Submarine Canyon Geomorphology of Turneffe Atoll, Belize

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Abstract

Turneffe Reef is an atoll considered part of the Mesoamerican Reef, off the east coast of Belize. The reef's southeast flanks extend to depths of over 1000 meters and demonstrate diverse geomorphological features throughout the carbonate platform. Using multibeam sonar data collected by NOAA Center for Coastal Environmental Health and Biomolecular Research aboard the Ocean Exploration Trust E/V *Nautilus*, variations within the geomorphology, bathymetry, and seafloor can be determined in order to further identify slumping and sediment distribution patterns among submarine canyons off the atoll's flanks within depths ranging from 200 to over 1200 meters. CARIS HIPS and SIPS 9.0 was used for post processing bathymetric and backscatter intensity data to compare seafloor topography, slope and hardness of two submarine canyons southeast of the atoll. Simple linear regression models revealed little correlation between the north and south sides of the canyon walls. Backscatter intensity data showed hardness in the ridge north between both canyons and soft substrate varied throughout study area.

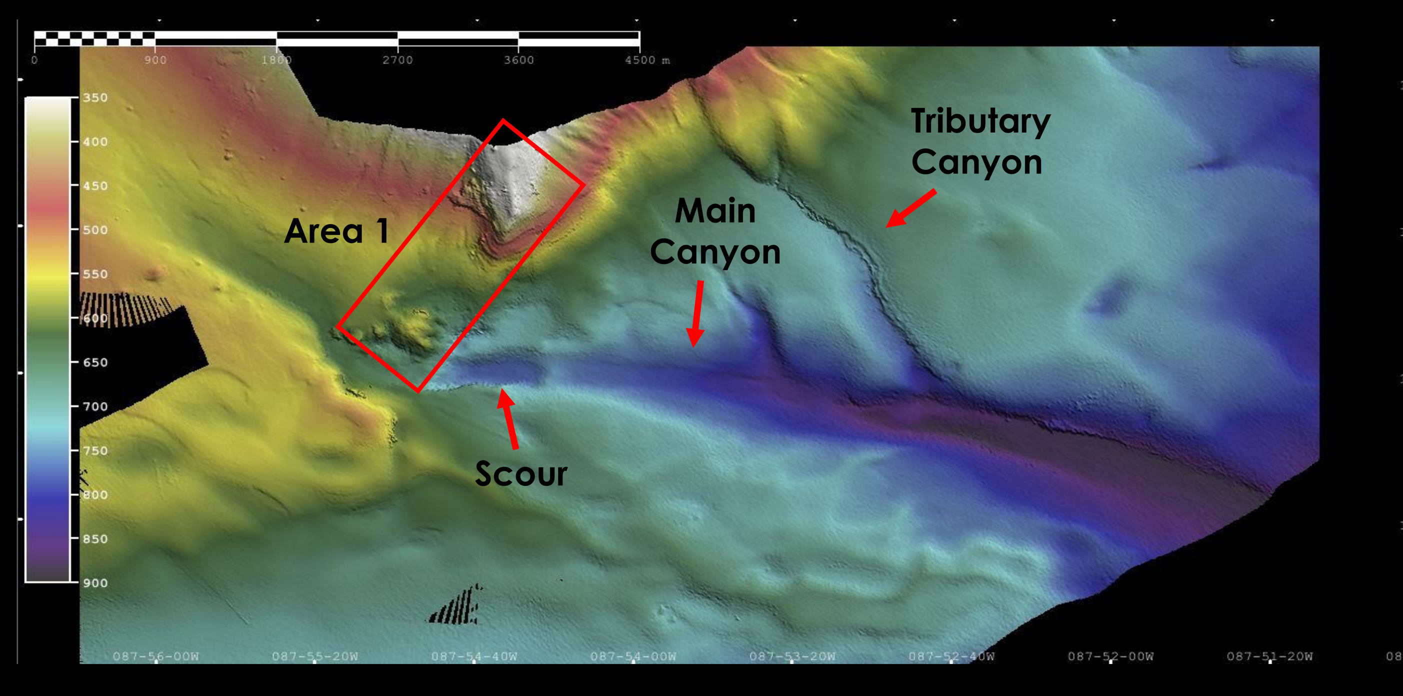

Figure 1. (left) 8m Interpolated CUBE BASE surface of the southeast flank of Turneffe Reef Atoll, Belize. The study areas are labeled.

