Geomorphologic Analysis of Baltimore and Wilmington Canyons on the United States Mid-Atlantic Slope

Samantha M. Bruce and Dr. Leslie R. Sautter

Department of Geology and Environmental Geosciences, College of Charleston, Charleston, S.C.

Abstract

Wilmington and Baltimore Canyons, located 140 km south-east of Delaware Bay along the U.S. Mid-Atlantic Slope, were explored in 2011 and 2012 by the NOAA Ships *Okeanos Explorer* and *Nancy Foster*. A Kongsberg EM302 (*Okeanos Explorer,* 2011 and 2012*)* multibeam echosounder was used to survey the region, and a Kongsberg EM1002 (*Nancy Foster*, 2011) was used to survey the Baltimore Canyon area. CARIS HIPS 7.1 software was used to process and analyze the sonar data and depict the bathymetry of the area. Slumps and evidence of turbidity flows within the submarine canyons were documented, and the region's geomorphology was characterized to inform marine spatial planning efforts specifically related to the management of deep water corals and demersal fish that inhabit rocky substrates.

NOAA Ship *Okeanos Explorer*

NGDC Survey Name (Date):
EX1106 (2011; Sept. 25, 26)
EX1201 (2012; Feb. 18, 20)
EX1204 (2012; May 30)
EX1205L2 (2012; July 27, 30, 31)
EX1206 (2012; Nov. 3, 4)

NOAA Ship *Nancy Foster*

NGDC Survey Name (Date):
NF-11-04-NC (2011; June 6-10)

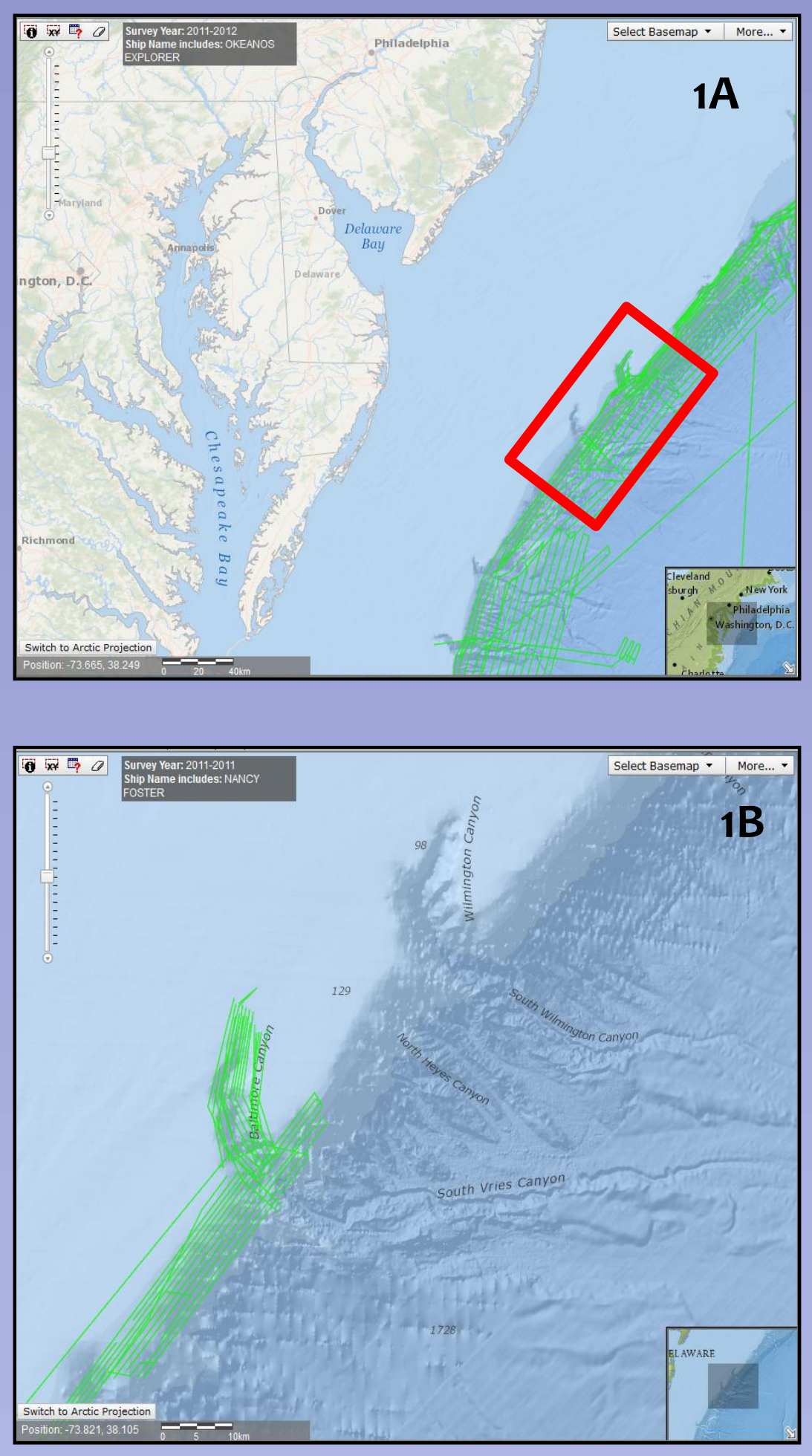


Figure 1:
Data for this project were downloaded from the National Geophysical Data Center (NGDC) interactive bathymetric map online (http://maps.ngdc.noaa.gov/viewers/bathymetry/). Data from five *Okeanos Explorer* cruises and one *Nancy Foster* cruise were processed to get a complete visualization of the seafloor in the vicinity of Baltimore and Wilmington Canyons.

