

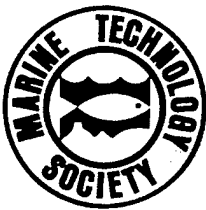
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<b>13. ABSTRACT</b> <i>(Maximum 200 words)</i> Several locations in the Chesapeake Bay were surveyed with an acoustic seafloor classification system to characterize and delineate areal distribution of surficial sediment properties. Predictions of acoustic impedance using this system provide a capability for initial assessment and prediction of sediment properties during the survey. Color-coded trackline maps created in real-time on a computer monitor represent estimated surficial sediment facies type and location. Analyses of the color-coded maps reveal a diversity of sediment types and distribution at each site and between sites. Thick sediment coverings are predominantly fine grained as identified by low intensity acoustic returns. Thin coverings consist of more dense, granular materials and are identified by higher intensity acoustic returns. Two locations south of the mouth of the Patuxent River and one near the mouth of the Choptank River consist primarily of fine and medium silts to silty clays. These sizes exhibit the lowest impedance levels on the trackline maps. Samples collected at one site slightly inside, and three sites north, of the mouth of the Patuxent River are composed of more dense, granular sands. Higher predicted impedances on the maps are indicative of dense sediments. Acoustically derived impedance predictions have been gridded and contoured to create a color-coded sediment facies province map at one of the sites. This province map provides a representation of relative sediment type and distribution at this site.			
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# SEDIMENT CHARACTERIZATION AND MAPPING USING HIGH FREQUENCY ACOUSTIC AND CORE DATA IN THE CHESAPEAKE BAY

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**Abstract** - Several locations in the Chesapeake Bay were surveyed with an acoustic seafloor classification system to characterize and delineate areal distribution of surficial sediment properties. Predictions of acoustic impedance using this system provide a capability for initial assessment and prediction of sediment properties during the survey. Color-coded trackline maps created in real-time on a computer monitor represent estimated surficial sediment facies type and location.

Analyses of the color-coded maps reveal a diversity of sediment types and distribution at each site and between sites. Thick sediment coverings are predominantly fine grained as identified by low intensity acoustic returns. Thin coverings consist of more dense, granular materials and are identified by higher intensity acoustic returns. Two locations south of the mouth of the Patuxent River and one near the mouth of the Choptank River consist primarily of fine and medium silts to silty clays. These sites exhibit the lowest impedance levels on the trackline maps. Samples collected at one site slightly inside, and three sites north, of the mouth of the Patuxent River are composed of more dense, granular sands. Higher predicted impedances on the maps are indicative of dense sediments. Acoustically derived impedance predictions have been gridded and contoured to create a color-coded sediment facies province map at one of the sites. This province map provides a representation of relative sediment type and distribution at this site.

## I. Background

The Naval Research Laboratory (NRL) and the Naval Facilities Engineering Service Center (NFESC) conducted a series of seafloor studies in the Chesapeake Bay, using a high-frequency acoustic subbottom profiling system, several geotechnical tools, and sediment cores. Operations were conducted out of Solomons, MD aboard the State of Maryland vessels R/V Elser and

R/V Discovery for approximately ten days in August 1994.

The objective of the study was to evaluate these geologic and geotechnical measurement techniques for rapid assessment of seafloor properties in real-time while underway. This area provided a diverse array of sediment types commonly found in shallow-marine areas within a relatively limited geographic region.

## II. Setting

Site locations are indicated by a (X) in Fig. 1. As shown, all sites are located in the northern (Maryland) section of the bay. One site is located in the Choptank River on the eastern side of the bay near Cook Point, three are north of the Patuxent River, one is near the mouth of the Patuxent River (third X from the bottom) and two are south of the Patuxent River.

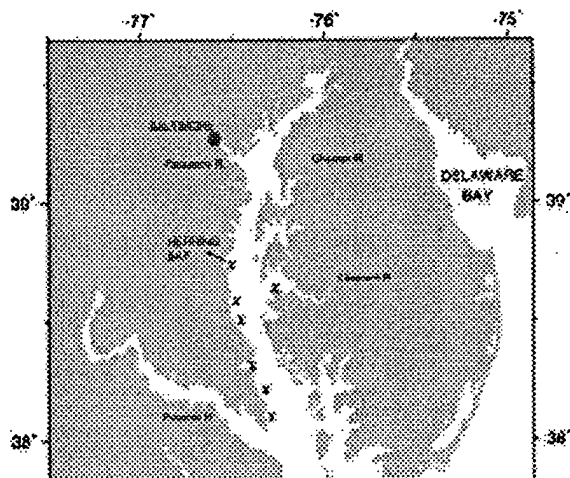


Fig.1. Location of seven study sites within the Maryland portion of the Chesapeake Bay.

