Geomorphic Characterization of Submarine Canyons within Glovers Reef

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Abstract

Multibeam sonar data from Glovers Reef atoll were collected by the NOAA Coastal Center for Environmental Health using a Kongsberg EM302 onboard the *E/V Nautilus* in August of 2014. Glovers Reef atoll is part of the Mesoamerican reef and is just south of Lighthouse Reef and Turneffe Reef atolls. 2D and 3D bathymetric images were generated using CARIS HIPS 9.0. This study focuses on utilizing quantitative indices to characterize Glovers Reef canyon geomorphology. Characterization analysis focuses on indices using length, channel relief and area. BASE Editor 4.1 was also utilized to examine canyon slope and aspect. Submarine canyons extend from the atoll's edge at depths of approximately 50 m to 2900 m where the areas and widths increase significantly. Geomorphologic characterization of submarine canyons can yield new information about canyon formation and sediment transport.

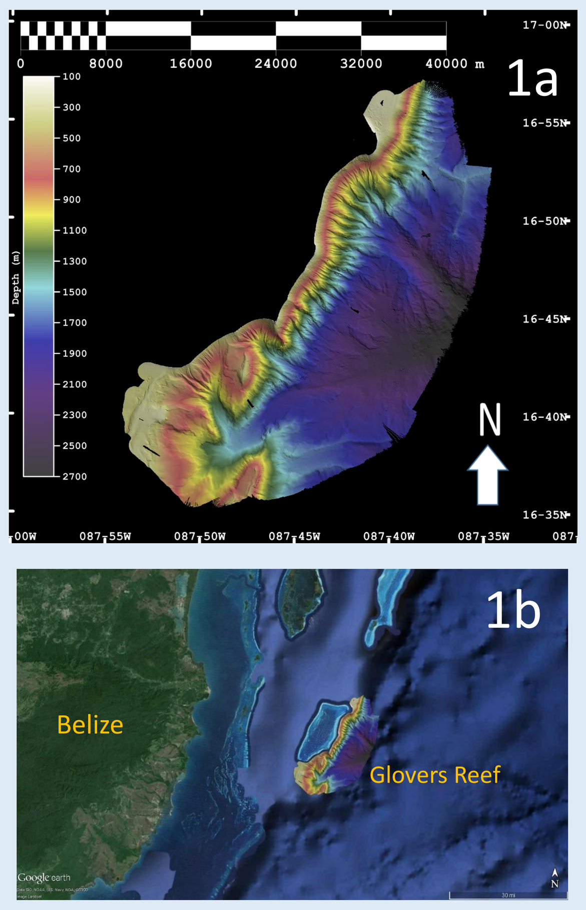


Figure 1
a) Glovers Reef BASE surface showing the area of study within Glovers Reef (white box).
b) Glovers Reef shown within its geographical location to the South East of Glovers Reef atoll. Image from Google Earth.

Background

Glovers Reef is an atoll within the Caribbean Mesoamerican reef system off the coast of Belize, and is one of only 15 atolls within the Atlantic (Gischler, 1994). The reef's eastern flank contains many submarine canyons which reach depths exceeding 2900 m. Some of the canyon segments are nearly 1000 m wide and have yet to be formally characterized. According to Haung et al., (2014) submarine canyons are important geomorphic features because of how they impact sediment transport, ocean currents, benthic ecosystems and ecology. In addition, an expedition led by NOAA's Dr. Peter Etnoyer in cooperation with the Ocean Exploration Trust showed that there are many areas within the eastern flank of the reef that are possible deep coral habitat sites (Etnoyer et al., in press). This study aims to characterize the submarine canyons at Glovers Reef using quantitative analysis to generate indices and novel methods of classifying and defining submarine canyons. This approach could be useful for future research that aims to classify and characterize submarine canyons that are likely to contain deep coral habitats.

