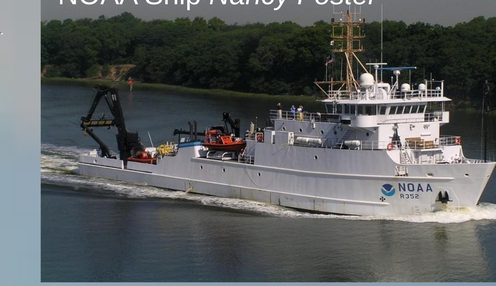
COLLEGE of CHARLESTON
DEPARTMENT OF GEOLOGY AND ENVIRONMENTAL GEOSCIENCES

Bathymetric Analysis of the Southern Portion of the Mid-Atlantic U.S. Continental Margin

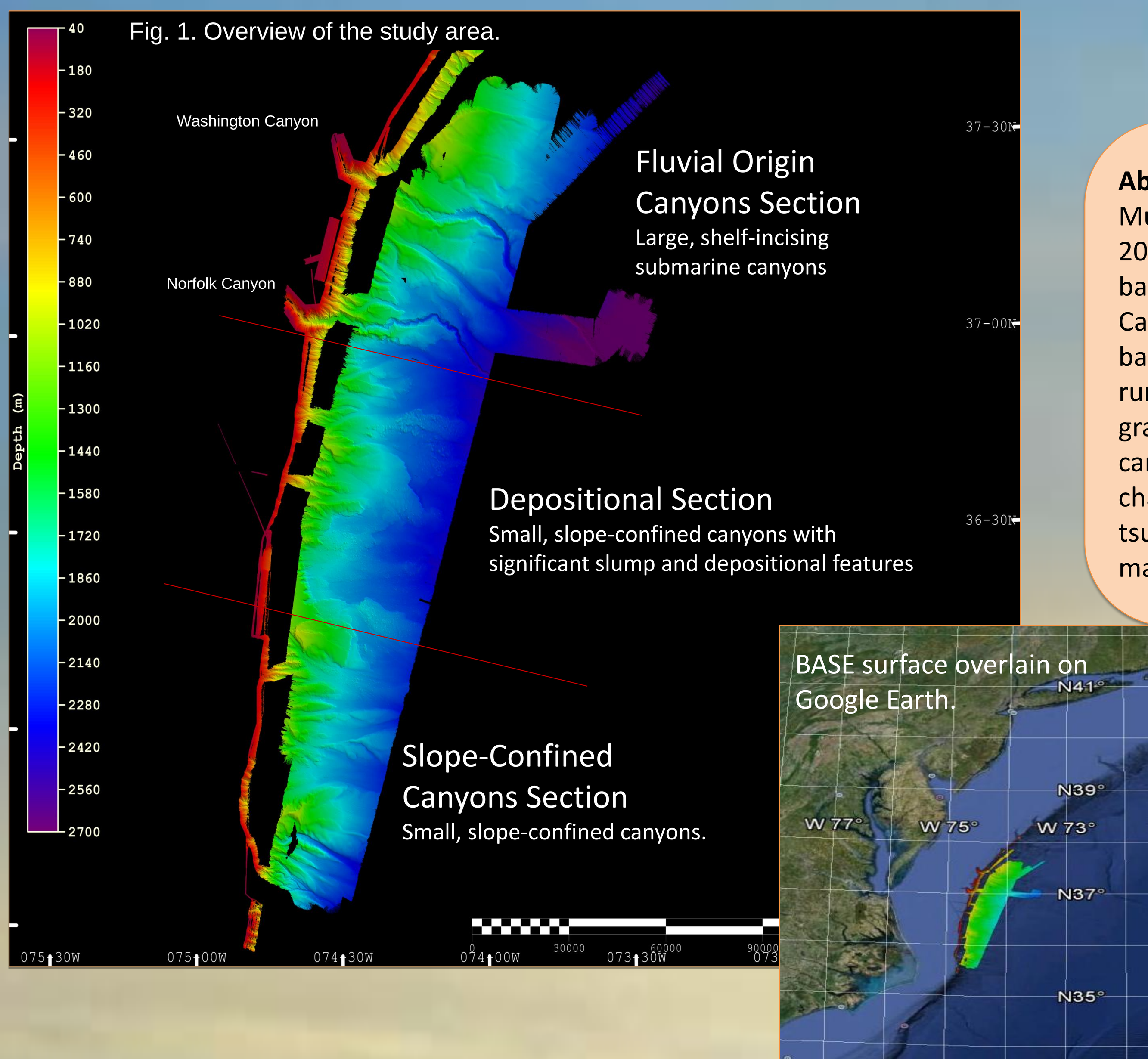
Per W. Lorentzen, Samir Younes, and Dr. Leslie Sautter