### III. Methods

The primary acoustic system used for this work, the NRL Acoustic Seafloor Classification System (ASCS), is a normal incidence, narrow beamwidth, multi-frequency, high-resolution, digital acoustic profiling system that records and displays raw acoustic water column, bottom, and subbottom data in real time. It is typically operated using a short pulse length (0.1 to 0.3 milliseconds) with a narrow-beam transducer ( $12^\circ$  at 15 kHz). Algorithms based on multi-layer acoustic theory (Clay and Medwin 1977) are used with the acoustic reflection to compute acoustic impedance for ten sediment column depth intervals in near-real time (Lambert 1988).

Acoustic impedance is used to estimate the amount of energy reflected from a boundary when a sound pressure wave passes from a medium of one impedance to a medium of a different impedance (Hamilton and Bachman 1982).

Each acoustic ping and its associated position is continuously mapped on a computer monitor in a color corresponding to the predicted value of surficial sediment impedance at that geographic location. This produces a map of the ship tracks that are color-coded in accordance with values of acoustic impedance (Fig. 2a).

The acoustic impedance data is used to predict various sediment properties by using previously developed empirical relationships established by Hamilton (1980) and Hamilton and Bachman (1982). The ASCS software to relate acoustic impedance to sediment property values uses these regressions. Samples of these relationships are presented graphically in Fig. 2b. To use them, select a location along the track in Fig. 2a, determine the track color at that location and then use the same color on the sediment property color scales (Fig 2b) to estimate the sediment property.

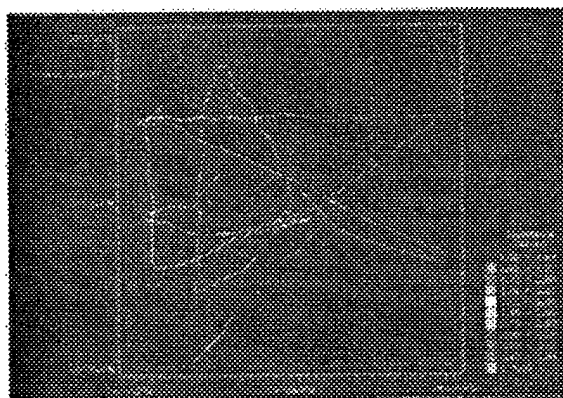
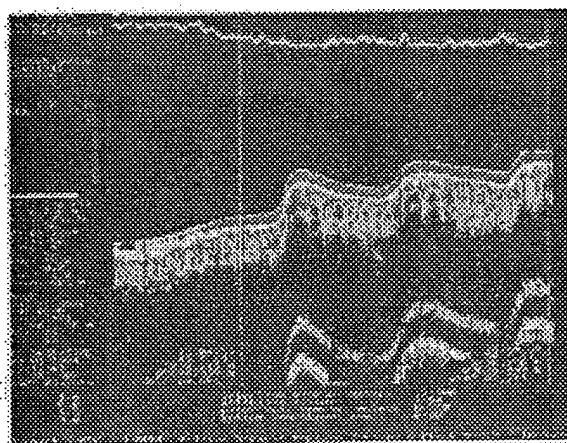
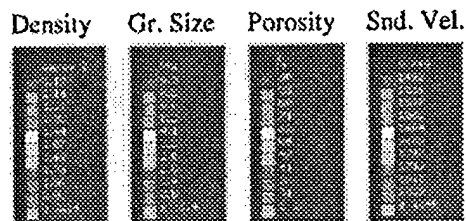


Fig. 2. (a) Color navigation map of Plum Point survey area. Center coordinates are  $38^\circ 36.4'$  N. and  $76^\circ 29.0'$  W. Track crossings near core location are denoted by white circle.

#### (b) Sediment Property Color Scales



↑ Approximate core location

Fig. 3. Acoustic imagery obtained near location of core site off Plum Point. Solid, horizontal lines indicate depth scale at 5m intervals. The distance between the two vertical event marks is approximately 750m.

