# A New View of Earth

## Seeing the seafloor from space

By RICHARD MONASTERSKY

After years of craving better seafloor charts, marine geologists are now feasting on a rich diet of data from a recently declassified U.S. satellite and a separate European spacecraft. The measurements strip away the watery shroud hiding two-thirds of Earth's surface, revealing hitherto unknown features and sparking new scientific theories.

"Other scientists and I have been dreaming about having this set of data for 15 years," says David T. Sandwell of the Scripps Institution of Oceanography in La Jolla, Calif. "In the next few years, we will really see some discoveries," he predicted at a press conference in late October.

The satellite measurements have already prompted scientists to question basic geologic theories about how volcanic island chains form. At the same time, oil companies plan to use the data for finding offshore deposits of petroleum.

Oceanographers say the trove of satellite measurements will keep them sated for many years. "It is going to take a decade of hard work by geophysicists to milk it of all its information," says Charles D. DeMets of the University of Wisconsin-Madison.

The newly released data were collected by the U.S. Geosat satellite and by the European Space Agency's ERS-1 satellite. Because spaceborne sensors cannot peer directly through kilometers of water, both satellites studied the sea bottom by precisely measuring the height of the ocean surface. These measurements, combined with accurate tracking of the satellites' positions, allow scientists to deduce the local strength of gravity.

The broad hills and valleys of the ocean surface reflect the gravitational pull of rock at the seafloor. Submerged mountains 2,000 meters tall, for instance, attract water from surrounding areas, producing a gentle, 2-meter-tall bulge over the peak. Imperceptible to passengers on a boat, this swell stands out clearly in satellite gravity measurements.

At the October press conference, Sandwell and Walter H.F. Smith of the National Oceanic and Atmospheric Administration in Silver Spring, Md., unveiled a floor-to-ceiling global map, showing the ocean floor in unparalleled detail. From the gravity image, scientists can identify seabed features such as towering ridges and plunging troughs.

Funded by the Defense Department, the Geosat mission collected gravity data from March 1985 through October 1986. During the Cold War, the Navy deemed such measurements necessary for guiding submarine-launched missiles, which can be nudged off course by the slight gravitational tug of underwater mountains. The Navy kept most of the data classified.

After Sandwell and other marine geologists petitioned for access to the classified data, the Navy released bits and pieces. The Defense Department first declassified ocean areas around Antarctica and later all data south of 30°S.

Geosat measurements lost their strategic importance when ERS-1 began collecting unclassified data of equivalent quality. Three months after the ERS-1 mission ended in April 1995, the Navy released all Geosat results.

The deluge of data from the two satellites will fill in vast gaps on charts of the seafloor, says Smith. In the past, oceanographers have relied mostly on ocean depth measurements collected by research ships and on fuzzy gravity images taken by the short-lived Seasat satellite, which died in 1976 after only 3 months in orbit. Because ships have crossed only limited parts of the remote ocean, large regions remain unsurveyed.

"The typical hole between ship surveys is the size of Kansas. With the satellite data, we now have reduced those gaps to [an area] smaller than the District of Columbia," says Smith.

The satellite gravity images have already revealed some unusual geological formations that do not fit standard theories about the ocean floor. While studying bits of unclassified Geosat data in 1987, Sandwell and colleagues discovered hints of an extremely long volcanic chain extending for thousands of kilometers east of Tahiti. They later took a ship to the area and charted the chain, which they named the Pukapuka Ridges after an island in the chain.

The complete Geosat and ERS-1 data suggest that the South Pacific and other parts of the globe have many similar mountain ranges that were previously unknown. In fact, approximately half the volcanoes visible on the new map are uncharted, says Sandwell.

In the past, scientists would have identified the Pukapuka Ridges as a "hot spot" trail—a long burn mark made as the Pacific plate passed over a stationary hot spot in Earth's mantle. Like dragging a rug over a nail in the floor, this process creates a linear scar, which is studded with progressively younger volcanoes. The Hawaiian Islands, the most famous hot spot trail, are part of a chain of seamounts that continue to the northwest nearly to Siberia.

