Submarine Canyon Variability on the Northern Slope of Puerto Rico

Cameron Troilo and Dr. Leslie Sautter
Department of Geology and Environmental Geosciences, College of Charleston

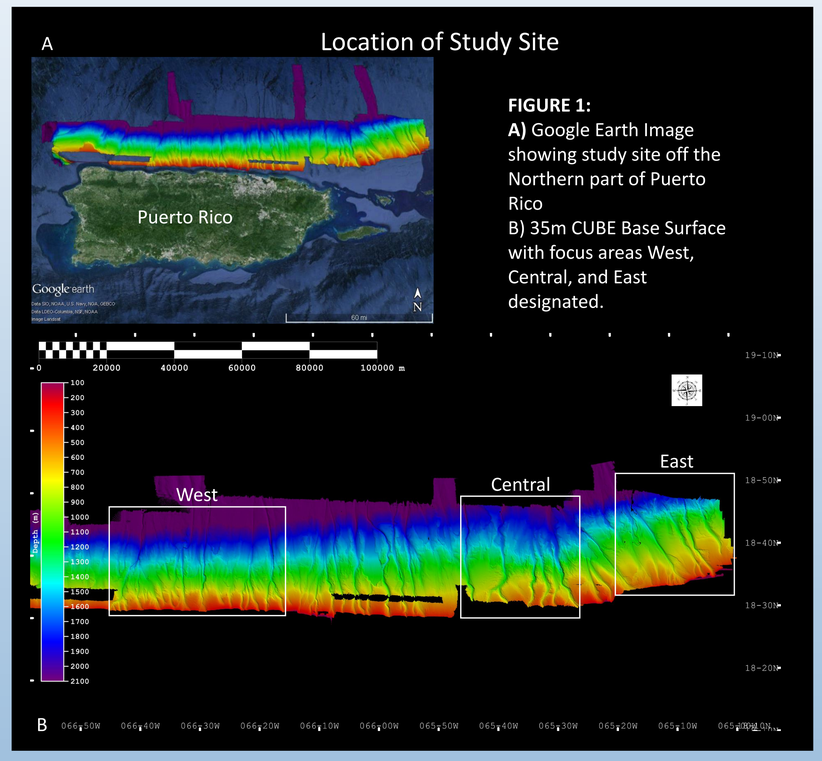

FIGURE 1:
A) Google Earth Image showing study site off the Northern part of Puerto Rico
B) 35m CUBE Base Surface with focus areas West, Central, and East designated.

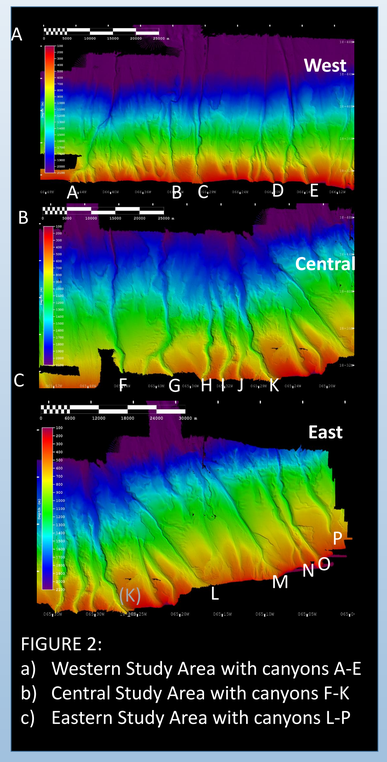

FIGURE 2:
a) Western Study Area with canyons A-E
b) Central Study Area with canyons F-K
c) Eastern Study Area with canyons L-P

Abstract

In 2015, the NOAA Ship *Okeanos Explorer* collected multibeam data using a Kongsberg EM302 off the northern coast of Puerto Rico. These data, post processed using CARIS HIPS 9.0, were used to create 2D and 3D surfaces at 25m resolution which revealed numerous submarine canyons spanning from depths of 100 to 2000 m. Each submarine canyon varies in width, depth, and the number of tributaries, but all evolve south to north. Geomorphic patterns regarding the width, depth, and cross-section profiles were examined. Canyon shapes were studied and analyzed to identify possible correlations between canyon shape and depth, and canyons were compared to characterized variability based on their location in order to determine a pattern of canyon creation. The variability of canyon shape allowed examination and determination of potential canyon creating forces located on the northern slope of Puerto Rico.