Google Earth image showing the location of the area of study on the southern flank of Turneffe Atoll.

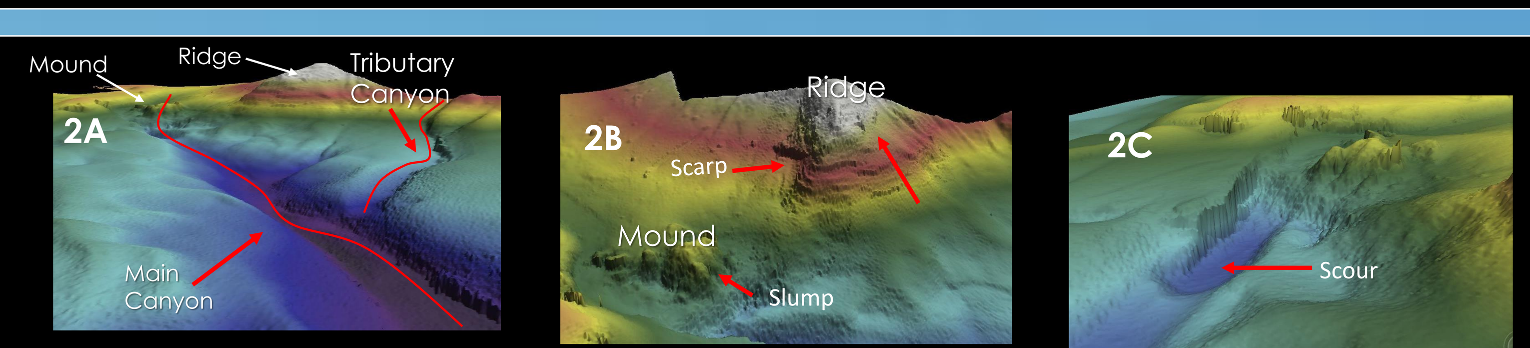

Figure 2. 3D images of all study areas. 2A outlines the main canyon of and the tributary canyon. Area 1 is depicted by 2B pointing to a sediment slump and an scour cut from the ridge above the slump. 2C shows where a scour is located in the upper part of the main canyon. Rectangular in shape, the depth of the scour is higher in the center then decreases as the canyon continues down.

Background

Turneffe Atoll is located on a fault ridge off the coast of Belize in Central America (McCloskey et al., 2013). This Caribbean atoll reaches seafloor depths of over 1200m with submarine canyons forming off its southern flanks. Submarine canyons are important areas for biodiversity and can act as sediment transport routes for terrigenous material (Tubau et al., 2015). Calculation of canyon slope and sinuosity combined with external factors including tide and current patterns may provide more detailed direction of sediment deposition. The direction of the currents may influence the net cross shelf break transport toward either the shelf or slope (Ahumad-Sempoal et al., 2015). Much of the sediments within the lagoons and mangroves of Turneffe are carbonate Holocene sands coming from the Mayan Mountains (Adomate et al., 2015) (McCloskey et al., 2013). The purpose of this research is to use mulitbeam data to characterize the submarine canyon geomorphology in order to further explore sediment transport and deposition.

Area 1

Figure 3. Area 1 profiles used to measure slope of ridge (A-A' to C-C'), and the mound to the ridge (D-D').