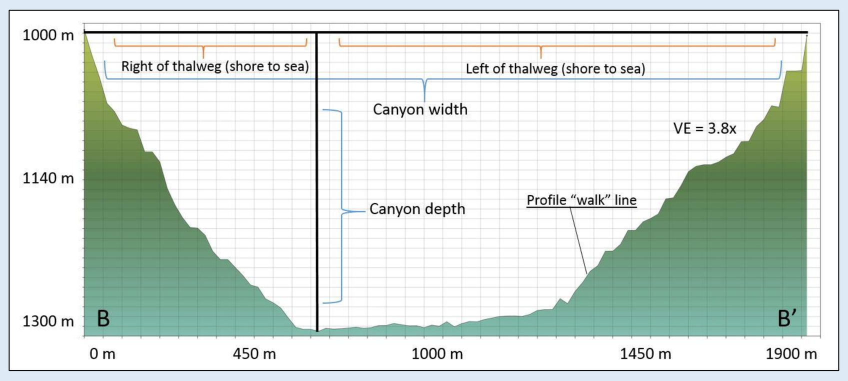


Figure 3
Profile B-B' with methods of measurements for Table 1.

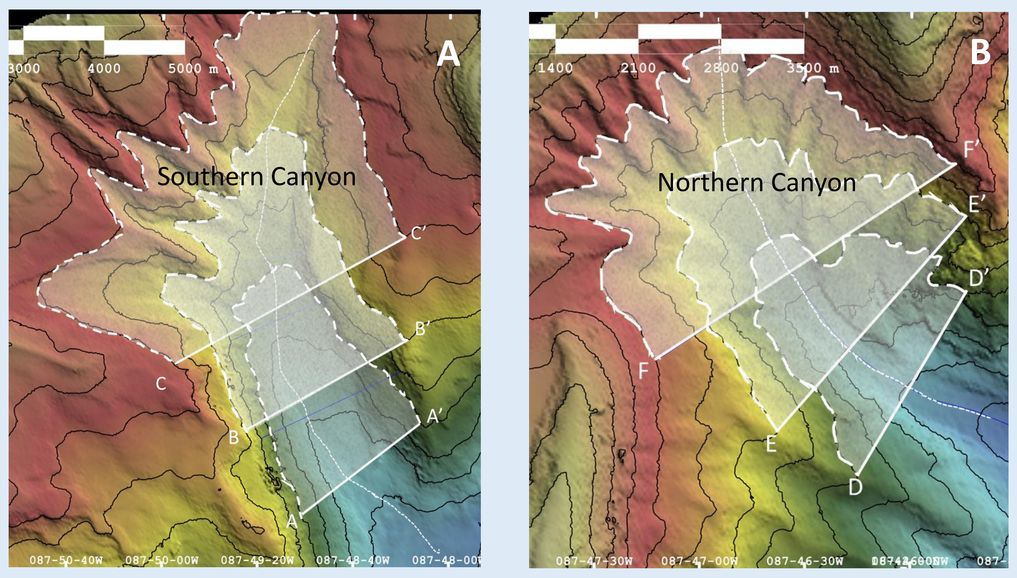
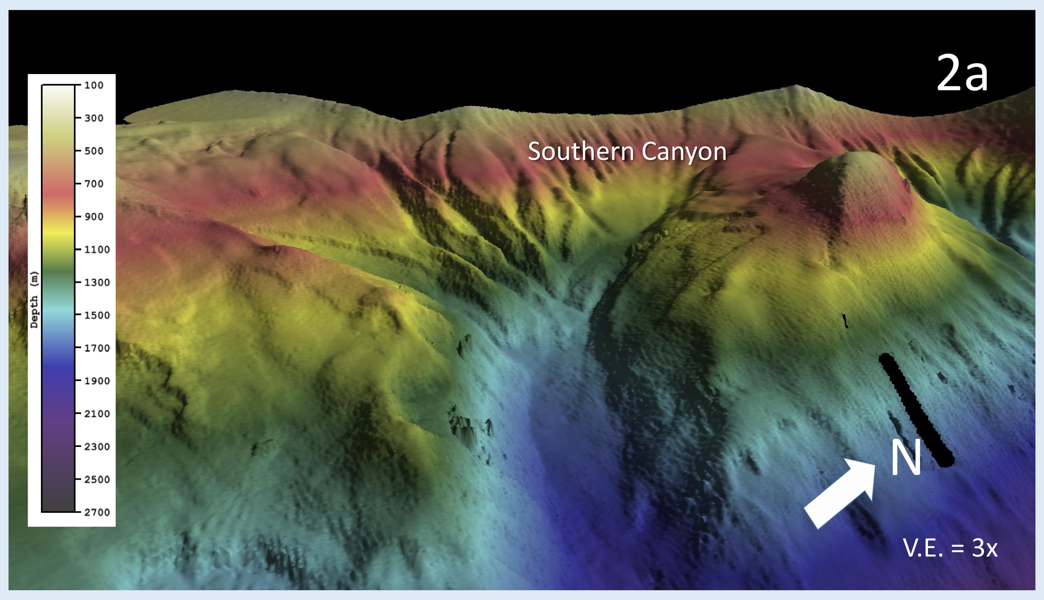


