Stratigraphic and Geoacoustic Characterization of the Outer New Jersey Shelf

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LONG-TERM GOALS

As a participant of the ONR Shallow Water Acoustics experiment conducted on the outer New Jersey shelf during the summer of 2006 (SWA06), the long term goal of this project is to understand the interaction of acoustic energy, at both medium and low frequencies, with the seabed.

OBJECTIVES

The objectives of this work are to (1) incorporate existing geological, geophysical and geoacoustic data into a seabed properties model applicable to the SWA06 experiment region, and (2) geologically interpret additional chirp seismic data that were collected as part of SWA06 (Altan Turgut, PI), and incorporate into existing interpretation based on analysis of prior data (primarily from the ONR Geoclutter program).

Expected products include:

(1) A structural/stratigraphic model of the subbottom, along primary acoustic propagation pathways of the SWA06 experiment and regionally with existing and newly collected chirp seismic data.

(2) A geologic interpretation of the regional stratigraphy based on both new and existing chirp seismic data and available ground truth information. This interpretation will focus on the outer shelf wedge (OSW) that forms the seafloor substrate over most of the SW06 experiment region.

(3) A geoacoustic rendering of the structural model based on predictive relationships between such properties and the stratigraphic/geologic interpretation. Available physical property measurements will be used to constrain such relationships.

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APPROACH

Seafloor and subseafloor data readily accessible to the PI (Figure 1) are listed below:

(1) Swath bathymetry and backscatter data were collected in 1996 as part of the STRATAFORM program (Goff et al., 1999) and more recently as an add-on to the Geoclutter program. The backscatter data derived from 95 kHz acoustic frequency. Ground truth data demonstrate that, in this region, these data are primarily responsive to the coarse content at the seabed (Goff et al., 2004). Combined analysis with chirp data has also revealed how the seabed morphology can be used to infer the locations of significant seabed erosion (Goff et al.,2005).

(2) Chirp seismic reflection data were collected in 2001 and 2002 for the Geoclutter program (Nordfjord et al., 2005; Gulick et al., 2005). These data have been interpreted structurally. Furthermore, along main dip transects of the 2001 data set, Dr. S. Schock (FAU) has derived seafloor impedance values for 1-4 kHz data (Goff et al., 2004).

(3) Grab samples were collected as part of both a JOI site survey augmentation grant (Goff et al., 2000) and the Geoclutter program (Goff et al., 2004). These samples have been analyzed for grain size distribution.

(4) At the locations of the 2001 grab samples, measurements of in situ velocity at 65 kHz were collected by colleagues at the University of New Hampshire. These values were shown to be correlatable to the mean grain size determined from the grab samples and to the seafloor impedance values derived from the chirp data (Goff et al., 2004).

(5) Three long cores were collected in 2002 using the AHC-800 drilling system. These cores are located within the chirp seismic data. They were analyzed for geologic structure and logged for the geoacoustic properties of velocity and density (Nordfjord et al., 2006).

(6) Additional cores were collected summer 2007 on the New Jersey outer shelf under a separately-funded ONR grant (Figure 1). These cores were located within the context of the Geoclutter and SW06 chirp surveys, and logged for velocity and density.

