Campeche Escarpment Submarine Canyon Geomorphic Characterization

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Abstract

Bathymetric surveys were conducted in the southern Gulf of Mexico along the Campeche Escarpment, north of the Yucatán Peninsula, by the Monterey Bay Aquarium Research Institute in March 2013. Multibeam sonar data were collected onboard the *R/V Falkor* and were post-processed using CARIS HIPS 9.1. Numerous submarine canyons were observed along the length of the escarpment, previously undetected by earlier seismic surveys. In this study, we characterize three of the larger submarine canyons using cross-channel profiles along each canyon's axis and measuring variations in channel width and symmetry at selected depths above the thalweg. The canyons were found to be strikingly different in size and morphology. The width of the canyons were found to fluctuate as distance from canyon head increased. The method of submarine canyon characterization used by this study displays the geomorphological uniqueness of these features; additional investigations of the canyons along Campeche Escarpment would provide further understanding of the geologic history of the Gulf of Mexico.

Location of Campeche Escarpment

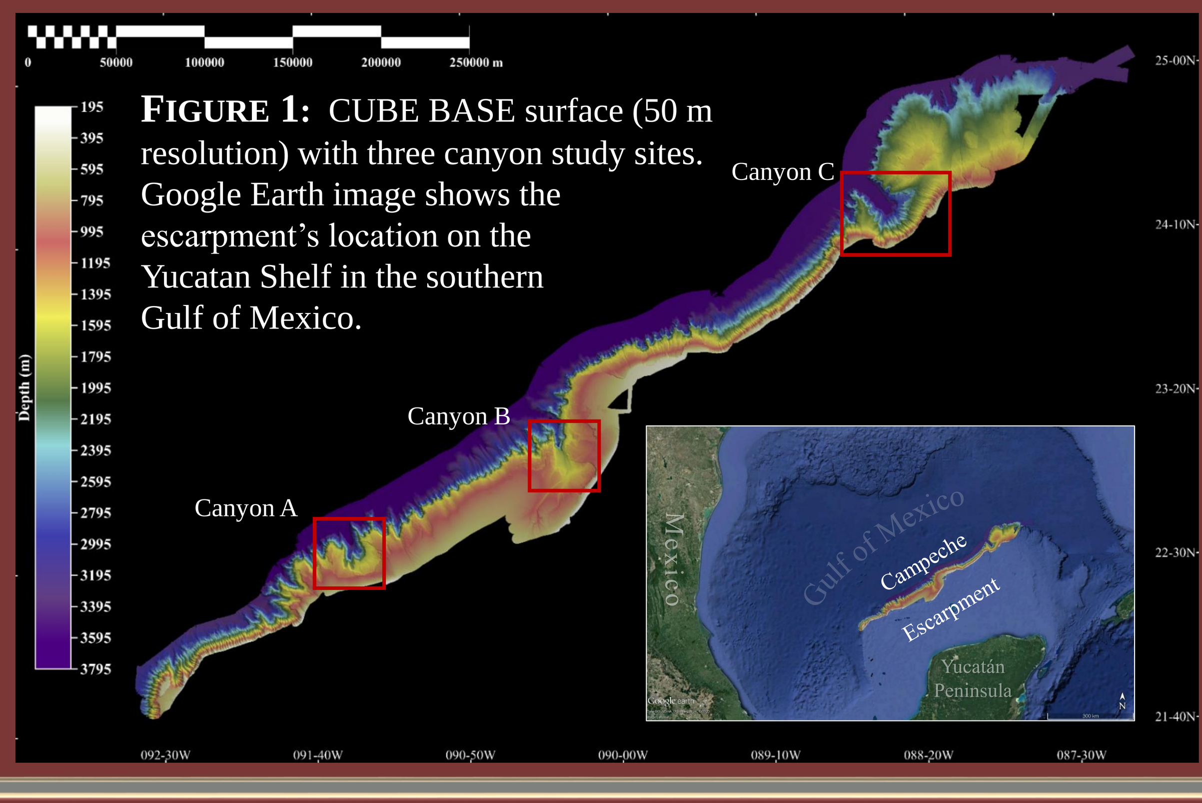


Figure 1: CUBE BASE surface (50 m resolution) with three canyon study sites. Google Earth image shows the escarpment's location on the Yucatan Shelf in the southern Gulf of Mexico.