Background

Wilmington and Baltimore Canyons cut into the continental shelf with a hook-like incision oriented from north to south-east and resemble large underwater riverine systems. Wilmington Canyon is the eroded product of several paleo-rivers, the most recent dating to the mid-late Pleistocene when the Delaware River drained to the canyon head (McGregor, 1981). Nearby Baltimore Canyon was a Pleistocene shelf-edge delta (Twichell et al., 2009). Large amounts of sediment were delivered to the Mid-Atlantic shelf during the Pleistocene forming the seaward thickening sediment wedge into which the canyons cut (Brothers et al., 2013). Submarine landslides of various magnitudes have been documented along the U.S. East Coast continental margin, with large landslides having the potential for tsunami creation (ten Brink et al., 2009). Submarine canyons have been cited by many as benthic hot spots for corals and fish (De Leo et al., 2010). Cold water corals are found throughout the world's ocean basins between average depths of 200 and 1000+ m, are believed to sustain on pelagic material transported by currents, and provide needed habitat for fish (Turley et al., 2007).

OBJECTIVES

- **Process sonar data to map and analyze the bathymetry of the study area.**
- **Document slumps as well as evidence of turbidity flows.**
- **Characterize the geomorphology to inform marine spatial planning efforts specifically related to the management of deep water corals and demersal fish that inhabit rocky substrates.**

Methods

- Survey data were downloaded from the NGDC Bathymetry Data Viewer (Fig. 1) and were imported into CARIS HIPS 7.1 for processing.
- 50 m resolution CUBE surfaces created using the data from each vessel and merged into one 50 m resolution CUBE surface.
- A surface filter (depth; 2 standard deviations) was applied to the combined CUBE surface and additional subset editing was completed.
- The surface was interpolated (5X5, 5 neighbors) three times to smooth areas of sparse data in the deep.
- Backscatter (Time Series) data were processed using *Geocoder* to produce a 50 m resolution mosaic.
- The mosaic was classified and draped over the CUBE surface.

