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14. ABSTRACT

The goal of this project was to advance an understanding of acoustic anomalies created by sub-seafloor paleochannels by investigating the geologic properties of channel-rich strata on the New Jersey continental shelf. Specific objectives were as follows: (1) perform a synthesis of chirp seismic stratigraphy and physical properties measurements of AHC-800 drill cores recovered for ONR's Geoclutter program in 2002; and (2) interpret channel sedimentary units with regard to mechanisms of formation and depositional environments. Three types of seismic reflectors consistent with the following stratal features were observed: 1) depositional surfaces; 2) erosional surfaces; and 3) diagenetic surfaces. Results indicate that the origin and physical properties of these surfaces are characteristic of siliciclastic shelves in general, but that the particular depositional history of the New Jersey shelf is such that all three types occur within a single, relatively short sediment column. Depositional and erosional surfaces were apparent in high-resolution seismic reflection profiles, whereas diagenetic surfaces displayed an indistinct acoustic signature.

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Continental shelf, sedimentation, marine geology

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Origins of Stratal Surfaces in Channel Fills on the New Jersey Continental Shelf

Final Report to the Office of Naval Research

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LONG-TERM GOAL

The overarching goal of this research is to advance our understanding of acoustic anomalies created by sub-seafloor paleochannels by investigating the geologic properties of channel-rich strata on the New Jersey continental shelf. This project parallels the PI's long-term research aims in the area of estuarine, coastal and shelf sediment dynamics.

OBJECTIVES

The main objectives of this research project are twofold: (1) to perform a synthesis of chirp seismic stratigraphy and physical properties measurements of AHC-800 drill cores recovered on the New Jersey shelf in support of ONR's Geoclutter program; and (2) to describe shelf paleochannel sedimentary units and bounding surfaces with regard to the mechanisms of formation and depositional paleoenvironments. These objectives were pursued toward a general understanding of the geoacoustic properties of shallowly buried paleochannels, which are ubiquitous on continental shelves worldwide.

APPROACH

To meet the objectives, the PI performed geophysical and geological studies in coordination with investigators from the University of Texas Institute of Geophysics (UTIG, J. Austin, J. Goff, S. Gulick and C. Fulthorpe), Florida Atlantic University (FAU, S. Schock), Skidaway Institute of Oceanography (SKIO, C. Alexander), and Georgia State University (GSU, B. Christensen). The technical approach involved groundtruthing chirp seismic stratigraphy obtained by FAU and UTIG in 2001. The seismic surveys were conducted in the Geoclutter study area on the New Jersey shelf in places where prior acoustic experiments mapped unfamiliar sub-seafloor anomalies. The seismics revealed that the anomalies were centered over shallowly buried paleochannels that comprise dendritic drainage systems formed by ancient rivers or estuaries. To determine the physical basis for seismic reflectors at selected paleochannel sites, three AHC-800 drillcores were recovered aboard the RV *Knorr* in 2002 (cruise KN168B). Aboard-ship, the PI conducted measurements of saturated bulk density and compressional wave velocity on the drillcores using a multi-sensor core logger to develop down-core profiles of acoustic impedance.

To correlate the lithology and seismic stratigraphy of the drilled sections, impedance profiles were interpreted with regard to the physical properties of strata (sediment grain size, sedimentary structures, bedding) recovered in cores. Visual examination, grain-size analysis, and microfossil studies were used to describe the deposits. Correlation was aided by synthetic seismograms that were created from impedance profiles and using GeoQuest ™ software. The seismically resolvable surfaces (i.e., seismic discontinuities) were categorized according to their mode of formation and interpreted in the context of the channel paleoenvironment.

WORK COMPLETED

All work originally proposed for this study has been completed, and manuscripts based on the collective results of Geoclutter geological studies have been published. Initial research results were presented at the Fall 2003 AGU meeting and at the Northeastern Section GSA meeting in Spring 2004.