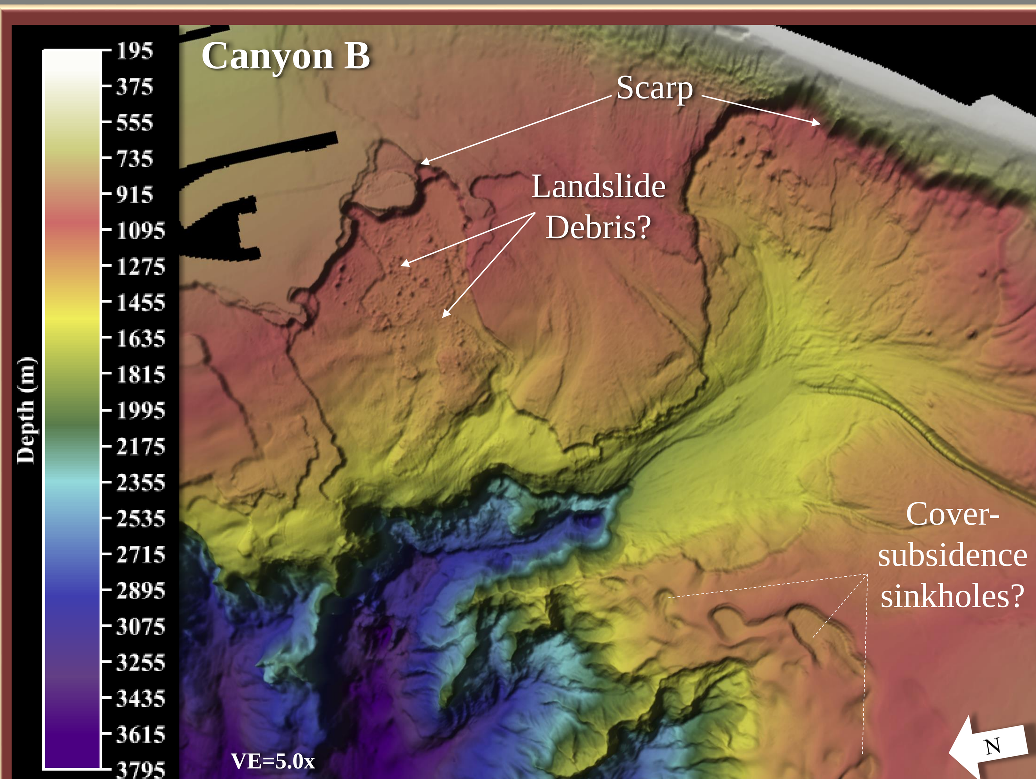


Figure 2: 3D image (VE=5.0x) of Canyon B failure scarp. Possible landslide debris from failure events can been seen below erosional scarps along the length of Campeche Escarpment.

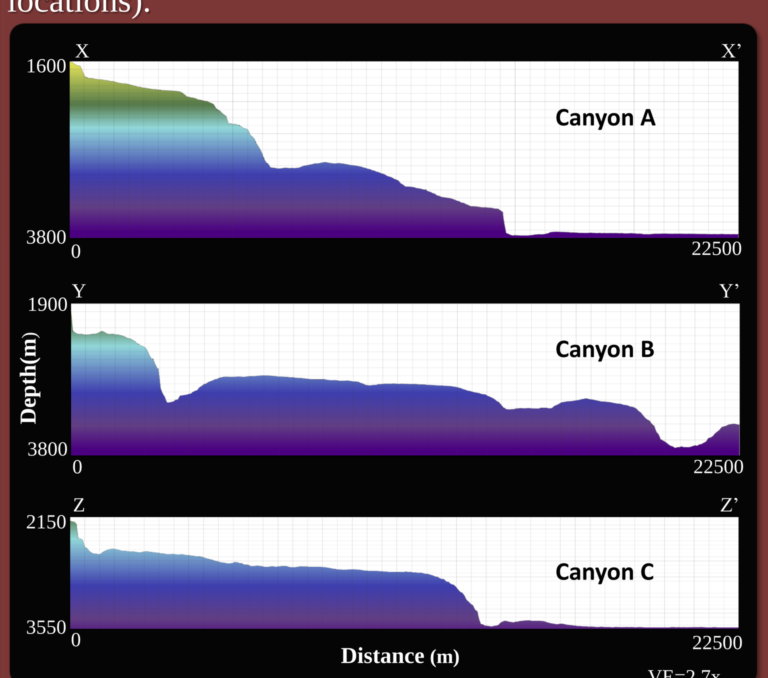


Figure 3. Scaled profiles (VE=2.7x) measured along the axis of Canyon A (X-X'), B (Y-Y'), and C (Z-Z'). Axis was determined by identifying the thalweg from contour maps (See Fig. 5 for profile line locations).