Sediment core samples were obtained by two methods, depending on bottom type. Gravity cores were obtained in the soft areas using a 3-m long by 7.79 cm. (Inner) diameter PVC core tube. Hard bottoms were cored using a vibratory coring apparatus with the same PVC pipe lining the aluminum coring pipe. Samples were analyzed for wet bulk density, porosity, water content, sound velocity, grain size/composition and distribution.

#### IV. Results and Discussion

Acoustic images and color-coded trackline navigation maps provide both a qualitative and semi-quantitative view of sediment type in selected areas surveyed during the summer of 1994. As discussed above, the combination of the track line navigation maps with the acoustic imagery provides a capability to estimate sediment properties as well as delineate property boundaries in real-time.

This is demonstrated by examining Figs. 2 and 3 in unison. Fig. 3 presents the subbottom record as the vessel transits along one of the tracks illustrated in Fig. 2a. The white circle denotes the location of the core site. The yellow vertical event mark at the left center of Fig. 3 also illustrates the closest passage of the vessel to the core site.

The color scale at the right portion of Fig. 3 represents the intensity of the acoustic signal from 96 dB at the top to 0 dB at the bottom. Inspection of the acoustic data shows that the signal intensity increases as the vessel proceeds into shallow water. The light blue lines at the top of the image are also analogous to the signal intensity for the previously described (ten) sediment increments. A noticeable increase in the separation of the lines away from the top of the image occurs just before the left event mark, indicating a "hardening" of sediments

along track. This feature is further illustrated by the change of color at the sediment water interface from yellow/red at left to purple at the core site and beyond. This is a classic representation of a bottom that transitions from a sandy mud to a dense sand. Core analysis indicates an average sediment wet bulk density of  $2.00 \text{ g/cm}^3$ , mean grain size of 1.88 phi, 38.7% porosity, and 1707m/sec sound velocity for the upper 0.48m at this location. Percent size fraction was dominated by granular/sand sizes in excess of 86%. Gravel and fine silt and clay sizes were equally represented near 7% each. Shear strength measurements were not obtained in these granular, non-cohesive, sediments. Calculated acoustic impedance (sound velocity [c]) \* wet bulk density [ $\rho$ ]) for this core is  $3.4 \times 10^6 \text{ kg/m}^2 \text{ sec}$ . Using the Wentworth (1922) size class scale these sediments are described as medium sands.

Reviewing the acoustic track data in Fig. 2a, the circle is located over a color (red2) that is associated with an impedance value in the range of  $3.29\text{-}3.62 \times 10^6 \text{ kg/m}^2 \text{ sec}$ . Using the sediment property color scales in Fig. 2b, empirically derived estimates of sediment properties are within the following ranges; wet bulk density  $\approx 1.91\text{-}2.03 \text{ g/cm}^3$ , grain size  $\approx 0.5\text{-}1.4 \text{ phi}$ , porosity  $\approx 31\text{-}36\%$ , sound velocity  $\approx 1815\text{-}1829 \text{ m/sec}$ , and acoustic impedance  $\approx 3.29\text{-}3.62 \times 10^6 \text{ kg/m}^2 \text{ sec}$ .

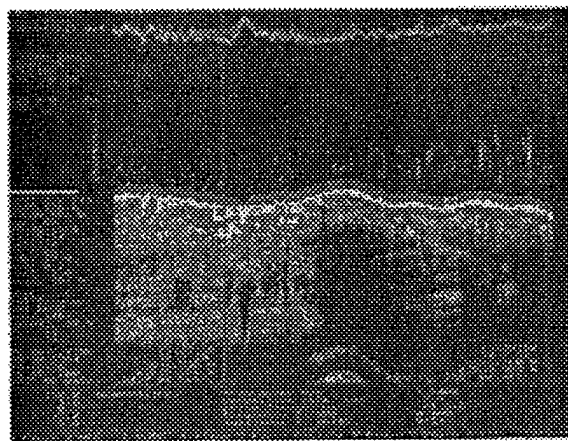
Analysis of the acoustic data from the six other study sites followed the same procedure of identifying the track color at or near the core location to acquire an estimate of the sediment property. Table 1 provides a summary of the sediment property values obtained from core samples and the associated acoustically predicted ranges in proximity to these sites.

