

Biostratigraphy and Paleoenvironmental Analyses of Pleistocene NJ Shelf Sediments

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Award Number: N00014-04-1-0036

LONG-TERM GOALS

The long-term goal of this project is to understand the patterns and timing of latest Pleistocene sedimentation in the Geoclutter area of the NJ margin. Paleoenvironmental reconstructions of the study area were developed using benthic foraminifera and sediment texture analyses of drill cores obtained in Fall 2002 using the ACHC-800 from the RV Knorr. This award was extended through October 31, 2005 to facilitate sediment texture analyses by graduate (masters) student R. J. Turner and the synthesis of paleoenvironmental analyses by Christensen and Alexander.

OBJECTIVES

The scientific objectives of this study are to:

- 1) reconstruct paleoenvironment using a multi-proxy approach;
- 2) evaluate sediment for provenance and sediment transport history using heavy mineral concentrations, sediment texture and radiochronology; and 3) integrate these data with other geological and geophysical data generated by rest of the scientific party to develop an integrated stratigraphy and history of deposition. This work provides a means of ground-truthing interpretations of geophysical data, and explaining variations in environment as a function of sediment source, age, and mineralogy.

APPROACH

1) *Faunal Analyses and Paleoenvironmental Reconstructions.* Paleoenvironmental reconstructions are based primarily on benthic foraminiferal faunal analyses and include supporting data such as grain frosting, macrofauna, and floral data. Benthic foraminifera have affinities for certain water depths and/or environmental conditions, and so are useful indicators of provenance and transport. The depth associations of benthic foraminifera on the NJ shelf are well documented (e.g., Katz et al., 2003) and these studies provide the species concepts used to identify individuals. Paleobathymetric estimates are based on neritic (0-200 m) subzonations [inner (0-50 m); middle (50- 100 m) and outer (100-200 m)] and transitional (estuarine, beach) and non- marine (fluvial) environments. Foraminifera are also used to identify transported sediments, which often contain a mixture of faunas: the *in situ* assemblage appropriate to the water depth, and a displaced shallower water fauna.

Report Documentation Page				Form Approved OMB No. 0704-0188	
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1. REPORT DATE 30 SEP 2005		2. REPORT TYPE		3. DATES COVERED 00-00-2005 to 00-00-2005	
4. TITLE AND SUBTITLE Biostratigraphy and Paleoenvironmental Analyses of Pleistocene NJ Shelf Sediments				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) Environmental Studies Program, Adelphi University, Science 103, 1 South Avenue, Garden City, NY, 11530				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 code 1 only					
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15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 10	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

2) *Sediment Provenance*. Assessment of sediment mineralogy is crucial to understanding the patterns of sediment deposition and erosion on the NJ margin. Potential siliciclastic sediment sources include rivers, Cenozoic coastal plain sediments, relict sediments, and IRD. These sources should yield distinct mineralogy and sedimentary texture, as well as associated biological differences. We attempt to identify the provenance of sediments to determine if they were associated with post-glacial Hudson River drainage or derived from other regions and transported to the site by icebergs (glaciers were proximal to the study area and icebergs likely grounded on the shelf, Duncan and Goff, 2001). Regionally derived sediments are distinguished from allochthonous sediments using heavy mineral separations and radiometric dating of hornblende and zircons. It is not expected that the sediments of the NJ coastal plain are a source, as previous studies have shown that the mineralogy of reworked surface sediments of the NJ shelf is dissimilar to that of the adjacent coastal plain: abundant hornblende, garnet and magnetite are not evident in Cenozoic coastal plain rocks (Frank and Friedman, 1973). Our results will provide important constraints on current and future acoustic, sedimentary and paleoenvironmental studies in the Geoclutter study area, both on the surface and down core. This work provides the foundation for a Georgia State master's thesis by R. Jessica Turner (Christensen, supervisor; Alexander, committee member).

