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# Geomorphology of Submarine Canyons and Related Slope Features Along the Western New England Continental Margin, USA

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NOAA Ship *Okeanos Explorer*

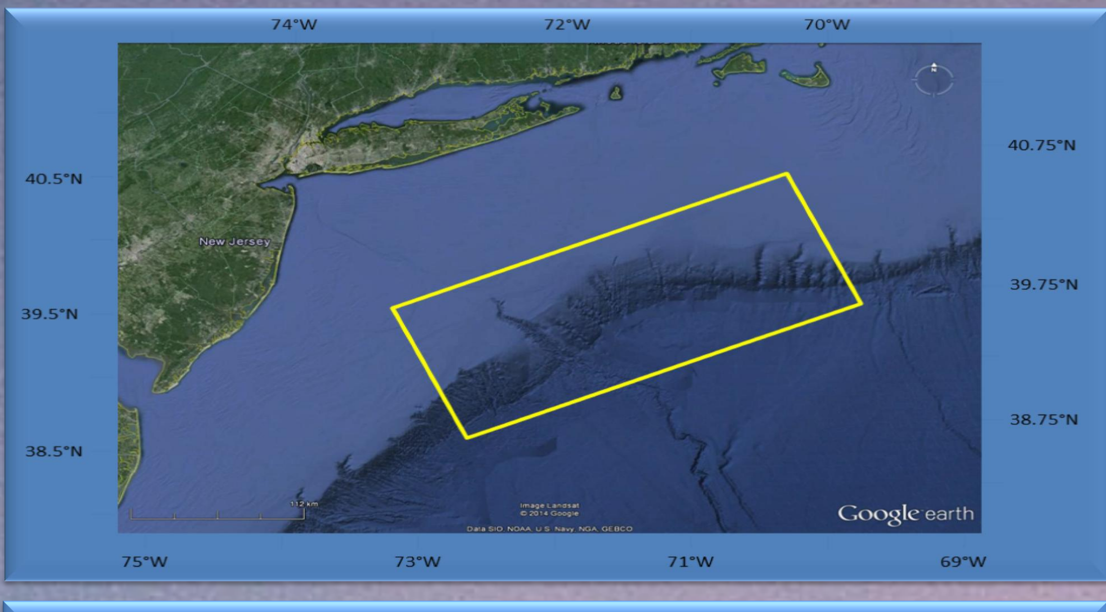


**Figure 1.** Image of the New England Margin with western study area outlined. Photo from Google Earth.

## Abstract

Submarine canyons are erosional features located on continental margins, acting as conduits for sediment transport from coastal and shelf regions to deep oceans. However, submarine canyons have an array of morphologies and these differences change erosional and depositional processes, and sediment distributions. Major slumping along the margin can alter morphology and generate tsunamis, potentially threatening nearby coastal communities. Two main types of submarine canyons exist along the New England margin from Middle Toms Canyon to Atlantis Canyon: 1) incised canyons, which originate on the continental shelf; and 2) slope canyons that initiate on the margin's slope. Multibeam sonar data were used to develop a canyon classification system, based on canyon length, relief, sinuosity, margin gradient, and general morphology. Based on observations, slumping is highly associated with margin gradient and canyon type. Slumping is found in canyons along a steep margin gradient and between canyons on gradual margins.

## Introduction

The continental margin on the east coast of the United States (Fig. 1) is a thickly sedimented passive margin in the Atlantic Ocean, characterized by the large continental shelf, moderate slope, and rise (Laughton & Roberts, 1978). Submarine canyons act as sediment transport mechanisms moving sediment due to turbidity currents and slumping (Brothers et al., 2013), and evolve either from continental slope slumping, or originate from fluvial-deltaic systems on the continent (Harris & Whiteway, 2010). The two types of canyons observed are incised and slope canyons, with slumping features found throughout. Incised canyons are defined as canyons that start on the shelf, whereas slope canyons are canyons that evolved on the continental slope without reaching shallower, onto the shelf. Slumping occurs as periodic small scale episodes or mass flows (Brothers et al., 2012). The gradient of the physiographic slope has a direct correlation with the amount of slumping that occurs: the greater the slope, the more likely slope failure will occur. Once a slump scarp forms there is an increase in the gradient (Harris & Whiteway, 2010). Slumping will continue, allowing for the formation of slope canyons. Research has led to the hypothesis that the larger incised canyons allow for greater sediment transport due to turbidity currents, and therefore have the ability to have larger mass sediment flows than smaller slope canyons. However, the slope canyons are more likely to have slope failures associated with them during their development. Large scale slumping events can possibly lead to tsunamis because of mass displacement (Driscoll et al., 2000).