Figure 5
Planar areas (shaded zones) at each profile contour depth are shown for Southern Canyon (A), and Northern Canyon (B). Each was measured in Google Earth Pro.

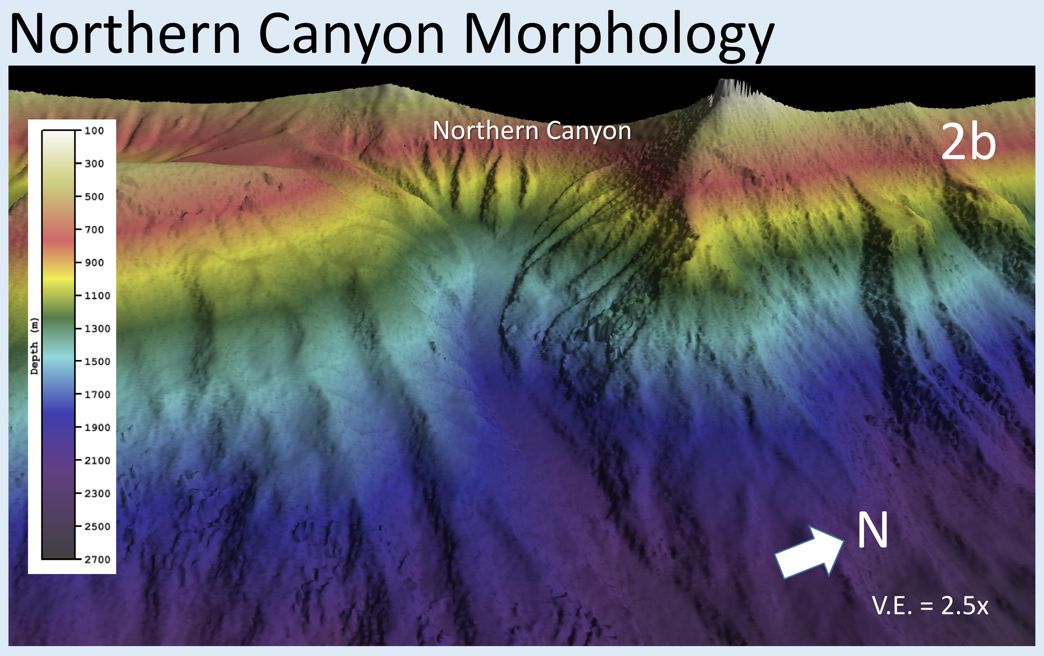
Canyon	Measurements: Canyons		
	Thalweg length (m)	Linear distance (m)	Thalweg slope (avg °)
Southern	7852.89	7502.18	5.5
Northern	4372.76	4114.42	11.7

Table 2
Canyon measurements using methods shown in Figure 4.