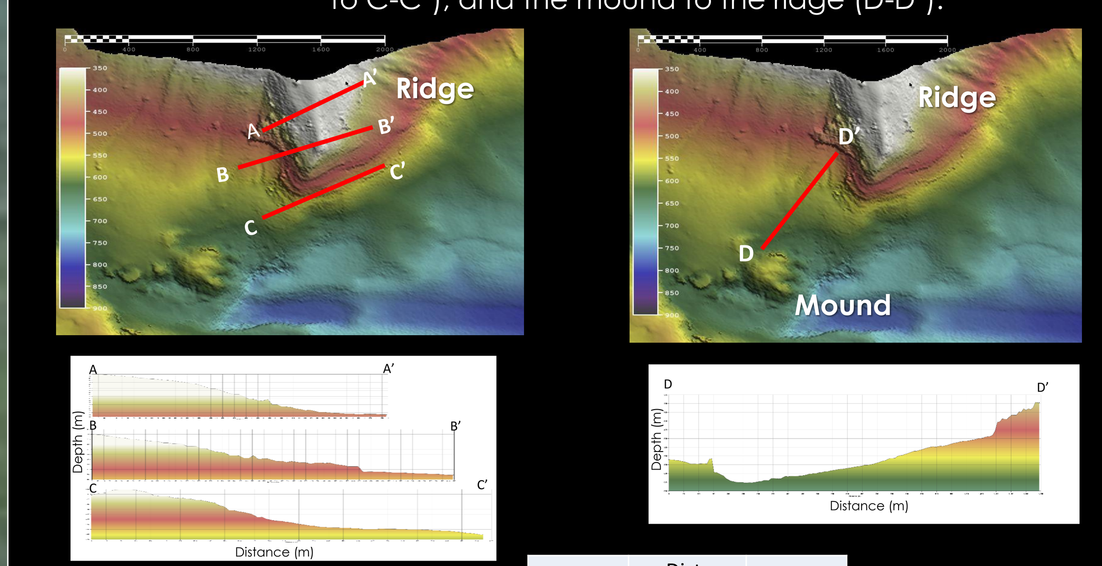

Table 1: Distance and slope for Area 1 profiles.

Profile	Distance (m)	Slope
A-A'	497.49	23.55
B-B'	608.22	22.07
C-C'	660.66	28.48
D-D'	841.63	9.19

Results

- Exaggerated by 3D imaging is a main canyon with a smaller tributary, a ridge at shallow depths with an outcropped side on the slope with a slump like structure below the ridge, and a scoured section in the upper main canyon (Fig. 2).
- The south side base of the ridge in Area 1 had a steep slope ranging between 22.07 to 28.47 (Fig. 3, Table 1). The mound is 841.63 m from the cutout on the Area 1 ridge and has a slope of 9.19. The slope of the ridge ranges from 23.5 to 28.5 (Table 1).
- A backscatter image shows relatively hard substrate with little variance excluding Area 1. There was higher intensity return on the right side of the ridge and continued down the right side of the mound (Fig. 7).
- Main Canyon had a slightly higher sinuosity than Tributary Canyon, with a difference of 0.07 (Table 3).
- Canyon slopes of the north and south slopes were not strongly correlated in either the Main or Tributary Canyons (Fig. 6).
- Areas of higher slope include the ridge in Area 1, The Tributary Canyon, and the lower Main Canyon (Fig. 7).
- The north and south slopes were higher on the north side in the Tributary Canyon.

