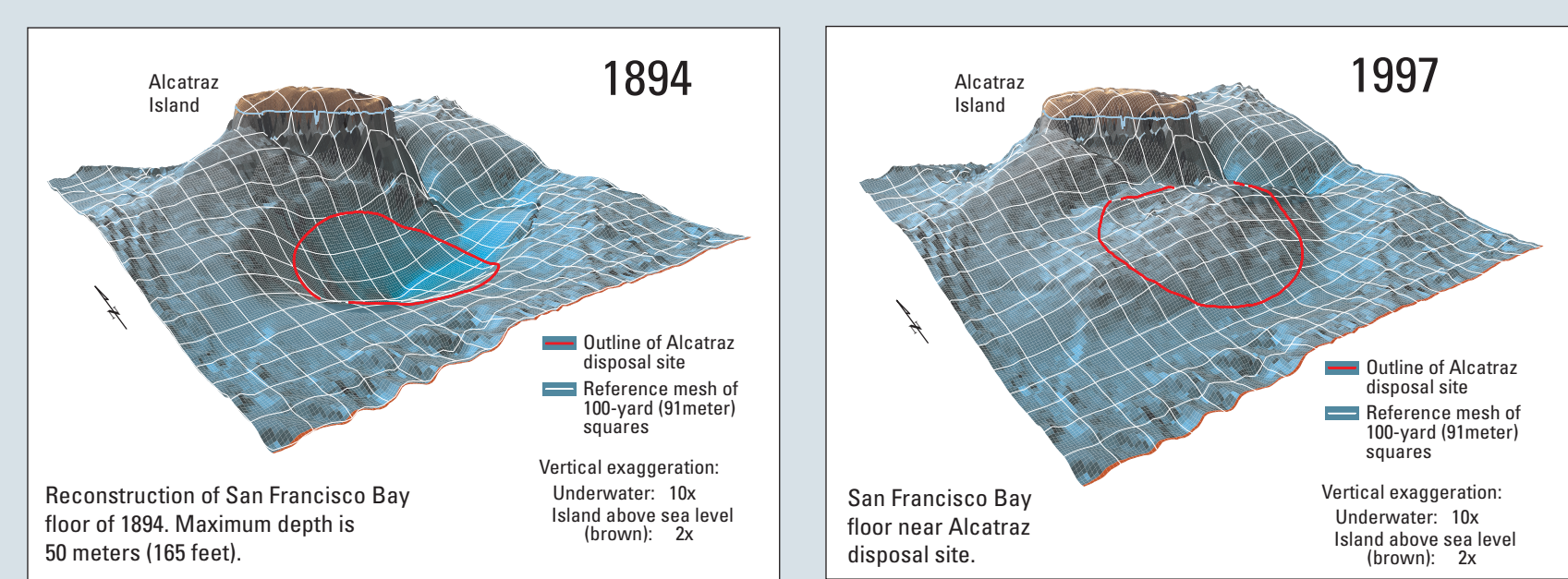
Sand and mud must be dredged from parts of San Francisco Bay and surrounding harbors to keep channels and berths deep enough for ships and other vessels. This dredging has gone on since the first shipping channel was created in the 1850’s. Some areas are dredged every few years, others every year, depending on how fast sediment builds up.

Dredging keeps harbors and waterways open but also creates the problem of where to put the dredged sediment, which not only takes up space but commonly contains pollutants such as droplets of oil and paint chips from ships’ hulls. Strict standards set by the Environmental Protection Agency (EPA) are used to determine which sediment gets dumped where. The most contaminated sediment is dumped on land. Cleaner sediment is dumped at sites in the open ocean and in the bay.

