An EM Survey of the New Jersey Continental Shelf

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Award#: Nooo14-98-1-0506

LONG TERM GOAL

Maps of sedimentary physical properties are essential to a complete understanding of processes shaping the continental shelf. We have demonstrated that measurements of electrical resistivity can provide exciting new insights into shelf structure, and aim to make electromagnetic (EM) surveys a routine component of seafloor classification programs.

OBJECTIVES

To image, in terms of electrical properties, buried paleo-channels within two regions surveyed in 3D by the Huntec seismic system (Davies et al., 1992; Davies and Austin, 1997). These Huntec surveys identified several buried channels at a depth of around 10m below the seafloor. Channels found in the northern survey area and one set at the western end of southern Huntec area are carved in a surface that is thought to represent an erosional surface exposed during a sealevel low-stand. A prominent channel surface that has also been mapped in 3D appears at the eastern end of the southern Huntec area, but this channel sits above the seismic reflector "R'' may mark a separate sealevel low-stand.

To investigate the porosity structure within the prominent current-carved sandbar features seen in bathymetry and also in sidescan data.

To characterize the electrical signature of several regions of notably high acoustic backscatter which lie at the northern tips of topographically high sandbars.

BACKGROUND

Sediment formations on the continental shelf contain detailed information not only about their primary deposition and subsequent reworking, but also of Earth's recent climatic history. Measurements of electrical resistivity, made by seafloor EM surveying tools, can provide a valuable additional constraint on the physical properties of seafloor sediments: this is especially true when an EM survey is carried out in a region that is also mapped seismically and through coring operations. Seafloor resistivity provides a good measure of sediment porosity as, to first order, the bulk resistivity depends on how much seawater is present within the sediment.

Our EM survey used a system owned and operated by the Geological Survey of Canada, the same as was used in 1996 in the Californian STRATAFORM area (Evans et al., in press). The system is towed along the seafloor and measures the electrical resistivity structure of the seafloor to a depth of about 20m. Empirical relationships allow the conversion of resistivity to porosity.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **1998**	2. REPORT TYPE	3. DATES COVERED **00-00-1998 to 00-00-1998**

4. TITLE AND SUBTITLE **An EM Survey of the New Jersey Continental Shelf**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Woods Hole Oceanographic Institution,Department of Geology and Geophysics,Woods Hole,MA,02543**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM002252.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**4**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

We focussed our efforts in water depths between about 60 and 100m, within areas that had been previously mapped using sidescan sonar and high-resolution bathymetric techniques. In addition, two specific areas of interest had been extensively surveyed in three dimensions using the high-resolution Huntec seismic system. The two Huntec surveys were completed in 1989 (Davies et al., 1992) and in 1993 (Davies and Austin, 1997). The earlier survey was near the southern end of the STRATAFORM region and focussed on the outer shelf wedge. The later survey, which was further north, studied the mid-shelf wedge.

APPROACH

The EM system forms a 50m array on the seafloor, which is towed on bottom at speed of 1-2 knots. Three receivers measure the magnetic field generated by a transmitter at the front of the array. Each receiver (4m, 13m and 40m behind the transmitter) provides structural information over a depth interval approximately one-half the distance between source and receiver. The furthest receiver which is 40m behind the transmitter, provides information to a depth of about 20m below the seafloor. Measurements are made on each receiver in turn and each takes about 10s to perform. The raw data are logged on board ship in real time. A raw data series consists of a series of apparent porosities, one profile for each receiver.

ACCOMPLISHMENTS AND RESULTS

During voyage 329 of the R/V Oceanus, we completed nearly four days of data acquisition, running lines through both Huntec survey regions, as well as lines providing regional coverage throughout the STRATAFORM area.

General Porosity Structure: In general, complex patterns of sedimentation were witnessed across the shelf. Unlike the Eel River basin, where three broad and consistent regimes could be identified on the basis of electrical resistivity, no such simple spatial partitioning of the New Jersey data set is possible. Surficial porosities (averaged over the top 2-4m of seafloor) are less than 50% and generally lie between 40-50%. In most regions, the porosity structure exhibits a normal gradient with depth, with the 4m receiver measuring highest apparent porosities, and the 40m receiver the lowest. In places, the 13m receiver approaches and even surpasses the 4m receiver. Porosity values on the 40m receiver are in the 35% range. All these values are consistent with a pre-dominantly sand facies. The porosity structure on all three receivers shows significant variability along any given tow-line, although the amplitudes of these variations are lower than the extreme swings seen on the Eel river shelf and are simply explained by grain size variations due to current controlled deposition.