Tributary Canyon

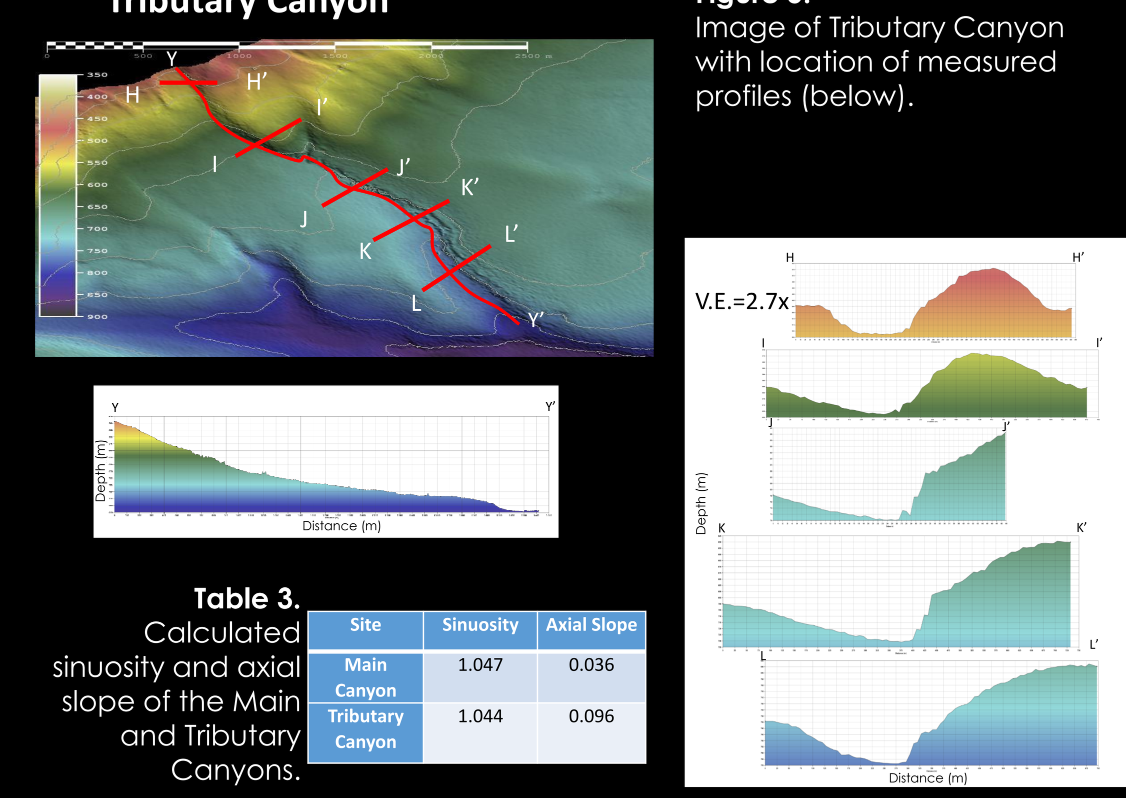

Figure 5. Image of Tributary Canyon with location of measured profiles (below).

Table 3. Calculated sinuosity and axial slope of the Main and Tributary Canyons.

Site	Sinuosity	Axial Slope
Main Canyon	1.047	0.036
Tributary Canyon	1.044	0.096

Methods

- Data for this research were collected aboard the Ocean Exploration Trust's E/V *Nautilus* by NOAA using a Kongsberg EM302 in August 2014 by Dr. Peter Etnoyer of the NOAA Center for Coast Environmental Health and Biomolecular Research.
- Raw data were processed using CARIS HIPS and SIPS 9.0 software.
- An 8m interpolated CUBE BASE surface and a backscatter mosaic of the data were made to interpret the geomorphology and relative hardness of the seafloor substrate.
- The created surface was split into 4 areas of study based on bathymetry and geomorphological structures.
- BASE Editor 4.0 was used to make a slope layer image in order to identify areas of high and low slope within the areas of interest.
- Using profiles and the distance and measure tool, the sinuosity, slope, distance, and dimensional analysis were calculated in order to further identify seafloor morphologies.

Main Canyon

Figure 4 Contoured images (50m intervals) showing the location of the measured profiles in the Main Canyon. The profiles measured are to the right, with the axial profiles used to measure sinuosity below them.