Dept. of Geology and Environmental Geosciences, College of Charleston

NOAA Ship *Nancy Foster*



NOAA Ship *Okeanos Explorer*

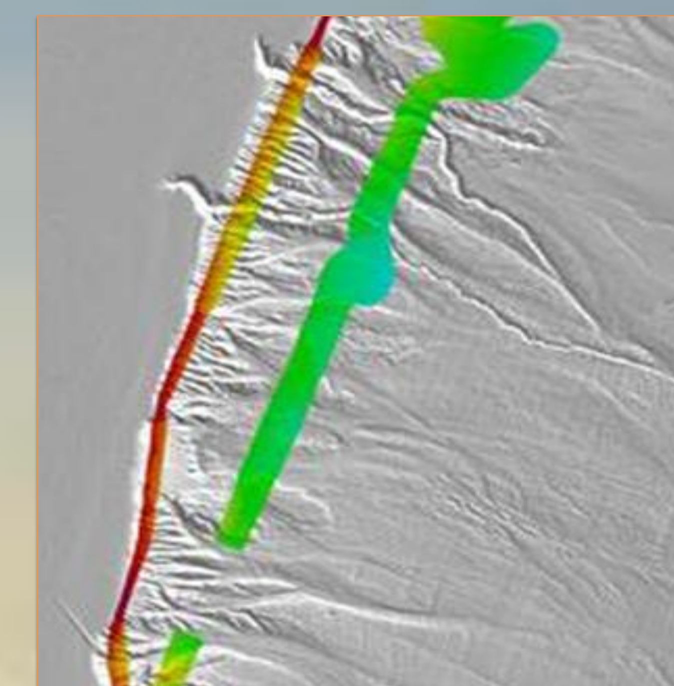


Abstract

Multibeam sonar data were collected by the NOAA Ships *Okeanos Explorer* (June, 2011 and November, 2012) and Nancy Foster (June, 2011) during three cruises to acquire high-resolution bathymetric and backscatter data of the continental slope due-east of the northern portion of the Outer Banks, North Carolina and southern Delaware coastlines. Kongsberg EM302 multibeam sonar was used, and bathymetric and backscatter data were processed using CARIS HIPS & SIPS 7.1 software. Surveys were run parallel to the shelf edge, ranging in depth from 100 to 3000 m. This area has some of the steepest gradients of the United States east coast. The shelf is well incised by many medium-sized submarine canyons in close proximity of each other as well as the large Norfolk and Washington Canyons that characterize the slope and rise. High-resolution bathymetry can help with predicting areas where tsunamis may occur as a result of major sediment slumping. The continental rise is seldom the focus of mapping projects, but within our data are three examples of sediment travelling from shelf to rise.

Methods

- Surveys were conducted by the NOAA Ships *Okeanos Explorer* during June of 2011 and two sails in November of 2012, and Nancy Foster (June of 2011) to collect data to be mapped.
- All multibeam and backscatter data was obtained with a Kongsberg EM302 multibeam sonar system.
- Seafloor Information System (SIS) was used to acquire data.
- CARIS HIPS & SIPS 7.1 was used to create a 5 m resolution CUBE surface.



__Older Bathymetric Reference:__ Lower resolution bathymetric reference borrowed to fill our data gaps. The area shown in color is for a different project (Ten Brink, 2009).

