Predicting the Distribution and Properties of Buried Submarine Topography On Continental Shelves

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LONG-TERM GOALS

Compile geological data and develop methods to predict the distribution and properties of features hypothesized to be responsible for sonar geoclutter. Contribute to the reduction or mitigation of geologic clutter observed on fleet sonar systems.

Two issues define the problem.

• *Landscape forming issue*: In area ‘x’, can the Navy expect geoclutter features and if so what are their sonar characteristics, i.e. channel orientation?

• *Landscape burial issue:* If geoclutter features are expected in area ‘x’, will the features be exposed or buried? Areas of low interest to the Navy include locations where Holocene deposits are thick. Areas of high interest to the Navy include locations where Holocene deposits are thin thereby allowing for the shallow burial of Pleistocene topography.

JUSTIFICATION

A major goal of the U.S. Office of Naval Research is to reduce or mitigate geologic clutter observed on fleet sonar systems. Geological structures just beneath the seafloor, with high-angle reflecting surfaces, can return false sonar alarms. Examples include steep-walled channels from buried paleo-river valleys, faults or iceberg furrows.

OBJECTIVES

- Define the character of different kinds of buried channels (size, shape, properties).
- Define the spatial distribution of these buried channels (river, tidal, hyperpycnal).
- Develop a global atlas of candidate geoclutter features and their characteristics.
- Develop and merge global databases of pertinent geological and oceanographic data.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
30 SEP 2003		**00-00-2003 to 00-00-2003**

4. TITLE AND SUBTITLE	
Predicting the Distribution and Properties of Buried Submarine Topography On Continental Shelves	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) **University of California,,Scripps Institution of Oceanography,San Diego,,La Jolla,CA,92093**	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

14. ABSTRACT
Compile geological data and develop methods to predict the distribution and properties of features hypothesized to be responsible for sonar geoclutter. Contribute to the reduction or mitigation of geologic clutter observed on fleet sonar systems. Two issues define the problem. ??? Landscape forming issue: In area ???x???, can the Navy expect geoclutter features and if so what are their sonar characteristics, i.e. channel orientation? ??? Landscape burial issue: If geoclutter features are expected in area ???x???, will the features be exposed or buried? Areas of low interest to the Navy include locations where Holocene deposits are thick. Areas of high interest to the Navy include locations where Holocene deposits are thin thereby allowing for the shallow burial of Pleistocene topography

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**13**	

• Develop predictive models and apply to margins of interest. Test predictive models in a known geoclutter rich area.

• Share and merge these databases, models and results with those in the Geoclutter Research Group working on tracking algorithms.

APPROACH

1) Compile a global database of pertinent geological and oceanographic data, for use as initial inputs and constraints for sediment flux models (*HydroTrend* and *SedFlux*).

2) Measure and analyze terrain attributes. Perform a comprehensive analysis of real and simulated elevation grids using RiverTools® and other GIS software. Calculate the geometric and statistical characteristics of landforms and how these characteristics vary from one geologic setting to another.

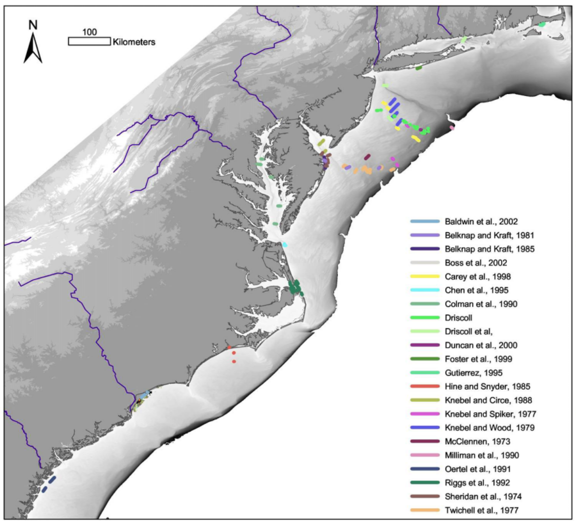
3) Classify terrain from geologic information. Classify "terrain types" in terms of the initial and boundary conditions (e.g. geology, erosion rates, excess rain rates) that produced the terrain types, using physics-based landform models.