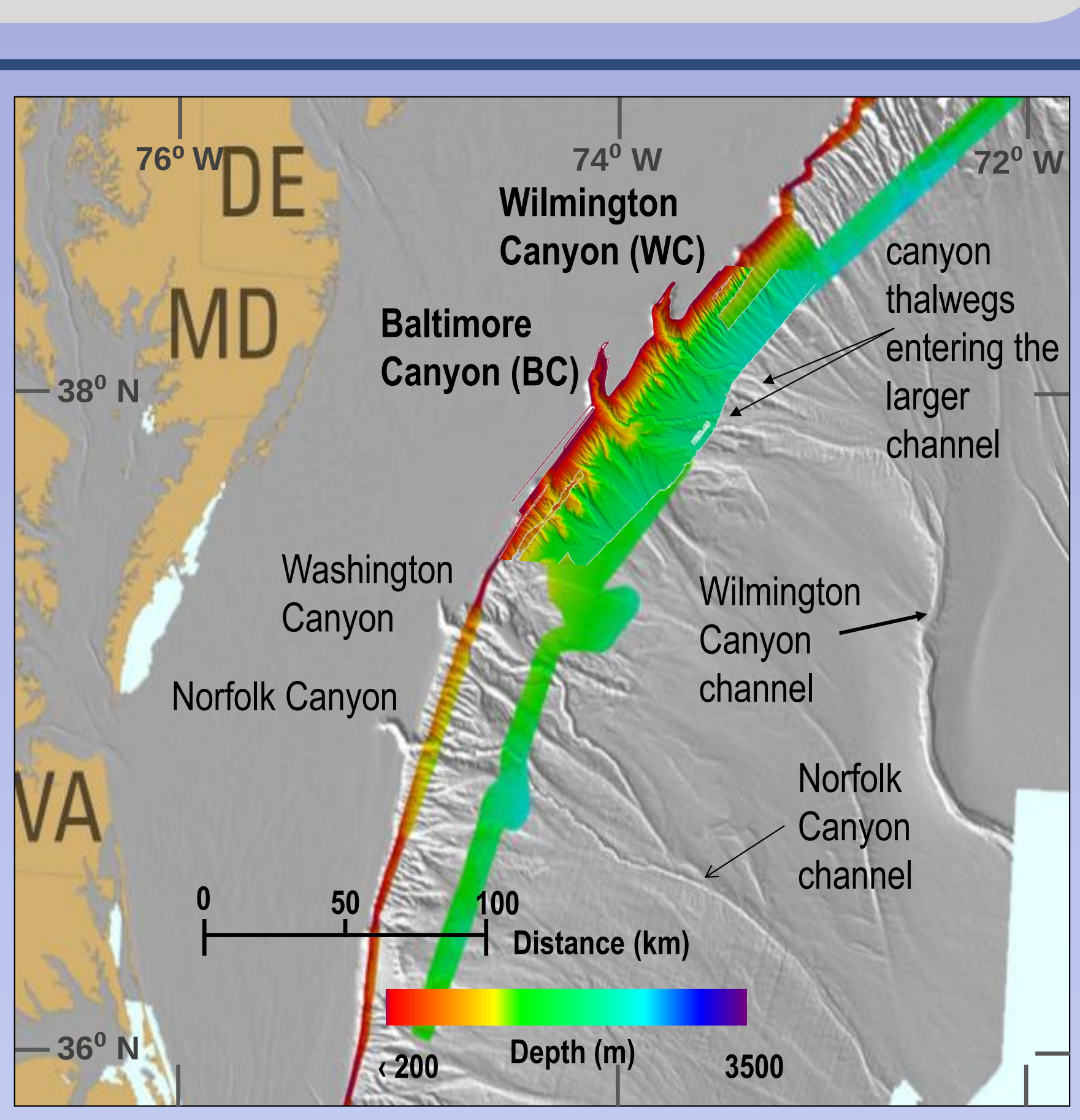


Figure 2: CUBE BASE surface of the Baltimore and Wilmington Canyons study area superimposed on top of a U.S. Atlantic Continental Margin map that includes multibeam data from the 2009 NOAA *Ronald H. Brown* cruise from Cape Hatteras to Georges Bank (ten Brink, 2009).

Results and Discussion

The BC and WC channels have been carved by turbidity currents, as only gravity underflows could form such entrenched seafloor features that resemble rivers (Imran et al., 2007). Less dense turbidity currents flow over the shelf edge, creating gullies and smaller, immature canyons that do not incise the shelf, yet exhibit dendritic patterns as do the larger BC and WC (Figure 4). The dendritic patterns further support river-like forces shaping the morphology of the region. Within the study area all channels including and north of BC converge into the WC channel, whereas channels south of BC flow in the direction of the Norfolk Canyon channel (Figure 2).

Gradients calculated (see profile captions) are consistent with previous findings generalizing most Mid-Atlantic slope canyons to have an average gradient of 4-8^o with larger canyons averaging 8-12^o (Twichell et al., 2009). Most slumping is found below the steeper sections of the slope and likely occurs as a mass gravity flow when sediments from the shelf eventually build-up over time (Figure 6). Backscatter intensities (Figure 5) suggest fine sediments are easily removed from the slope, and the area with the highest intensity of return observed south of BC may be representative of a submarine landslide scar.

Both BC and WC exhibit flat bottoms (A-A') and may support a rich demersal fish population as has been documented in canyons with similar morphologies (De Leo et al., 2010). The relatively high backscatter intensities observed in BC (Figure 5) also suggest that it may serve as a prime habitat for deep water corals and demersal fish that inhabit rocky substrates. High backscatter intensities are observed in some outcrop areas within WC and deep water corals may be found in these regions, but not in as great of abundance as what possibly exist in BC.

