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Geomorphology of Submarine Canyons and Related Slope Features along the Eastern New England Continental Margin, USA

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Abstract

Multibeam sonar data of submarine canyons and slump features was analyzed along a 390 km segment of the Eastern New England continental margin. Submarine canyons are erosional features located on continental margins that transport sediments from shelf regions to the deep ocean. Major slumping along the margin can alter seafloor morphology and has the ability to generate dangerous tsunamis. In the study area, eight incised canyons and numerous slope canyons were identified, from Veach Canyon to Munson Canyon. Incised canyons were classified based on canyon length, relief, sinuosity, and general morphology. In between incised canyons, the study area displays a transition between areas of dominant slumping features to areas dominated by slope canyons. All incised canyons narrowed in width as depth increased. However, Hydrographer and Lydonia Canyons had the highest degrees of sinuosity, and canyon width increased before ultimately narrowing as depth increased.

Methods

- Kongsberg EM302 multi-beam sonar data collected by the NOAA Ship *Okeanos Explorer* was downloaded from NOAA National Geophysical Data Center for cruises EX1204, EX1206, EX1301, EX1303, EX1304 legs 1 and 2
- Data were post-processed in CARIS HIPS 8.1 and 10 m resolution CUBE BASE surfaces were generated.
- CARIS 8.1 distance and profile tools were used to provide quantitative analyses.

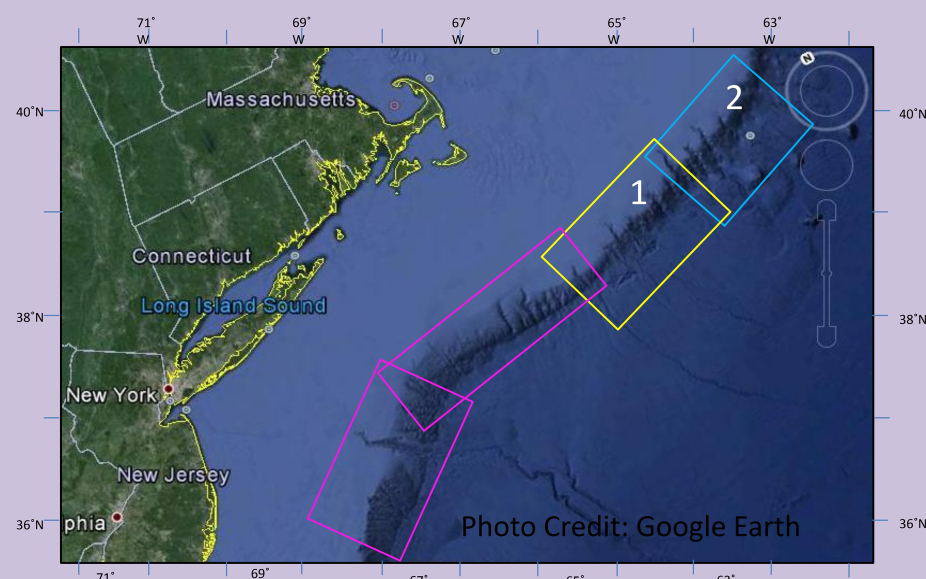


Figure 1. Image of the New England Margin highlighting study area with boxes 1 & 2 shown in the composite BASE surface (Fig. 2). Pink outlines indicate western study area of the margin discussed by Rollings & Tyson.