Background

Submarine canyons are major geomorphic features of continental shelves that are conduits for sediment export from coastal and shelf to deep sea environments (Shepard and Dill, 1966). Most submarine canyons are thought to have steep-walled, sinuous valleys with V-shaped cross sections, with canyon axes having relief comparable to the largest of land canyons (Shepard, 1972). They can be found throughout the world, and come in various shapes and sizes.

Along the northern slope of Puerto Rico, numerous submarine canyons can be found. These canyons vary in length, width, and sinuosity. Some canyons are long and straight while others are short and undulating. Similar types of canyons seem to be created close to one another. By analyzing sinuosity, depth range, and many characteristics of each canyon, identifying a creational pattern was attempted to be defined along the Northern Slope of Puerto Rico. Canyon sinuosity, vertical relief and horizontal distance at various depths, and canyon slope were used to aid in the study of the canyons.

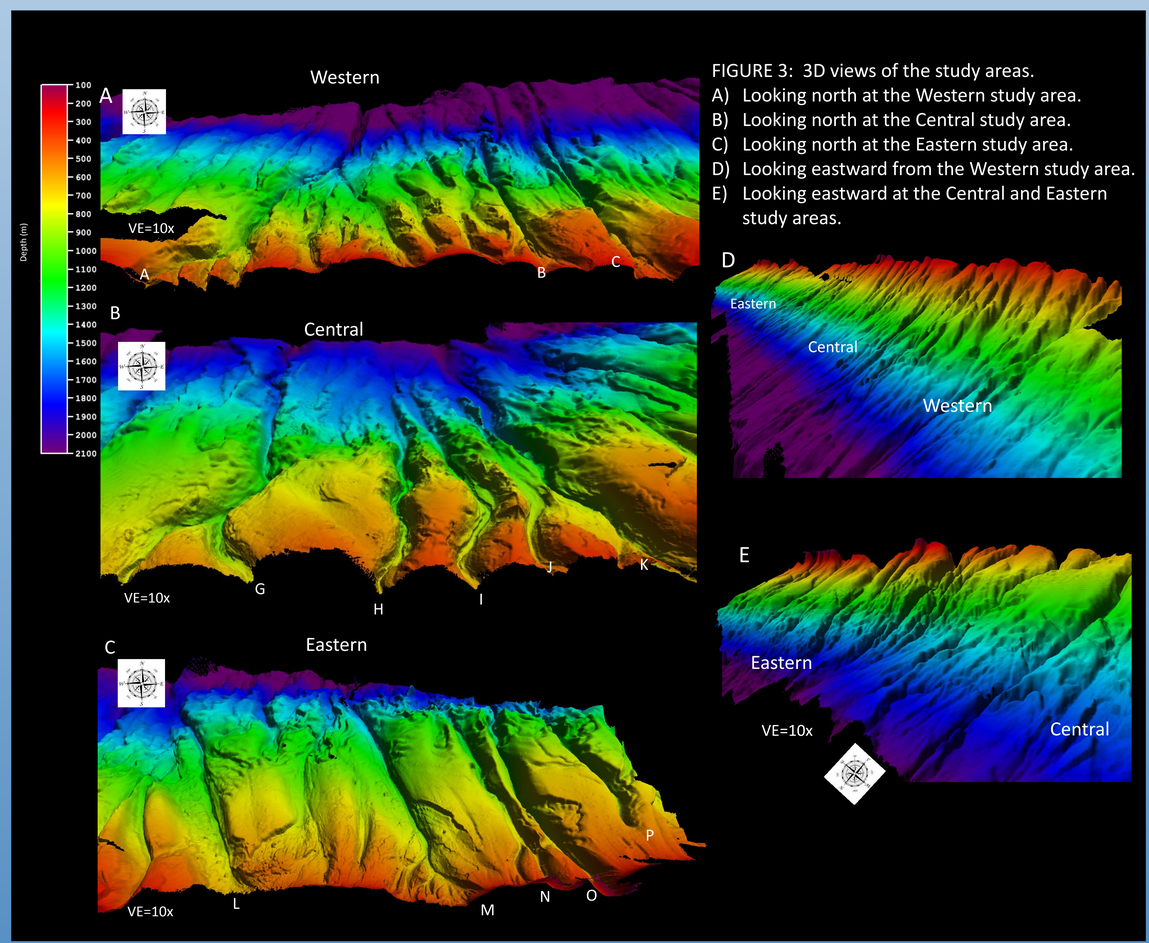

FIGURE 3: 3D views of the study areas.
A) Looking north at the Western study area.
B) Looking north at the Central study area.
C) Looking north at the Eastern study area.
D) Looking eastward from the Western study area.
E) Looking eastward at the Central and Eastern study areas.

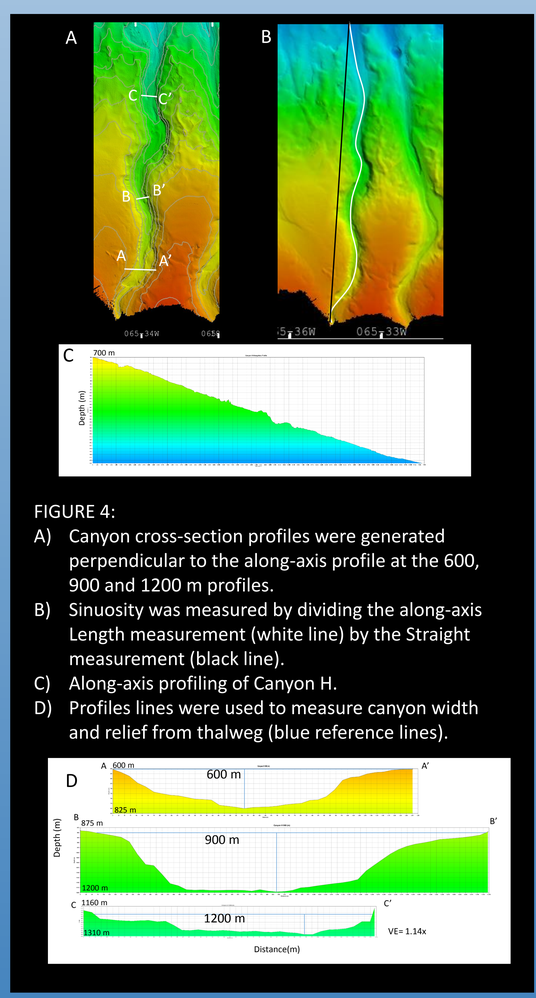

FIGURE 4:
A) Canyon cross-section profiles were generated perpendicular to the along-axis profile at the 600, 900 and 1200 m profiles.
B) Sinuosity was measured by dividing the along-axis Length measurement (white line) by the Straight measurement (black line).
C) Along-axis profiling of Canyon H.
D) Profiles lines were used to measure canyon width and relief from thalweg (blue reference lines).

