OCEANOGRAPHY

Watery Echoes Give Clues to the Past and Future of the Seas

A handful of oceanographers and geophysicists are recording seismic whispers of the ocean's structure

Last spring, Katy Sheen listened to the sounds of the ocean from a ship off the coast of Spain. A relaxing vacation? Hardly. Sheen, a graduate student at the University of Cambridge in the U.K., is one of a handful of scientists adapting a technique called seismic profiling to oceanography. By observing the changing speeds of sound waves propagating through water, geophysicists and oceanographers hope to extract information about the ocean's temperature, salinity, and velocity.

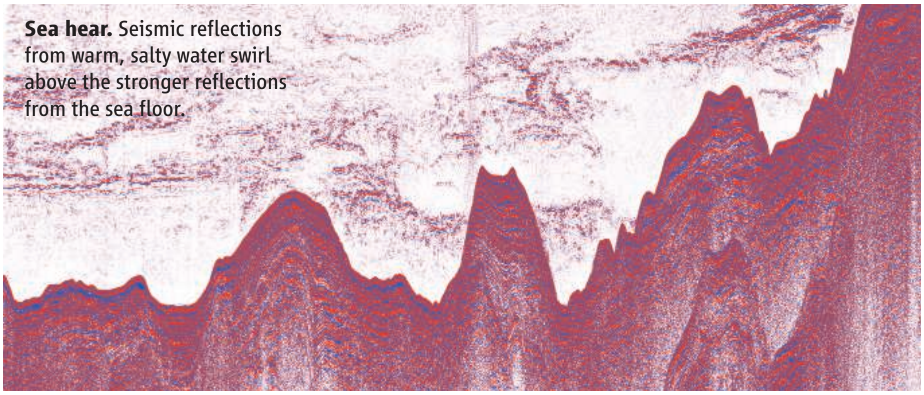
Geologists and oil companies have long used ship-based seismic profiling to probe density changes in the solid earth beneath the sea, but the technique of mapping the ocean's internal structure this way is less than a decade old. If efforts like Sheen's succeed as expected, scientists will gain a powerful new tool that could unlock the volume of the ocean to rapid and remote study, much as satellites did for the ocean's surface. "When satellite observations came along, the oceanographic community … said, 'Well, it's not going to tell us anything new,' but it did and it was important," says Nicky White of the University of Cambridge, Sheen's supervisor.

Particularly exciting, White and others say, is the prospect of tapping a jackpot of knowledge from decades of "legacy data" that energy companies have gathered while sounding sea floors in search of oil. The results could prove invaluable for measuring how the ocean's waters interact and assessing the impact of such mixing on past and future climate change.

First, however, ocean scientists must quantify the subtle ways sound waves veer and bounce as they pass through currents of differing temperature and salinity. Researchers plan to discuss results of their calibration cruises at this week's European Geosciences Union (EGU) meeting in Vienna. W. Steven Holbrook of the University of Wyoming in Laramie, whose team introduced seismic profiling as an oceanography tool in 2003, says he hopes EGU will provide "a real 'meeting of the minds' between seismologists and oceanographers."

To map ocean structure, oceanographers traditionally slow their ship to a crawl, lower instruments every 10 kilometers or so, and interpolate the data points. They have also tracked the spread of dyes, measured surface temperature by satellite, and anchored buoys for long-term observations of ocean currents. In 2000, Holbrook and his team began profiling the ocean with sound. By timing faint echoes from an array of seismic air guns towed behind a ship, they created sub-10-meter-resolution pictures of different water layers across large swaths of sea (*Science*, 8 August 2003, p. 821).

Oceanographers admired the pictures but challenged the geophysicists to put numbers on them. Since 2003, a handful of research cruises, including Holbrook's current U.S. National Science Foundation–funded efforts off Costa Rica, have sought to do that by combining seismic profiling with traditional oceanography. Sheen's 2007 voyage, for example, was part of the European Union–funded Geophysical Oceanography (GO) project led by Richard Hobbs of Durham University in the U.K. GO researchers tested new instruments and techniques aimed at collecting "a definite calibration data set," says Hobbs. One ship dropped instruments as often as every 2 kilometers behind an air gun–towing ship to obtain more detailed oceanographic data than have historically accompanied seismic profiles. Riffing on the geologists' "ground truth," John Huthnance of the Proudman Oceanographic Laboratory in Liverpool, U.K., says the GO project has given "sea truth to the seismic data."



Sea hear. Seismic reflections from warm, salty water swirl above the stronger reflections from the sea floor.

CREDIT: (DATA) TGS NOPEC; GO PROJECT, R. HOBBS, E. VSEMIRNOVA AND E. QUENTEL (UBO), DURHAM UNIVERSITY

Once seismic profiling has been fully calibrated, researchers say, terabytes of seismic records from past oil exploration will become ripe for reanalysis. Oil companies stored seismic data from the ocean, which was so much noise to them, in order to subtract it from the much stronger reflection profiles they made of the solid sea floor. "We can happily plug away at legacy data," says White. Mining old data would also bypass the enormous costs of new voyages, which Stephen Jones of Trinity College Dublin in Ireland says cost upward of $25,000 a day.

Legacy data sets aren't perfect. Until the late 1980s, hydrocarbon exploration was largely limited to shallow continental shelves, whereas oceanographers and climate researchers are most interested in ocean-mixing hot spots in deeper waters and at bottlenecks such as the Drake Passage and the Strait of Gibraltar. The biggest limitation on the legacy data is that the petroleum geologists who collected them didn't take enough oceanographic measurements. "There are lots of seismic reflection profiling sections available, but few of them have even a single temperature profile to tell us about the water column," says Raymond Schmitt of Woods Hole Oceanographic Institution in Massachusetts.

Even without completing all their calibrations, oceanographers have published quantitative studies of ocean mixing and in Vienna will discuss imaging eddies with sound. Aided by such progress, they are slowly persuading funding bodies to support seismic profiling despite initially "having some difficulty," says White; the U.K.'s Natural Environment Research Council rejected his and Hobbs's proposals three times. "It's natural to be hesitant to spend money on something which is a little bit unknown," says U.S. Navy oceanographer Warren Wood, a collaborator of Holbrook's, who has obtained internal funding from the Navy.

But Wood says he is "quite impressed by the first results of the GO project." White expects even more later this year, pending analyses by graduate students such as Sheen. For oceanographers, he concludes, seismic profiling "hasn't laid its golden egg, yet."

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