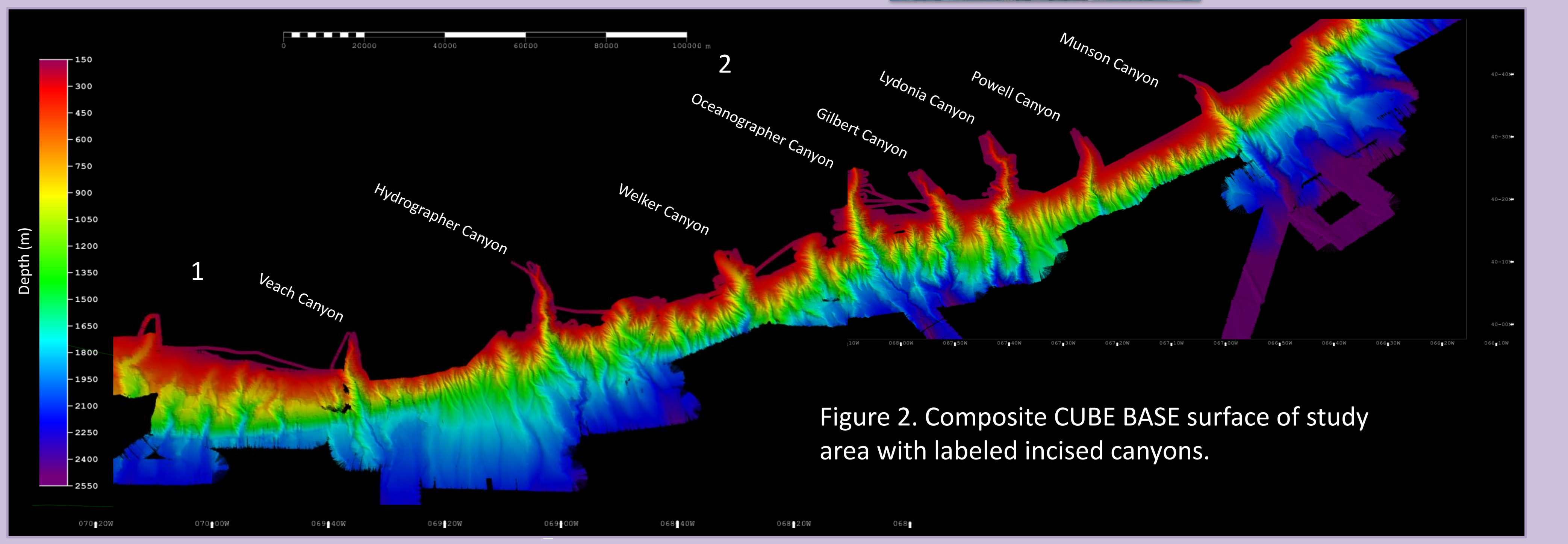


Figure 2. Composite CUBE BASE surface of study area with labeled incised canyons.

Introduction

Classifying continental margins around the globe is an important task, as tsunamis can be generated by displacement which occurs during slope failures. The submarine canyons along the eastern New England Margin (Figure 1) were surveyed by the NOAA Ship *Okeanos Explorer* during 2012 and 2013. The study area stretches from Veach Canyon to Munson Canyon, on the east coast of the U.S. continental margin. The New England Continental Margin is a passive margin characterized by the shelf, slope, and rise physiographic provinces (Laughton et al., 1978). Passive margins evolve through continental rifting, seafloor spreading, and post-rift evolution. The New England Margin was glacially influenced, which increased the amount of sediment deposited on the continental margin (Twichell et al., 2009). Submarine canyons form from sediment flow and turbidity currents, which allow for sediment transport from the continent to the deep sea (Brothers et al., 2013). Two types of canyons in the study area have been classified: **incised canyons** and **slope canyons**. Incised canyons are significantly longer and begin on the inner to mid-continental shelf, continuing to the continental slope and rise, whereas slope canyons originate on the continental slope, and may continue onto the rise. Larger incised canyons allow for greater sediment transport than smaller slope canyons. Slumps are features formed by mass flows of sediment and are more commonly associated with slope canyons (Brothers et al., 2012). Large scale slumping events can generate tsunamis due to mass displacement (Driscoll et al., 2000). Shallow continental slopes produce slumping at the slope-rise boundary, whereas steep continental slopes generate incised and slope canyons due to a strong influence by gravity, enabling turbidity currents to cut through the continental slope (Twichell et al., 2009 and Pratson, 2001).