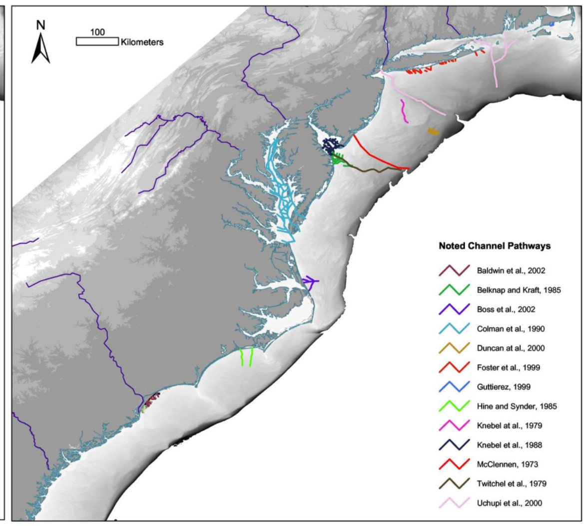
4) Determine the potential burial depth of topography produced during lowstands of sea level. Develop simple scaling relationships for deposition rate as a function of sediment input rates from rivers, wave and current conditions, and shelf geometry. Refine these bulk estimates with more detailed consideration of the nature of sediment delivery to the shelf (e.g., episodic storm-driven flooding vs. seasonal snowmelt flooding; the role of estuaries) and sediment redistribution, bypassing and deposition on the shelf (e.g., the long-term manifestation of short-term, episodic, storm-driven transport on the shelf).

5) Model the flux of sediment to and across continental shelves. Use process-based models (*HydroTrend*) to obtain a detailed consideration of the nature of sediment delivery to the shelf and sediment redistribution, bypassing and deposition on the shelf.

WORK COMPLETED

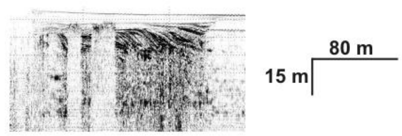
1) From the U.S. East Coast shelf (NY to Georgia), pathways and attributes of paleochannels (e.g., width, depth, sidewall slopes) have been compiled in a database using available field data (i.e., chirp sonar) and data from extensive literature searches. Surficial sediment samples and core locations from a variety of sources are also contained in the database.



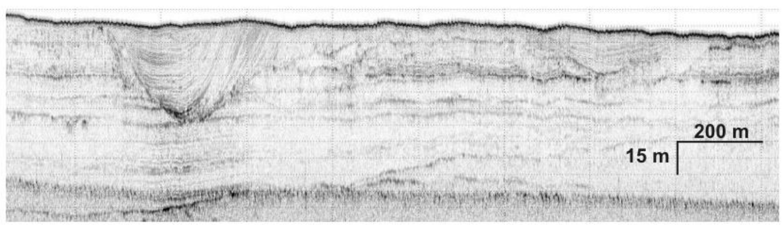


Great diversity is evident in the shape, size and fill of channels on the U.S. East Coast continental shelf (below). The Albemarle Sound channel has pronounced laterally filled beds with areas of high reflectivity with acoustic blanking below, which is interpreted to be the result of trapped gas. It is believed to represent a former tidal inlet. Two moderately large channels (B) are filled by upbuilding beds. These are probably associated with waning river or estuarine flow. A broad channel with a relatively flat but rough bottom is shown in C. These characteristics combined with mostly transparent fill suggest formation during a large and episodic discharge event at lowered sea level. Several V-shaped channels with transparent fill are located on the outer shelf. Data from the Geoclutter Field Group indicate they form a dendritic drainage pattern. Massive channels found in Block Island Sound (E) were likely carved during catastrophic drainage of glacial lakes and maintained by tidal currents.