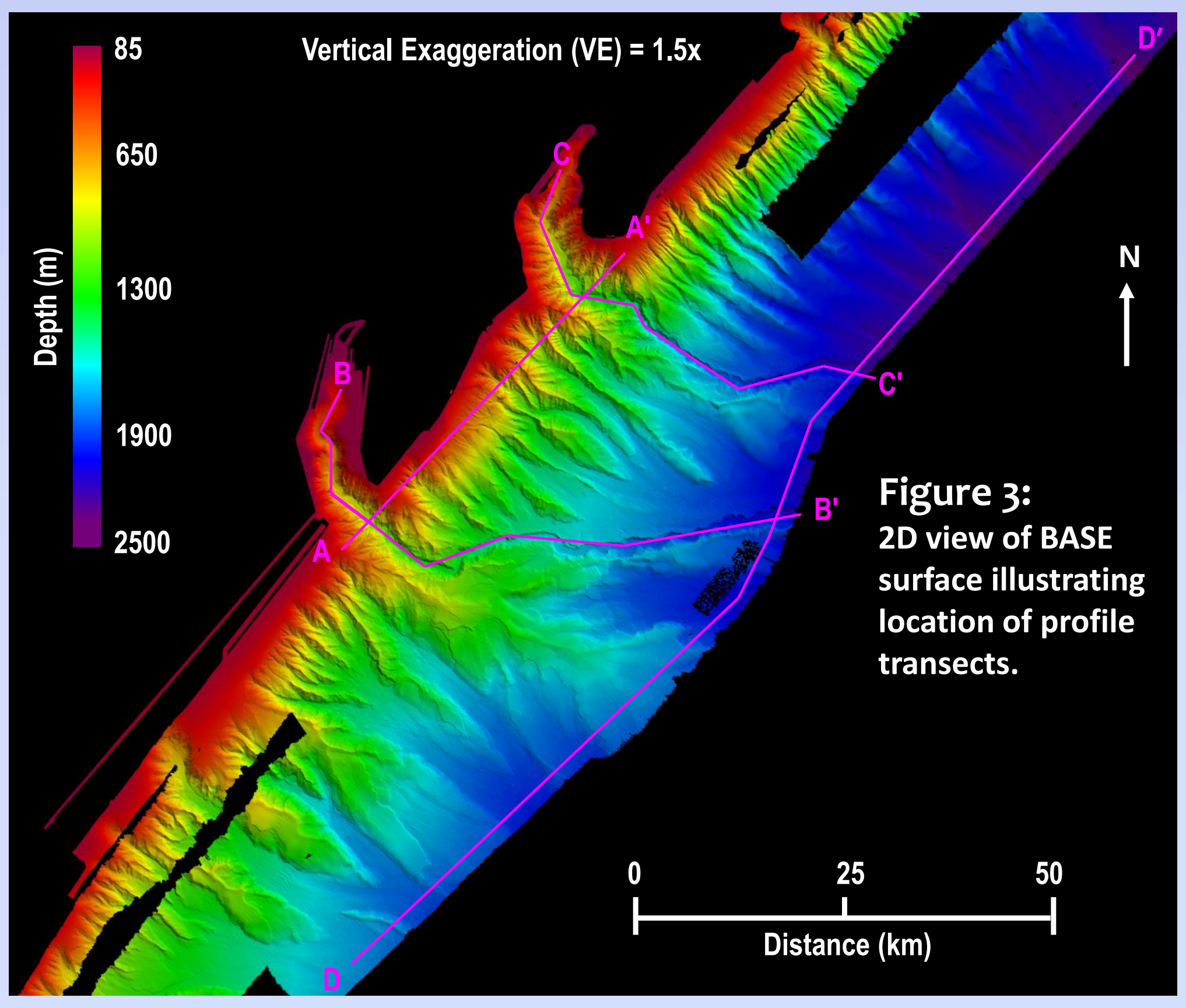


Figure 3: 2D view of BASE surface illustrating location of profile transects.

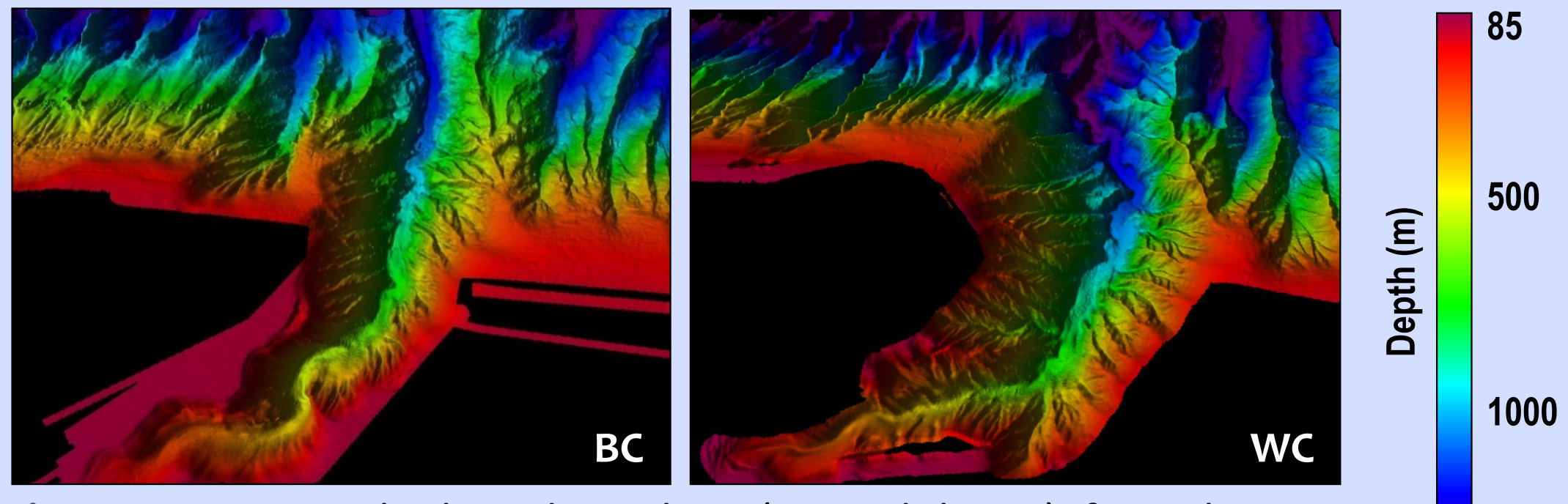
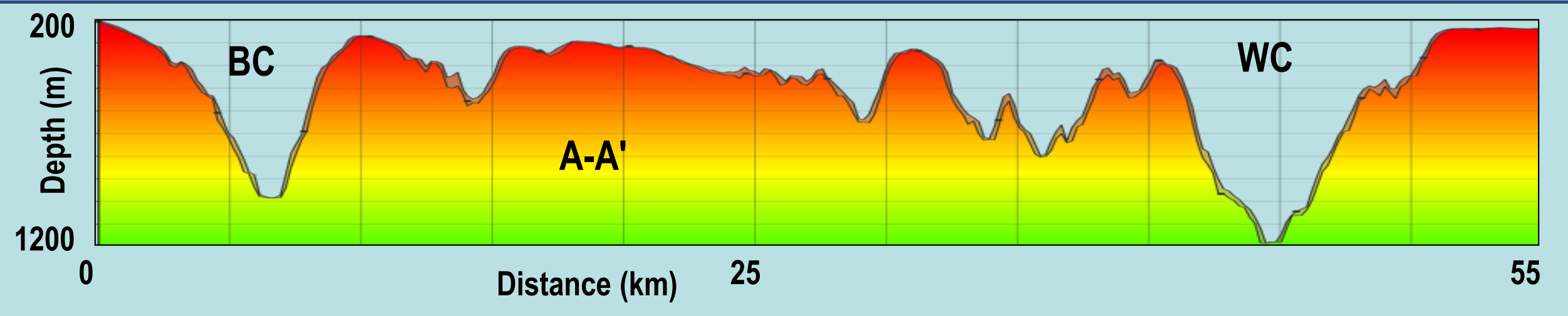
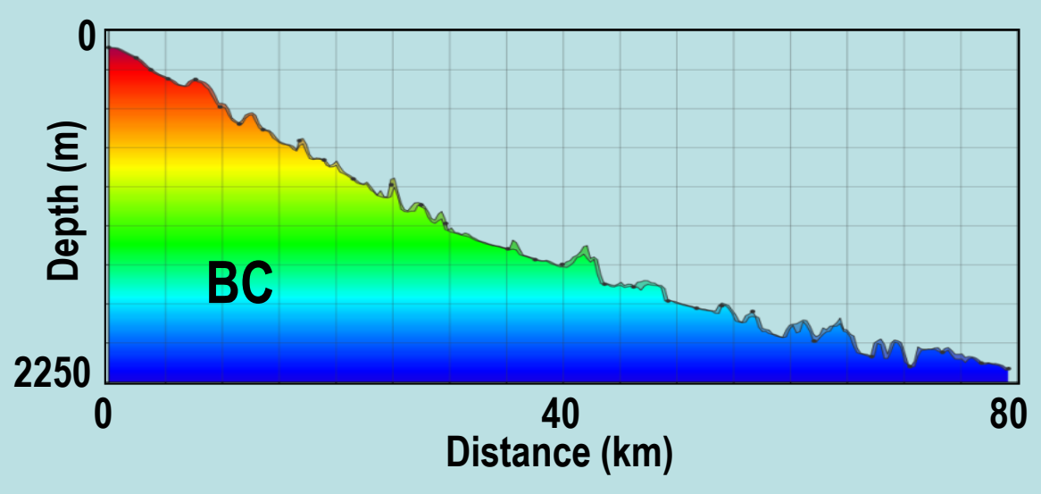
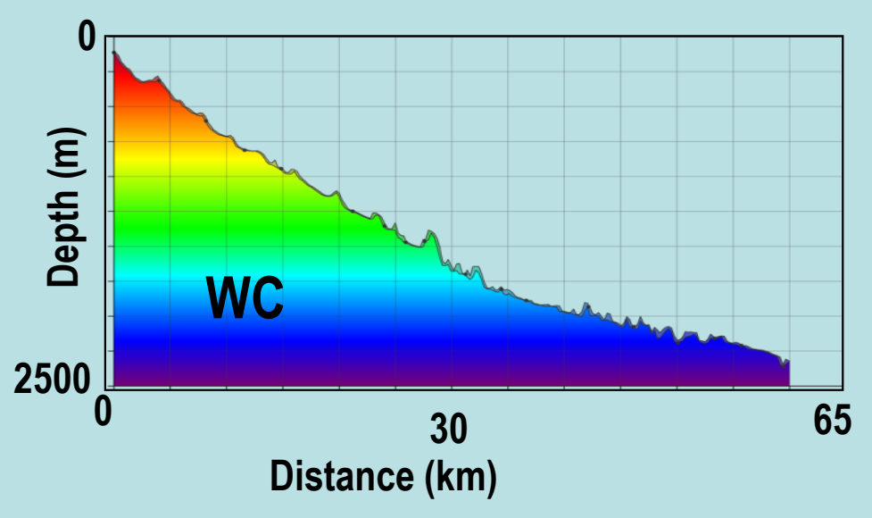