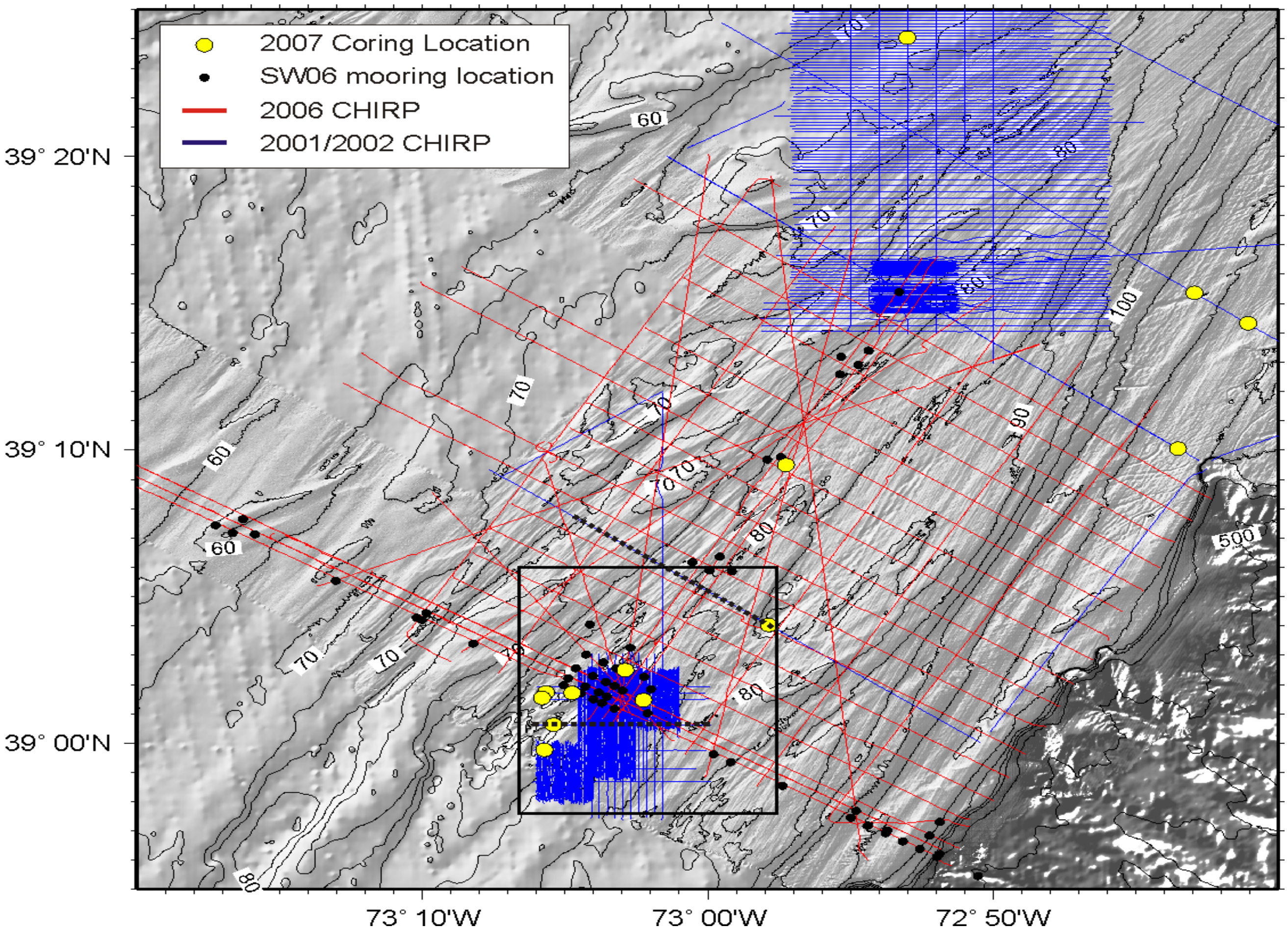

Figure 1. Location of recent chirp seismic reflection data and core locations, superimposed on multibeam bathymetric map of the NJ outer shelf. The region of the SW06 experiment is defined by the mooring locations.

The primary objective of this work is to develop a structural model of the seabed and subsurface along the SWA06 propagation pathways, and to populate that model with measured and predicted geoacoustic properties. The structural model will be based upon the interpreted seismic horizons derived both from the 2001/2002 Geoclutter and 2006 SW06 chirp data. Most of the 2001/2002 Geoclutter chirp data have been interpreted by UTIG colleagues, and exist, along with seismic data, within a Geoframe (a commercial seismic interpretation software package) data bases that reside at UTIG. The 2006 chirp data have been processed and also loaded into the same Geoframe project, and have been interpreted in the same context.

The new chirp data (Figures 2 and 3) should provide an important geologic product: a structural connection between the northern and southern sectors of the 2001/2002 chirp data (Figure 1). Populating any structural model with geoacoustic properties will pose a significant challenge, given the constraints on collecting new ground truth data for the SWA06 project. Physical property measurements, of course, will be used as much as possible. These include: *in situ* measurements at the seabed, core logs, geoacoustic inversion (Holland et al., 2005), and impedance values estimated from chirp seismic data. However, available measurements are limited, particularly along the planned dip and strike lines for the SWA06 experiment, and also particularly at depth below the seafloor. Some form of prediction will be required. The expectation here is that the geologic interpretation of the stratigraphic structure will guide the prediction. Guided by available ground truth and inference from chirp seismic, the PI will, in close collaboration with SWA06 participants, seek to formulate geoacoustic model for the primary geologic units that takes into account spatial variability (both laterally and with depth) as well as mean properties. This model will then form the basis for filling the structural model with geoacoustic properties.