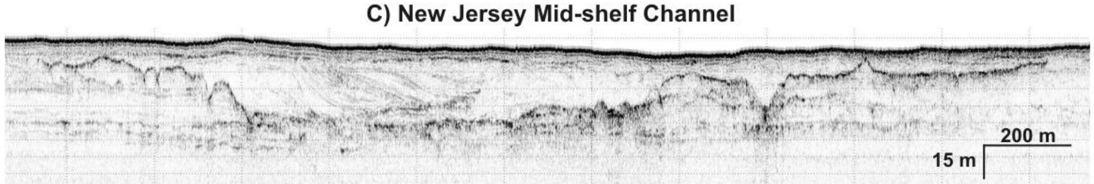
A) Albemarle Sound Channel



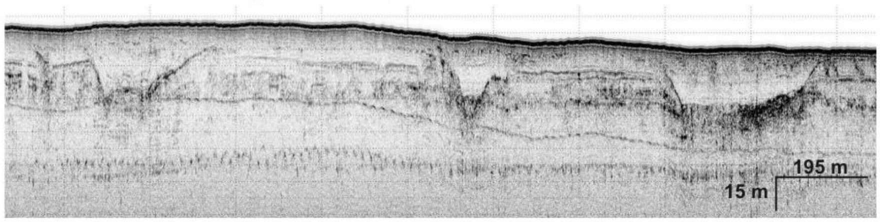
B) New Jersey Mid-shelf Channels



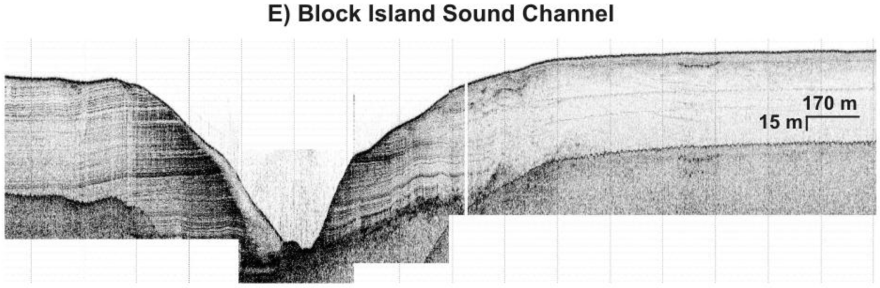
C) New Jersey Mid-shelf Channel



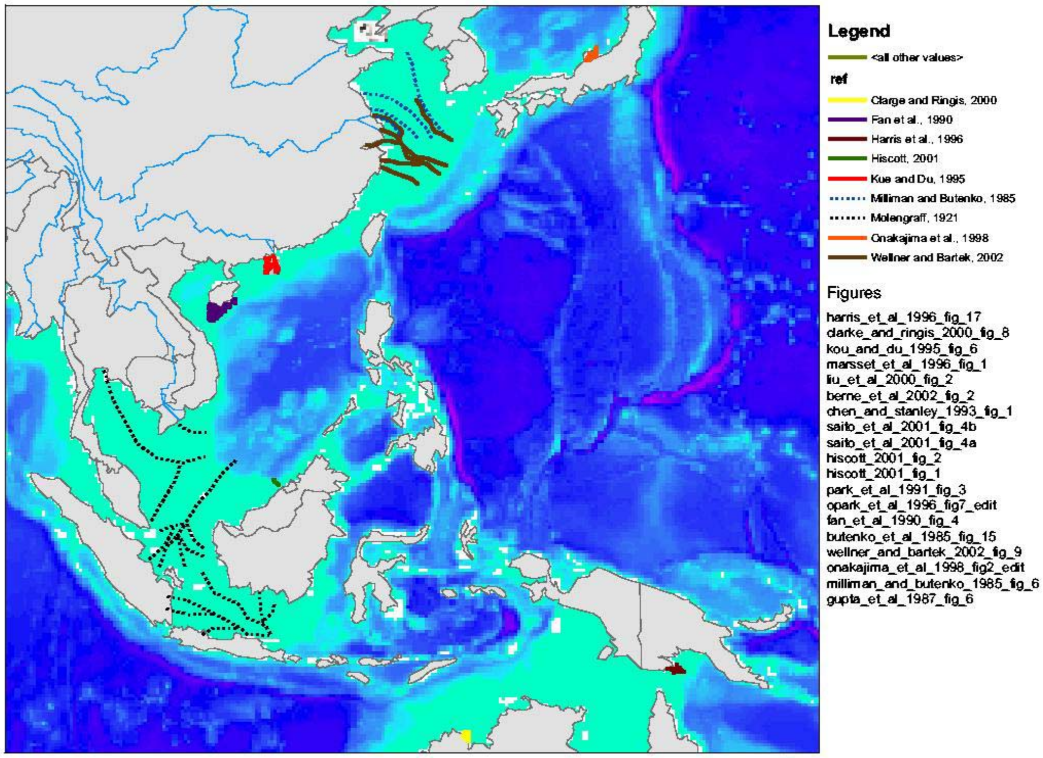
D) New Jersey Outer-shelf Channels



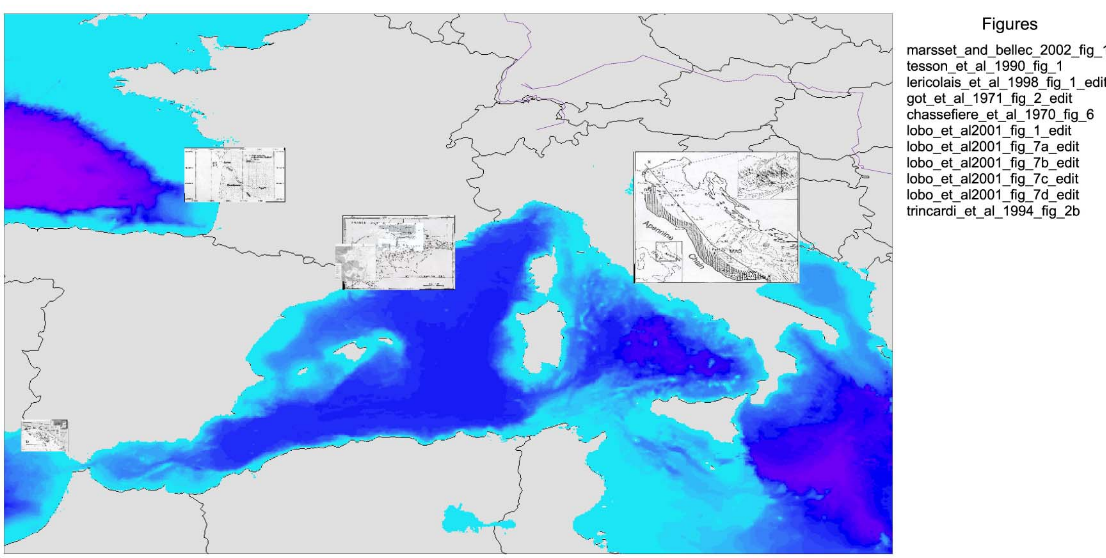
E) Block Island Sound Channel



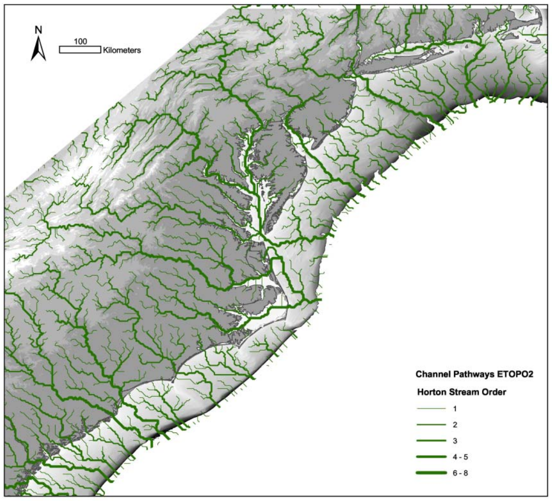