Methods

- Preliminary data were collected using a Kongsberg EM302 by the NOAA Ship *Okeanos Explorer.*
- Data were post-processed using CARIS HIPS 9.0 in which 2D and 3D surfaces were created with a 35m resolution.
- Three areas were identified for study: West, Central, and East. Specific canyons were identified within each.
- Along-canyon axis at the channel thalweg was measured for each of the 15 canyons from 800 to 1200 m along with the straight distance in order to calculate sinuosity (along-axis length/straight length).
- Slope for each canyon from 800 to 1200 m was also calculated using the profiling tool in CARIS HIPS.
- Cross-channel profiles were made perpendicular to the along-axis profile at canyon wall contours 600 m, 900 m, and 1200 m. These profiles were measured to find the vertical relief and horizontal distance from each side of the canyon at each depth point. Canyon Breadth was calculated using horizontal distance/relief. Canyon F was omitted because it could not be measured at 600 m for the profile or 800 m for the canyon sinuosity.

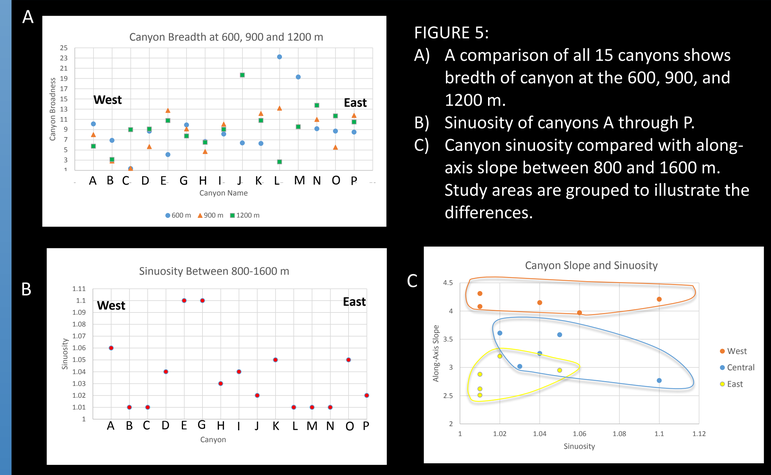

FIGURE 5:
A) A comparison of all 15 canyons shows bredth of canyon at the 600, 900, and 1200 m.
B) Sinuosity of canyons A through P.
C) Canyon sinuosity compared with along-axis slope between 800 and 1600 m. Study areas are grouped to illustrate the differences.