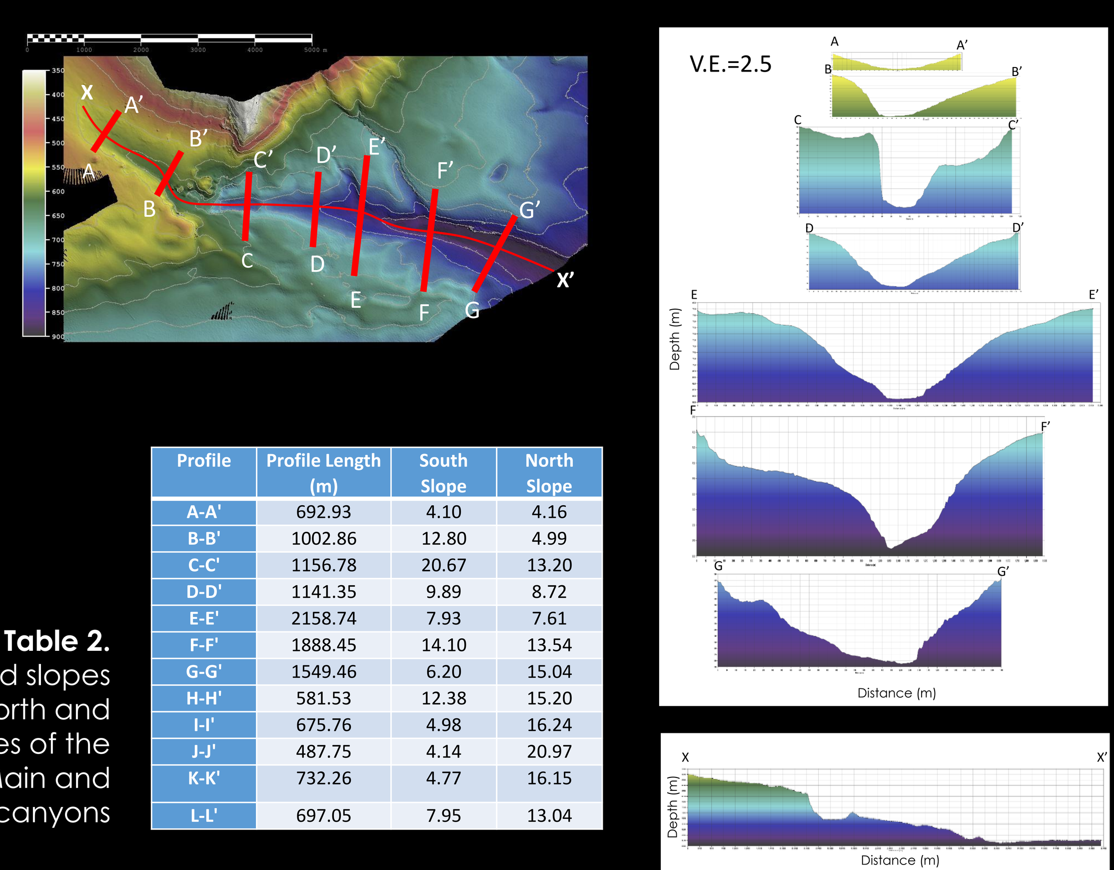

Table 2. Calculated slopes of the north and south sides of the Main and Tributary canyons

Profile	Profile Length (m)	South Slope	North Slope
A-A'	692.93	4.10	4.16
B-B'	1002.86	12.80	4.99
C-C'	1156.78	20.67	13.20
D-D'	1141.35	9.89	8.72
E-E'	2158.74	7.93	7.61
F-F'	1888.45	14.10	13.54
G-G'	1549.46	6.20	15.04
H-H'	581.53	12.38	15.20
I-I'	675.76	4.98	16.24
J-J'	487.75	4.14	20.97
K-K'	732.26	4.77	16.15
L-L'	697.05	7.95	13.04

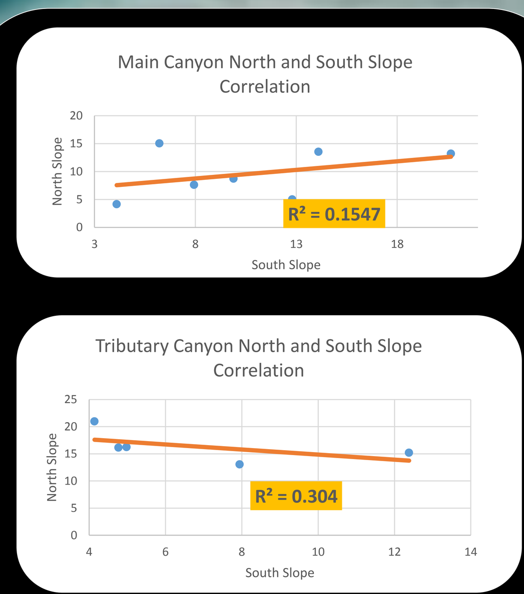

Figure 6. The north and south slopes of Main Canyon (top) and Tributary Canyon show only a weak correlation.