Southern Canyon Morphology



Northern Canyon Morphology



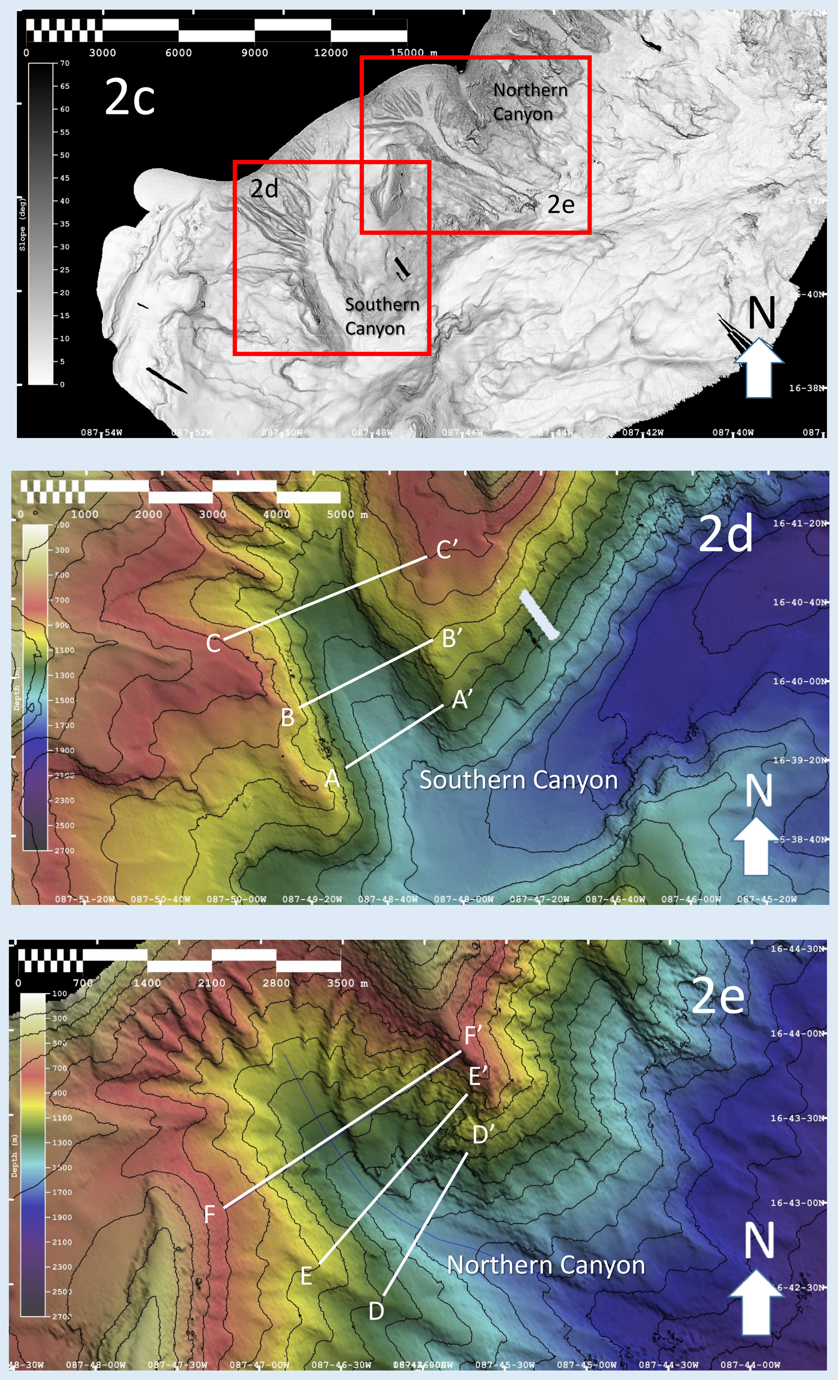


Figure 2
a) 3D view of the Southern canyon. b) 3D view of the Southern canyon. c) Glovers Reef BASE surface grayscale slope map with red boxes indicating extent of canyons studied. d) BASE surface showing the location of profiles A-A', B-B' and C-C'. e) BASE surface showing the location of profiles D-D', E-E' and F-F', illustrated in Figure 3.