RESULTS

Paleochannel geomorphology

Two dendritic drainage systems buried just meters below the modern seafloor in 70-100 m water depths on the New Jersey outer shelf were mapped in sufficient detail to investigate paleohydraulic properties on the basis of channel form and pattern (Sommerfield et al., 2004; Nordfjord et al., 2005). The channel networks are composed of three- and four-order segments that are not contiguous with drainages of the modern coastal plain and which developed under regional slopes of $\leq$0.001. Although the nature (fluvial vs. tidal) and timing of channel cutting is unclear, radiocarbon dating at two sites indicates that they backfilled rapidly during 15.5-12 yr B.P. as the shoreline transgressed across the shelf (Alexander et al., 2003). Morphometric and sedimentological data suggest that the channels drained small watersheds (500-1000 km^2 drainage area) and were probably tidal and estuarine during their final evolutionary stage. Following empirical relationships derived from the hydraulic geometry of modern tidal channels, paleotidal discharges (bank-full, spring tide) would have been on the order of $1\text{-}5 \times 10^3$ m^3/s with corresponding peak velocities of 0.3-1.5 m/s. These flows would have been sufficient to transport particles up to 10 mm in diameter as bedload and finer-grained material in suspension. This estimate is consistent with the grain-size distribution of the drillcores. Interestingly, though these particular drainages are located just south of the Hudson Shelf Valley, through which the Hudson River flowed at the last glacial maximum, they appear to be unrelated to paleo Hudson drainage.

Origins of seismic-stratal surfaces

A sub-seafloor seismic discontinuity is produced when a generated acoustic pulse reflects from the contact of two stratigraphic surfaces across which there is a contrast in acoustic impedance, the product of saturated bulk density and compressional wave (P-wave) velocity. Impedance contrasts are almost always due to lithological changes below the seafloor, variations in sediment grain-size or compaction for example, yet there is no simple way to deduce lithology from seismic records alone. Accordingly, it is necessary to correlate high-resolution seismic and coring data for the same stratigraphic section to establish the physical basis for individual reflections (e.g., Slowey et al., 1996).

The highly heterogeneous nature of seismic discontinuities within and around the New Jersey shelf paleochannels reflects the extreme variability of sediment types and transport processes associated with fluvial and nearshore environments in general. Three types of reflectors are observed: 1) depositional; 2) erosional; and 3) diagenetic.

Depositional reflectors mark the contacts of stratal of dissimilar grain size, and are a consequence of sediment accretion in the depositional environment. Within the paleochannel sections the most prominent depositional reflectors correspond to thick beds of shell fragments, which increase the density, velocity, and acoustic impedance of the formation relative to adjacent strata (Figure 1). Erosional reflectors are present at stratal contacts across which pronounced changes in consolidation state occur. These contacts are created when erosion of the sediment column is followed by deposition, abutting strata of different bulk density. In some cases, erosional reflectors are mantled with coarse-grained lag deposits winnowed from the eroded strata, but these deposits are generally thin compared to depositional reflectors. A rather conspicuous erosional reflector occurs at the base of the channel incision at drillcore Site 2 (Figure 1). Diagenetic reflectors correspond to 1) strata that have been subaerially exposed at some time during its history, or 2) indurated or cemented beds. Porewater drainage during emergence renders sedimentary deposits extremely stiff and rock-like, and these strata tend to form strong seismic reflectors when resubmerged and buried. An example in the study area is the "R" reflector, a regionally traceable surface that was sampled directly by drillcoring at Site 3 (Gulick et al., 2003). The lithology of the "R" reflector is shallow-marine silt and sand that is iron-oxide stained and partially cemented, evidence of subaerial exposure during a sea-level lowstand.

To summarize, the origin and physical characteristics of seismic reflectors on the New Jersey shelf appear to be similar to those observed in other shelf environments. However, because a wide range of paleodepositional systems are preserved in the shallow subbottom, a particularly wide range of reflector types are present within a single stratigraphic section (Goff et al., 2005). Additionally, closely spaced drillcores are needed to determine how reflector properties vary horizontally with the paleochannels.

IMPACT/APPLICATIONS

The goal of this and related Geoclutter studies was to characterize the sub-seafloor geology of shallowly buried paleochannels at sites on the New Jersey shelf. This goal has been met. The sediment physical properties datasets developed for this work will be used by acousticians to design signal-processing algorithms and models that distinguish natural features from man-made objects present at (and just below) the seafloor. At the same time, fundamental knowledge concerning shelf paleodrainage systems has been gained, and this new insight will be of value to researchers studying shelf sedimentation and stratigraphy worldwide.

TRANSITIONS

No specific products have resulted from this research to date.

RELATED PROJECTS

Related projects include seismic stratigraphy and geomorphology (J. Austin, J. Goff, C. Fulthorpe, and S. Gulick at UTIG), and downcore sedimentology and paleoenvironmental reconstruction (C. Alexander at SKIO and B. Christensen at GSU).