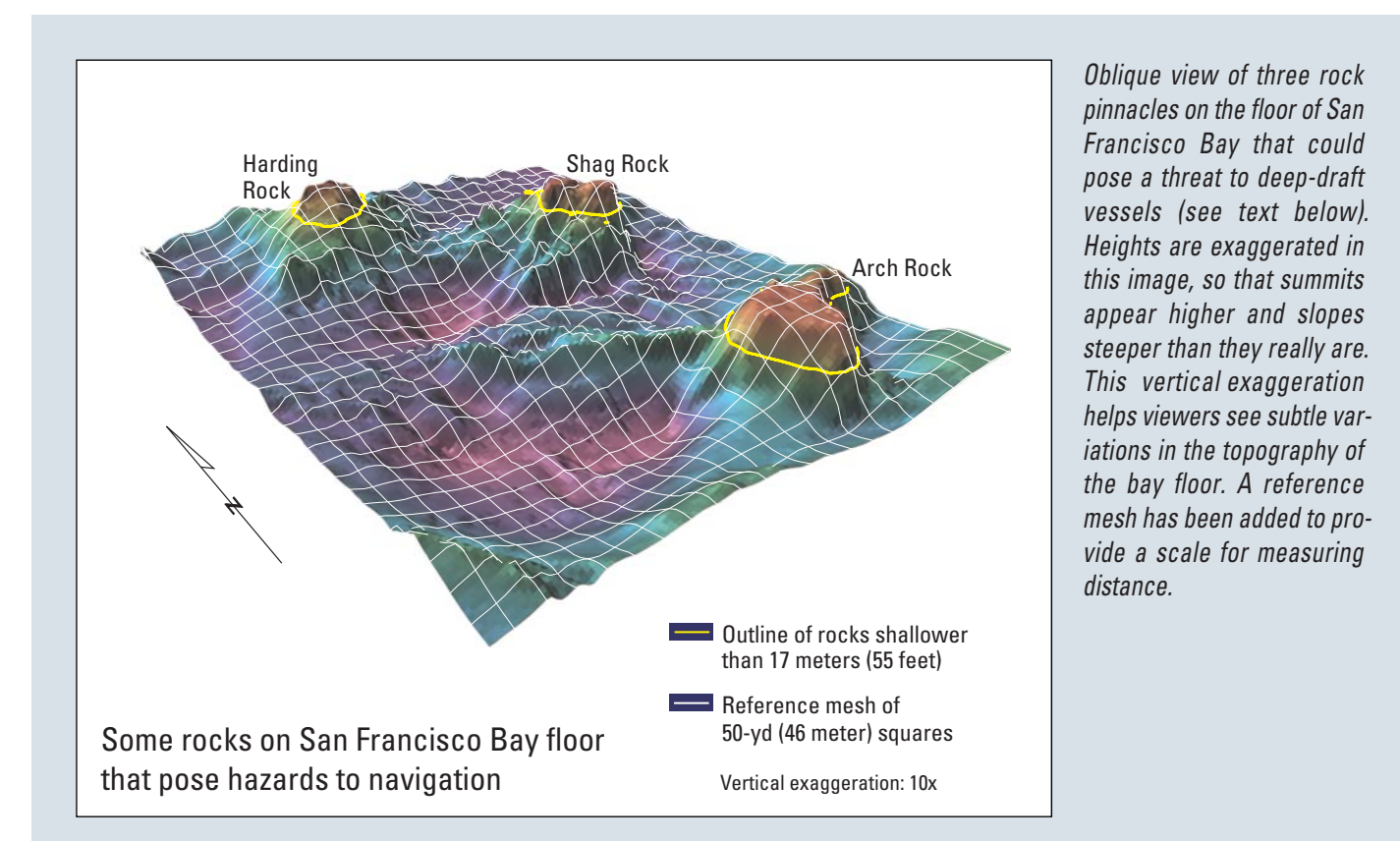
One disposal site in San Francisco Bay—currently in limited use—is just south of Alcatraz Island. Before dumping began there in 1894, the site was a hole on the bay floor 50 meters (165 feet) deep. By the mid-1980’s, the dumped sediment (more than 6 million cubic meters, or 8 million cubic yards) had formed a mound that rose to within 10 meters (33 feet) of sea level and began to pose a threat to deep-draft vessels (see images below). The mound has also raised questions that apply to any sediment dumped in the bay:

- Will the sediment be eroded?
- Will currents carry the sediment to other parts of the bay?
- Will pollutants in the sediment harm bay ecosystems?

The data used to create this poster will help identify sites where dredged sediment will stay put and not drift back into channels or sensitive bay ecosystems.