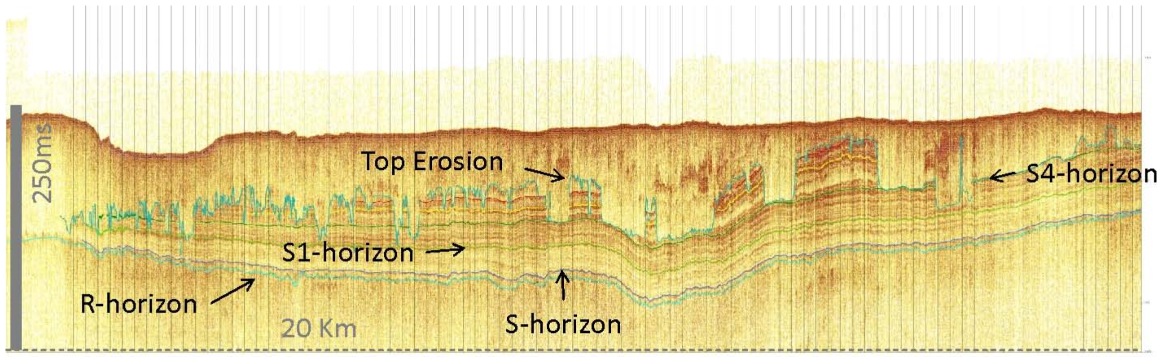

Figure 2. Regional CHIRP seismic strike profile (southwest-to-northeast), from the 2006 SW06 CHIRP survey, illustrating primary stratigraphic components of the outer shelf wedge underlying the SW06 experiment region.

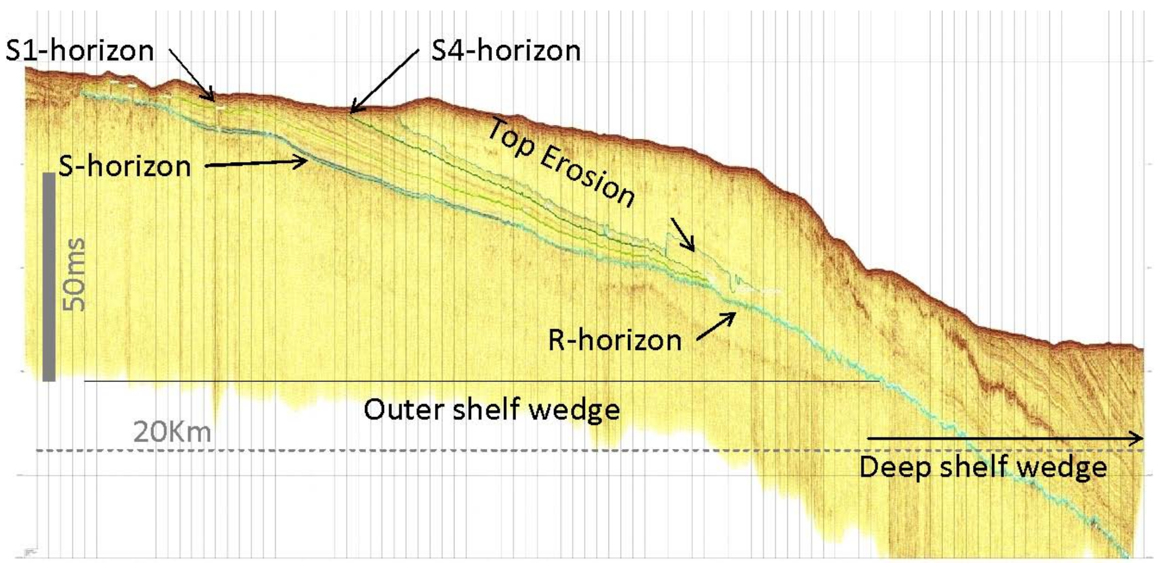

Figure 3. Regional CHIRP seismic dip profile (northwest-to-southeast), from the 2006 SW06 CHIRP survey, illustrating primary stratigraphic components of the outer shelf wedge underlying the SW06 experiment region.