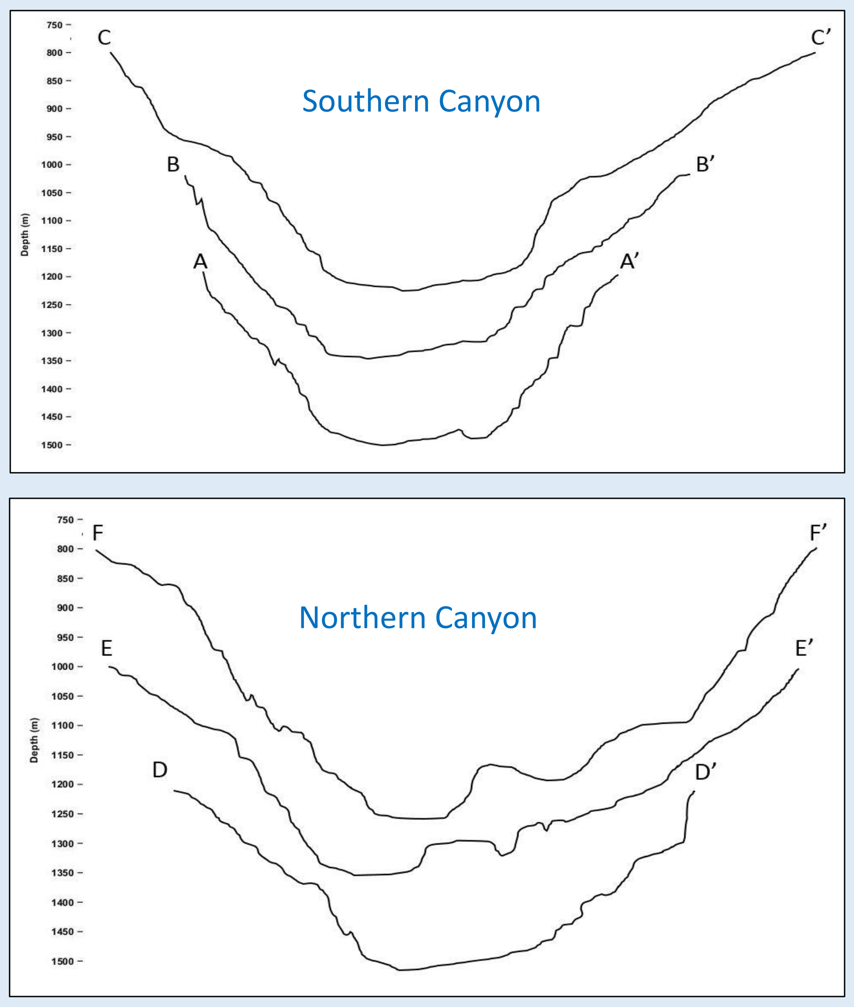


Figure 4
Bathymetric profiles for the Southern and Northern Canyons with individual profile lines (Figure 2d and 2e) overlain on top of each other to show how the two canyons' shape change as depth increases.

Sites	Profiles	Contour depths (m)	Measurements: Profiles						
			Width of profile (m)	Height of profile (m)	Right to thalweg (m)	Left to thalweg (m)	Contour length (m)	Profile "walk" length (m)	Planar area (km^2)
Southern Canyon	A-A'	1200	1829.94	264.4	757.71	1072.23	6869.62	1897.71	3.23
	B-B'	1000	2374.73	375.2	735.89	1568.84	10274.45	2450.87	5.15
	C-C'	800	3347.91	444.9	1431.99	1882.99	14194.04	3357.78	9.68
Northern Canyon	D-D'	1200	1813.86	303.6	823.83	1013.26	5135.81	1994.82	2.08
	E-E'	1000	2370.19	423.7	916.48	1444.69	6797.39	2754.91	3.55
	F-F'	1200	3224.92	503.1	1500.89	1748.49	9267.91	3542.37	4.95

Table 1
Profile measurements for both canyons, from Figure 4. Methods for measurements shown in Figures 3 and 5.