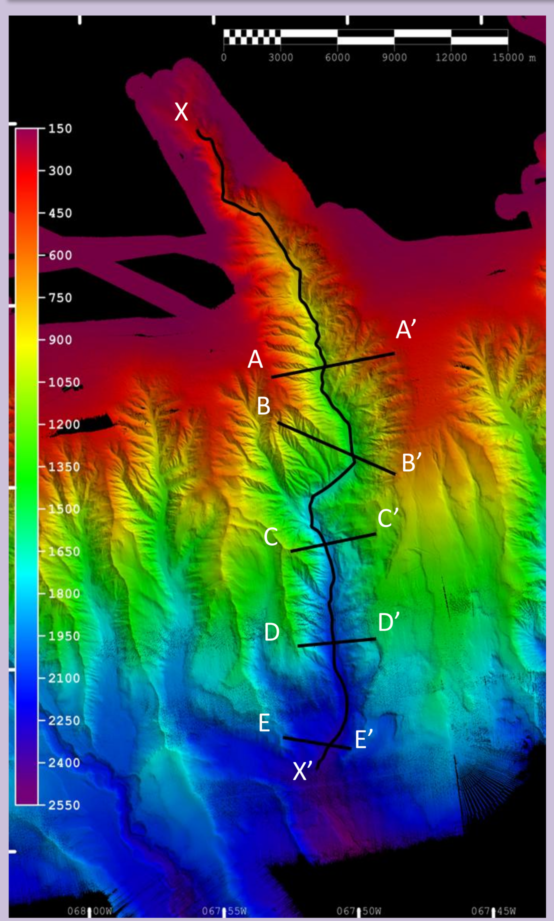


Figure 3 (above). CUBE BASE surface of Gilbert Canyon. Profiles of each canyon (Fig. 4) were made by measuring along-axis of the canyon (X to X'). Cross-sections of each canyon (Fig. 5) were produced by measuring across the axis starting and ending at the isobath depths of 400m (A-A'), 800m (B-B'), 1200m (C-C'), 1600m (D-D'), and 2000m (E-E').

Canyon Name	Linear Distance (m)	Cumulative Distance (m)	Sinuosity	Average Slope	Slope (measured between 900-1800m of canyon trough)
Veach	32800	36400	1.110	0.050	0.066
Hydrographer	43600	50300	1.154	0.042	0.065
Welker	14200	15200	1.070	0.077	0.073
Oceanographer	34500	39500	1.145	0.034	0.038
Gilbert	32800	37300	1.137	0.056	0.076
Lydonia	34700	40500	1.167	0.051	0.059
Powell	20400	21700	1.064	0.071	0.089
Munson	51600	54600	1.058	0.048	0.084

Table 1 (above). Quantitative measurements of incised canyons based on the profiles in Figure 4.

Canyon Name	Vertical Relief at 400m (m)	Vertical Relief at 800m (m)	Vertical Relief at 1200m (m)	Vertical Relief at 1600m (m)	Vertical Relief at 2000m (m)
Veach	690	670	470	220	N/A
Hydrographer	760	705	530	395	210
Welker	985	660	515	320	N/A
Oceanographer	1195	975	670	375	195
Gilbert	805	730	650	500	270
Lydonia	850	690	600	495	275
Powell	1670	535	330	172	N/A
Munson	2735	705	460	275	145

Table 2 (left). Depths of the incised canyons at multiple canyon-wall depths were measured using the profiles in Figure 5.

Canyon Name	Width at 400m (m)	Width at 800m (m)	Width at 1200m (m)	Width at 1600m (m)	Width at 2000m (m)
Veach	6100	4800	4800	3600	N/A
Hydrographer	6100	5800	4900	6600	2850
Welker	8800	5700	4550	2850	N/A
Oceanographer	10700	9600	8000	5900	4300
Gilbert	6750	6750	4600	4175	3640
Lydonia	5800	4250	7275	3050	3095
Powell	5000	4475	1450	3825	N/A
Munson	10250	5750	4000	3325	2510

Table 3 (left). Cross-section widths and the relief of the incised canyons were measured using the profiles in Figure 5.

Results

- The study area consists of 8 incised canyons and 74 slope canyons.
- Hydrographer and Munson Canyons are the longest, each with cumulative distances >50 km (Figure 4).
- Welker Canyon, Powell Canyon, and Munson Canyon have the smallest degrees of sinuosity (Table 1).
- Powell Canyon and Munson Canyon display dramatically higher vertical relief between the 400 m and 800 m isobath, but generally all canyons show a similar trend in vertical relief in the deeper isobaths (Figure 5).
- There is a general trend of narrowing canyon width as depth increases (Figure 6).
- Munson Canyon has the greatest depth (864 m), whereas Veach Canyon is shallowest (513 m) (Table 3).
- Major slumping is observed west of Veach Canyon and on the east side of Munson Canyon, with slope canyons dominating inbetween.