Table 2. Measurements made along the canyon axis.

Site	Profile Line	Thalweg Length (m)	Straight Line Distance (m)	Sinuosity	Along Axis Slope (°)
Canyon A	X-X'	15007.9	14114.6	1.063	8.38
Canyon B	Y-Y'	22513.5	20514.7	1.097	3.83
Canyon C	Z-Z'	22532.5	20511.9	1.099	3.69

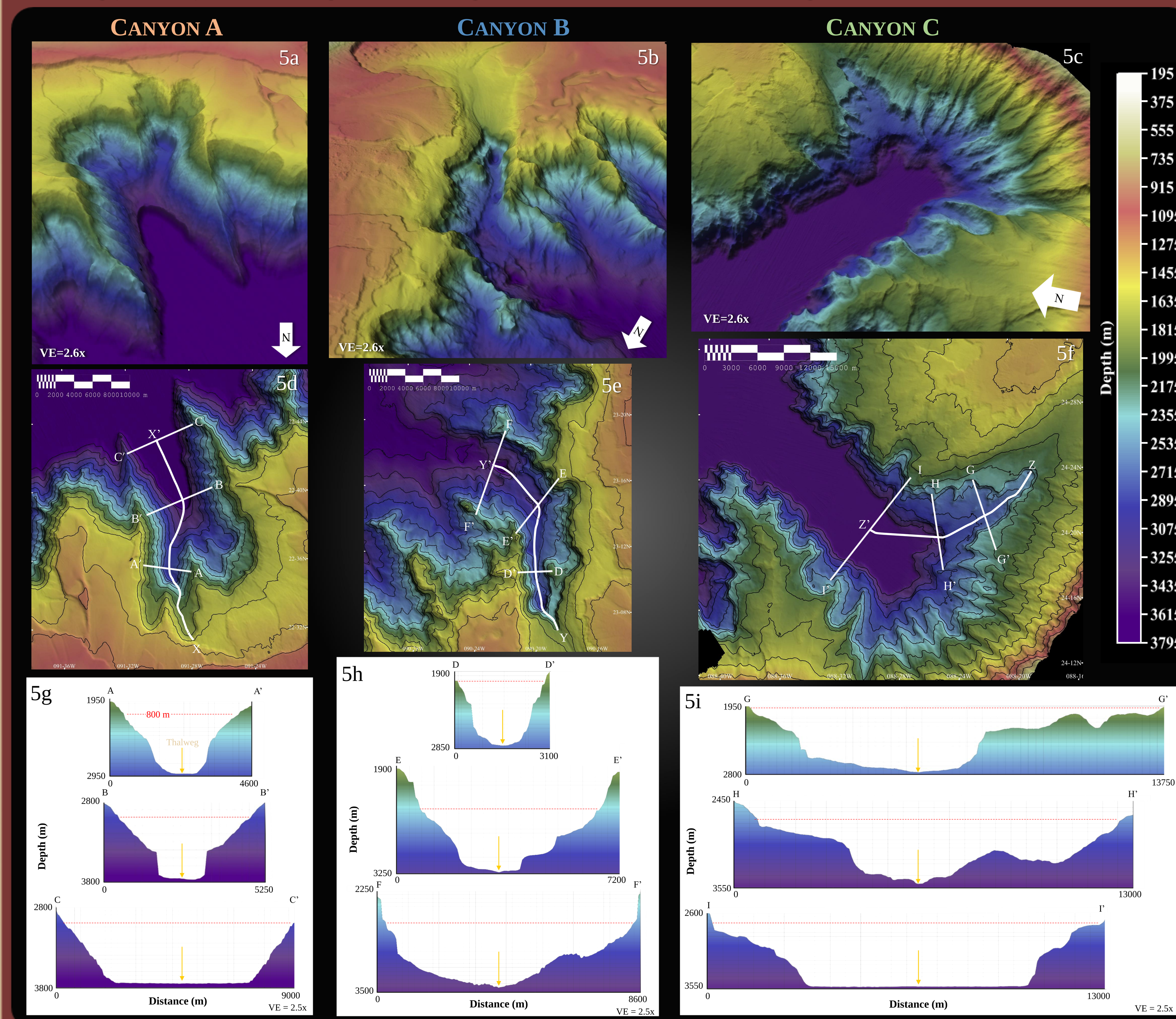
Background

The Campeche Escarpment forms the northern margin of the Yucatán Shelf in the Gulf of Mexico (Fig. 1). Earlier seismic studies (Lindsay et al, 1975) identified 15 canyons cutting into the face of the shelf; however, the high-resolution multibeam data shows that the steep and heavily eroded escarpment is characterized by over 80 submarine canyons cutting into its 612 km long face. A distinct feature of Campeche Escarpment is the ~500 m high cliffs that form the top of many of the canyons. Despite their frequency, only one canyon, Canyon B, has a well-developed channel that cuts across the cliff face and onto the gentler slopes above (Fig.2) (Paull et al., 2014).

The geomorphology and stratigraphy of Campeche Escarpment are relatively unknown especially when considering its proximity to Chicxulub impact structure. Locker and Buffler (1983) used seismic profiling to contrast the Campeche Escarpment to the West Florida Escarpment, a similarly steep carbonate escarpment, and noted that Campeche is significantly more complex than West Florida. It was not until recently that the intricacies of Campeche were understood to be associated with large scale slope failures likely induced by the Chicxulub impact event (Chaytor et al., 2016). The resulting scarps, failure scars, and blocky debris can be found along the length of escarpment (Fig. 2).