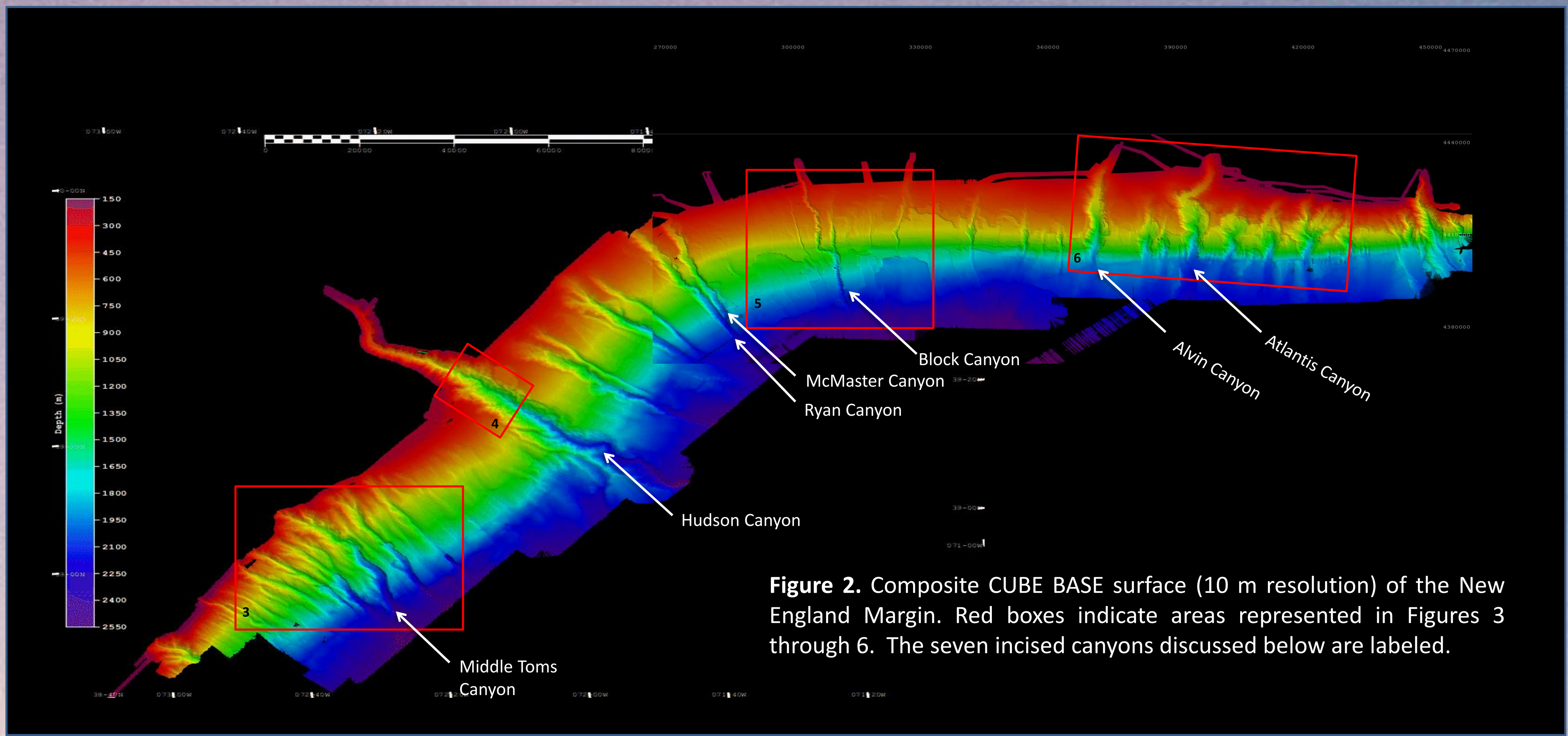


**Figure 2.** Composite CUBE BASE surface (10 m resolution) of the New England Margin. Red boxes indicate areas represented in Figures 3 through 6. The seven incised canyons discussed below are labeled.