Results

- The two large canyons, Washington and Norfolk Canyons, incise the continental shelf. Sediment is transported to depths beyond our BASE surface (Fig. 2).
- Washington Canyon has a wider channel than Norfolk Canyon, and has a very narrow channel *within* the main channel (Figure 2, profiles "A" and "C"). This small channel is evident in the center of The Fluvial-Origin Canyons Section (Fig. 2, Profile "A", and 3D view).
- Norfolk Canyon has a deeper, narrower channel (Figure 2, profiles "B" and "D", and 3D view).
- Areas where slumping activity has occurred contain large blocks of sediment. These blocks are deposited further down the slope than the sediment was originally deposited, most l likely due to slope failure. The volume of sediment displaced may have been significant enough to produce tsunamis (Fig. 3).
- One area of major slumping appears to have created the heads of several new canyons in our Depositional section (Fig. 3, Profile C-C').
- Multiple inter-canyon channels in the south (Fig. 4) combine to form a single deeper and appears to be a faster channel that transports sediments to depths uncharacteristic of such small canyons.
- Smaller canyons to the south demonstrate evidence of sediment deposition on the slope and upper rise.

Introduction

Our area of focus is the continental margin from Cape Hatteras, North Carolina to Maryland. The southern half of the region is within the upper Carolina Trough, while the northern half lies in the lower Baltimore Canyon Trough. Bathymetry in the study area is characterized by many small canyons in the southern portion and fewer, but larger canyons in the northern portion, though there is a steep gradient on the continental slope throughout. Occurrences of slumping are also evident for this region.

Two populations of submarine canyons occur along the central U.S. Atlantic margins: slope-confined and shelf-indenting (or shelf-incised) canyons that represent different stages of canyon evolution (Vachtman et al., 2013). The submarine canyons of the Hatteras Outer Ridge have been affected by continuous geostrophic contour currents (Meekins, 1999). Quaternary sediment supply to the region between Hudson Canyon, south of Long Island, New York, and Cape Hatteras, North Carolina, has been fluvially influenced (Twichell et al., 2009). Gradients within canyons can be much steeper than those of the open continental slope and rise. Because of the steeper canyon gradients, sediments are more susceptible to detachment as a result of small seismic triggers (Twichell et al., 2009). Water displacement by these sediments can be large enough to create dangerous tsunamis. Along the U.S. Atlantic margin, triggering of submarine landslides is commonly attributed to earthquakes, but other processes including over-steepening, can pre-condition the sediment for future failure (Twichell et al., 2009). In this study, the BASE surface is broken into three sections for comparison of the different submarine morphologies present. The continental rise and slope are examined in detail to distinguish sediment transportation and deposition styles, and slumping within each section.