Buried Channels: Within each Huntec survey region were seen sets of buried channels which appeared seismically as depressions in a reflector dubbed “channels’’. The northern Huntec area (NHA) contains a set of channels within the mid-shelf wedge, and at this point the channels reflector coincides with another prominent reflector “R’’ within the confines of the channel (Davies and Austin, 1997). The seismic reflector “R’’ is thought to represent an erosional surface exposed during a sealevel low-stand. The southern Huntec area (SHA) covers a portion of the outer-shelf wedge. Here, “R’’ is deeper than the most prominent channels reflector. In addition, there is a further channel set at the western end of the southern Huntec region in which “R’’ shoals and approaches the channels reflector.

The buried channels for which the channels reflector and “R’’ are spatially close, show clear EM signatures. Within the NHA region we witnessed clear signatures of buried channels in agreement with the seismic surveys. In fact, only 5 lines running through the NHA were needed to allow us to reproduce the geometry of two sets of channels shown in Davies and Austin (1997). One of these sets of channels consisted of three branches to the north that merged into a single channel at the south. The signature of the channels was marked by the apparent porosity on the 13m receiver rising to meet that of the 4m receiver. In some cases there was also an increase in the apparent porosity on the 40m receiver. In addition, numerous examples of channel signatures were seen on lines surrounding the NHA.

A channel signature at the western end of the SHA also matched results seen in seismic profiling. The response of this channel was seen only on the 4m and 13m receivers, indicating a shallower depth extent than in the NHA. The prominent channel reported by Davies et al., (1992) which is in a different sequence of sediments and lies well above the “R’’ reflector, showed no electrical signal. Instead, a broad band of lower porosity material was seen in this region, trending roughly NE.

Correlation with Topography and Backscatter: Several lines were run to specifically test links between the surficial (2-4m) porosity structure, seafloor topography and acoustic backscatter. The line crossed two regions of high acoustic backscatter which lie at the northern edge of elongate sand bars aligned roughly parallel to the shelf break. Over both acoustic highs, surficial porosity increases abruptly in concert with the backscatter. The correlation between surface porosity and topography is less well determined: while there are numerous instances of local minima in surficial porosity at local topographic highs, there are also exceptions to this rule. Along one line were seen numerous topographic highs created by sandbars subparallel to the shelf edge. As the system was towed across these features, we saw sharp gradients in porosity on the seaward sides of the slope, with porosity decreasing to a minimum at the topographic high. On the landward side of the sandbar, porosity gradually increased again. In contrast, there were other instances of topographic highs with maxima in surficial porosity, and places where the correlations between porosity and topography were less obvious. These links will need to be more thoroughly examined over the coming months to fully understand the processes controlling grain size and topography.

Towards the shelf -edge, in a water depth of 85-90m just to the south-east of the NHA, the apparent porosities on both 4m and 13m receiver are highly oscillatory on short spatial wavelengths. The magnitude of these oscillations is in the range of 3-5%. The 40m receiver also shows some oscillation, but of lower amplitude, and also shows values slightly higher than the 13m receiver. At the end of the line, the surficial porosities, which decrease steadily, are around 40%.

IMPACT AND APPLICATIONS

An extensive EM data set has been collected in the New Jersey STRATAFORM region. These new data are complementary to those from the Eel River shelf and provide insights into a shelf influenced in recent geological time by changes in sealevel and climate. Numerous phenomenological features are seen in the raw data that will provide understanding of sand wave structure and erosional-depositional processes shaping the shelf.

PUBLICATIONS

Evans, R.L., L.K. Law, B. St. Louis, S. Cheesman and K. Sananikone, The Shallow porosity structure of the Eel shelf, northern California: results of a towed electromagnetic survey. Marine Geology, 154, (in press).