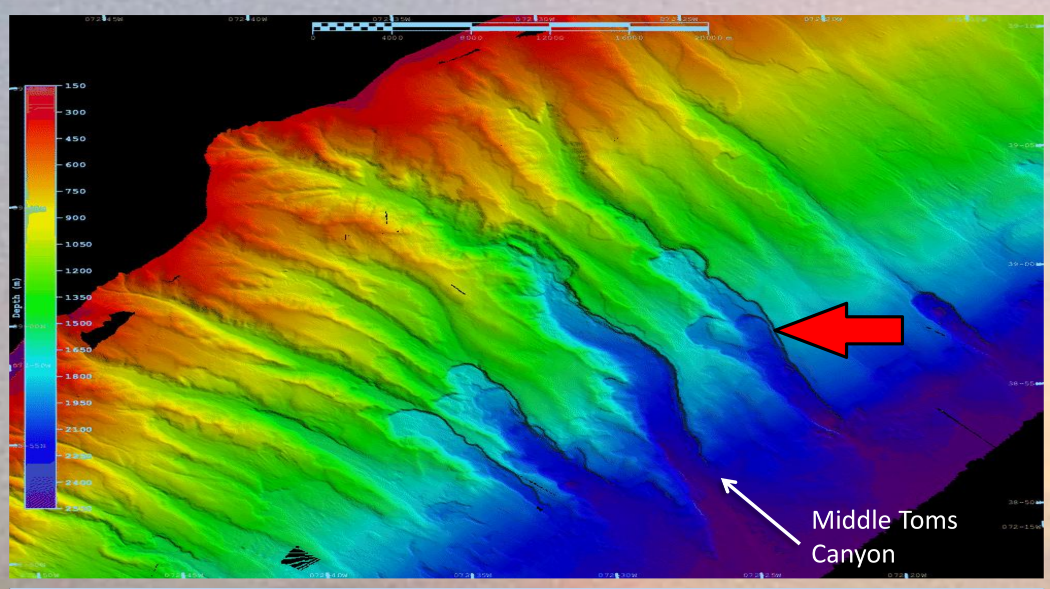


**Figure 3.** 2D image of Middle Toms Canyon Area at 15000 m scale. Arrow shows slump features. Numerous slumps are present on the lower slope, indicating landward growth of slope canyons in this region.