2) Southeast Asia is potentially an important area for buried paleochannels due to its wet, tropical nature and extensive continental shelf area. As a result, a similar channel database is in production for this region. An extensive literature search has been conducted.

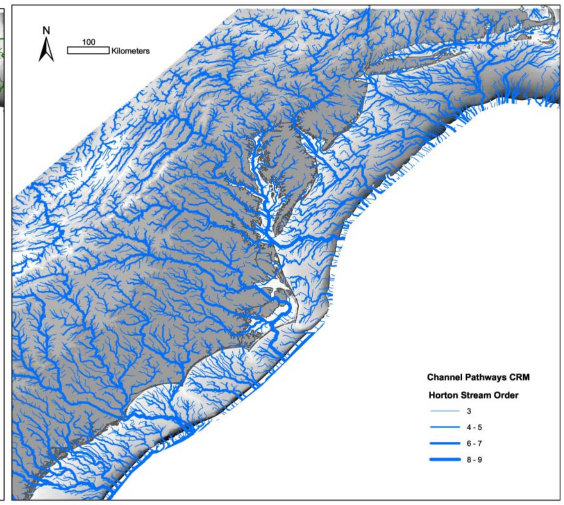


3) Similar to the U.S. East Coast, extensive geologic and oceanographic studies have been conducted along the European margins. A database for paleochannels in this region is under development.

