Tiny Bubbles

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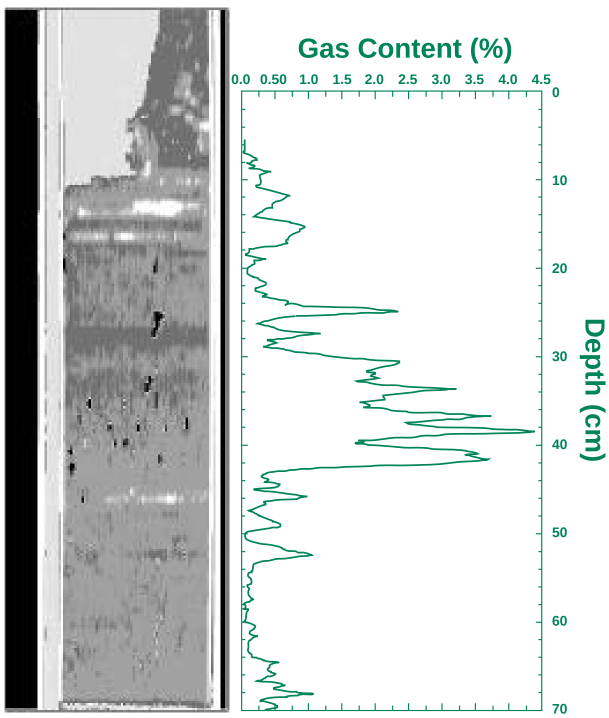
Scientists have long known that small bubbles of air have a strong effect on the propagation of sound waves in the ocean, largely due to the different physical properties of gases and liquids. Seafloor sediments can also contain gas bubbles which are usually filled with methane. The gas bubbles can absorb energy out of an incoming sound wave and redirect or scatter the energy in all directions. These bubbles have an impact on acoustic remote sensing systems, such as subbottom profilers and sidescan sonars, and subsequently affect our ability to identify and characterize the properties of the seafloor effectively. Part of my dissertation focused on gaining a better understanding of the effect of scattering of acoustic waves by small bubbles in seafloor sediments. I used acoustic-scattering computer models, seafloor sediment samples, and acoustic data.

My study was greatly enhanced by an experiment carried out in the spring of 1993 by the Naval Research Laboratory (NRL) as part of their Coastal Benthic Boundary Layer Program. This experiment took place in Eckernförde Bay, Germany on the Baltic Sea. In many parts of Eckernförde Bay biogeochemical processes (bacterial activity) cause layers of methane bubbles to form in the seafloor. These layers significantly affected the response of acoustic remote-sensing systems that were in use during the experiment. Sediment cores were taken in locations surveyed using NRL's Acoustic Sediment Classification System (ASCS). The colocation of cores and acoustic data allowed the perfect chance to use the core information in a bubble scattering model which could then be compared with the ASCS data.

To prevent gas in the bubbles from expanding as samples were raised, cores from Eckernförde Bay were sealed in pressure-tight containers on the seafloor then transferred to the surface where they were scanned using x-ray computed tomography (CT or CAT scans) while still under pressure. The CT-scan images of the cores showed the layers of bubbles as they existed when the sediment was in place on the seafloor. With information from the CT scans, the sizes, depths, and number of bubbles were determined. The bubbles measured between 0.5 millimeters (the smallest bubble a CT scan can discern) to 8.0 millimeters in radius. Most of the bubbles seen in the CT scans, especially the larger ones, were not spherical but coin shaped. These "coins" of gas were aligned vertically, rather than horizontally as expected, an attribute which remains unexplained.



This vertical section image reconstructed from CT scan data shows methane bubbles inside the sediment of an Eckernförde Bay core. The gas content (volume concentration %) is directly related to these bubbles.

The computer model I used to analyze the scattering of acoustic signals by bubbles differed in several aspects from models used to study bubbles in water. My model had to account for the stiffness that the sediment frame provided for the bubbles as well as their non-spherical shape. Using the model I discovered that a non-spherical bubble can have a larger scattering effect on acoustic signals than a spherical bubble of the same volume. Thus, a non-spherical bubble in sediment will appear to have larger volume than it actually has when surveyed acoustically. When included in an algorithm to account for contributions from all bubbles in the layers, model predictions of the return of acoustic signals agreed with ASCS data. Both showed long returns (in time) from the bubble layers and high attenuation within the layers. The acoustic response of the bubble layers over a range of frequencies calculated with the model showed that higher frequencies might penetrate a sediment better when its bubble distribution resembles that of Eckernförde Bay.

The study of scattering by bubbles in gassy sediments involved the interplay of theoretical and experimental work. In this case it was possible to construct a model of the seafloor which captured enough of the complexity of the real seafloor to simulate observed acoustic returns. Thus validated, the model is more open to testing. In this way greater insight into the interaction of sound with gassy sediments can be obtained. This can lead to better ways of remotely sensing sediments which contain gas bubbles or better ways to remotely sense the bubbles themselves if they are the object of interest. ❂

Editor's Note: Tony graduated from Texas A&M in May 1995 with a Ph.D. He works as a scientist for NATO's SACLANT Undersea Research Centre in La Spezia, Italy, where he continues to study the interaction of sound and the ocean environment. He can be reached at lyons@saclantc.nato.int.