But the hot spot model cannot explain the Pukapuka Ridges. Rocks collected during the ship survey there show that widely separated parts of the chain erupted almost simultaneously. With a single hot spot beneath the ridge, distant volcanoes could not erupt at the same time.

Sandwell suggests that the Pukapuka Ridges formed because forces tugging on the Pacific plate stretched the ocean floor in this region. The plate thinned and cracked, allowing molten rock from below to erupt at the surface along volcanic ridges, Sandwell and his coworkers theorize in the Aug. 10 JOURNAL OF GEOPHYSICAL RESEARCH.

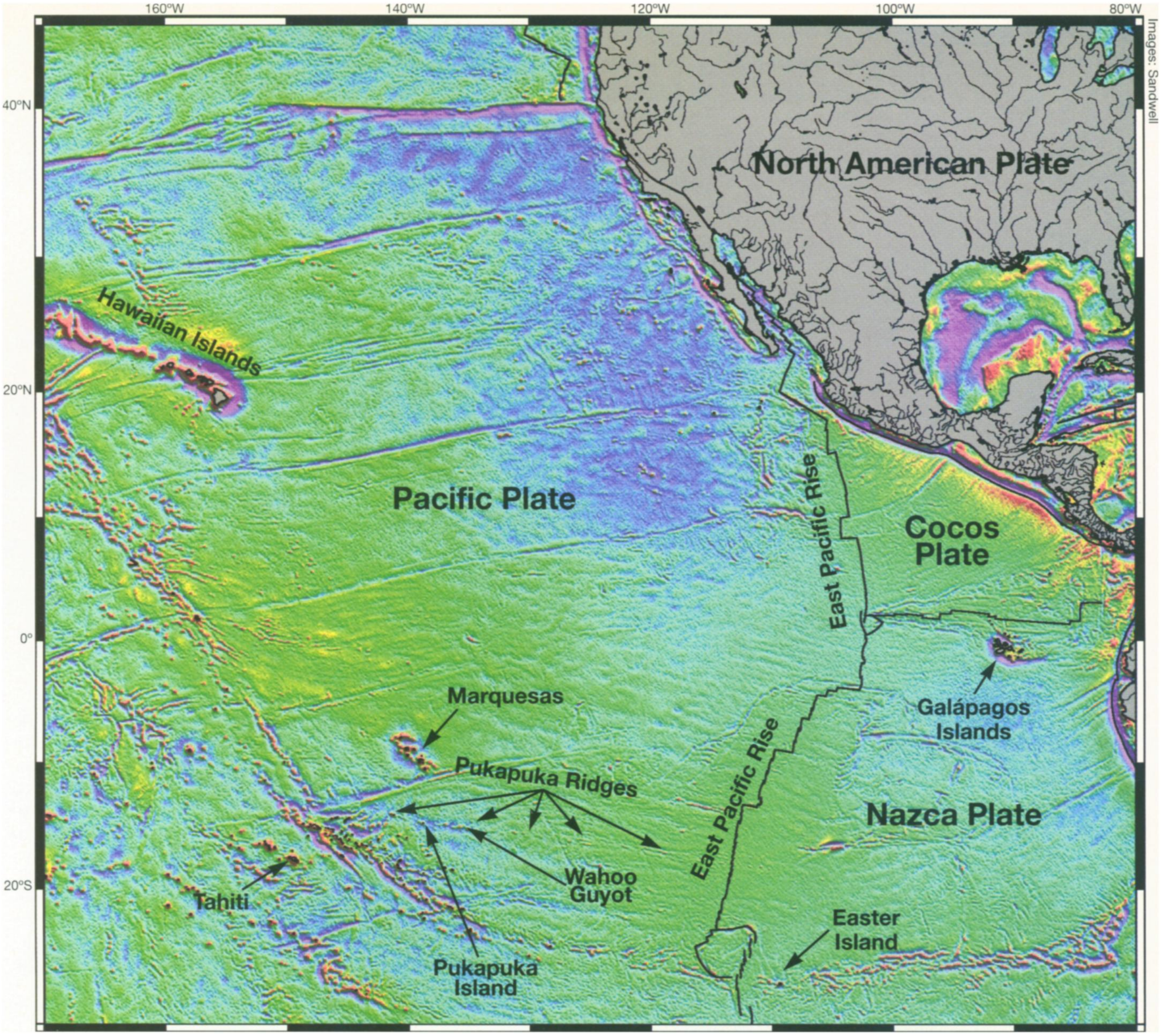
This discovery prompts Sandwell to wonder whether scientists have misidentified other mountain chains. "A lot of so-called hot spot traces might not be," he says.