Figure 4: 3D views looking downslope (toward the SE), from the shelf. Dendritic patterns are observed on the walls of both canyons. WC (C-C') has a larger gradient than BC (B-B') suggesting more powerful turbidity currents and/or older age.

3D View
VE = 10x





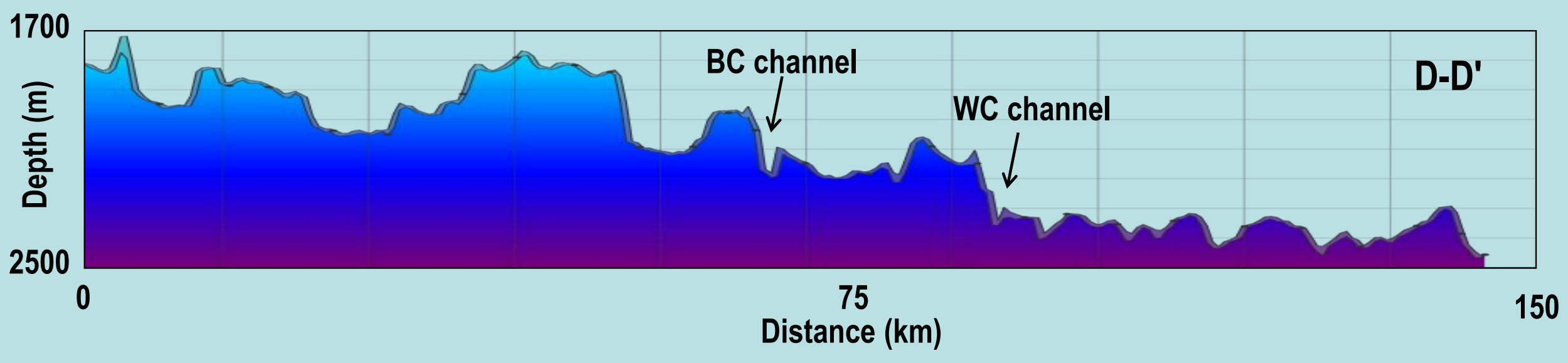


A-A': Cross-section between Baltimore and Wilmington canyons. The distance between the canyon centers is 38km. Average gradient of BC and WC walls as measured from profile = 11^o.