WORK COMPLETED

Turgut and Goff successfully completed the SW06 chirp survey in July of 2006. The survey utilized the NRL-owned Edgetech 1-16 kHz chirp system during a 9-day cruise aboard the *R/V Sharp*. Completed survey lines are displayed in Figure 1, along with locations of the primary acoustic deployment. Two priorities were identified for the planned track lines: (1) along primary acoustic propagation pathways for SW06 experiment (phase 1), and (2) a regional grid survey (phase 2) to enable the SW06 region to be placed within the geologic and stratigraphic context of our understanding of Areas 1 and 2. Despite some technical difficulties with the main tow cable in the beginning of the survey, we successfully surveyed all the phase 1 track lines and all but three of the phase 2 lines.

Over the previous several years, the PI has formulated a 3-dimensional structural model of the subsurface stratigraphy and geoacoustic properties. Initial modeling work focused on a smaller region focused on the axis of the SW06 experiment. This effort was detailed in the previous progress report. Since then, the model has been expanded to include most of the CHIRP coverage shown in Figure 1. The structural models have been used by a number of SW06 acousticians in their work: Knobles, Dahl, Ballard, Chapman, Frisk and Potty. Goff has co-authored papers with Knobles, Dahl, and Ballard.

New geoacoustic logging results are also now available from the 2007 coring cruise. These results were also detailed in the previous planning letter. In addition, we now have a substantial number of radiocarbon age constraints from the outer shelf wedge sediments, which help us to constrain the depositional history.

Stratigraphic interpretation of the chirp data are being conducted by Goff and a student of the University of Texas, Manasij Santra, who is working on this project for his thesis. Major structural horizons have been completed, and characterization of the internal stratigraphy of the OSW is complete. New results from this work, detailed below; a paper is currently in preparation peer-review publication.

RESULTS

Geologic Characterization of the New Jersey Outer Shelf Wedge (Santra et al, manuscript in preparation)

Pleistocene sediment wedge on outer New Jersey Shelf has been studied in the past using a variety of data including high resolution shallow seismic data, core data and biostratigraphic information. Milliman et al. (1990) described the geometry and thickness variation of the outer shelf sediment-wedge that overlies the widespread regional reflector known as the R-Horizon. Assuming R-horizon to be representative of an erosional unconformity formed during the last eustatic sea level fall event, Milliman et al. (1990) attributed the origin of this sediment wedge to sediment supplied by reworking of Hudson Apron which was in turn supplied by large glacial melting event between 18 and 13 Ka. Subsequent to the findings by Milliman et al. (1990) several studies have been published based on new shallow seismic surveys, biostratigraphy and C^{14} age data (Knebel et al., 1979; Davies et al., 1992; Duncan et al., 2000; Alexander et al., 2003; Gulick et al., 2005; Goff and Austin, 2009) that reinterpreted the stratigraphic position of R-horizon and that of the Pleistocene sediment-wedge(s) under the present-day outer New Jersey shelf. Consequently, a different depositional model for these sediment wedge has been put forward (Gulick et al., 2005). Gulick et al. (2005) highlighted the presence of two distinct sediment wedges with offlapping stacking pattern and named these wedges as the 'Outer Shelf Wedge' (more proximal of the two wedges) and the 'Deep-shelf Wedge' (distal) respectively. Gulick et al. (2005) attributed the origin of the wedges to erosion and re-deposition of sediments controlled by two inflection zones on R-horizon that can be observed below present day 75m isobath (approx.) and 100-115m isobath respectively. This depositional model for the wedges does explain the inverted age observed from C^{14} dating (Gulick et al., 2005) but it does not adequately explain the processes and the sediment sources that contributed to the origin of these areally extensive and volumetrically significant depositional features. The total length of progradation associated with these wedges appear to be as much as 20km. Exclusively erosion and redistribution of sediments, without contribution from a terrestrial sediment-source (e.g., a river) appears to be an inadequate explanation for the extent of progradation associated with these sediment wedges. The two-fold subdivision of this sedimentary unit into ‘Outer Shelf Wedge’ and ‘Shelf Edge Wedge also needs a re-evaluation as we observe that this unit consists of at least four partially preserved clinothems marked by change in foreset-gradient and also by possible change in direction of progradation.