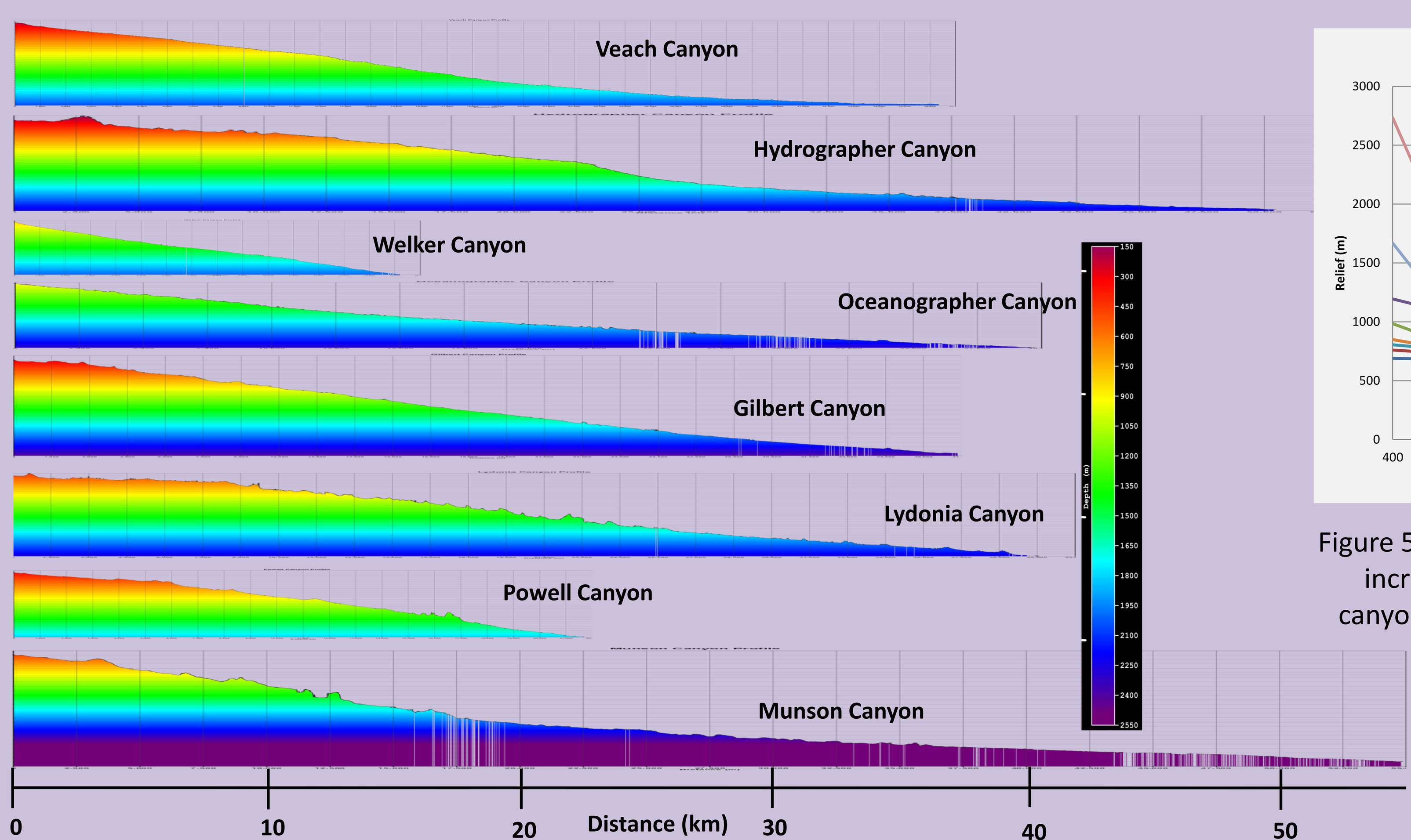


Figure 4 (above). Profiles were generated along the axis of each incised canyon in the study area. Cumulative distances of canyon length fluctuates between Welker (14 km) and Munson (52 km) Canyons (Table 1).