B-B': Profile along the BC canyon channel, with channel gradient = 1.5^o

C-C': Profile along the WC canyon channel, with channel gradient = 2.3^o

D-D': A SW-NE cross-section along the continental rise, roughly parallel to the shelf-edge. The rise is deeper off the northeastern section, indicating steeper overall gradients, and perhaps less well-developed submarine fans, and transport further into the abyssal plain.



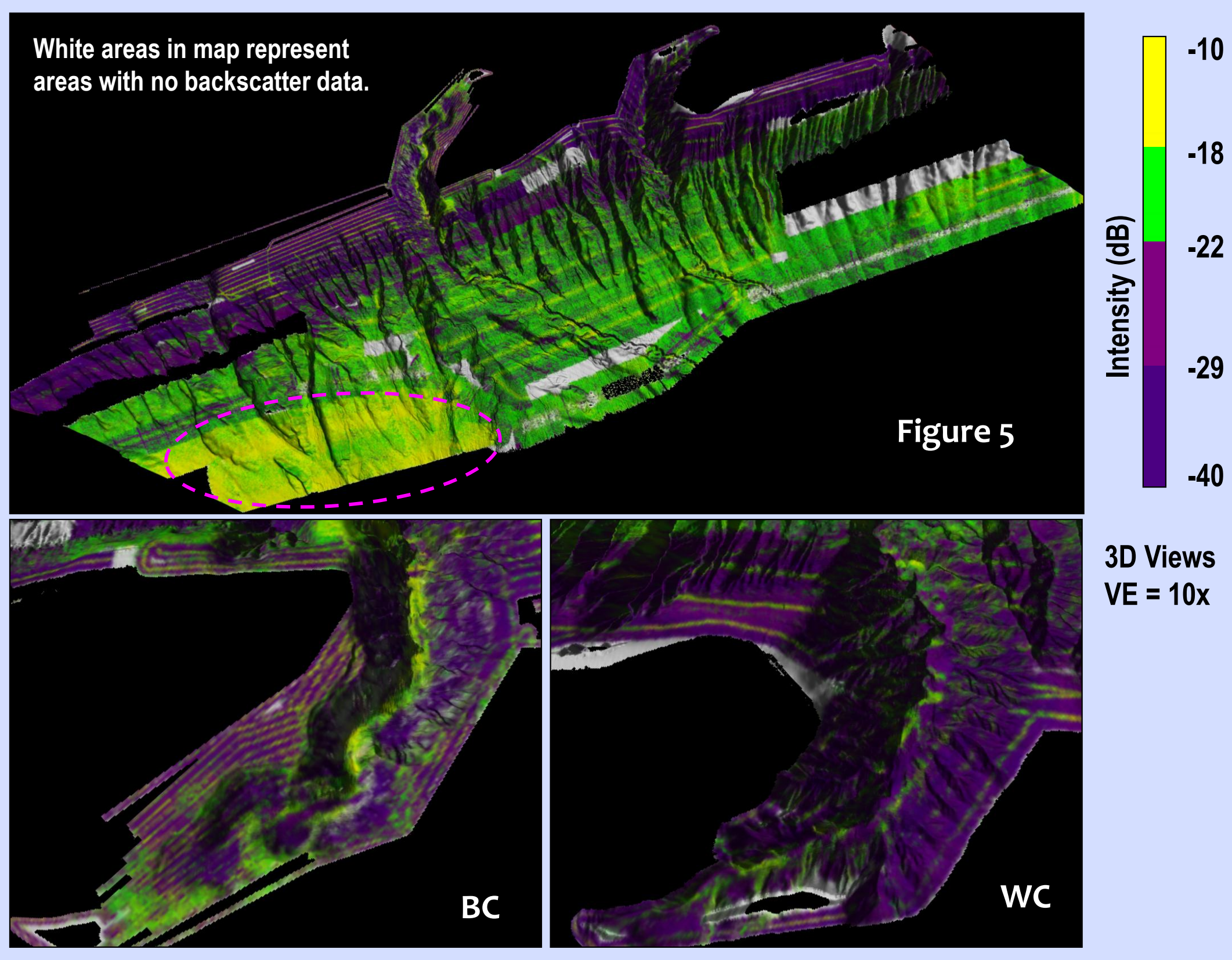
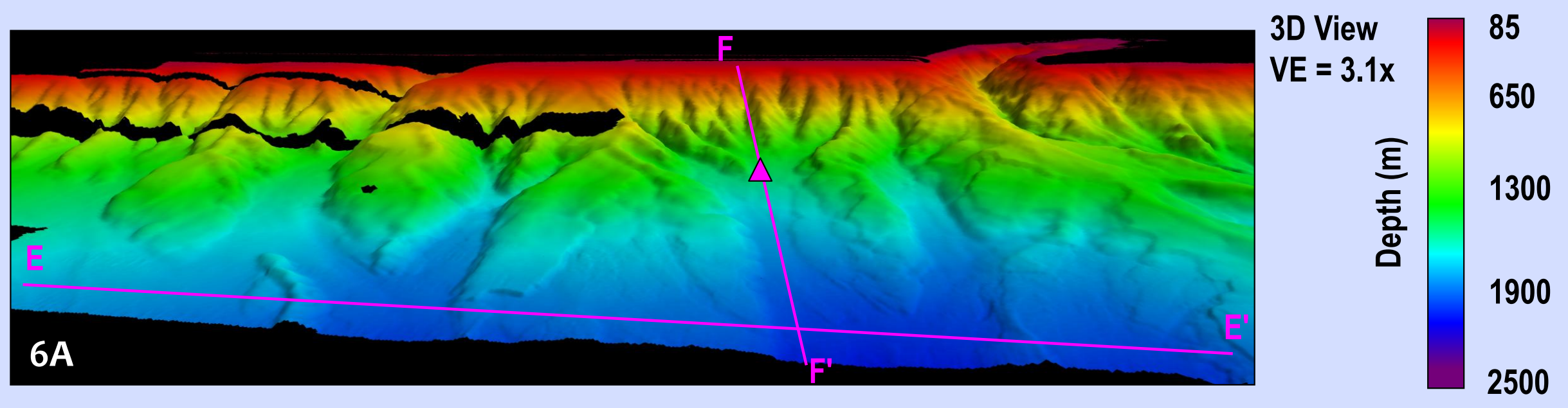