Sites	Profiles	Indices			
		Channel Skewnes	Channel Gradient	Channel Profile	Sinuosity
Southern Canyon	A-A'	0.707	3.62	6.92	1.05
	B-B'	0.469	4.19	6.33	
	C-C'	0.761	4.23	7.53	
Northern Canyon	D-D'	0.813	2.57	5.98	1.06
	E-E'	0.634	2.47	5.59	
	F-F'	0.858	2.62	6.41	

Table 3
Indices for all profiles and canyon measurements calculated using data from Tables 1 and 2. Indices measurements are used for relative analysis of canyon features

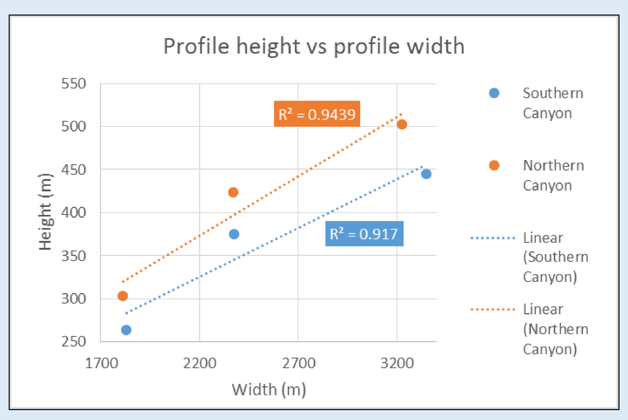


Figure 6
Canyon width at the profiled intervals of 800, 1000, and 1200 m for the two canyons is highly correlated to canyon depth (Figure 7), with R^2 = 0.917 for Southern Canyon and R^2 = 0.9439 for Northern Canyon.

Heading (degrees)		
Southern Canyon	Northern Canyon	Depth (m)
172	164	700
195	162	800
189	151	900
201	109	1000
186	113	1100
170	111	1200
164	114	1300
145	112	1400

Table 4
Channel headings at the thalweg, measured for both canyons and their associated depths at which the measurements were taken.

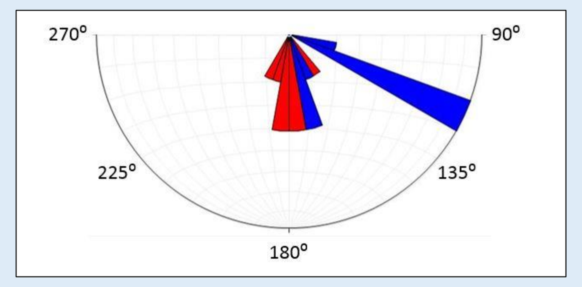


Figure 7
Rose diagram showing orientation headings of the channel axis (Table 4).