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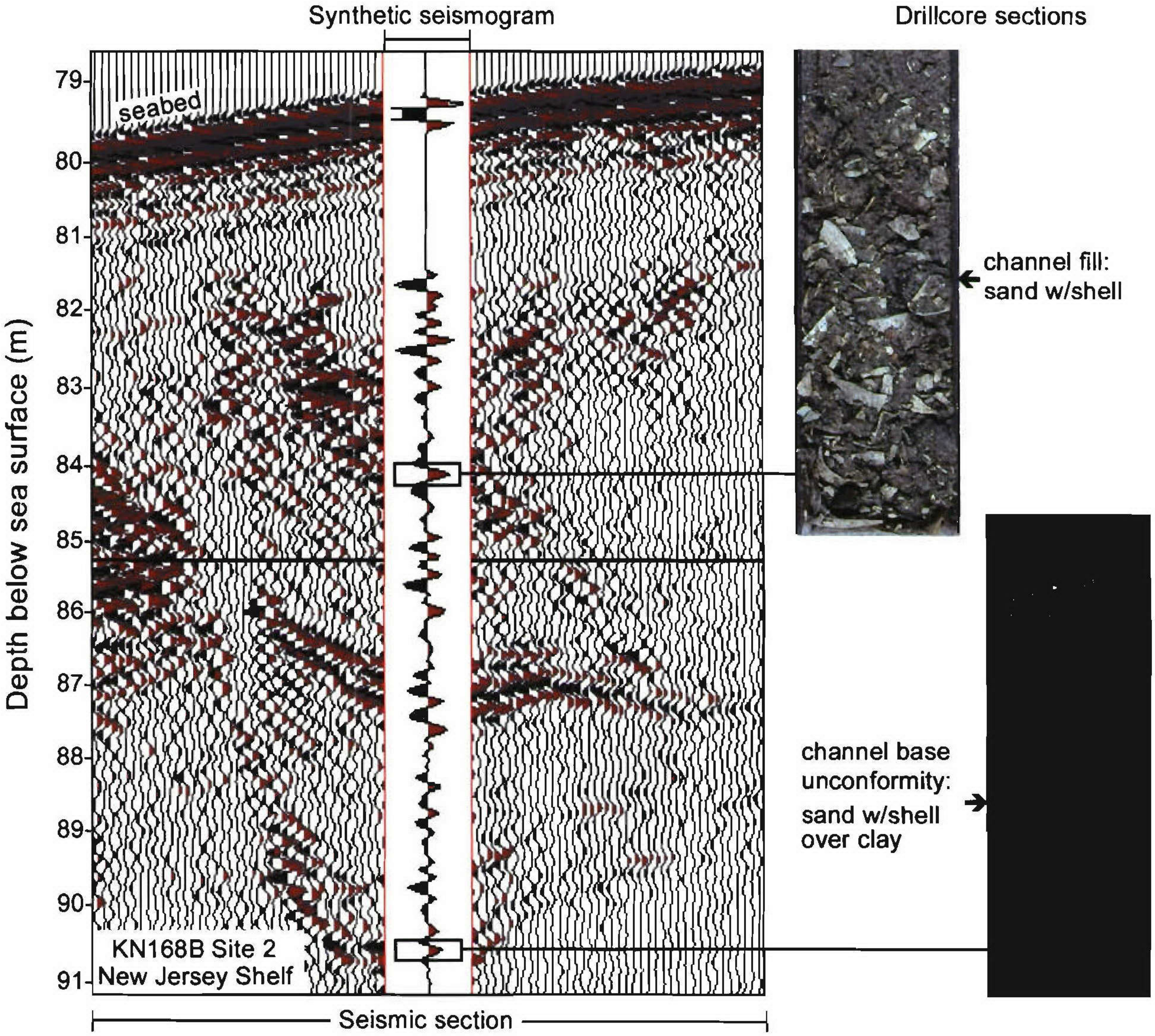

Figure 1. Example seismic reflectors within paleochannel fills on the New Jersey continental shelf. Shown is the chirp seismic section for drillcore Site 2 (wiggle plot), a synthetic seismogram constructed from downcore seismic velocity and density profiles, and photos of two core intervals at seismic discontinuities. The upper interval corresponds to a depositional reflector, sand and shell emplaced when the channel was being backfilled. The lower interval shows an erosional reflector, stiff clay that was eroded when the channel incised the shelf.