Figure 5: Classified backscatter mosaic draped over 3D BASE surface. A landslide scar is revealed along the lower left side of the mosaic, representing the largest area of high intensity on the surface and circled with a pink dashed line.

BC: High backscatter intensities are observed along the BC channel and outcrop areas.

WC: Outcrop areas exhibit high backscatter intensities, but intensities are not as great along the bottom channel as observed in BC.



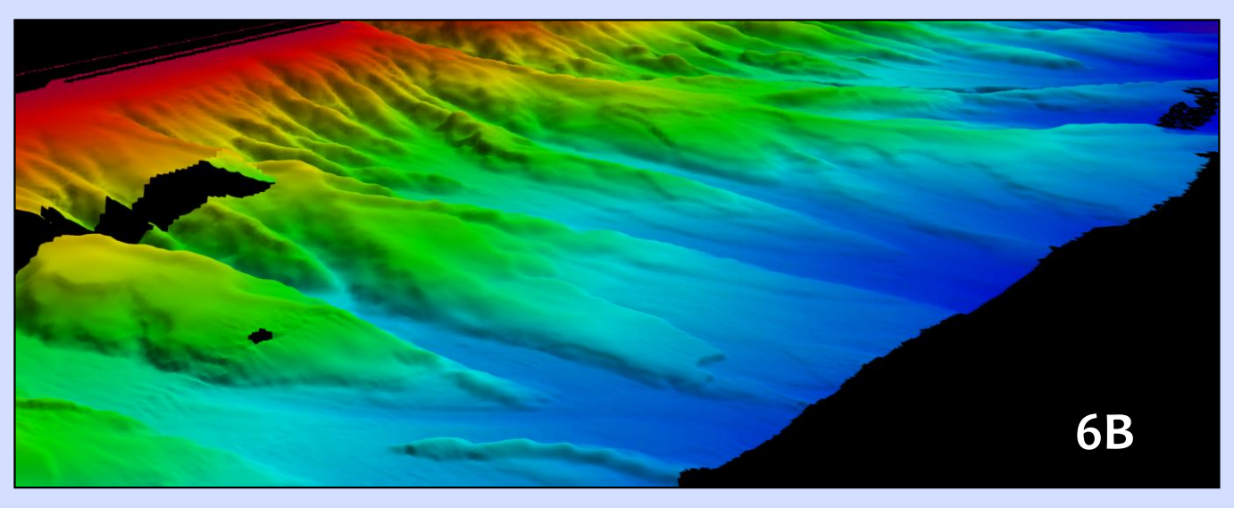
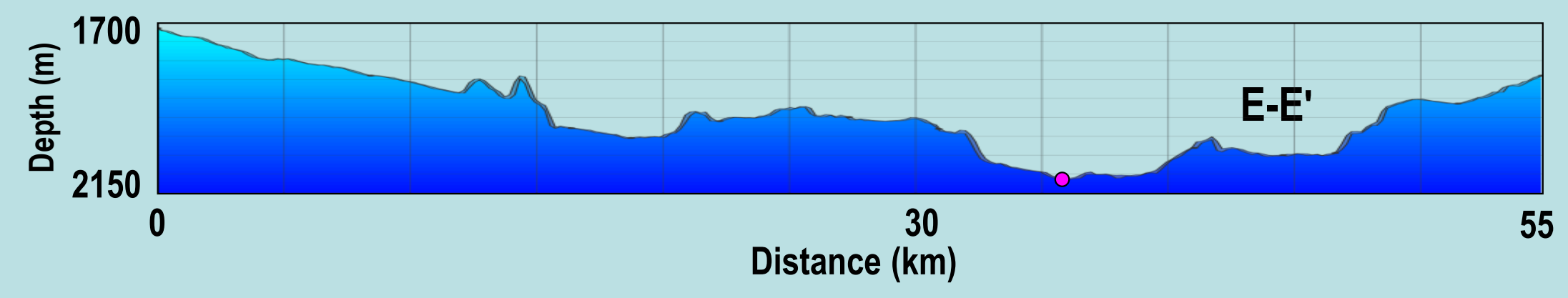
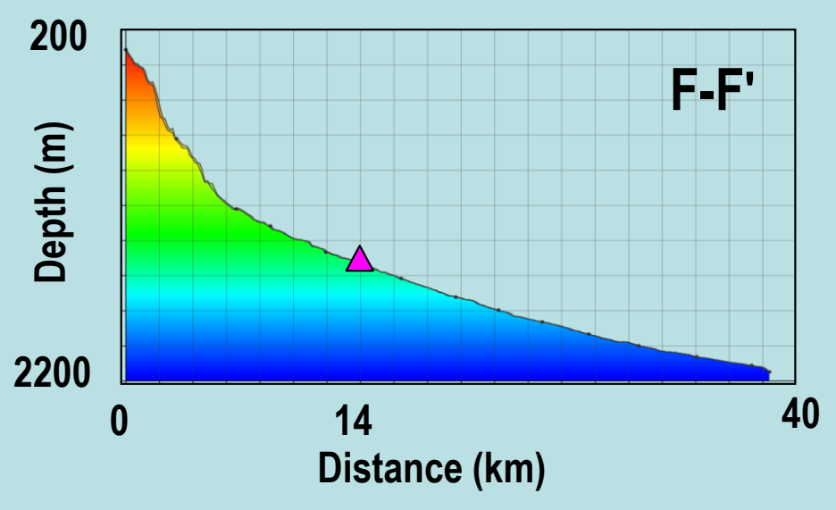