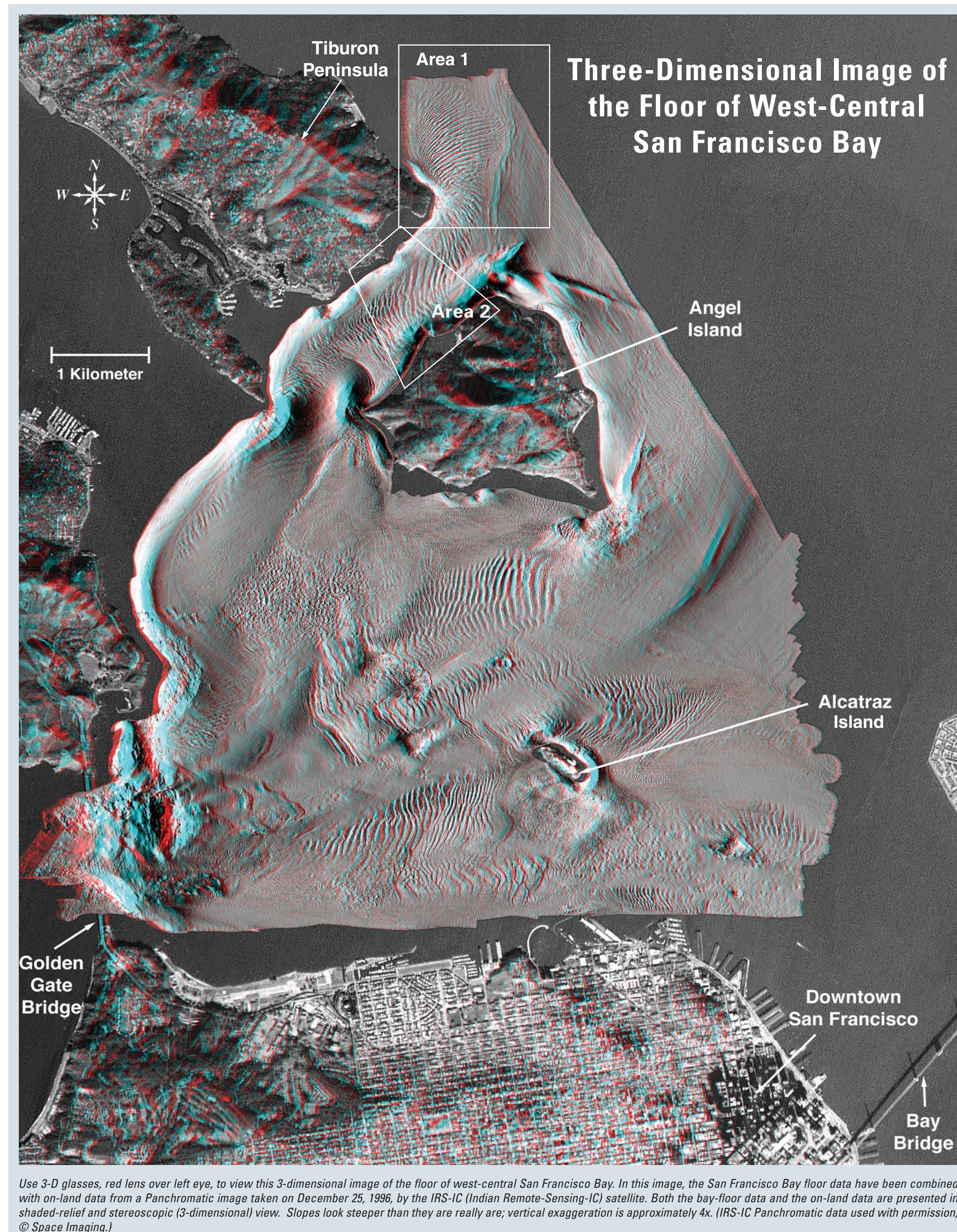
Oblique views of the floor of San Francisco Bay south of Alcatraz Island. On the left is a view of the bay floor in 1894, reconstructed from sparse historical data. On the right is a view of the bay floor in 1997, constructed from the new USGS data. Dredged sediment dumped since 1894 has formed a depression in the bay floor into a mound that could pose a threat to deep-draft vessels. Heights are exaggerated in these images, so that summits appear higher and slopes steeper than they really are. This vertical exaggeration helps viewers see subtle variations in the topography of the bay floor. A reference mesh has been added to provide a scale for measuring distance.