TABLE 1: Data from collected for each study area

Western Study Area					Channel						Channel		
Canyon	Along-Axis Length 800 to 1600 (m)	Straight Length 800 to 1600 (m)	Sinuosity Between 800 m to 1600 m contours	Along Axis Slope	Vertical Relief at 600 (m)	Vertical Relief at 900 (m)	Vertical Relief at 1200 (m)	Horizontal Distance at 600 (m)	Horizontal Distance at 900 (m)	Horizontal Distance at 1200 (m)	Distance/ Relief at 600 (m)	Distance/ Relief at 900 (m)	Distance/ Relief at 1200 (m)
A	12441.5	11744.8	1.06	3.97	100	100	100	1011.3	800.8	573.8	10.1	8.0	5.7
B	11295.2	11197.8	1.01	4.08	101	101	103	695.3	286.8	324.3	6.9	2.8	3.1
C	10411.6	10265.4	1.01	4.31	105	105	101	143.1	147.2	908.1	1.4	1.4	9.0
D	11460.2	11065.5	1.04	4.15	103	104	102	894.7	588.3	928.9	8.7	5.7	9.1
E	12029.6	10888.9	1.10	4.21	100	105	104	409.3	1338.2	1119.8	4.1	12.7	10.8
Central Study Area					**Channel**						**Channel**		
Canyon	Along-Axis Length 800 to 1600 (m)	Straight Length 800 to 1600 (m)	Sinuosity Between 800 m and 1600 m Contours	Along Axis Slope	Vertical Relief at 600 (m)	Vertical Relief at 900 (m)	Vertical Relief at 1200 (m)	Horizontal Distance at 600 (m)	Horizontal Distance at 900 (m)	Horizontal Distance at 1200 (m)	Distance/ Relief at 600 (m)	Distance/ Relief at 900 (m)	Distance/ Relief at 1200 (m)
F	N/A	N/A	N/A	2.63	N/A	190	103	N/A	584.8	890.4	N/A	3.1	8.6
G	16932.5	15404.6	1.10	2.77	200	101	115	1981	921.7	891.1	9.9	9.1	7.7
H	14961.8	14571.1	1.03	3.02	200	102	101	1332.2	479.4	656.3	6.7	4.7	6.5
I	15236.5	14606.6	1.04	3.25	90	105	102	731.9	1057.1	923	8.1	10.1	9.0
J	13707	13376.8	1.02	3.61	101	100	137	644.7	3340.4	2694.6	6.4	33.4	19.7
K	13860.6	13234.1	1.05	3.58	163	275	250	1022.2	3340.4	2694.6	6.3	12.1	10.8
Eastern Study Area					**Channel**						**Channel**		
Canyon	Along-Axis Length 800 to 1600 (m)	Straight Length 800 to 1600 (m)	Sinuosity Between 800 m to 1600 m contours	Along Axis Slope	Vertical Relief at 600 (m)	Vertical Relief at 900 (m)	Vertical Relief at 1200 (m)	Horizontal Distance at 600 (m)	Horizontal Distance at 900 (m)	Horizontal Distance at 1200 (m)	Distance/ Relief at 600 (m)	Distance/ Relief at 900 (m)	Distance/ Relief at 1200 (m)
L	17641.4	17472.1	1.01	2.62	103	102	98	2393.3	1345.7	262.3	23.2	13.2	2.7
M	18503	18385.3	1.01	2.51	103	101	103	1987.6	973.8	983.3	19.3	9.6	9.5
N	16392.6	16166.9	1.01	2.88	102	100	103	935	1099	1416	9.2	11.0	13.7
O	16619.2	15757.1	1.05	2.95	105	104	101	914.6	576.4	1178.7	8.7	5.5	11.7
P	14505.5	14221.5	1.02	3.2	104	103	107	883.6	1211	1122.5	8.5	11.8	10.5

Results

- The majority of the canyons, (with the exception of J, L, and M) have similar breadth as depth increases, however, no general overall trend can be identified (Fig. 5 A).
- Overall, the canyons in all study areas have low sinuosity and are relatively straight, canyon sinuosity generally decreases from west to east. Canyons E and G have the highest sinuosity (Fig. 5 B).
- The Western canyons have the greatest along-axis slope, and the Eastern canyons have the lowest slope and least sinuosity (Fig. 5 C).
- The majority of canyons have 100 m vertical relief from 600 m to 1200 m (Tab. 1).
- The breadth of the canyons does not increase as depth increases, and no particular pattern can be identified (Fig. 5 A).

Discussion

Off the Northern slope of Puerto Rico, numerous sub-marine canyons were mapped and measured. As one moves from west to east, the canyons decrease in slope significantly, and their sinuosity decreases minutely. The variable breadth of the canyons has no specific pattern and does not display the typical increase as depth increases within the given depth range. If more data were to be obtained, more information could be gathered about the breadth of the canyons as a greater depth range could be examined. The canyon sinuosity does not increase as slope increases, as seen in Figure 5 A. Despite the increase in slope in the Western Study Area, no particular pattern of increased sinuosity in this area can be identified.

Overall, the 15 canyons studied on the Northern Slope of Puerto Rico are all similar with a similar vertical canyon relief and sinuosity. No outlying examples were identified, which could hint at extremely similar forces of creation acting on the majority of these canyons. If more data were to be obtained into the deeper parts of this area, further examination could be made at lower depths where sinuosity, breadth, slope, and vertical and horizontal relief could be very different.

References

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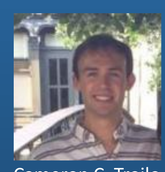
Acknowledgements

We would like to thank NOAA for their bathymetric data, the College of Charleston for the use of their facilities, CARIS for Academic Partnership, School of Science and Math, and the Department of Geology and Environmental Geosciences.



Cameron C. Troilo