The hot spot model is also drawing fire from other geophysicists. "From what I've seen in the new Geosat data, I think that most of the tenets of the hot spot model are wrong," says Marcia K. McNutt of the Massachusetts Institute of Technology.

The South Pacific, she notes, has many separate volcanic chains, each attributed to separate hot spots. But many of the chains line up inexplicably along the same track. "Before Geosat, people liked to downplay the problem. But now it looks like they all do that. We're no longer able to sweep this under the carpet. I think we really need to come up with new models for these things," says McNutt.

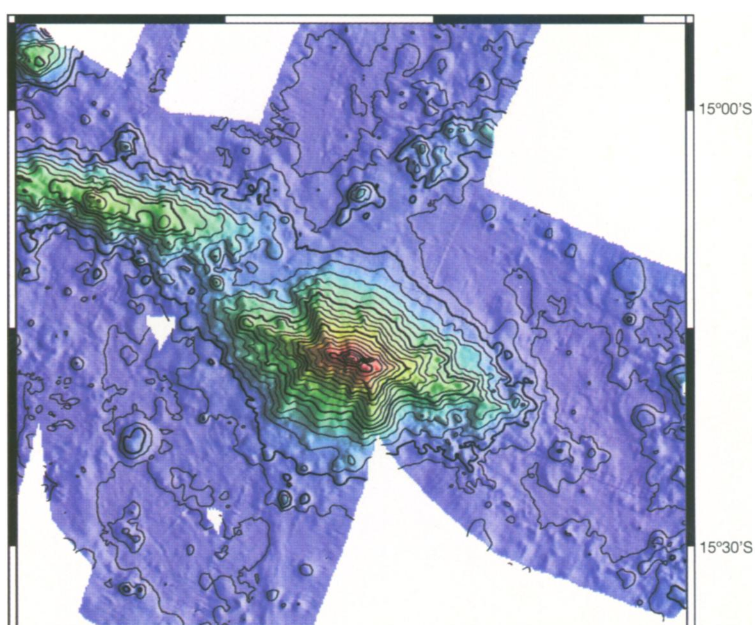
Even as they raise problems, the gravity measurements may also provide the path to a solution. The availability of the satellite data on CD-ROM and on the Internet opens up the field to a wide range of geophysicists, many of whom lack the funding for expensive ship surveys.

"They can now do world-class, cutting-edge oceanography anywhere in the oceans while sitting at a small teaching college somewhere in the middle of the country," says Smith. "It allows everybody to be an oceanographer." □




*Turmoil in the Pacific: Beneath placid waters, the ocean floor bears scars and scabs from the tectonic forces that shape the planet. This new map (above) comes from satellite measurements of Earth's gravity. Areas of enhanced gravity (yellow) are often linked to mountains and ridges on the seafloor. Gravity lows (purple) signal deep regions.*

*The parallel lines between North America and Hawaii are ancient faults called fracture zones, created by the process of seafloor spreading that gives birth to new ocean crust. Today, seafloor spreading goes on along the East Pacific Rise (denoted by a black line). In the South Pacific, previously unknown volcanic chains, including the Pukapuka Ridges, run across the map.*




*Gone fishing: Early Geosat data led oceanographers to explore the region east of Tahiti, where they discovered this seamount (right), which they named Wahoo Guyot, along part of the Pukapuka Ridges. Their bathymetric measurements revealed a flat-topped mountain rising 4 kilometers from the seafloor to within 380 meters of the surface. The peak (shown in red) provides a rich habitat for fish and lobster, according to a New Zealand fisherman who subsequently explored the area.*