3) *Integrated Analyses*. Correlation of the down core benthic foraminiferal data with the grain size data generated by Alexander enhances interpretations and discriminates between texturally similar environments. A unimodal, coarse grained sediment may be interpreted as fluvial (but would be identified by the absence of benthic foraminifera), or shallow marine (identified by abundant inner continental shelf benthic foraminifera). Similarly, a mud may be estuarine (and contain abundant marsh foraminifera) or outer shelf (and contain outer neritic benthic and abundant planktonic foraminifera). Planktonic foraminifera are anticipated to provide supporting data, e.g., marsh sediments should contain few if any planktonics whereas abundance should increase in deeper water environments. These comparisons are ongoing, and will be finalized when all of the foraminiferal and sedimentological data have been collected.

WORK COMPLETED

1) Knorr 168 Sites 1, 2 and 3 (= ODP Site 1071 Holes H to P) were sampled for foraminifera at each major facies change, and in occasional clay clasts. A total of 113 samples were taken for stratigraphic analyses and dried, weighed, washed in de-ionized water through a 63 μm sieve, dried at 60°C, and weighed to determine weight percent sand. This work was performed by two undergraduate students (Robert Neurath and Vanessa Donnelly) and a graduate student technician (Jacqueline Shea). A total of 51 and 10 grab samples were picked for planktonic and benthic foraminifera, sorted into species and counted to determine relative abundance. They were also evaluated qualitatively for grain rounding and texture; an additional 32 samples are being investigated currently. Those samples for which post-cruise investigations revealed some disturbed and re-cored intervals were not analyzed (30 samples). Foraminiferal data are presented as relative abundance (%). Many samples did not achieve a sufficient numbers of individuals (300) for statistically valid quantitative biofacies analysis; however, the species diversity on the inner to middle shelf is lower than in the pelagic realm and so the relative abundance is probably accurate for samples with 100 or so individuals.

2) A total of 31 samples grab and 6 down core samples were sorted for grain size at 1 phi intervals and separated into heavy minerals using heavy liquid (sodium polytungstate). Hornblende crystals from 5 grab samples were analyzed to determine age using K-Ar methods on an Atomic Absorption Spectrometer 3100 in Wampler's laboratory at Georgia Institute of Technology. This work was

performed by Christensen's masters student, R. Jessica Turner, in association with Marion Wampler (K-Ar dating of hornblende; Georgia Institute of Technology) and Eirik Krogstad (ICPMS dating of zircon and rutile; Georgia State University). Heavy mineral separations using a Frantz magnetic barrier separator were performed to determine weight percent of the heavy mineral suite of grab and down core samples. An attempt was made to date zircon crystals in the ICPMS lab but no appropriate material could be isolated.

3) Foraminiferal analyses were integrated with grain size and radiocarbon data generated by Alexander, and compared with CHIRP profiles to link paleoenvironmental changes with significant features such as the reflector R (Alexander et al., 2005).

RESULTS

A. Foraminiferal Analyses

Site 1 (~129 m w.d.) This site penetrated the outer shelf wedge and possibly a channel. Foraminifera are abundant in the upper 161 cm, very low or absent to 246 cm, and present in lower abundances from, 352.5 – the base of the core. Overall, then, this site was dominated by inner neritic *in situ* deposition at the base, overlain by inner or inner to middle neritic environment, and capped by *in situ*, outer shelf sediments of the outer shelf wedge. The deeper water assemblage includes species found on the outer shelf such as *Cibicides* spp. (middle to outer neritic; Brunner and Culver, 1992); *Bulimina marginata* (Barlett and Molinsky, 1971), *Angulogenerina angulosa* (>100 m; Gevirtz et al., 1971; Lagoe et al., 1997; Parker, 1948), and *Sphaeroidina bulloides* (>140 m wd; Matoba and Fukasawa, 1992). *Elphidium* spp. commonly achieves 100% abundance, especially in intervals where the total number of benthics is very low (e.g., 178.5 cmbsf). The presence of *A. becarri*, an indicator of nearshore saline conditions (Poag, 1981), at the lowermost sample (460 cm) at 8%, and in sands at 60 and 150 cmbsf, suggests transport of sediments from shallower water depths at these intervals.