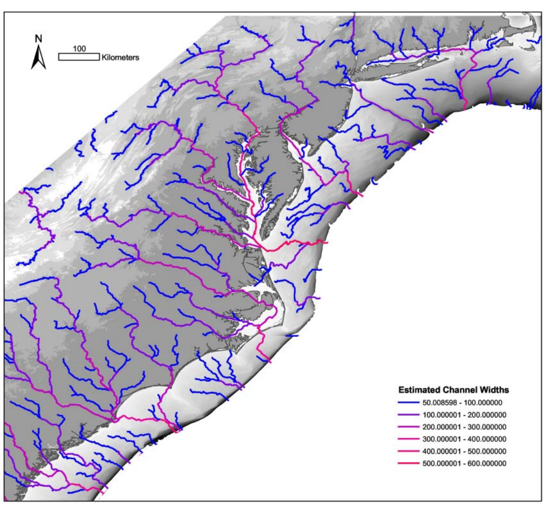


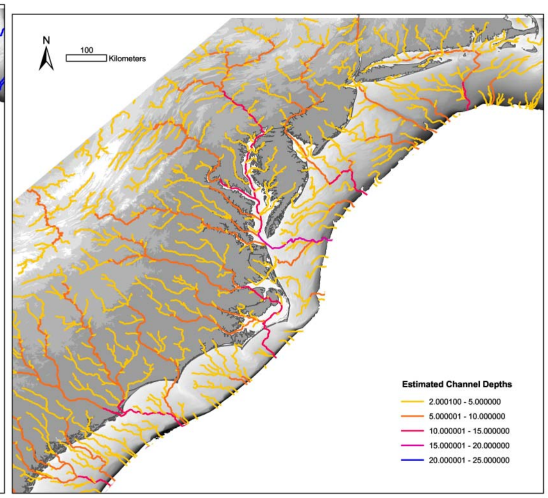
4) Topographic data from ETOPO2 and the Coastal Relief Model (CRM) were used as inputs to RiverTools (software developed by Scott Peckham, INSTAAR) to evaluate the pathway of paleo-rivers across the continental shelf. Results from these analyses indicate that the relatively low-resolution data of ETOPO2 (2 minute pixel size) produce drainage pathways comparable to the CRM (pixel resolution initially at 3 seconds but averaged to 12 seconds). Interestingly, the observed paleo-Delaware River appears to flow more northerly on the outer shelf (see above; Twichell et al., 1977). This is hypothesized to result from glacial loading during the LGM.





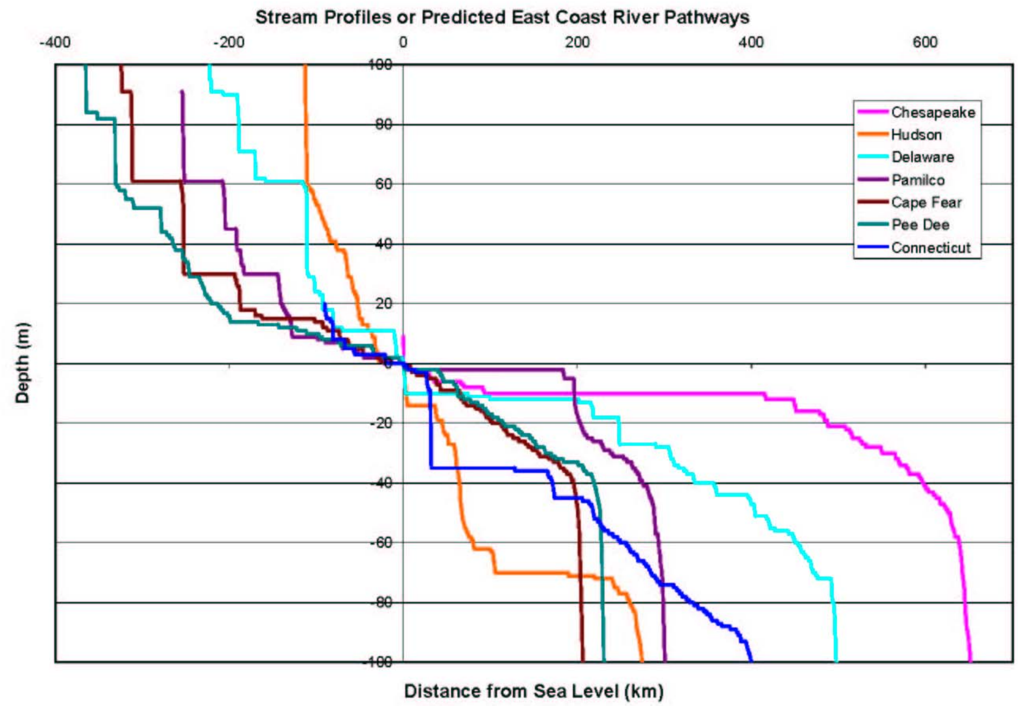
5) To compare the geometry of observed channels with that predicted by fluvial drainage, we used modern hydraulic geometry relationships to predict the width and depth of paleo-river channels on the continental shelf. Based on these relationships, channel widths on the continental shelf are predicted to be <500m. Many observed channels are considerably greater in size than predicted, supporting the idea that these features are "incised valleys". However, several potential "valleys" have characteristics of channels (i.e., shape, fill, geometry), possibly reflecting large discharge events.