On the basis of observation made from detailed mapping of the R-horizon and the overlying sediment wedge using additional high resolution CHIRP acquired in 2006 (Figure 4), we reinterpret the depositional model for the offlapping sediment wedge as a falling stage shelf-edge delta system fed by possible pre-LGM paleo-Hudson River Channel(s). The sediment wedge is composed of several prograding and offlapping clinothems. Within our dataset, which does not extend down to the basinward end of the wedge, we do not observe any preserved topset. Significant parts of the foresets of these clinothems are also not preserved, which is particularly distinct in the proximal part of the wedge. The sediment wedge appears to be highly strike-elongated (Figure 4), which does indicate along strike redistribution of sediment by processes like longshore current. Within our dataset we do not observe time-equivalent fluvial channels at the proximal end of the sediment wedge. This can be attributed to two possible factors, including (1) relatively large spatial separation between the deltaic wedge and the fluvial deposit under a falling stage sea-level condition; and (2) lack of preservation of the stratigraphic record of the channels resulting from continued erosion of the topset during the falling stage of sea level and possibly also during the subsequent flooding event after the last glacial maximum. The clinothems within the sediment wedge show systematic variation in thickness, indicating a northward shift of main depocenter (Figure 5). This northward migration of depocenter might also be an indication of gradual north-ward migration of the location of principle fluvial sediment-input. This possibility is supported by the presence of possible paleo-Hudson Channel deposits reported by Knebel et al. (1979) south of present-day Hudson Shelf-Valley.