Fluvial-Origin Canyons Section

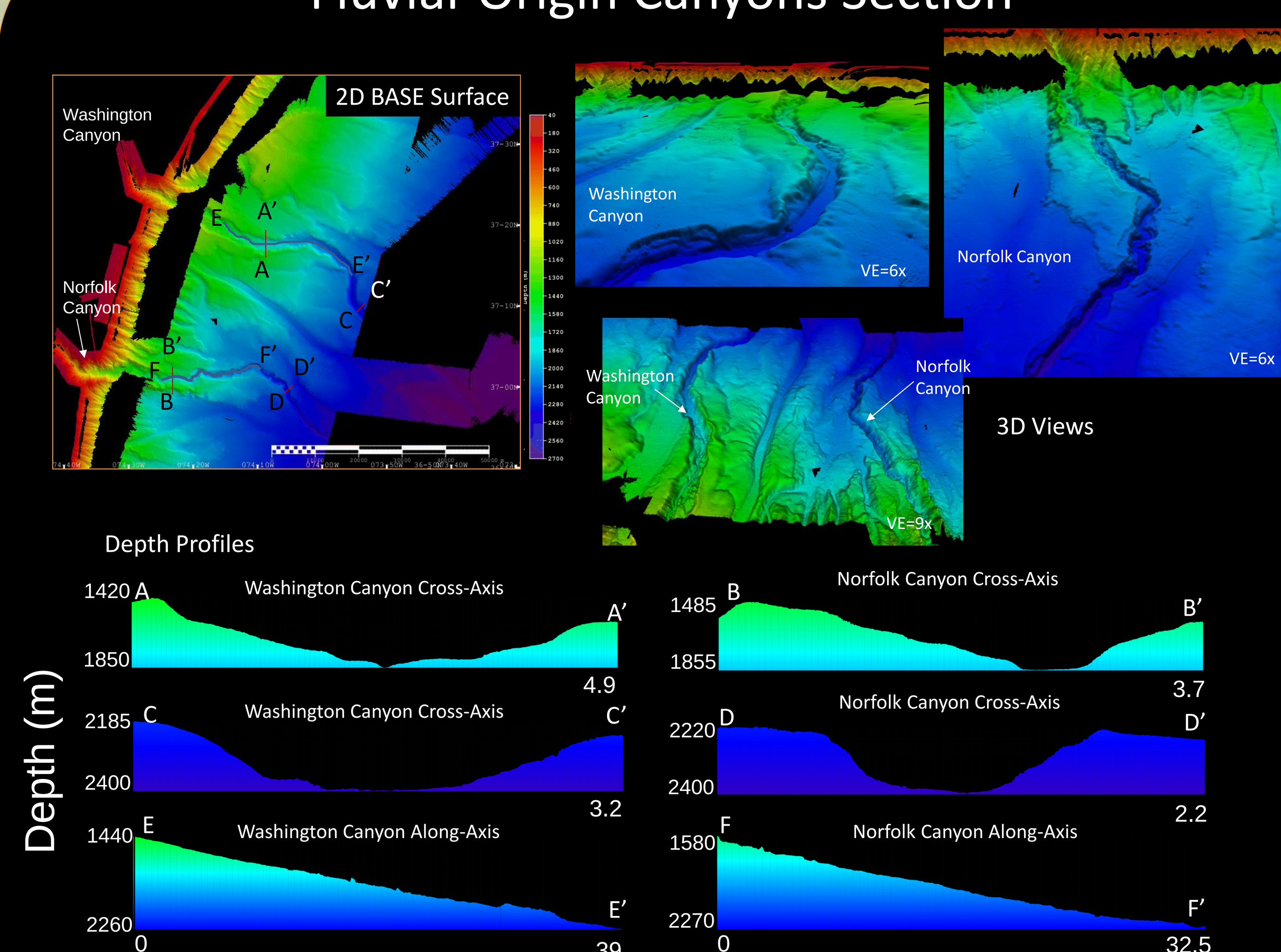


Fig. 2. Two large canyons, Norfolk and Washington Canyons, are unique to the Fluvial-Origin Canyon Section. These Canyons incise the shelf edge. Profiles of both canyons were made at 1850m and 2400m depths, and along the main channel from roughly 1500 to 2300m.