Figure 6A: Upslope view of landslide area on the continental rise, observed in Figure 5, marked with a pink dashed circle. Additional profile transects are marked.

Figure 6B: Rotated side view of landslide area.





E-E: Cross-section of submarine landslide area.
Relief from left to deepest point ● = 0.7^o
Relief from right to deepest point ● = 0.88^o

F-F': Downslope profile of gully along shelf edge.
Thalweg gradient = 1.5^o

F -▲ : Thalweg gradient = 5.1^o

Conclusions

Further analysis of slump features and adjacent areas is critical for hazards planning and identification of potential sites of tsunami generation. Low-lying areas built-up by sediment should be monitored to document temporal change and predict events of mass wasting. BC should be explored by submersible to verify and document the existence of deep sea corals within and study the relationships between the benthic community structure and productivity. WC should also be explored to determine if rocky outcrop areas house corals, and if not, document the differences between BC and WC that may affect ecosystem design. State and federal partners should work together to manage the activities in the areas of BC and WC to protect what may be vulnerable and valuable ecosystems.

Next Steps

- Incorporate additional multibeam data from other cruises (e.g. NOAA Ship *Ronald H. Brown,* 2009) into BASE surface and mosaic to expand study region in the vicinity of the landslide and improve imagery.
- Create additional profiles along the slope to further document relief down thalwegs of shelf and canyon walls to better understand sediment transport.
- Continue to process and edit backscatter data to rectify high intensities at nadir.
- Conduct further analysis of backscatter data to match intensities observed with the sediments they most likely represent.

References

- Brothers, D.S., ten Brink, U.S., Andrews, B.D., and Chaytor, J.D. "Geomorphic Characterization of the U.S. Atlantic Continental Margin". *Marine Geology* (2013) (In press).
- De Leo, F.C., Smith, C.R., Rowden, A.A., Bowden, D.A. and Clark, M.R. "Submarine Canyons: Hotspots of Benthic Biomass and Productivity in the Deep Sea." *Proceedings of the Royal Society B* 277 (2010) 2783-2792.
- Imran, J., Mohammed, A.I., Huang, H., Kassem, A., Dickerson, J., Pirmez, C., and Parker, G. "Helical Flow Couplets in Submarine Gravity Underflows." *Geology* 35 (2007): 659-662.
- McGregor, B.A. "Ancestral Head of Wilmington Canyon." *Geology* 9 (1981): 254-257.
- Sweeney, E.M., Gardner, J.V., Johnson, J.E. and Mayer, L.A. "Geological Interpretation of a Low-Backscatter Anomaly Found on the New Jersey Continental Margin." *Marine Geology* 326-328 (2012): 46-54.
- ten Brink, U. "Submarine Landslides as Potential Triggers of Tsunamis That Could Strike the U.S. East Coast." *Sound Waves Monthly Newsletter*. USGS, August 2009.
- ten Brink, U.S., Lee, H.J., Geist, E.L., and Twichell, D. "Assessment of Tsunami Hazard to the U.S. East Coast Using Relationships Between Submarine Landslides and Earthquakes." Marine Geology 264 (2009): 65-73.
- Turley, C.M., Roberts, J.M., and Guinotte, J.M. "Corals in deep-water: will the unseen hand of ocean acidification destroy cold-water ecosystems?" *Coral Reefs* 26 (2007): 445-448.
- Twichell, D.C., Chaytor, J.D., ten Brink, U.S, and Buczkowski, B. "Morphology of late Quaternary Submarine Landslides Along the U.S. Atlantic Continental Margin. *Marine Geology* 264 (2009): 4-15.