Site 2 (79 mbsf) This site penetrated dominantly sands and muds forming channel infill. Foraminifera are rare to absent in much of the core, with the exception of the coretop samples (0-24 cmbsf) and middle of the core (649.5 – 1039 cmbsf). The Holocene coretop samples are dominated by a mid to outer shelf assemblage. The remainder of the core to the exposure surface is dominated by *Elphidium* spp. and was deposited in latest stage 2. Below the exposure surface (~1100 cm), the Stage 3 sediments are estuarine. Deeper water is possible at 635 cmbsf by a pulse of *Cibicides* spp. although the benthic abundance (12 specimens) is extremely low, and no other deeper water indicators such as *Bulimina* spp. are present at that depth.

Site 3 (75 mbsf) Site 3 is dominated by *in situ* middle to outer shelf Holocene sedimentation to 252 cmbsf. Underlying this unit is a nearshore probably estuarine deposit, from 252- 300 cmbsf. Based on the *Cibicides* and *Elphidium* dominated assemblage from 526 - 559 cmbsf, it is likely that these sediments were transported. The near dominance of *Elphidium* spp. in the lowermost sample indicates an inner shelf depositional environment during Stage 3.

B. Sediment Provenance

Results from K-Ar isotopic analyses of hornblende grains from select grab samples and Sites 1 and 3 indicate two clusters of apparent ages: ~960- 910 Ma, and 880-810 Ma (Turner, 2005). Those apparent ages greater than 900 My., derived from pristine hornblende grains, are consistent with a

proximal Grenvillian such as Precambrian amphibolites or gneisses (e.g., NJ Highlands, Reading Prong). The second cluster of younger age values suggests a mixture of hornblendes from older and younger rocks (e.g., Cortland complex). IRD has not been identified through mineralogical assessment.

For Site 1, the youngest K-Ar apparent ages for hornblende crystals are associated with the boundary between the Stage 3 inner to middle neritic assemblage and the Holocene outer shelf assemblage. These young ages indicate a mixed (Hudson River) source for Stage 3 sedimentation. The K-Ar apparent ages in the Holocene outer shelf wedge sediments are derived from a Precambrian source, possible the NJ Highlands. For Site 3, as at Site 1, the lowermost Stage 3 unit indicates a mixed source. The channel infill is associated and Holocene coretop indicate a single, Precambrian source.

C. Integrated Analyses

Preliminary relationships indicate the sediments below reflector R were deposited in Marine Isotope Stage (MIS) 3, and the environments experienced *in situ* sedimentation consistent with the lower sea level at that time. It is possible that deltaic sedimentation was occurring at Site 3 based on the estuarine paleoenvironment. Sediment supply was likely a combination of Hudson Valley and NJ Highlands. This interval was followed by a period (32-13 Ky BP) of downcutting associated with the lowered sea levels of MIS 2. Subaerial exposure at Sites 2 and 3 is evident in the sediment record. This period may have terminated with a catastrophic event at ~ 13 Ky BP, as suggested by recent studies. Deposition occurred at all three sites as sea level transgressed the shelf with a dominantly Highlands source. Sites 2 and 3 experienced estuarine and inner shelf sedimentation from ~15 – 3 Ky BP, with deeper water sedimentation at Site 1 until ~10Ky BP.

IMPACT/APPLICATIONS

Paleoenvironmental interpretations provide an essential foundation for acoustic energy – seabed interactions studies. These studies require accurate understanding of the sediments being evaluated, particularly in a region with such great variability temporally and spatially. Geophysical methods (CHIRP, backscatter) can only estimate sediment type and depositional environment and do not offer any temporal context. Furthermore, geophysical methods require estimates of essential parameters such as depth and sediment velocity, which can only be determined from ground truth coring.

