EARTH SCIENCE

Ocean Floor Is Laid Bare by New Satellite Data

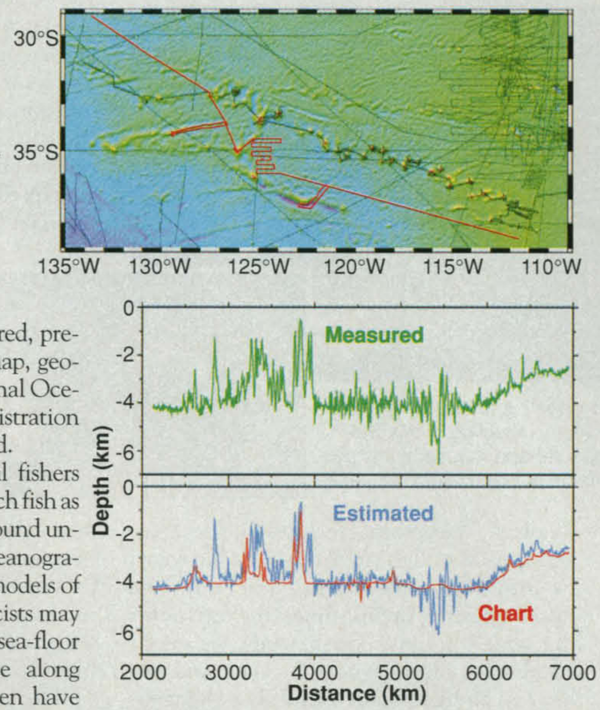
Just a few kilometers of water hide the ocean floor from view, yet its features are less familiar than those of the moon. Ships mapping the depths miss huge tracts of ocean floor; satellite measurements of gravity variations give only indirect clues to bottom topography. Now, a team of geophysicists has tried to remedy the shortcomings of both approaches by combining them. Using ship soundings to correct new and recently declassified satellite data, they have produced the most detailed global map of the ocean floor so far: a 68-million-pixel panorama described on page 1956 of this issue.

Some researchers are hailing the new database as our best view yet of this remote landscape, offering more than twice the resolution of the best previous global map. Others fault it for still failing to meet a cartographer's standard of literal accuracy. Either way, it won't be ignored, predicts one of the developers of the map, geophysicist Walter Smith of the National Oceanic and Atmospheric Administration (NOAA) in Silver Spring, Maryland.

With the new map, commercial fishers may find new locations to hunt for such fish as orange roughy, which congregate around underwater volcanoes (seamounts); oceanographers may be able to improve their models of the ocean circulation; and geophysicists may have to refine their views of the sea-floor spreading process that takes place along midocean ridges. The map may even have geopolitical uses: The view of the continental shelves it offers may allow some countries to define larger claims of territorial waters. "For a user who is aware of the drawbacks, it's a very useful database," says Steven Cande, a marine geophysicist at the Scripps Institution of Oceanography in La Jolla, California.

Nearly all experts in ocean-floor topography warn, however, that because the new map relies so heavily on satellite data, it should not be interpreted too literally. "The map looks stunning and does a great job of pinpointing the location and trends of underwater features—[but not] their amplitudes," says Andrew Goodwillie, a geophysicist at Scripps. "It can't be used for shallow-water navigation, because it is an estimate," adds Bill Haxby of Columbia University's Lamont-Doherty Earth Observatory in Palisades, New York, who produced similar but lower resolution gravity maps of the ocean in the mid-1980s with Smith's NOAA collaborator, David Sandwell.

The only way to obtain precise depths in the open ocean is with traditional bathymetry, in which a ship measures the distance to the ocean floor by bouncing sound waves off the bottom. Unfortunately, a ship can take soundings only in a narrow strip. "There are places as large as the state of Oklahoma where no sounding data are available," says Smith. Here the contours of the ocean floor have to be drawn



A better likeness. Compared to a traditional chart, "estimated topography" is a closer match to actual soundings along a track near Tahiti (*top*).

W.H.F. SMITH AND D. SANDWELL/NOAA

based on geological guesswork. "It's like drawing a map of a city, where you know a lot about one street, then nothing for 10 miles, then a lot about another street," says David Monahan, a geophysicist at the Canadian Hydrographic Service. "If there are buildings on one street and buildings on the other, you assume there are buildings in between."

A satellite, by contrast, covers a wide swath, but cannot sense the bottom of the ocean at all. Instead, it bounces microwaves off the surface to measure its shape, and the resulting pattern of lumps and bulges reflects what is underneath. A seamount, for example, exerts a small but measurable gravitational pull on the water around it, creating a bump 2 or 3 meters high that is easily detectable by a satellite. Smith and Sandwell were also able to take advantage of what Haxby calls a "quantum leap" in gravity mapping: new data from the European Space Agency's ERS-1 satellite and from Geosat, a U.S. Navy satellite. The Geosat data were collected from 1985 to 1986 but not fully declassified until 1995, after the ERS-1 data were released.

Unfortunately, "gravity is not bathymetry," as Goodwillie puts it. The satellite data can't reveal features smaller than about 12 kilometers across; converting the gravity data to depth runs into nonlinear complications in shallow water; and local variations in the density of the ocean floor can produce gravity anomalies mimicking those produced by seamounts. Sediments pose a special problem for satellite bathymetry. Because the basalt of oceanic crust is denser than sediment, a buried seamount or fracture zone will still show up in the gravitational field. So a geophysicist who relies on satellite data alone runs the risk of predicting a mountain where there isn't even a molehill.

To address these problems, Smith and Sandwell calibrated satellite measurements against ship measurements wherever possible. "We twisted arms all over the international community to get data," Smith says. When they knew both the ship depth soundings and the satellite gravity measurements at a certain place, they constructed a mathematical "transfer function" to convert gravity data into topography. They could then apply the same transfer function to the satellite gravity data over nearby regions that had not been covered by ship. The result was a "predicted bathymetry" for the whole region, with a resolution as fine as 1.1 kilometers at high latitudes.

In areas like the midocean ridges, where there is little sediment, Cande calls the map "spectacular." Among other things, it reveals discontinuities that apparently migrate along the ridges—a process not expected in traditional theory. Moreover, when Smith and Sandwell compared their predicted bathymetry near the Foundation Seamounts, southeast of Tahiti, to a hand-drawn bathymetric chart, they found that their map is better at capturing the texture of the ocean floor. A comparison with actual soundings from a ship survey this year showed, however, that some of the predicted depths were off by hundreds of meters.

Still, Smith points out that, satellite mapping has two great advantages: speed and uniformity of coverage. A committee convened by the U.S. Navy, he says, estimated that it would take more than a century of survey time by a state-of-the-art ship, at a cost approaching $1 billion, to fully map the oceans, says Smith, "There is some value in covering the world in 1 year for [Geosat's cost of] $60 million."

–Dana Mackenzie

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