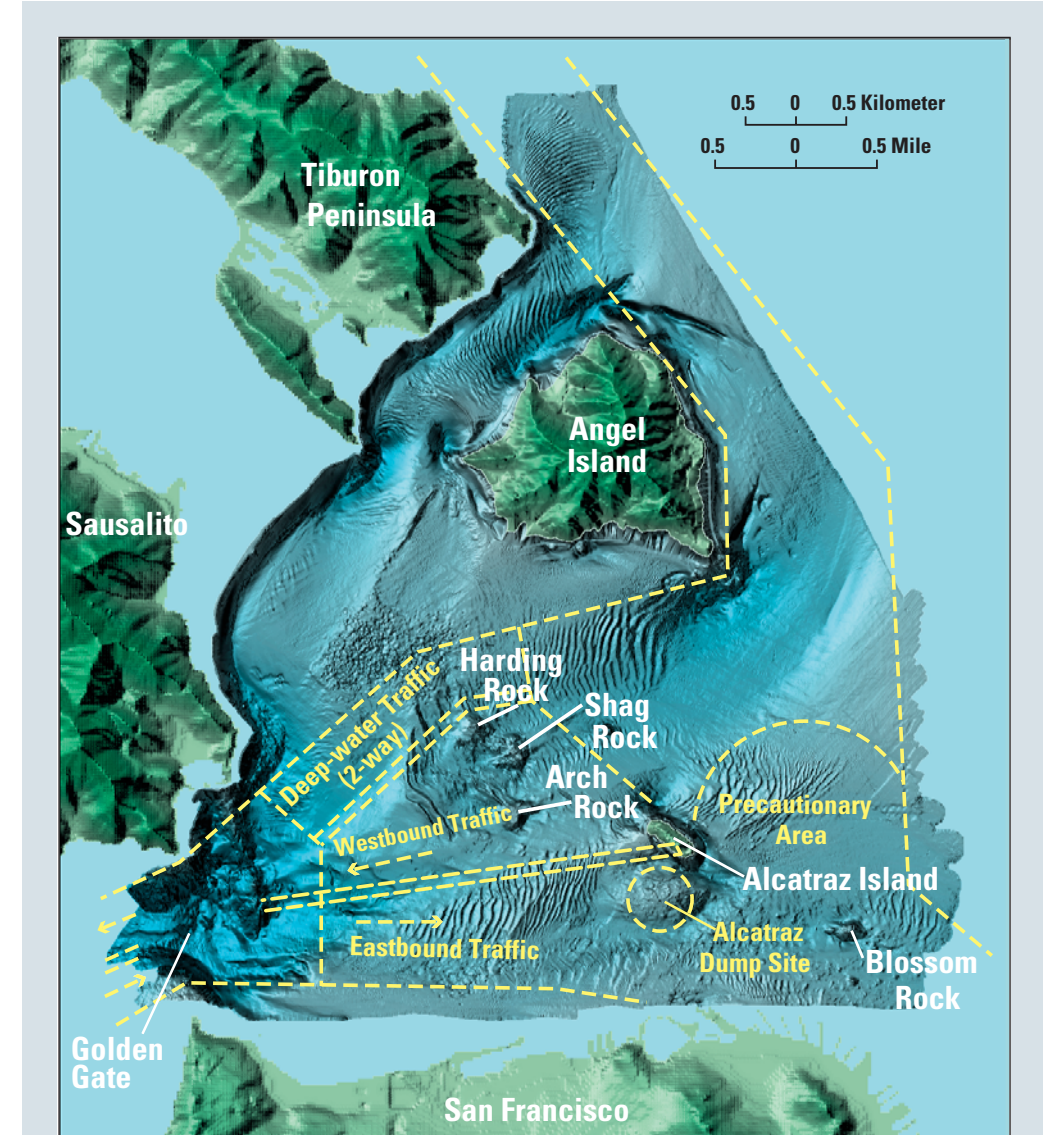
3. Rock Pinnacles: How much to remove for safer shipping?

West-central San Francisco Bay is a geographic bottleneck that ships must navigate on their way to ports, harbors, and waterways in the bay area (see map below). This part of the bay has several rock pinnacles that rise from the bay floor to within 11 meters (36 feet) of the water surface. Of the thousands of ocean-going vessels that travel yearly through the west-central bay, more than 200 have drafts in excess of 12 meters (39 feet). When loaded, the bottoms of these deep-draft vessels are deeper than the tops of the rock pinnacles.