Table 1. Core measured properties and ASCS estimates obtained from color-coded navigation plots at all Chesapeake Bay sites. Sites are listed in descending order from high to low values of core measured sound velocity.

	velocity (m/sec)		density g/cm <sup>3</sup>		imped (10 <sup>6</sup> kg/m <sup>2</sup> sec)		gr. size (phi) (Wentworth Term)		porosity (%)	
	Core	ASCS (trk color)	Core	ASCS (trk color)	Core	ASCS (trk color)	Core	ASCS (trk color)	Core	ASCS (trk color)
<b>Pkr Crk</b> 0-40cm	1751	1560-1604 (green 2)	2.23	1.32-1.44	3.91	2.01-2.22	0.7	4.1-5.2 CsSand CsSilt	24.7	62-71
<b>Plum Pt.</b> 0-40cm	1707	1815-1829 (red 2)	2.00	1.91-2.03	3.41	3.29-3.62	1.9	0.5-1.4 M.Sand Cs/M.Sand	38.7	31-36
<b>Hog Isl.</b> 0-40cm	1673	1815-1829 (red 2)	2.01	1.91-2.03	3.36	3.29-3.62	2.8	0.5-1.4 F.Sand Cs/M.Sand	38.2	31-36
<b>Holl Pt.</b> 0-40cm	1544	1604-1670 (yellow 1)	1.51	1.44-1.57	2.33	2.22-2.44	5.4	3.2-4.1 M.Silt vfSa/Cs Silt	66.0	54-62
<b>St. Jer.</b> 0-40cm	1518	1560-1604 (green 2)	1.44	1.32-1.44	2.19	2.01-2.22	6.2	4.1-5.2 M.Silt Cs/M.Silt	72.6	62-71
<b>Biscoe</b> 0-40cm	1510	1492-1516 (blue 1)	1.37	1.1-1.14	2.07	1.50-1.64	8.0	8.2-9.3 vf/silt/cl vf/silt/cl	78.1	89-95
<b>Cook Pt.</b> 0-40cm	1481	1560-1604 (green 2)	1.40	1.32-1.44	2.07	2.01-2.22	7.3	4.1-5.2 fSilt Cs/M.Silt	74.7	62-71

Core samples from the upper three sites listed in Fig. 1; Parker Creek, Plum Point and Hog Island have sediments that are dominated by granular materials, having combined gravel and sand fractions in excess of 88%. The Holland Point and St. Jerome samples have less granular content with gravel and sand fractions below 35%. Silt and clay fractions are in excess of 65% in these samples. Samples from the softest sites, off Biscoe Pond and Cook Point are dominated by silt and clay fractions at greater than 87% each. Gravel and sand fractions here are 13% or less.

Fig. 4 illustrates an acoustic profile obtained along a track near the core site at Holland Point (yellow event mark in the left portion of the image). Note the mottled nature of the acoustic return below the seafloor at left and the slight decrease in signal intensity towards the right side of the image.



↑ Approximate core location

Fig. 4. Acoustic imagery obtained near location of core site off Holland Point. Solid, horizontal lines indicate depth scale at 5m intervals. The distance between the two vertical event marks is approximately 750m.

Fig. 5 presents the color-coded trackline map of acoustic impedance obtained along this track. The black circle indicates the location of the core site. Based

on the core data presented in Table 1, the sediment here is described as medium silt (5.4 phi), consisting of 40% clay, 20% silt, 25% sand and 14% gravel sizes. Core measured impedance is  $2.33 \times 10^6 \text{ kg/m}^2 \text{ sec}$ . The acoustic impedance prediction obtained from the trackline map at the circle is in the  $2.22 - 2.44 \times 10^6 \text{ kg/m}^2 \text{ sec}$  range.

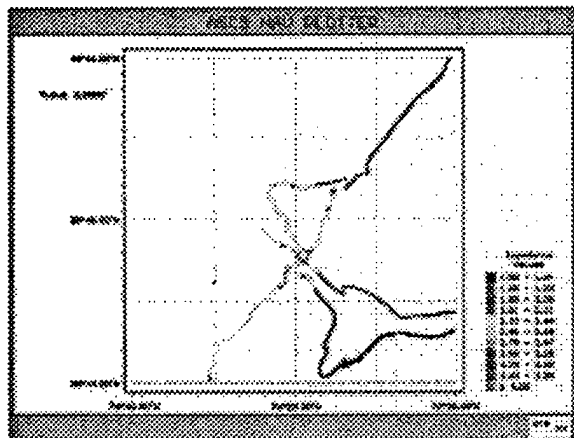


Fig. 5. Color navigation map of Holland Point survey area. Center coordinates are  $38^{\circ} 45.0' \text{ N}$ , and  $76^{\circ} 29.8' \text{ W}$ . The black circle denotes the location of the sediment core sample.