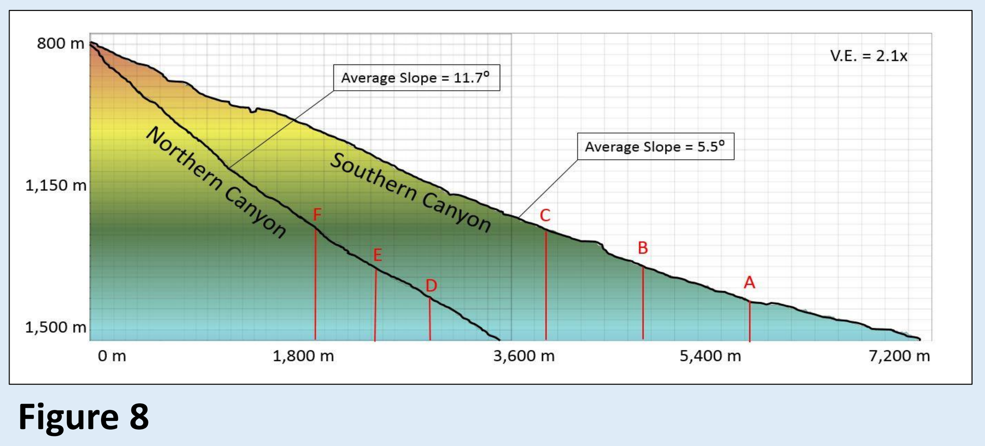


Figure 8
Scaled along-axis profiles of the Southern and Northern Canyons with the approximate locations of where profile lines A-F intersect the channel axis.

Methods

- The Ocean Exploration Trust's E/V *Nautilus* was used to acquire data using a Kongsberg EM302 multibeam sonar system. Dr. Peter Etnoyer (NOAA National Centers for Coastal Ocean Science Center for Coastal Environmental Health and Biomolecular Research) was the lead scientist for the expedition.
- CARIS HIPS and SIPS 9.0 was used to post process raw data and create a 20 m resolution BASE surface.
- HIPS was also used to generate contour maps and profiles. Profile locations were selected using the canyon mouth as a starting point with profile orientations oriented perpendicular to the thalweg.
- Slope map was generated using CARIS BASE Editor 4.1.
- Profiles for each canyon were characterized using measurements of width to channel relief (P), thalweg skewness (S), profile area, gradient (G), sinuosity (Si), and orientation.

$$G = \frac{Contour\ length}{Profile\ walk\ length} \qquad S = \frac{Right\ to\ thalweg}{Left\ to\ thalweg}$$

$$P = \frac{Width\ of\ profile}{Height\ of\ profile} \qquad Si = \frac{Thalweg\ length}{Linear\ distance}$$

- Measurements of planar area were collected using Google Earth Pro.
- Measurements of canyon orientation were made using Google Earth Pro and rose diagrams were generated using Stereonet.

Results

- Canyon profiling shows that Northern Canyon is more dynamic than Southern (Figure 4).
- Rose diagram analysis shows a slight difference in the two canyon's orientation (Figure 7), (Table 4).
- The Northern Canyon thalweg was shown to be less skewed than the Southern Canyon (Table 3).
- The Northern Canyon was shown be slightly more sinuous than the Southern Canyon (Table 3), (Figures 2a and 2b).
- A strong, positive correlation exists between canyon channel relief and width for both the Northern and Southern canyons.
- The Southern Canyon was shown to have a more positive gradient than the Northern Canyon (Table 3).
- The Northern Canyon has a consistently smaller planar surface area which was expected given its relatively steeper slope (Figure 8).

References Cited

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Discussion and Conclusions

Geomorphic characterization of submarine canyons is vital to gaining a greater understanding of submarine canyon formation, sediment discharge volume and rates, deep ocean currents, and deep marine habitats. This study examined and employed multiple methods and techniques to characterize and classify the Northern and Southern Canyons within Glovers Reef. Tools like the Rose diagram (Figure 7) and Google Earth were used to show the canyons' overall orientation, which is useful when characterizing canyons that are close together. Both canyons were shown to have similar sinuosities even though their dominant orientations are different. In addition, Google Earth was used to find the planar area of each canyon, which was useful in showing how each canyon's slope and overall shape are related (Figure 5). Multiple indices were calculated which serve as useful tools for measuring relative differences between the canyons' morphology. The width and relief of both of the canyons in this study are strongly correlated, with an R^2 value of 0.819 (Figure 6). All of the different analyses and methods used in this study can be applied to any submarine canyon. This study serves as a guide to future research into submarine canyons, particularly studies of sediment transport and erosion, benthic ecosystems and further geomorphologic characterization.

Acknowledgments

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