Taking Harding Rock as an example (see image above), USGS scientists estimate that approximately 38,000 cubic meters (50,000 cubic yards) of rock would have to be removed to lower the pinnacle to a depth of 17 meters (55 feet). Shag Rock and Arch Rock pose similar hazards. Currently under study is a plan to lower rock pinnacles in the bay in order to promote safe ship travel and prevent oil spills that might occur if tankers or other vessels hit the rocks.



Use 3-D glasses, red lens over left eye, to view this 3-dimensional image of the floor of west-central San Francisco Bay. In this image, the San Francisco Bay floor data have been combined with on-land data from a Panchromatic image taken on December 25, 1996, by the IRS-1C (Indian Remote Sensing-1C) satellite. Both the bay-floor data and the on-land data are presented in shaded-relief and stereoscopic (3-dimensional) view. Slopes look steeper than they really are; vertical exaggeration is approximately 4x. (IRS-1C Panchromatic data used with permission, © Space Imaging.)



View of the floor of west-central San Francisco Bay with shipping lanes (approximate) superimposed. Shipping lanes were approximated from U.S. National Oceanic and Atmospheric Administration National Ocean Survey Chart 18649, “San Francisco Entrance,” 48th edition, 1981.

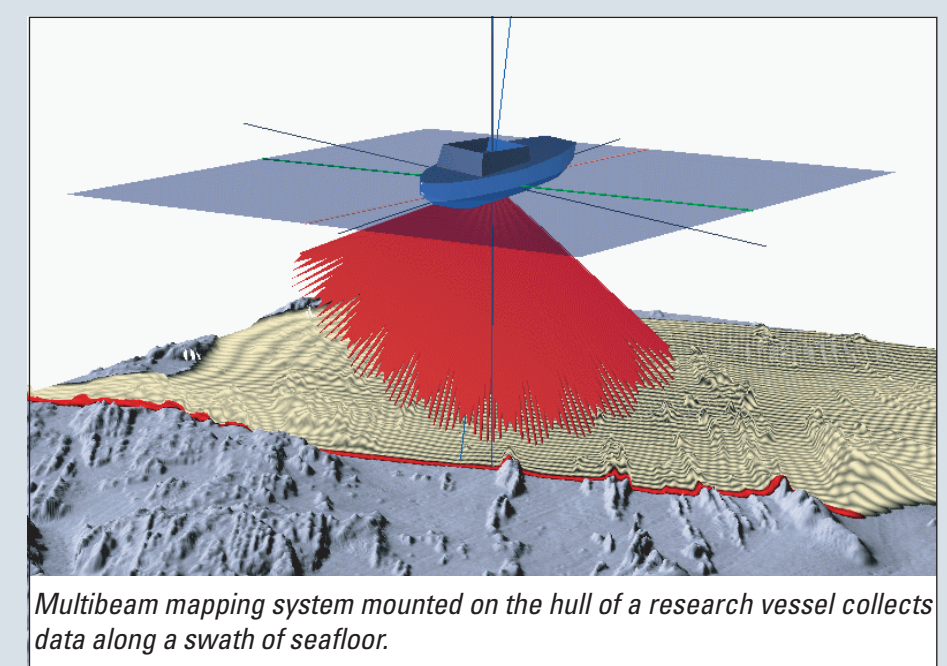
High-resolution seafloor maps support studies like those described here and many others, including studies of offshore earthquake faults, seafloor habitats of fish and shell fish, and saltwater intrusion into coastal aquifers. Making such maps is part of the work of the U.S. Geological Survey’s Coastal and Marine Geology Program, which conducts scientific research along United States coastlines and in adjoining ocean waters. USGS research aims to reduce the risk from coastal geologic hazards and to support the sound management of the Nation’s coasts and seas. To learn more about the program, visit <http://marine.usgs.gov/>.