Slope-Origin Canyons Section

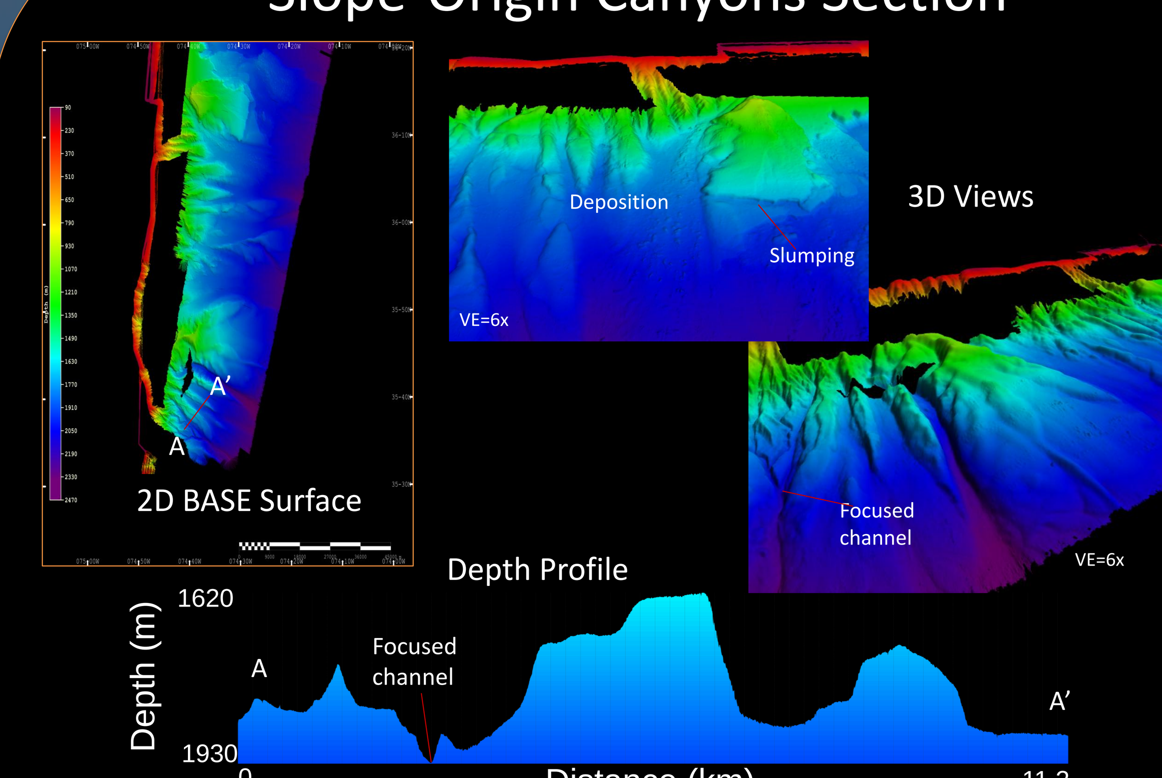


Fig. 4. Relatively small slope-origin canyons are seen along the southern edge of the study region. Some slump features and sediment deposition are also evident. 3D views show that in the far south (left) turbidity current channels from several canyons combine to form one slope-incising channel. Profile A-A' shows a cross-axis view of the small southern canyons. The narrow focused channel is also shown.