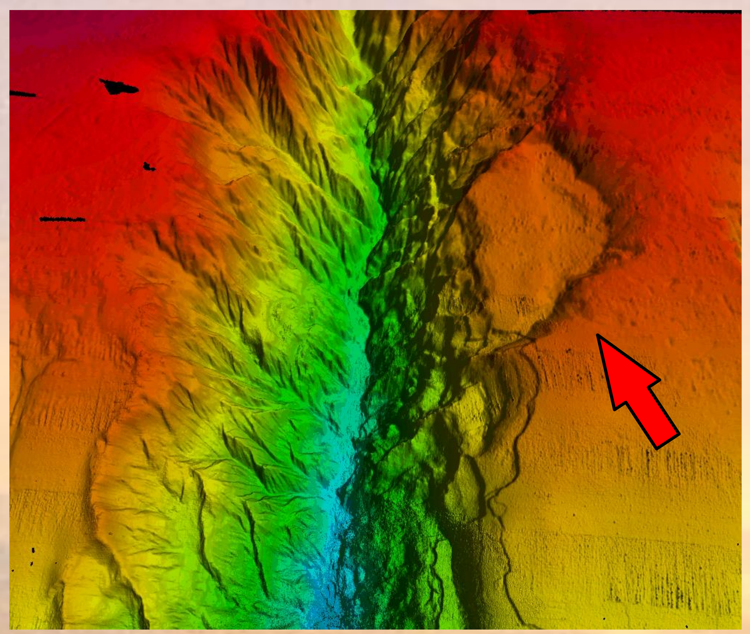

**Figure 4.** 3D image of Hudson Canyon. Arrow shows massive slump scarp on eastern side of the canyon. (VE=6x)

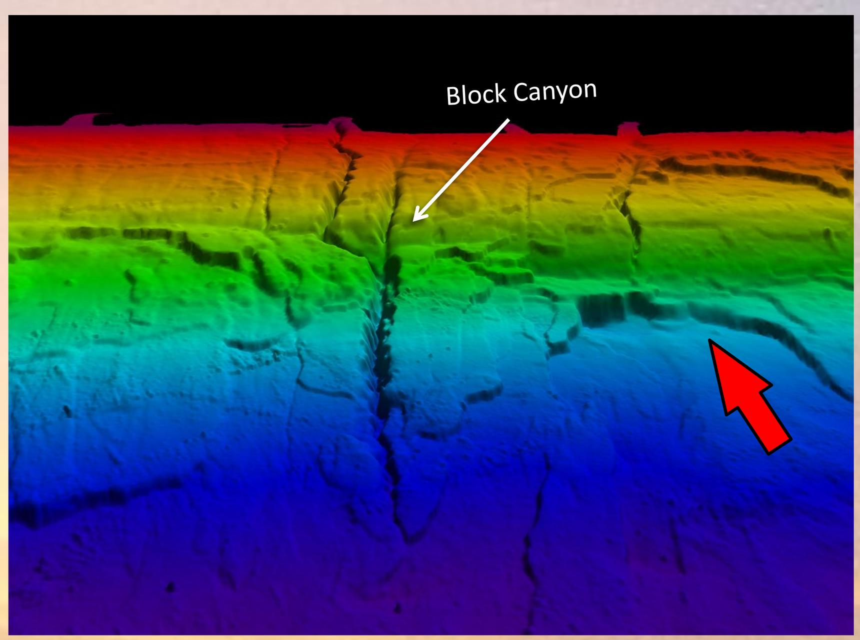


**Figure 5.** 3D image of Block Canyon. Arrow shows large slump scarps due to mass wasting. (VE=6x)

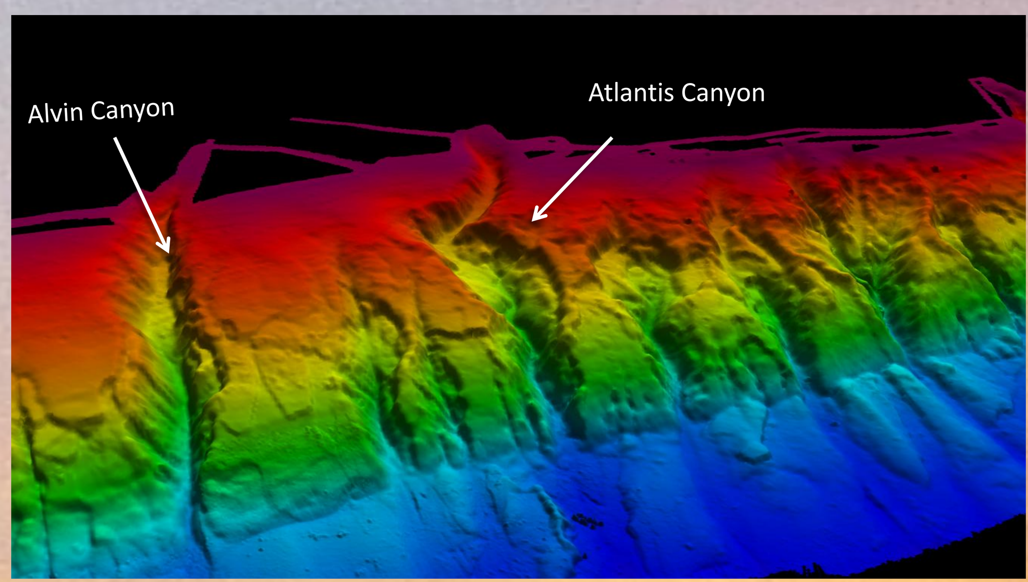


**Figure 6.** 3D image of Alvin (left) and Atlantis (middle) Canyons. The increased margin slope of this area correlates to a higher concentration of slope canyons. (VE=6x)