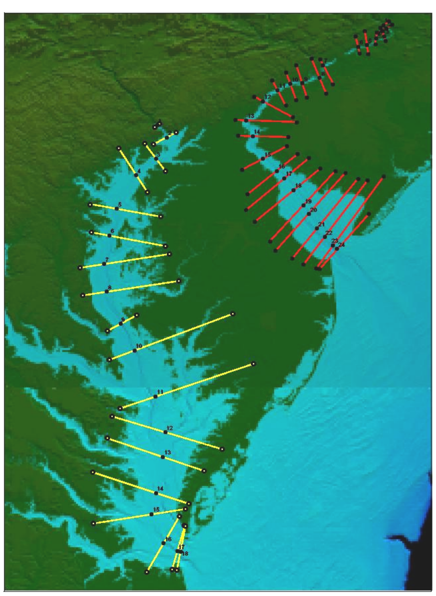


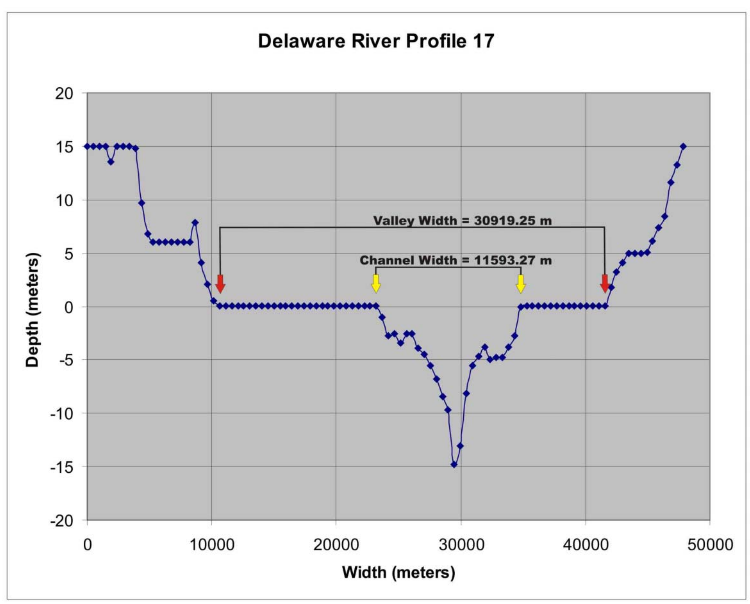
Also, to better understand areas of likely fluvial incision and deposition during periods of lowered sea level, stream elevation profiles of the estimated channel pathways were determined. These data highlight the potential for fluvial deposition on the New York Bight shelf during lowered sea level.

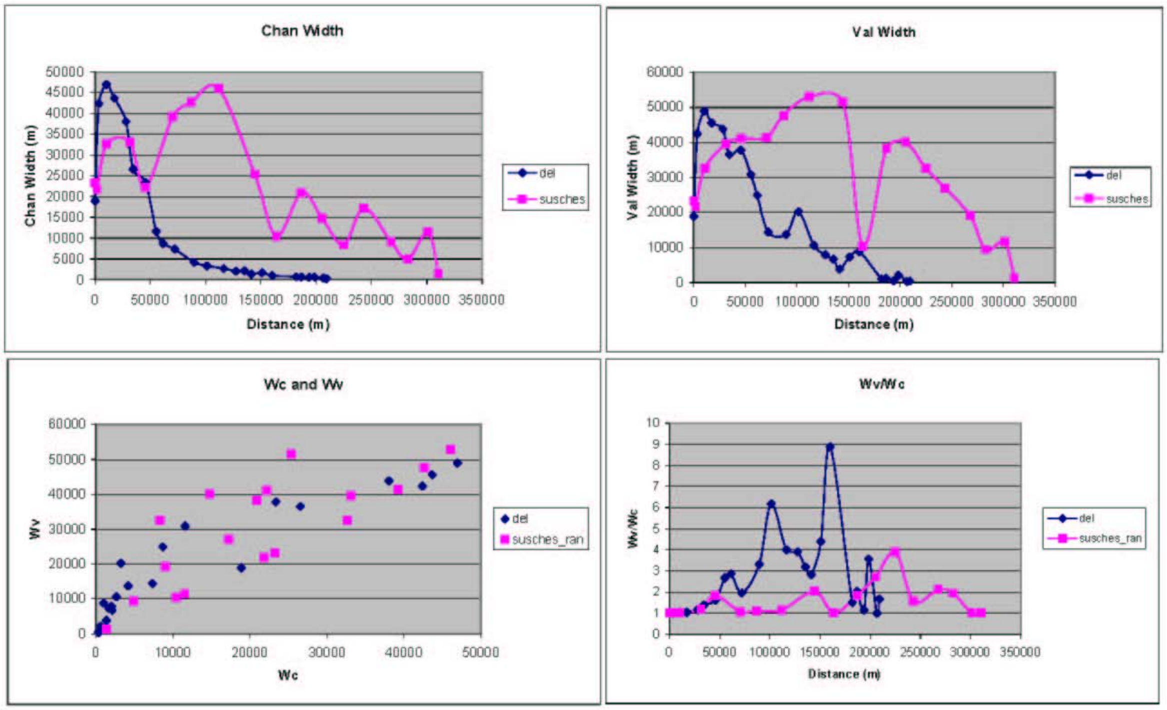
Furthermore, coastal and outer-shelf areas are highlighted as possible locations for enhanced fluvial incision.