Depositional Section

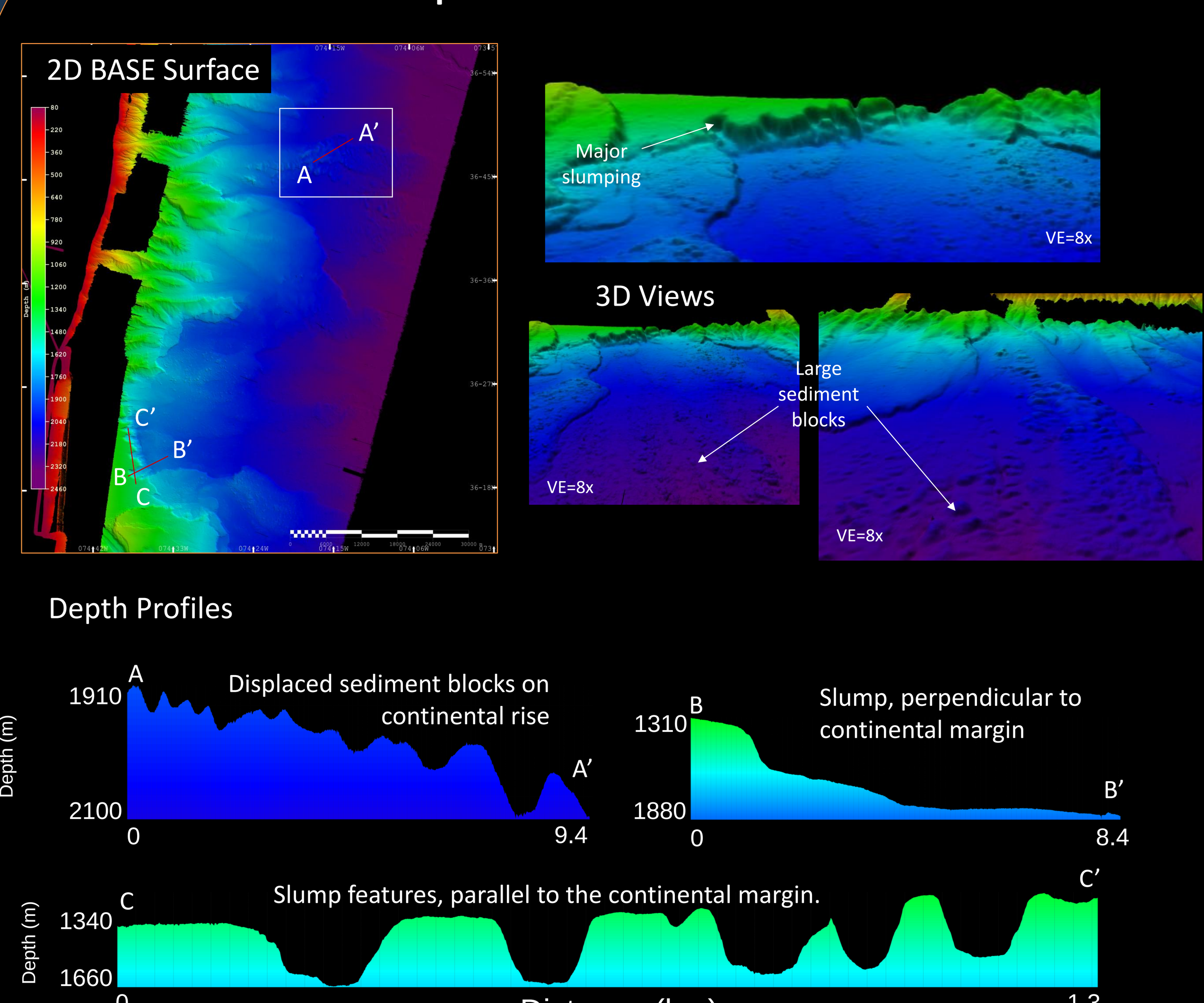


Fig. 3. Large slumping events characterize the Depositional Section. Blocks of sediment rest atop this displaced area, shown in the bottom 3D views and in profile A-A'. Note the mound of sediment deposit at the foot of the slump (B-B'). The white box on the 2D surface shows the area of backscatter mosaic in Figure 5.

Discussion

Three distinct sections of different margin morphology are present in this study area. The northern section, referred to here as the "Fluvial-Origin Canyons" is dominated by Norfolk and Washington Canyons, which have long, deep channels reaching great depths before depositing sediment. This section is illustrated in Figure 2. Evidence of slumping is relatively minor in this section; small areas of steep-angle slopes are, however, present within the canyons. Overall, the channels follow a uniform, gentle angle down the continental slope and rise (Figure 2, profiles "E" and "F"). These submarine canyons probably originated from the remnants of rivers during periods when sea levels were lower. What is now the continental shelf-break was once the site of river mouths. As sea levels rose, continuous turbidity currents followed the existing channels and further incised the shelf and slope. Turbidites deposited on the ocean floor are generally coarser grained than the immediately overlying lower-slope deposits (Underwood et al., 2013).

The middle section, illustrated in Figure 3, referred to as the "Depositional Section", is characterized by small canyons and slumping. One area in particular shows evidence of a major slump (shown in 3D and profiles "B" and "C"). Steeper-than-normal gradients at the head of the slump and along the sides create a depression in the overall geomorphology that indicates a very large displacement of sediment (In 3D and profile "B"). This displacement is potentially large enough to have created a tsunami. There are two categories of slope failure: (1) smaller scale failures that either form canyons, or occur within and are channeled by existing canyon systems; (2) larger scale, catastrophic failures that undermine large areas of canyons and effectively erase preexisting canyon morphology (Driscoll et al., 2000). This slump appears to be a type (1) slope failure, and has created the heads for future canyons (Profile "C"). The seafloor within this depression is marked by large blocks of sediments that appear as bumps on the surface (shown in all 3D views). Backscatter imagery (Fig. 5) reveals differences in acoustic return intensity between these sediment blocks and the surrounding seafloor. The sediment blocks have a higher intensity return than the surrounding seafloor deposits, likely indicating that they are harder than the surrounding plain of sediments.

The southern, "Slope Origin Canyons Section" is illustrated in Figure 4. It contains several small canyons and an area of potential slumping (shown in 3D view). Interestingly, a large channel is present that allows for sediment to be transported deeper than is usual for canyons of small size. This large channel is the result of several small channels converging (Profile A-A', Fig. 4) of these small canyons, at lower depths where the channels haven't yet merged (3D View, Fig. 4).