TRANSITIONS

As results are determined, they have been shared with the working group. Goff has incorporated the grab sample data into his recently submitted paper. Alexander and Christensen are preparing a manuscript on the integrated results. Christensen is preparing a manuscript on the grab sample and down core foraminiferal data. She is supervising Turner, who is preparing a manuscript on sediment provenance studies.

RELATED PROJECTS

Alexander (SKIO) is developing a paleoenvironmental assessment using grain size parameters, Austin (UTIG), Goff (UTIG), Fulthorpe (UTIG), and UTIG PhD student Nordfjord are providing additional assessments of the regional geophysics using the data from this project. Sommerfield (UDeI) is utilizing these data (as well as Alexander's data) to groundtruth his high resolution physical property data, essential for preparation of synthetic seismograms, which in turn permit better interpretation of the high resolution CHIRP data and regional patterns by the UTIG group.

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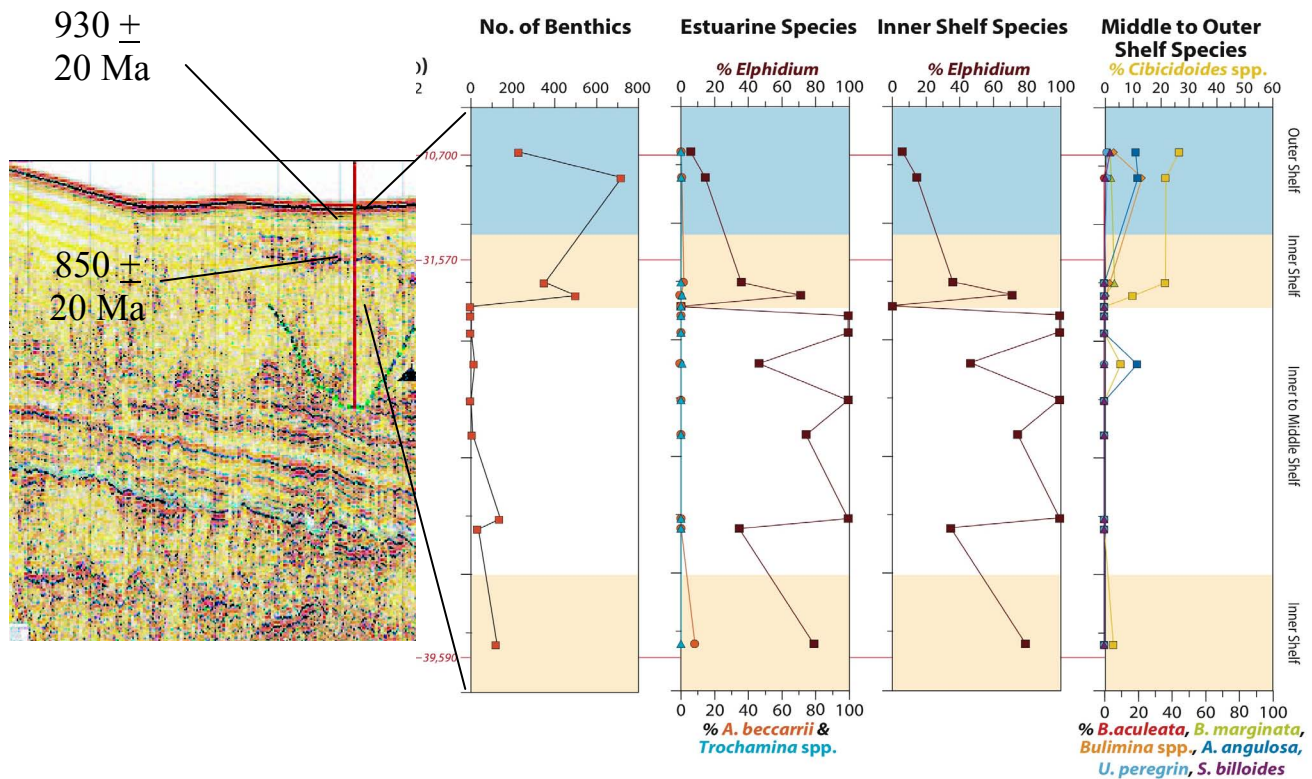