For More Information:

- <http://TerraWeb.wr.usgs.gov/projects/SFBaySonar/centralbay.html>
“San Francisco Bay Multibeam Bathymetry Data: West-Central Bay Area”
- <http://walrus.wr.usgs.gov/outreach/sfbay/>
“Sediment and Pollutant Transport in Central San Francisco Bay”
- <http://sfbay.wr.usgs.gov/access/mapping/multibeam/>
“Multibeam Data and Socio-Economic Issues in West-Central San Francisco Bay”
USGS Open-File Report 98-139
- <http://walrus.wr.usgs.gov/pacmaps/>
“Pacific Sea Floor Mapping Project”
- <http://walrus.wr.usgs.gov/seeds/>
“USGS Bedform Sedimentology Site”
- Bathymetry and selected perspective views of central San Francisco Bay, California, 2000**, by James V. Gardner, Peter Dartnell, Larry A. Mayer, John E. Hughes Clarke, and J. Christopher Stone. U.S. Geological Survey Water-Resources Investigations Report 00-4164, 2 map sheets.
- Contributors:** David A. Cacchione, Paul R. Carlson, Pat F. Chavez, Jr., John L. Chin, Peter Dartnell, James V. Gardner, Helen Gibbons, David M. Rubin, Miguel Velasco, and Florence L. Wong
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- Cooperating Agencies:** National Oceanic and Atmospheric Administration, U.S. Army Corps of Engineers, San Francisco Bay Harbor Safety Committee

High-Resolution Multibeam Mapping

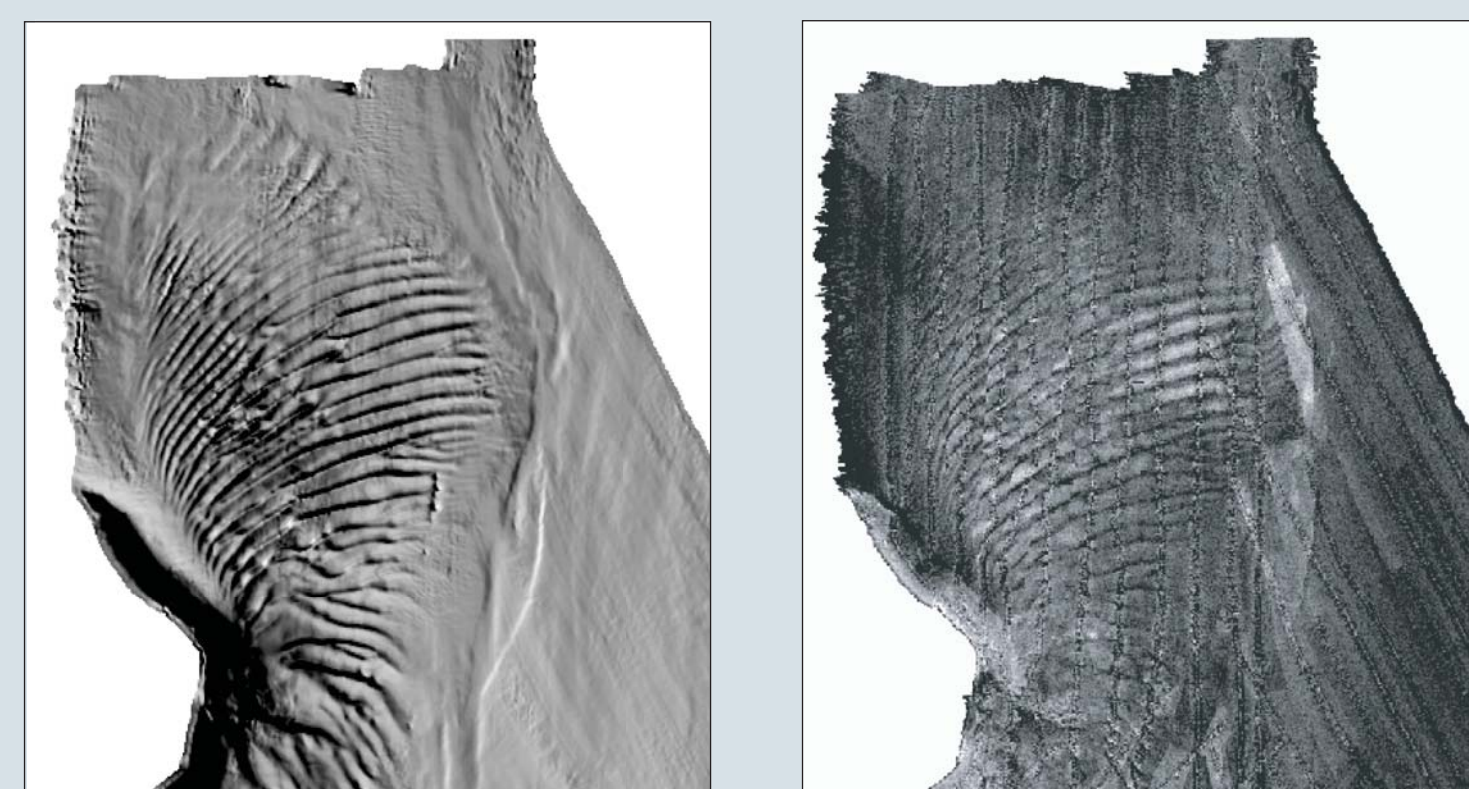
High-resolution multibeam mapping is a variation on echo sounding, a technique oceanographers have used since the 1920’s to measure water depths. In the simplest form of echo sounding, a pulse of sound sent from a ship travels to the seafloor and bounces back to a receiver on the ship. The time lapse between sending the sound pulse and receiving its echo is used to calculate water depth.