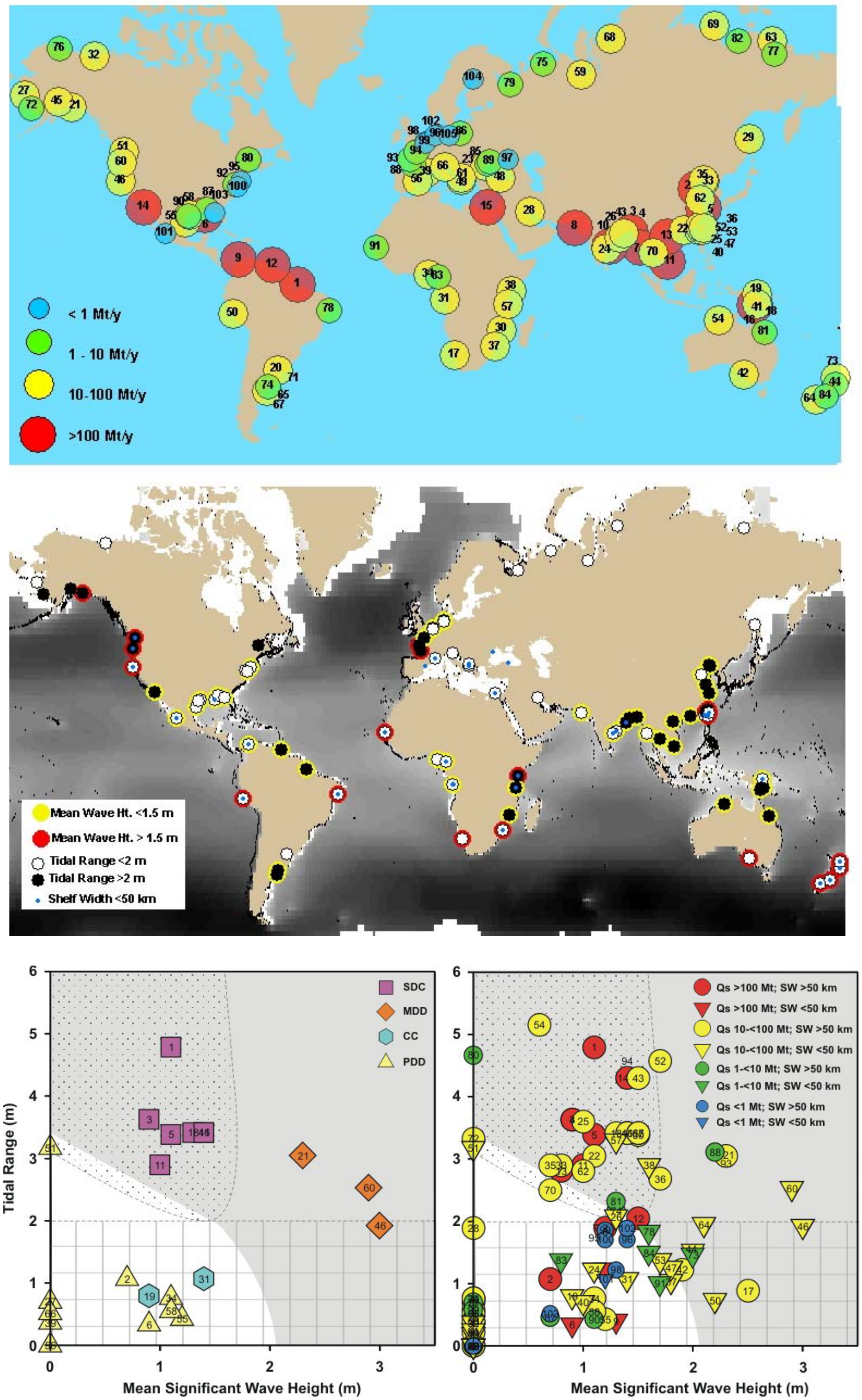
6) It is evident from this and other research that many "channels" on the U.S. East Coast are "incised valleys". To better understand relationships between valleys and their associated river channels, measurements are being made on valley/channel characteristics of major East Coast coastal-plain systems. This preliminary research gives insight into how estuarine processes can impact the evolution of a river channel.







7 The burial of sediment by river systems is also a major concern of the Geoclutter Program. Several studies have examined sedimentation seaward of individual river systems in detail, but little attempt has been made to integrate observations. To evaluate river-sediment accumulation on continental shelves around the world, a database of river sediment discharge, mean significant wave height, tidal range and continental shelf width was created for >100 major rivers. These data reveal that 4 basic types of river sediment dispersal exist and these are predictably related to hydrological and oceanographic factors.


