SEASONAL VARIATIONS IN THE ACOUSTICAL PROPERTIES OF BLACK SILT IN THE NEW YORK AND NEW JERSEY HARBOR

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A black sediment, variously called anthropogenic sediment, harbor mud, ooze, "black mayonnaise," or black silt, is found in many industrial harbors and urban estuaries throughout the world. An example of this sediment from New York Harbor shows remarkable acoustic properties that effect sonar imaging of the bottom, and sonar and seismic imaging of the sub-bottom below the channel floor. The material appears to be a strong acoustic reflector, masking the hard bottom, in the summer and nearly acoustically transparent in the winter.

This 'black silt" material grades from a suspension at the water-sediment interface to an ooze to interbedded laminae with sands and muds. Black silt is widespread throughout the harbor, but patchy in distribution and varies greatly in thickness. Within the deeper channels the black silt is geographically separate from coarser sediments and commonly occurs as an ooze. On the shallow flats black silts are more commonly interbedded with coarser sediments.

Because the black silt is unsuitable for disposal at sea, harbor dredging, remediation and restoration projects depend on accurate mapping of the distribution and thickness of the black silt.

We have used distinctive acoustic properties to map the distribution of black silt in selected areas for production geophysical projects for harbor improvement in New York and New Jersey. The lateral extent of the black silt is mapped with orthosonographs at 400 kHz. The thickness of the black silt is measured through sub-bottom profiling at 4-24 kHz and reflection seismic surveys at 0.1-5 kHz.

In the summer, ultrasonic measurements indicate that some samples of black silt (ooze) have acoustic velocities significantly lower than seawater. In the winter and early spring the slowest velocities are in the range of seawater. In seismic profiles, the black silt appears almost a strong reflector with a negative polarity in the summer. The black silt is almost acoustically transparent with a positive polarity in winter.

Our measurements to date suggest a seasonal variation that is hypothesized to be controlled by temperature variations. In New York Harbor, the water temperature at West Bergen Point shows a periodic variation of near-surface water temperature from 0 to 25^{o}C.

A working hypothesis is that a primary component of the pore fluid is liquid hydrocarbons deposited from industrial processes over the past 200 years. The modulus of the hydrocarbon liquid in the pores varies differently with temperature than the harbor water.

The effect of temperature on the sound velocity of water contrasts with the effect on hydrocarbon. Wood's equation models the effective bulk modulus of a suspension as

$$\frac{1}{K_c} = \frac{1-\phi}{K_s} + \frac{\phi S_w}{K_w} + \frac{\phi(1-S_w)}{K_o}$$

in which K is bulk modulus, the subscripts c, s, w, and o refer to composite, solid grains, water and oil, respectively, Sw is the ratio of oil to water in the pores or water saturation, and ϕ is the porosity. The density, ρ, is estimated as

$$\rho_c = (1-\phi)\rho_s + \phi S_w \rho_w + \phi(1-S_w)\rho_o$$

We have plotted the velocity of the suspension as a function of water saturation and temperature. We find that the black silt as a function of temperature would be acoustically transparent in February and reflective in July.

Alternative hypotheses for the seasonal variation in behavior may be (a) gas/liquid phase from industrial hydrocarbons, (b) biologically generated gas, (c) seasonal runoff and water column effects, and (d) changes in sediment concentration in the suspension. The hypotheses are testable and separable by frequency dependence and other critical experiments.

These measurements also imply that the colder months are acoustically the best time to image through and below the black silt. The warmer months offer the best time to image the geographic distribution black silt when there is the strongest contrast between black silt and other sediment.