Figure 1. Site 1 (129 m w.d., core penetration 6.8 mbsf). Seismic profile (Alexander et al., 2003) with showing approximate position and depth of coring. Benthic foraminiferal distributions are organized by water depth; approximate position of hornblende apparent ages are shown in black (Turner, 2005); radiocarbon dates are shown in red (Alexander, 2004).

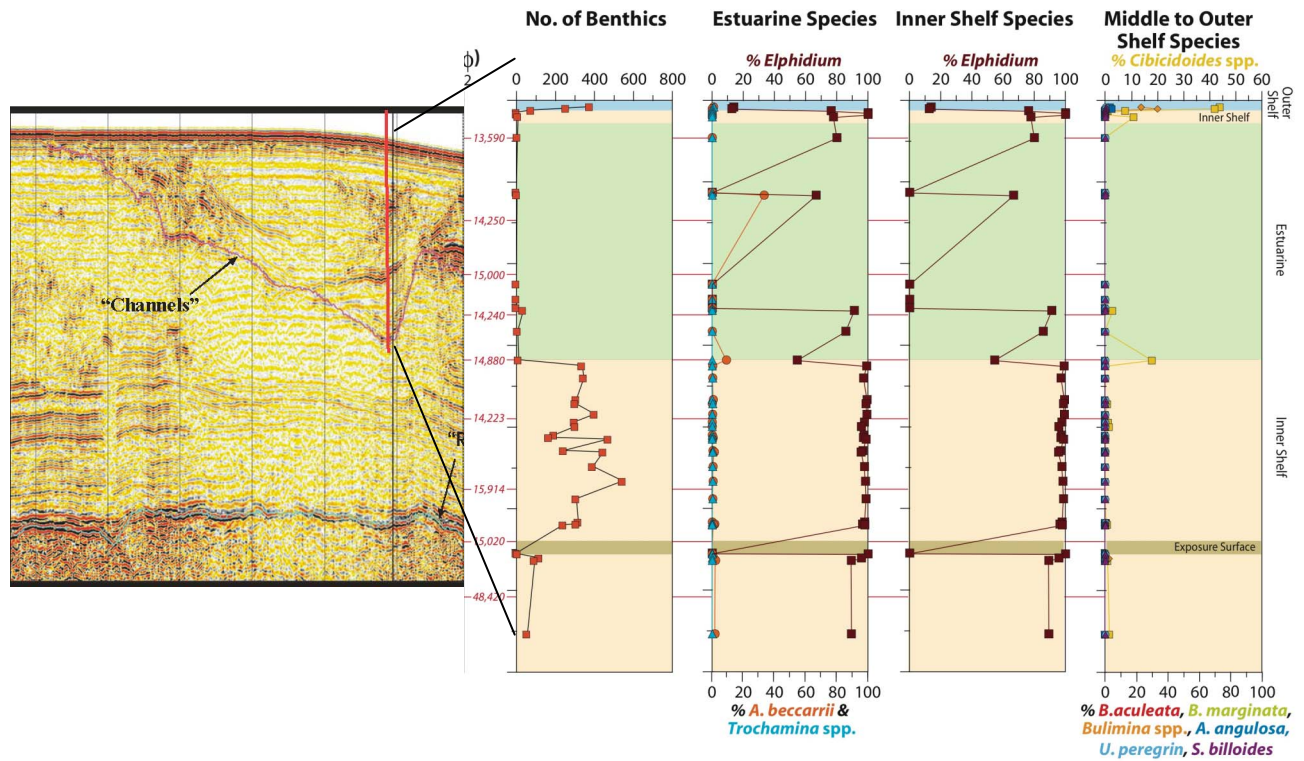


Figure 2. Site 2 (79 m w.d., core penetration 13.2 mbsf). Seismic profile (Alexander et al., 2003) with showing approximate position and depth of coring. Benthic foraminiferal distributions are organized by water depth; radiocarbon dates are shown in red (Alexander, 2004).