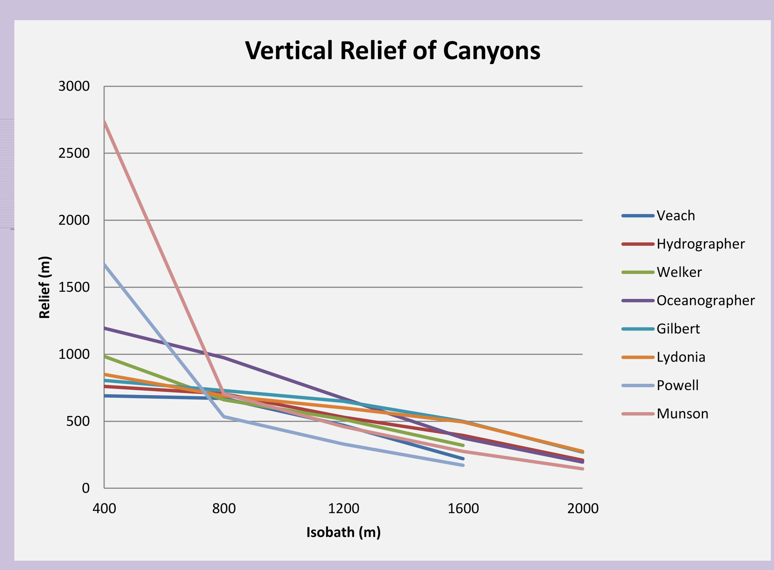


Figure 5 (above). Vertical relief of each canyon along increasing isobath values down the length of the canyon. Refer to Figure 3 for measuring technique.