Each section contains different methods of transporting sediment to greater depths. The northernmost section, with the two large canyons, allows for coarse sediments to reach the greatest depths. Slumping and channel convergence are two other interesting ways in which sediment can move down the slope. The sediment blocks deposited within the slumped area demonstrate how sediment can be transported in packets even when a major slumping event is not taking place.

Backscatter Imagery of Sediment Blocks

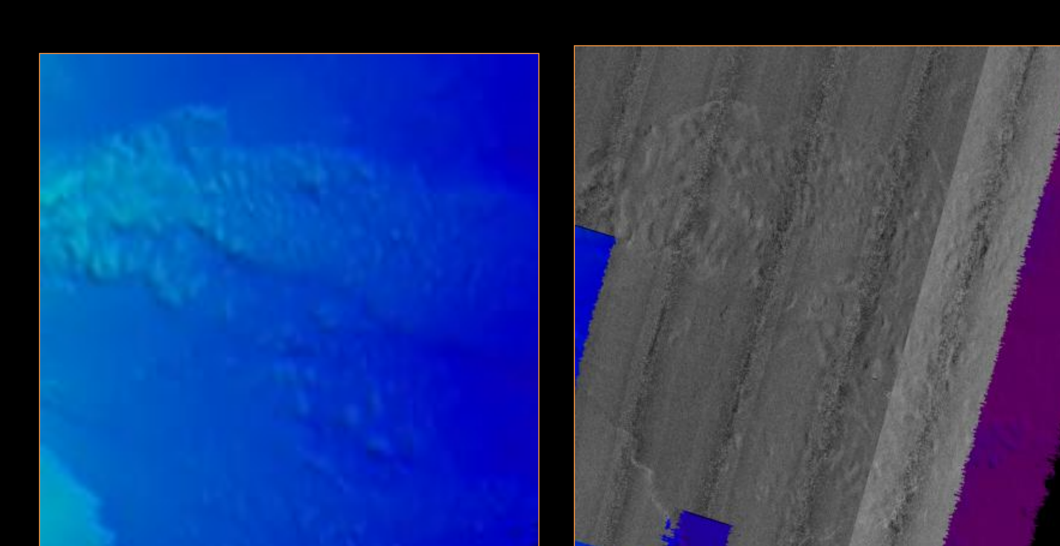


Fig. 5. Backscatter mosaic in Depositional Section showing sediment blocks depicted in Fig. 3 (3D Views). The blocks are shaded lighter, and thus are harder than the surrounding seafloor. This supports the idea that the blocks are compacted sediments.

References:

Driscoll, Neal W., Jeffrey K. Weissel, and John A. Goff. "Potential for Large-scale Submarine Slope Failure and Tsunami Generation along the U.S. Mid-Atlantic Coast." Geology. Geologic Society of America, 2000. Web.

Meekins, K.L., 1999, *Geology and Exploration of the Manteo Prospect off North Carolina*, v. 17, p. 117-122.

Ten Brink, U. "Submarine Landslides as Potential Triggers of Tsunamis That Could Strike the U.S. East Coast." *Sound Waves* (Aug. 2009). *U.S.Geological Survey*. USGS, Aug. 2009. Web

Twichell, D. C., Chaytor, J.D., Brink, U.S., and Buczkowski, B., 2009, *Marine Geology*, v. 264, p. 4-15.

Underwood, Micheal B., and Daniel E. Karig. "Role of Submarine Canyons in Trench and Trench-slope Sedimentation." College of Charleston Libraries. Geologic Society of America, Sept. 1980. Web. 16 Mar. 2013.

Vachtman, D., Mitchell, N.C., and Gawthorpe, R., 2013, *Morphologic signatures in submarine canyons and gullies, central USA Atlantic continental margins*, v. 41, p. 250-263.

Acknowledgments

We are grateful to the CofC BEAMS Program, and for travel Support from the CofC Department of Geology and Environmental Geosciences, the School of Sciences and Mathematics, and SC Sea Grant. We also thank Josh Mode of CARIS USA for his help with HIPS training, and the crew and scientists of NOAA *Okeanos Explorer* and NOAA *Nancy Foster*