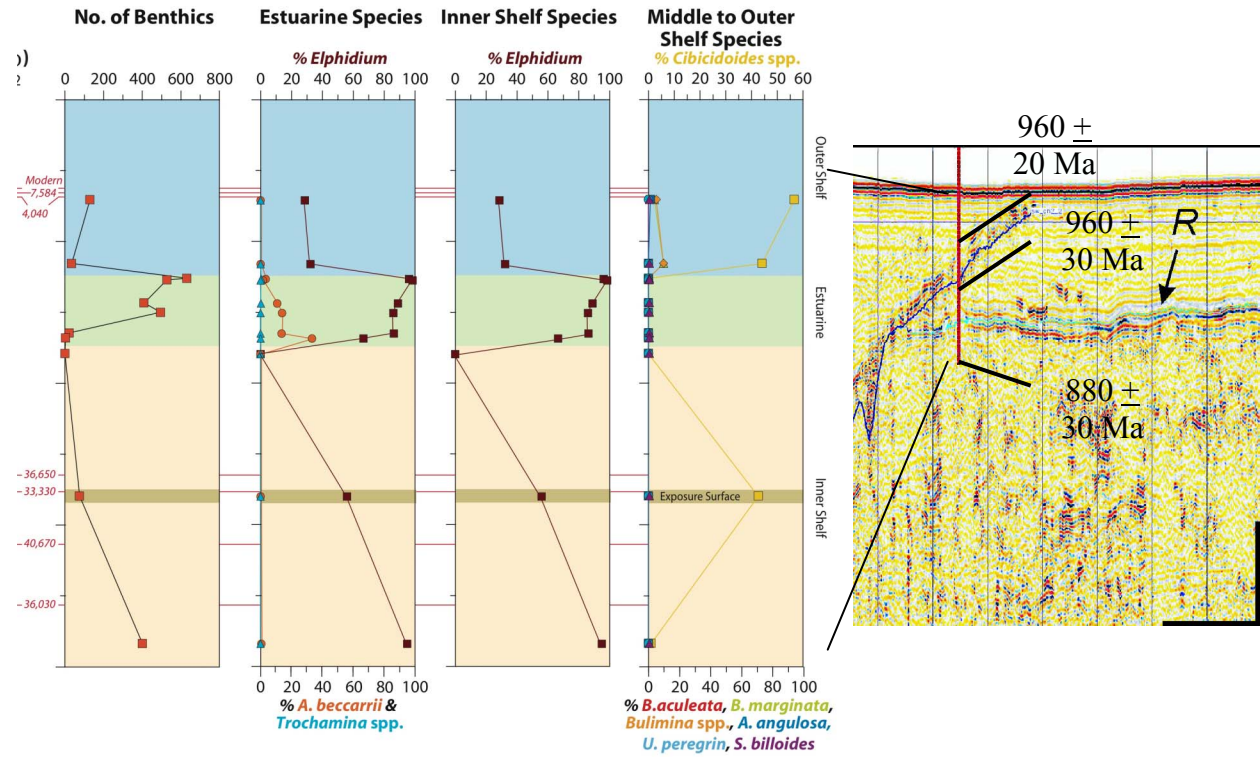


Figure 3. Site 3 (75 m w.d., core penetration 7.7 mbsf). Seismic profile (Alexander et al., 2003) with showing approximate position and depth of coring. Benthic foraminiferal distributions are organized by water depth; approximate position of hornblende apparent ages are shown in black (Turner, 2005); radiocarbon dates are shown in red (Alexander, 2004).