## Results

- The gradient of the continental slope around Middle Toms Canyon starts out relatively steep for the US east coast , declines heading north, and then steepens again around Atlantis Canyon further to the east (Table 2 & Fig. 8).
- There is an increase in the number of slope canyons seen in the steeper regions (Table 1 & Fig. 2).
- The area around Block Canyon has a relatively low marginal gradient, which allows for an increase in Block Canyon sinuosity compared to other canyons (Table 2).
- Slumping is seen throughout the study area , but discernible areas including the lower shelf around Middle Toms Canyon, both sides of Block Canyon, and within the Hudson Canyon (Fig. 3, 4, and 5).
- In the Middle Toms Canyon Area, the increased gradient of the margin allows for slumping at the base of slope canyons, resulting in growth of canyons (Fig 3).
- The Hudson Canyon - the largest canyon in the region (Fig 8) - has massive slump features along the walls (Fig 4).
- In the Block Canyon Area, slump scarps are large and arc shaped and do not have canyons associated with them (Fig 5).

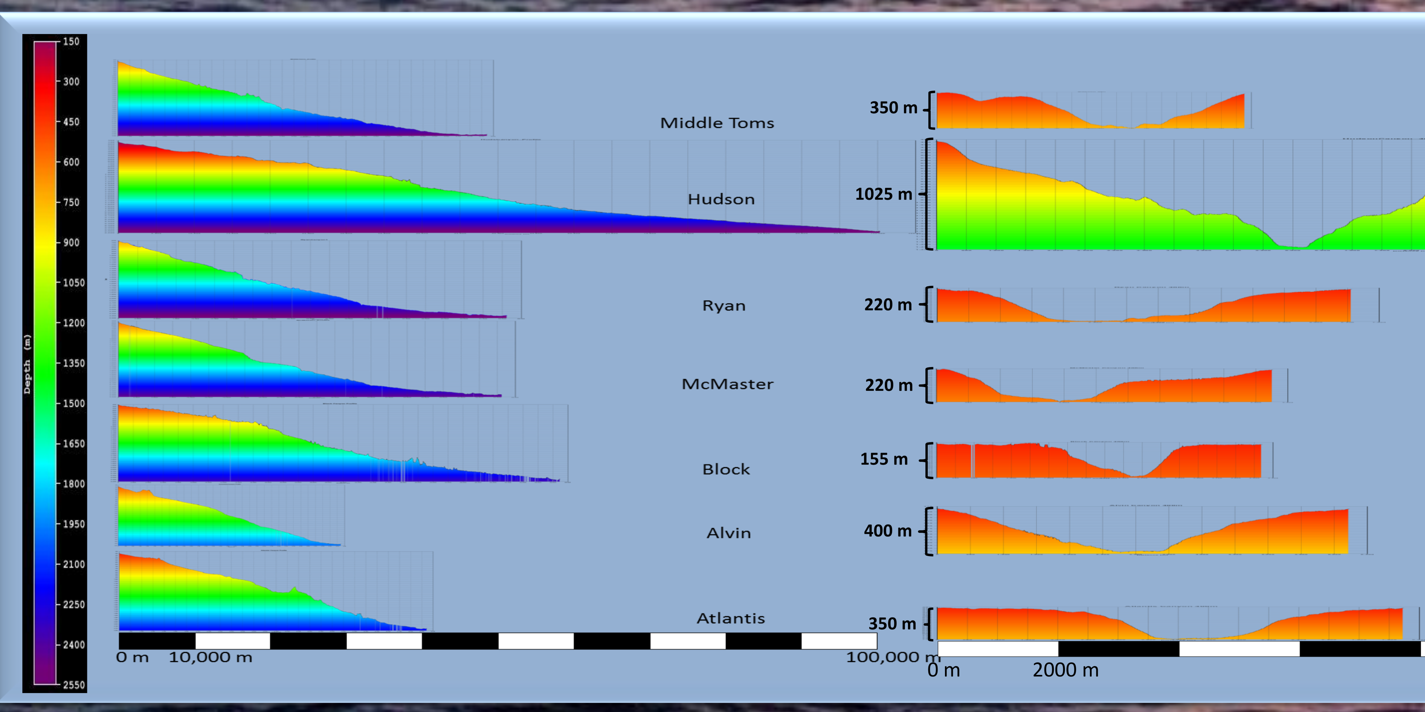


**Figure 8.** Along-axis (far left) profiles, and cross-axis profiles beginning at the 400 m isobath (left) of incised canyons within the study area. Vertical relief is indicated on y-axes. Depth scale for all profiles is shown at left, and horizontal distance scale is below. See Table 2 for measurements.