There is a transition in sediment properties indicated by the change in acoustic response at the center portion of Fig. 4. The image represents a portion of the track that lies northeast of the core location indicated on the map. The bottom property transitions are illustrated by the change in color along this trackline. Inspection of the color scales in Figs. 4 and 5 indicate that the sediments have a lower impedance as this track progresses further to the northeast.

After completing the survey, a pseudo-3D map was created by draping the contoured impedance surface over the seafloor bathymetry. This map delineates the hard (sand and consolidated clay) and soft (mud) sediment facies of the surficial sediment cover (0.0-0.4m) at the Holland Point study site (Fig. 6).

As indicated in this map, the core was obtained at the edge of the light yellow, high impedance zone. This bottom type is most prominent in the northwest sector, whereas the sediment cover to the east is predominantly soft as indicated by the low impedance blue color on the map. Examination of the subbottom records along tracks to the northeast and southeast of the core location validate this observation. This transition is indicated in both the trackline map (Fig. 5) and the contour map (Fig. 6) by the color changes along the northeast and southeast tracks.

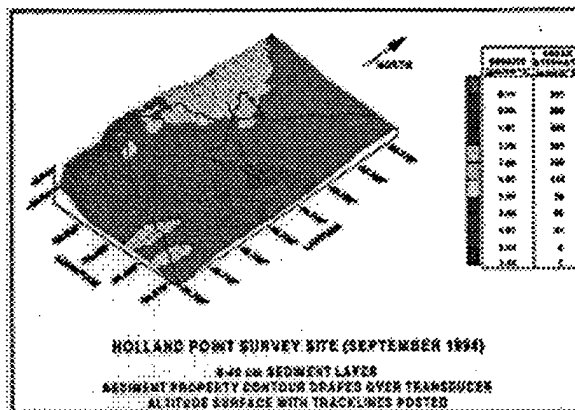


Fig. 6. Color contoured map of acoustic impedance for the surficial sediments (0.0-0.4m) at study site off Holland Point. A circle denotes the approximate location of the core site.

## V. Conclusions

In general, a comparison of the core measured property values with the predicted values in Table 1 shows good agreement. All of the core calculated impedance values fall within the predicted impedance ranges except for the Parker Creek and Biscoe Pond data. The core location at the Parker Creek site lies approximately 35m north and 24m east of the vessel track. However, all sites were surveyed using standard SA code (Selective Availability) GPS for navigation because differential GPS receivers were not part of the system at that time. Intentional errors are introduced into SA/GPS

measurements that could account for the position anomalies between the ASCS tracks and the core locations. Although a subbottom image along the track south of the core site at Parker Creek shows a 70m wide bottom exposure of high impedance sand, the high impedance return is only observed for a few pings. It is very likely that the cores and ASCS data are not truly co-located and, given the areal variability of these sediments indicated by the ASCS imagery, it is likely that a comparison the two data sets at these sites is not feasible.

In addition, the empirical regressions used for deriving the sediment properties were originally developed using core data from deep, continental terrace sites. It is highly likely that new regressions are required for confident quantitative use of this technique. This is particularly evident in reviewing the sound velocity comparisons, which are predicted consistently high by the ASCS. Obviously, further work is required to develop more confident relationships between acoustic impedance and these sediment properties in shallow, nearshore, especially estuarine, environments.

The color-coded tracklines of acoustically predicted impedance can however provide a rational representation of surficial sediment type and distribution within the boundaries of a surveyed area. The relatively good correlation of wet bulk density and porosity at the other sites substantiates this observation. In addition, although the grain size ( $\phi$ ) values are not exactly matched, they are for the most part in a comparable Wentworth size class. Some variation is expected due to the combined effects of sediment spatial variability and positioning variance between the actual core locations and the acoustic survey lines.

Using either the core data or the ASCS predictions, the sites may be divided into two separate categories: i.e., the hard, granular sediments in and north of the Patuxent River, Hog Island, Parker Creek and Plum Point; and the soft, fine grained, cohesive sediments south of the river, St. Jerome, Biscoe Pond and Cook Point.

Analysis of the impedance trackline maps also indicates that all of the sites except Cook Point have medium to coarse sands on the shoreward side with a fining and thickening trend offshore into deeper water. Sediment cover thickens and softens towards the axis of the bay.

#### Acknowledgments

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