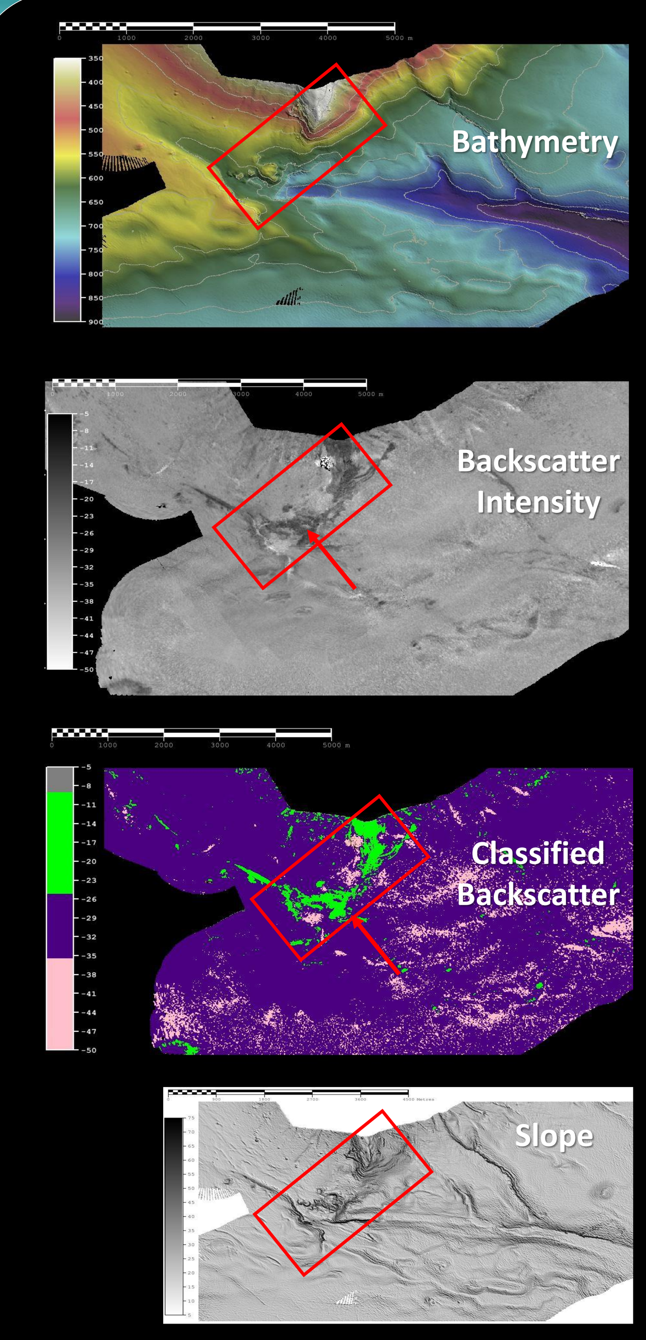

Figure 7. Backscatter intensity relates to relative substrate hardness, with high intensity (darker areas) indicating a hard substrate. The classified backscatter shows green as the hardest substrate. Area 1 is outlined in red and shows the hard substrate surrounding the mound and slope with similar intensity return values. The Slope layer of the 8m interpolated CUBE BASE surface shows much steeper slope (darker areas) in the same areas as hard substrate.

RIGHT

Discussion and Conclusions

The morphologies within submarine canyons are often indications for sedimentary processes (Tubau, 2015) and, in particular, slope can be used to determine sediment transport through the canyon. The north and south slopes of both the Turneffe Atoll Main Canyon and Tributary Canyon did not show a strong correlation possibly indicating an uneven distribution of energy throughout the canyons. The Main Canyon had a smaller axial slope of .036 compared to the Tributary Canyon's axial slope of .096. The low sinuosity of both canyons reveals inactivity of downstream sediment flows, however more information must be known on the identity of the substrate to classify the energy flow through the canyons (Tubau, 2015). Slumps, scours, and scarps all seen in the surrounding submarine canyon margins suggest movement and flow effect the seafloor morphology (Espinosa, 2016). Based on the backscatter, the steep slopes of the south side of the ridge in Area 1 could potentially have contributed to the slumping below, increasing the risk of structure failure.

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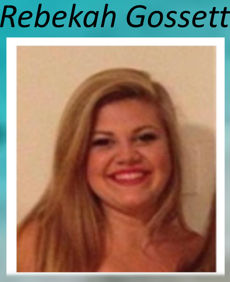

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