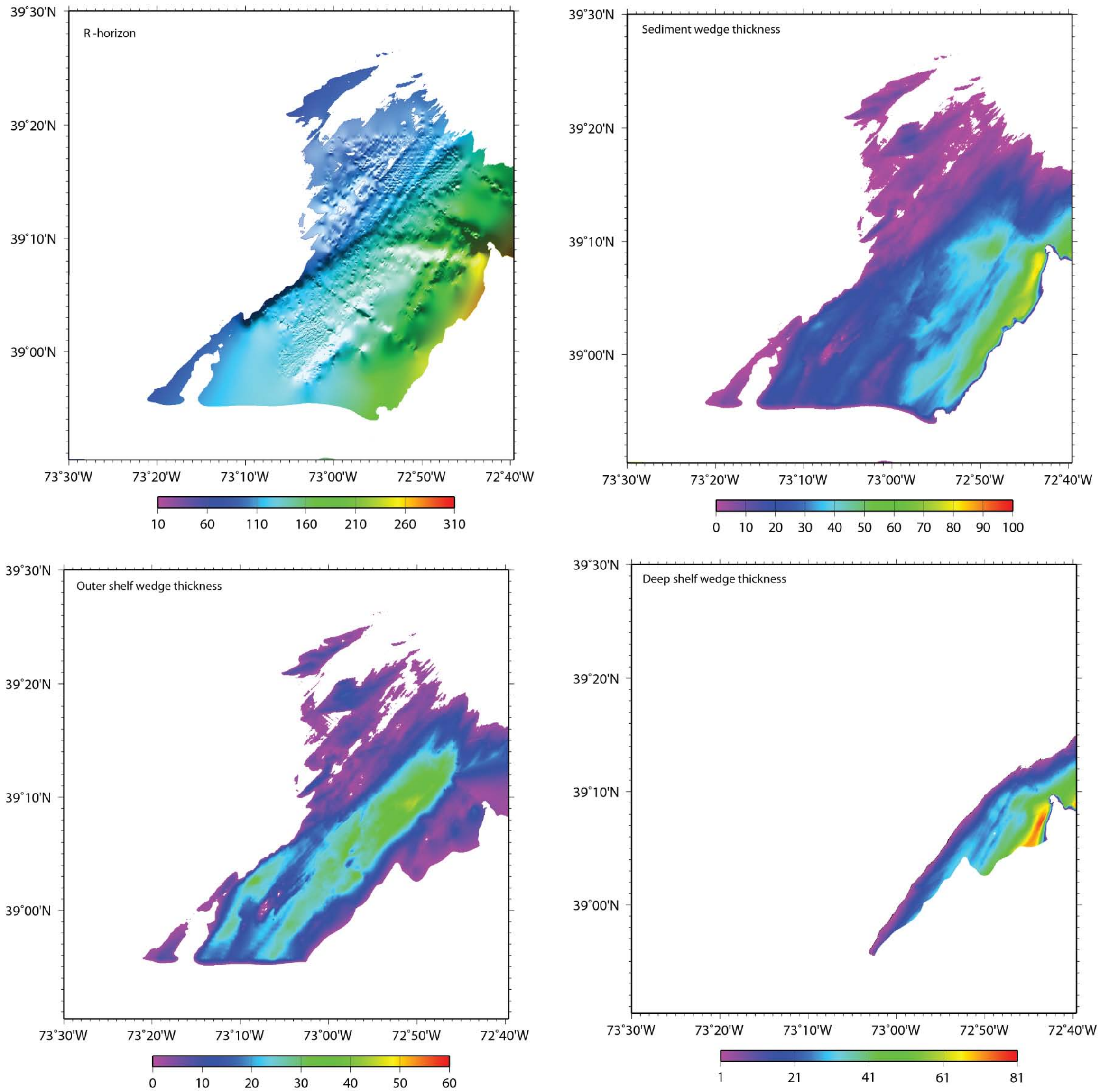

Figure 4. (top-left) Most recent interpolation of the "R" horizon (mbsl), which forms the base of the outer shelf and deep shelf wedges. (upper-right) Total sediment thickness (m) above the "R" horizon. (lower left) Sediment thickness (m) for the outer shelf wedge. (lower right) Sediment thickness (m) for the deep shelf wedge.

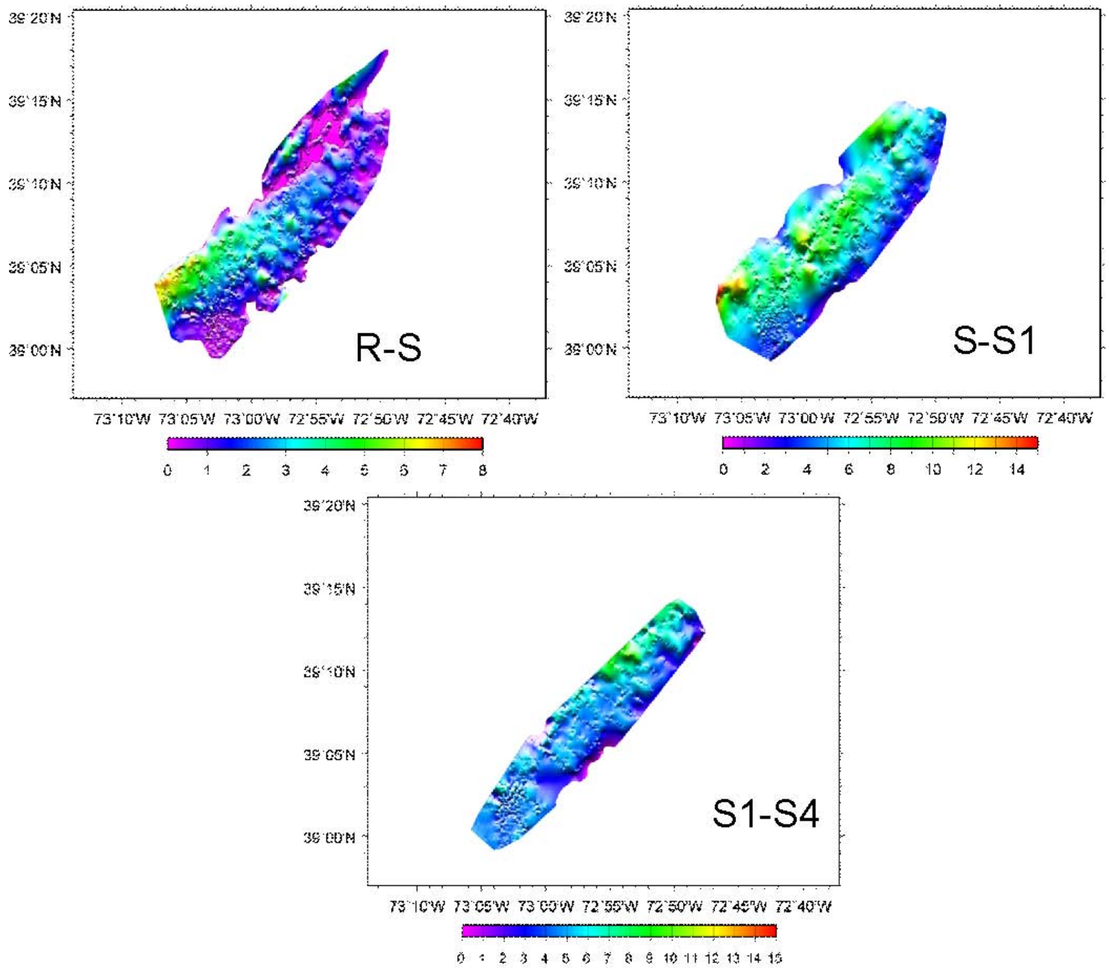

Figure 5. Interpolated isopach maps for the intervals between the horizons identified within the outer shelf wedges. Color scales are in two-way travel time. Images are artificially illuminated from the north. Note progressive shift in thickness distribution from south to north, implying a northward shift in the depocenter through time, possibly corresponding to a shift in the course of the Hudson River.