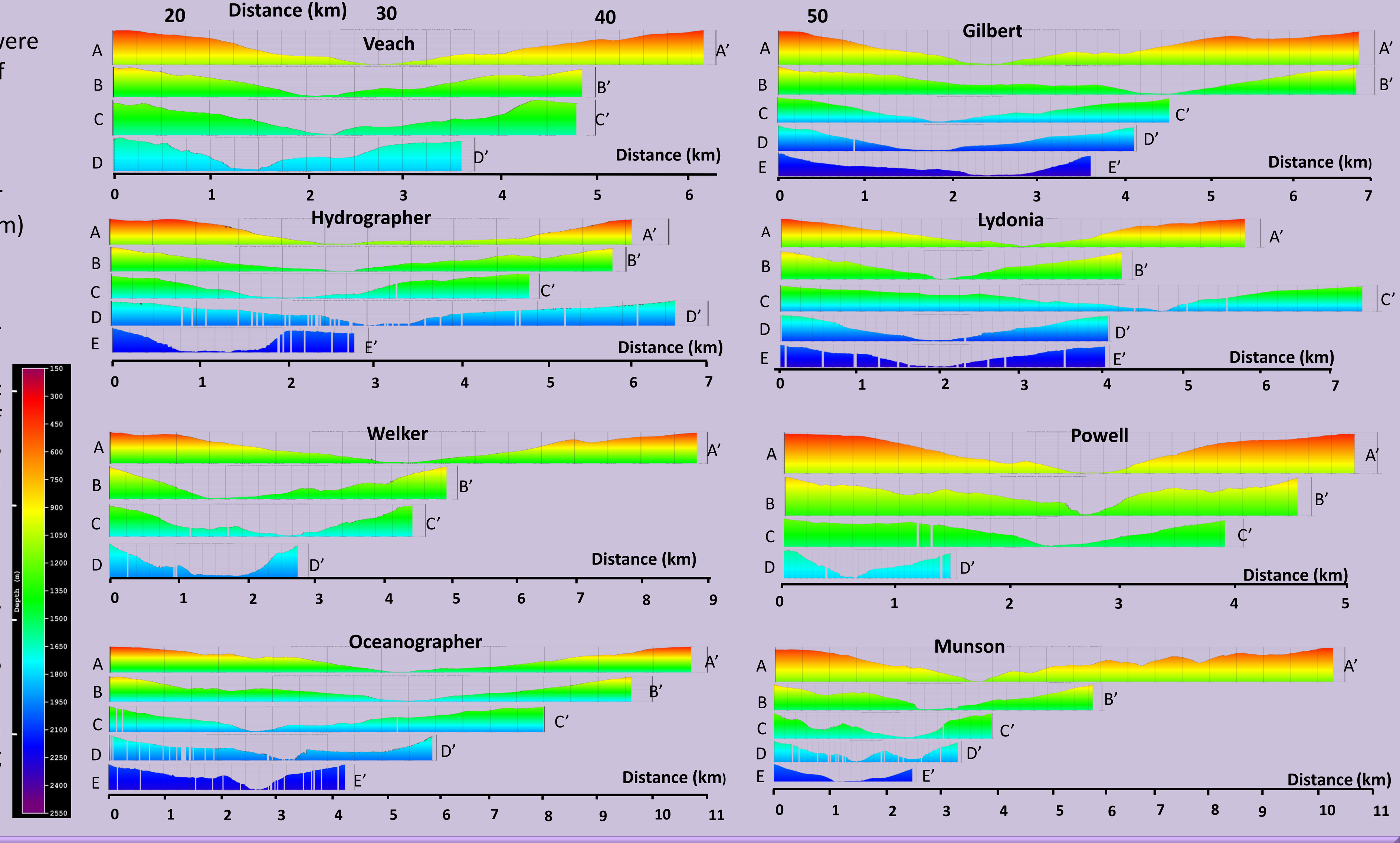
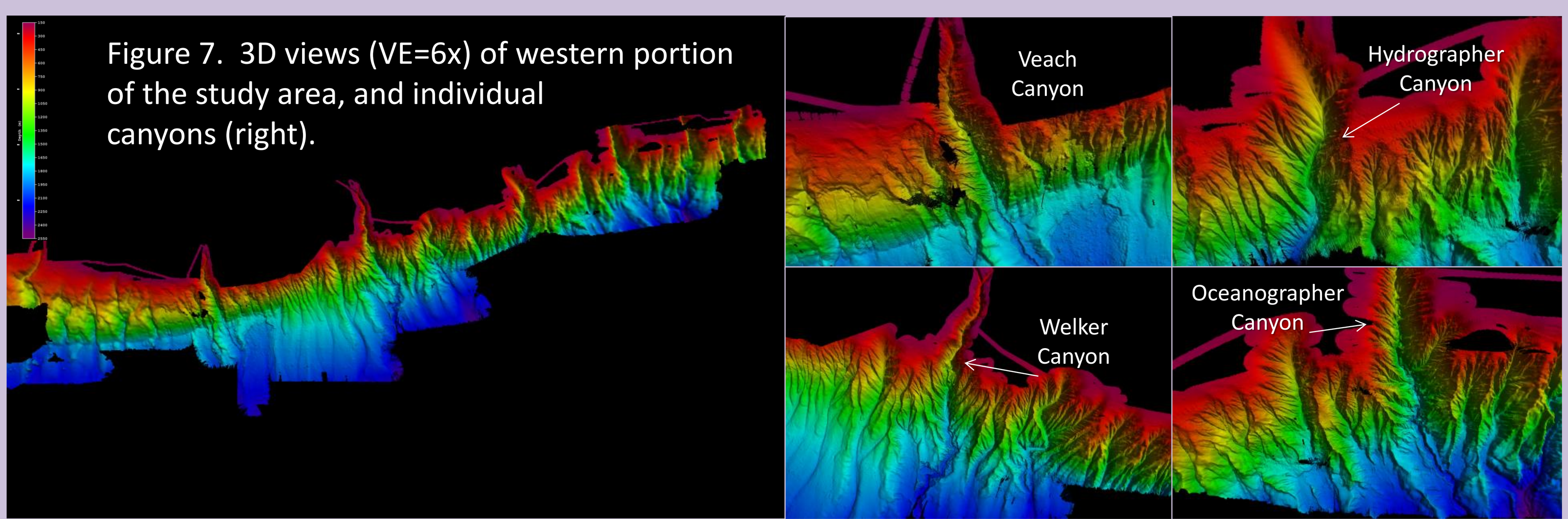
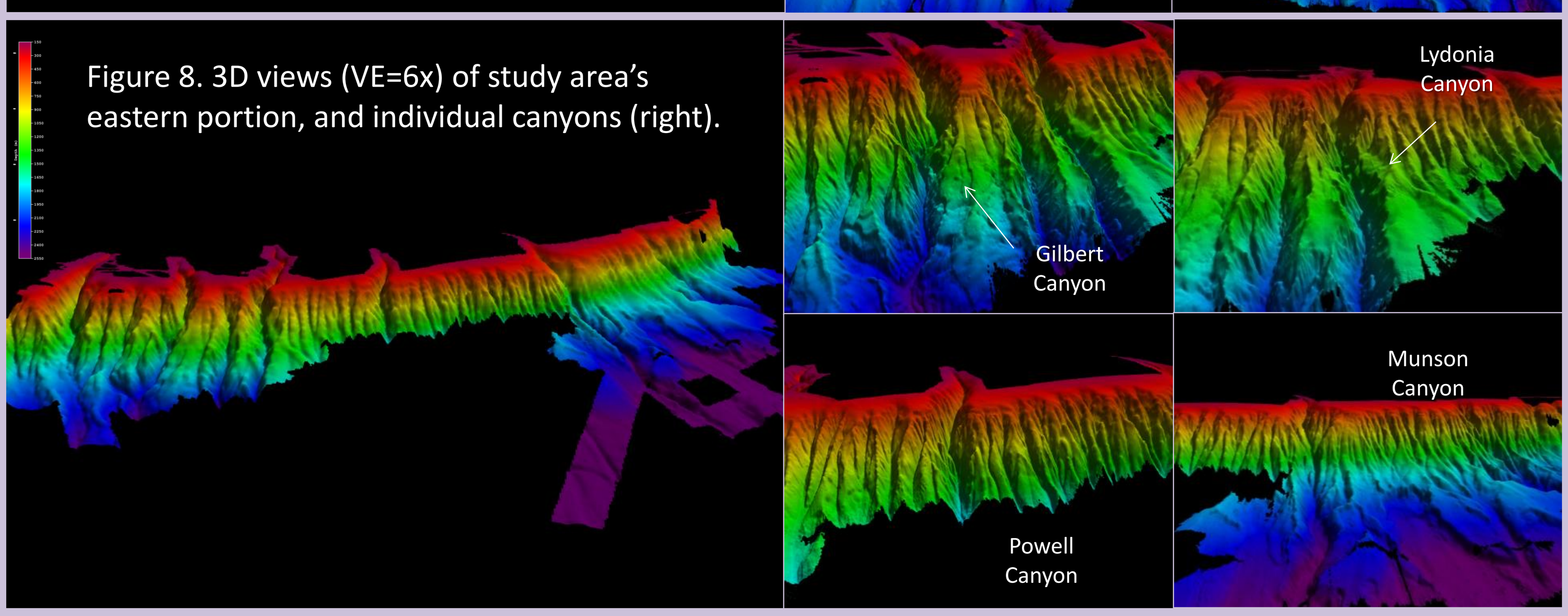