Multibeam mapping system mounted on the hull of a research vessel collects data along a swath of seafloor.

Since its introduction in the early 20th century, the use of sound for seafloor mapping has become increasingly sophisticated. The mapping system that collected the data used to create this poster is a multibeam echo sounder. Mounted on a ship’s hull, it sends out approximately 3 pulses of sound per second. Returning echoes are received by 60 narrow receive apertures, each of which records data from a precisely located point on the seafloor. The time an echo takes to return to the system is used to calculate depth to the seafloor, and the depths are combined to make a bathymetric map (see first image to the right). The strength of the returning echoes—called acoustic backscatter—provides information about what types of material are on the seafloor. Hard rock reflects more sound back to the ship than soft mud, for example, and the near sides of sand waves return more sound than the far sides. The second image to the right is an acoustic-backscatter map.

This poster highlights bathymetric data. The data used to create the poster have a horizontal resolution of 4 meters (13 feet) and a depth resolution of 30 centimeters (12 inches). That means that any object larger than 4 meters long by 4 meters wide and 30 centimeters high will be revealed (for example, see image of sunken vessel at far right).



Sand waves, or underwater sand dunes, on the floor of San Francisco Bay east of the Tiburon Peninsula (see Area 1 on 3-dimensional image, above). On the left is a shaded-relief image of the area created from bathymetric data. On the right is an image of the area created from acoustic-backscatter data. Bathymetric images can be manipulated to make them look much like photographs—by adding shadows, for example, as in the left image. Acoustic-backscatter images are harder to interpret, but they have the potential to tell scientists a great deal about the material at and just below the seafloor surface. These sand waves are up to 3 meters (10 feet) high and 30 to 40 meters (100 to 130 feet) from crest to crest.



A sunken vessel can be seen in this view of the floor of San Francisco Bay northeast of Angel Island. The presence of this object was already known to the U.S. Coast Guard, but its identity has not been determined. This image was created from the recently collected bathymetric data (for the bay floor) and USGS topographic data (for the land). View is from the north, looking south toward San Francisco.

The U.S. Geological Survey (USGS) mapped about 95 percent of the bay floor pictured on this poster, and the National Oceanic and Atmospheric Administration (NOAA) mapped about 5 percent (in a wedge-shaped area opening to the northeast from Alcatraz Island). The data were collected from December 1996 to February 1997 with a Simrad EK600 90-kHz multibeam swath-mapping system. This system uses 80 independent beams in an arc to collect a swath of bathymetric and backscatter values. These values have been plotted on a 4-meter resolution grid of bathymetry and a 2-meter resolution grid of backscatter. All bathymetric values have been tide-corrected to mean lower low water using measured tide values. The surveys were navigated using a differential Global Positioning System (GPS). The data were collected under contract by C & C Technologies, Inc., of Lafayette, Louisiana. The multibeam image strips were processed into digital mosaics by the USGS using a software package developed by the Ocean Mapping Group of the University of New Brunswick, Canada. The digital image mosaics were post-processed and enhanced using USGS MIPS (Mini Image Processing System) software. (Not for navigational purposes. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.)