| Canyon Range | Number of Slope Canyons | Distance Between Canyons (m) |
|---|---|---|
| Before Middle Toms | 4 | |
| Middle Toms to Hudson | 3 | 54500 |
| Hudson to McMaster | 4 | 57000 |
| McMaster to Block | 0 | 31100 |
| Block to Alivn | 5 | 65000 |
| Alvin to Atlantis | 2 | 20400 |
| Atlantis to Veach | 6 | 50550 |

**Table 1.** Observed slope canyons and distances between each incised canyon within the study area.

| Canyon Name | Linear Distance (m) | Along-Axis Distance (m) | Sinuosity | Canyon Slope | Margin Gradient | Average Width (m) | Average Depth (m) |
|---|---|---|---|---|---|---|---|
| Middle Toms | 43,363 | 47,500 | 1.095 | 0.987 | 0.060 | 5040 | 1649 |
| Hudson | 91,231 | 102,000 | 1.118 | 0.999 | 0.055 | 11870 | 1940 |
| Ryan | 49,253 | 50,500 | 1.025 | 0.987 | 0.048 | 4780 | 1460 |
| McMaster | 50,597 | 52,500 | 1.038 | 0.989 | 0.051 | 3560 | 1428 |
| Block | 42,450 | 59,000 | 1.390 | 0.032 | 0.049 | 2047 | 1715 |
| Alvin | 29,740 | 31,500 | 1.059 | 0.046 | 0.055 | 4455 | 1555 |
| Atlantis | 31,210 | 35,691 | 1.144 | 0.044 | 0.526 | 4842 | 1582 |

**Table 2.** Table includes data collected on all incised canyons on the western New England Margin.

## Discussion & Conclusion

The ability to characterize the continental margin allows researchers to identify slumping features and possibly predetermine failures that could threaten lives. After analyzing data and determining which canyons classify as incised or slope canyons, a major objective was to determine where mass flows may occur next. Slumping or other forms of mass wasting and erosional turbidity currents are two separate mechanisms that drive submarine canyon geomorphology (Harris & Whiteway, 2010). An increase in observed slope canyons along the steep margin gradient confirms previous research by Harris and Whiteway (2010) and Twichell and Roberts (1982). The decreased spacing of canyons is seen around Middle Toms and Atlantis Canyons where slope canyons are more concentrated (Fig. 3 and 6). Each identified slumping area could cause different effects on the margin. The slump features at Middle Toms Canyon could cause sediment layers above the slump scarps to fail further, widening and/or deepening the canyons in the area. The area around Block Canyon is of special concern due to fluid seepage and gravity flows that drive further failures in unknown locations along the scarp (Harris and Whiteway, 2010). The abundance in size and slump scarps within Hudson Canyon is due to erosive turbidity flows derived from the fluvial shelf and upper slope (Harris and Whiteway, 2010). The increased flow within the canyon keeps sediment from depositing in thick layers on the canyon floor, but also affects the sides of the canyon allowing for the formation of the massive slump scarp. Whether the slum occurred as one mass flow or episodic smaller failures is unknown, but the possibility for large scale slumping is evident. The seafloor instabilities addressed as focal points cause concern, due to the potential hazard of tsunami generation from rapid changes in morphology from slumping along the east coast continental margin (Driscoll et al., 2000). Collection of sediment samples would provide further investigation of seafloor stability providing knowledge of locations that are more susceptible to failure (Pratson, 2001).

## Methods

- Kongsberg EM302 multi-beam sonar data collected by the NOAA ship *Okeanos Explorer* was downloaded from NOAA National Geophysical Data Center for cruises EX1106, EX1201 EX1204, EX1205 leg 2, EX1206, EX1301, EX1303, EX1304 leg 1 and 2.
- Data were post-processed in Caris HIPS 8.1 to make a CUBE BASE surface for analysis.
- The data were evaluated within Caris HIPS 8.1 using distance and profile tools to provide quantitative analysis on dominant incised canyons within the 29,223 $km^2$ area of interest.
- Observations on slumping and orientation were made based on images produced within Caris HIPS 8.1

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