Geoacoustic Modeling

A new geoacoustic model was generated for George Frisk, who conducted a low-frequency acoustic experiment along a profile that was north of the SW06 focus area, but still well within the chirp coverage both for Geoclutter and SW06 chirp data sets. The experiment profile crossed two buried channels, which appeared to have a significant effect on the acoustic results. Special attention was therefore given to formulating a geoacoustic model that reflected the primary lithologies present within the channel fill sediments. The resulting geoacoustic model profile is shown in Figure 6.

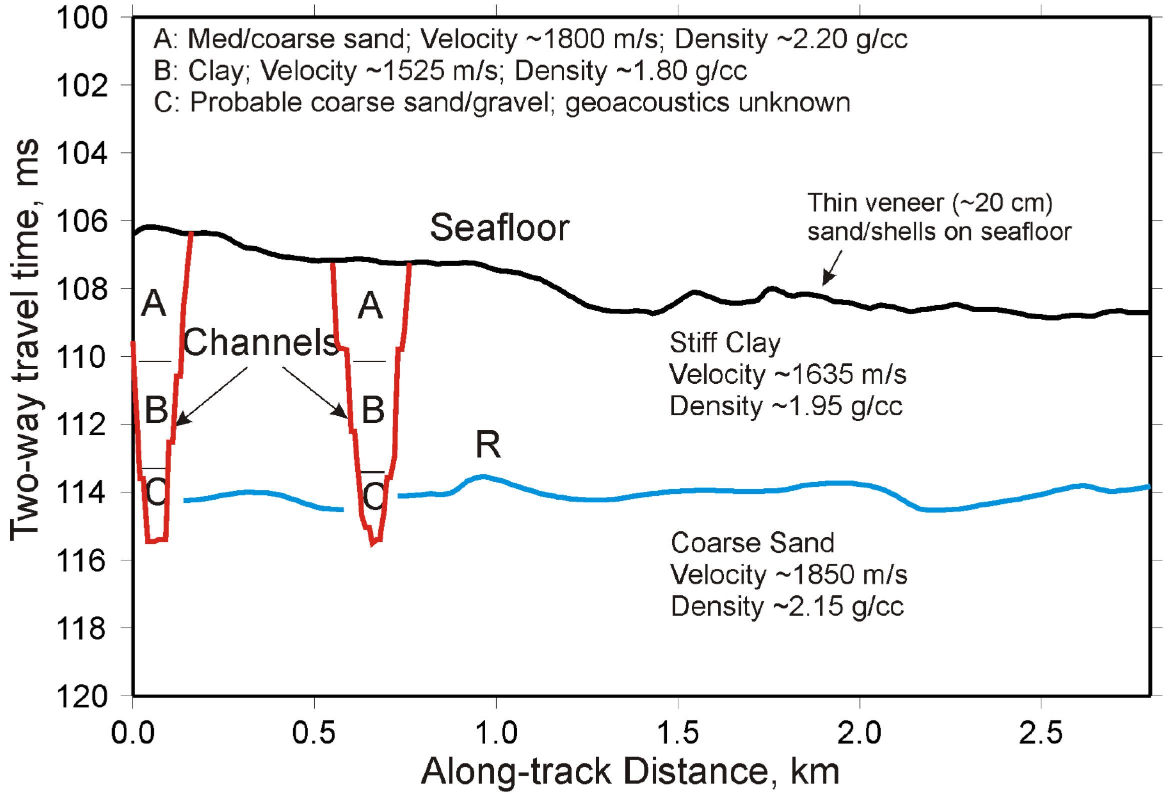

Figure 6. Geoacoustic model profile sampled from SW06 3-D model for low-frequency acoustic experiment run by George Frisk.

IMPACT/APPLICATIONS

The merged bathymetry and backscatter data will be a direct benefit to acoustic and oceanographic modelers working for the SWA06 project.

RELATED PROJECTS

The ONR Geoclutter, STRATAFORM and Uncertainty in the Natural Environment projects have provide significant data and modeling inputs for this project.

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