< 1 Mt/y
1 - 10 Mt/y
10-100 Mt/y
>100 Mt/y
Mean Wave Ht. <1.5 m
Mean Wave Ht. > 1.5 m
Tidal Range <2 m
Tidal Range >2 m
Shelf Width <50 km
SDC
MDD
CC
PDD
Qs >100 Mt; SW >50 km
Qs >100 Mt; SW <50 km
Qs 10-<100 Mt; SW >50 km
Qs 10-<100 Mt; SW <50 km
Qs 1-<10 Mt; SW >50 km
Qs 1-<10 Mt; SW <50 km
Qs <1 Mt; SW >50 km
Qs <1 Mt; SW <50 km
Tidal Range (m)
Mean Significant Wave Height (m)
Mean Significant Wave Height (m)

RESULTS AND INSIGHTS

A marked variety in channel architecture is observed along the U.S. East Coast, and this records the interplay of different processes operative during different times. Furthermore, the database highlights areas lacking data; more high-resolution geophysical data are required on the middle and outer continental shelf. Despite the plethora of research that has been conducted on the U.S. East Coast, paleo-river pathways across the continental shelf are poorly constrained by the existing data.
Several studies have described “incised valleys” in estuaries and inner continental shelf areas. These features typically have width/depth ratios of >100 and can show complex cut-and-fill geometries related to channel migration. However, a few anomalously large channels are evident in the NY Bight and Block Island Sound and likely were carved during catastrophic lake drainage following the LGM. Tidal channels commonly are thought to be small features, but large river valleys are known to evolve into estuaries during the ensuing sea level rise. These channels have subparallel infill that mimics the underlying erosive surface. A wide diversity of channels is also evident in SE Asia and European region. The compiled database will provide valuable inputs and constraints for the modeling efforts, which will help understand the distribution and architecture of channels in response to different forcing functions.

Prediction of paleo-channel pathways and architecture using modern bathymetric data is a useful exercise as it provides results that can be compared directly to observed data. These differences can yield valuable constraints on modern and ancient conditions. For example, the observed paleo-drainage pathway for the Delaware River is farther north than predicted using Rivertools. This discrepancy may be explained in terms of glacio-isostatic loading. Differences between model predictions and observations will help focus further research.
Modern hydraulic relationships indicate that most river channels on the continental shelf would have been relatively narrow (50-100 m) with shallow relief (<5 m). If true, the majority of these channels would likely be cannibalized during sea level rise. Numerous large channels (or valleys) are observed on the U.S. East Coast continental shelf that are not predicted by the models. Possible explanations for their occurrence must be further evaluated.

Understanding the burial of channels is a critical component to this project. Wave, tide, sediment discharge and shelf width data from >100 major river indicate that 4 basic types of sediment dispersal patterns exist. These findings have important implications for potential channel burial as well as the fate of carbon.

PUBLICATIONS

Publications from Phase I of the Geoclutter project

Driscoll, N.W., E. Uchupi, W. C. Schwab, J.P. Donnelly, L.D. Keigwin, and E. R. Thieler (prep). Catastrophic drainage of Late Wisconsin glacial lakes: Morphologic and Climatic Implications. Science.

Swift, J.P., N.W. Driscoll, J.C. Borgeld, and J. Crockett (in prep) Transgressive facies assemblages and sequence development on an active margin: Northern California. Strataform Volume.

Uchupi, E., N.W. Driscoll, R.D. Ballard, and T. Bolmer (2001). Drainage of Late Wisconsin glacial lakes and the morphology and Late Quaternary stratigraphy of the New Jersey Southern New England Continental Shelf and Slope, Marine Geology v. 172: 117-145.

Walsh, J.P., C.A. Nittrouer, C. Palinkas, A.S. Ogston, R.W. Sternberg, and G.J. Brunskill. Accepted. Clinoform mechanics in the Gulf of Papua, New Guinea. Continental Shelf Research.

Walsh, J.P. and C.A. Nittrouer. Submitted. Mangrove sedimentation in the Gulf of Papua, New Guinea. Marine Geology.

Walsh, J.P., C.A. Nittrouer, and N.W. Driscoll. In prep. Marine dispersal of fine-grained river sediments: environmental controls on subaqueous delta clinoforms. Geology.

Walsh, J.P. and N.W. Driscoll. In prep. Preservation of paleochannels: examining the link between process and product. Geological Society of American Bulletin.

Walsh, J.P., N.W. Driscoll, and C.A. Nittrouer. Accepted. Marine Dispersal of Fine-grained River Sediment: Environmental Controls on Subaqueous-Delta Clinoforms. GSA Geoscience Horizons Meeting, Seattle.

Walsh, J.P., N.W. Driscoll, W.C. Schwab, P.T Gayes, and W.E. Baldwin. 2002. Distribution and architecture of channels preserved on continental shelves: a comparison of the Carolinas and the U.S. East Coast. Eos Transactions, 83, No. 47: OS71B-0272.

Woodruff, J.D., W.R. Geyer, C. Sommerfield, and N.W. Driscoll 2001. Seasonal variation of sediment deposition in the Hudson River estuary. Marine Geology, 179: 105-119.