Figure 6 (right). Cross-sections of the incised canyons made at specific isobaths along the sides of each canyon from west to east at 400m (A-A'), 800m (B-B'), 1200m (C-C'), 1600m (D-D'), and 2000m (E-E'), listed in Tables 2 and 3. Vertical exaggeration varies to emphasize canyon details. In all but two canyons (Hydrographer and Lydonia), canyon width narrows with increasing depth.





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Discussion & Conclusion

There are eight incised canyons and seventy-four slope canyons on the eastern New England Margin (Figure 2). The incised canyons have average slopes near to or exceeding 4°, defined as a steep gradient, likely influenced by an underlying steep continental slope (Pratson, 2001). Widths of the incised canyons decreased with depth, correlating to a decrease in canyon gradient (Figure 4 and Figure 6). Hydrographer Canyon and Lydonia Canyon have the two highest degrees of sinuosity (Table 1), and do not display a continuous narrowing with depth, unlike the other canyons (Table 3 and Figure 6). This fluctuation in canyon width may be caused by sinuosity. All canyons in the study area display a similar vertical relief beginning at the 1200 m isobath, where canyons begin to flatten out on the continental rise likely due to the depth and slope (Figure 5). Powell Canyon and Munson Canyon display a very steep vertical relief in the 400 m to 800 m isobath portions of the canyon, perhaps due to certain characteristics in this location not explored in this study, such as substrate hardness.

The area between Veach Canyon and Oceanographer Canyon shows a transition in canyon morphology, changing from an area of dominant slump features to an area dominated with slope canyons (Figure 7 and Figure 8). This transition in submarine canyon geomorphology likely correlates to the degree of substrate hardness increasing from west to east. Oceanographer Canyon is interpreted as having the hardest substrate of the canyons, based on backscatter data interpreted by Norvell and Sautter (2013). Slumping observed near Munson Canyon likely indicates a softening of substrate moving eastward on the margin, similar to the transition observed adjacent to Veach Canyon. Further research must be conducted to verify interpretations on slumping and substrate hardness.