Characterization of submarine canyons is crucial to the understanding of the stratigraphic and geomorphological history of carbonate platforms. Here we apply a unique methodology for canyon characterization for three of the most prominent submarine canyons incised on Campeche Escarpment.

Figures 5a-5c: 3D images of canyons with 2.6x vertical exaggeration.
Figures 5d-5f: Contoured bathymetry with locations of along-axis profiles lines (Fig. 4) and cross-channel profiles lines.
Figures 5g-5i: Cross-channel profiles for each canyon taken 7.5, 15.0, and 22.5 km from canyon head at equal scales and aligned perpendicular to the thalweg (VE = 1.6x). Yellow arrow represents the thalweg. Red dashed line is 800 m above the thalweg.



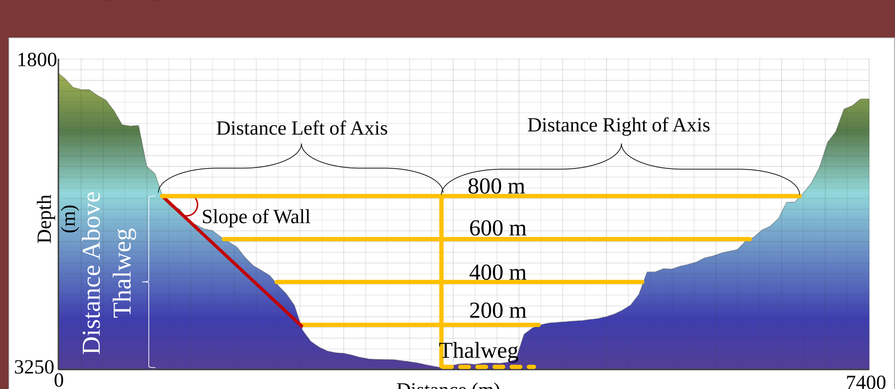
Methods

- Bathymetric surveys were conducted by the Monterey Bay Marine Research Institute (MBARI) on board the R/V *Falkor* with a Kongsberg EM302 and EM710.
- CARIS HIPS & SIPS 9.1 was used to post-process raw multibeam sonar data and render CUBE BASE surfaces at 50 m resolution.
- 3D images, contour maps, and profiles were generated, and slopes and distances were measured.
- Canyon heads were identified at the 200 m isobaths where the slope was greater than 20°.
- Profiles were measured along the canyon axis (thalweg) to 22.5 km from the canyon head, and cross-sectional profiles were made perpendicular to the thalweg at 7.5, 15.0, and 22.5 km from the canyon head.

Measurements (Figure 4):

- Canyon width and distance to canyon wall measurements were made for each cross-sectional profile at 200, 400, 600, and 800 m above the thalweg.
- Canyon wall slope was calculated between 800 and 200 m above the thalweg using trigonometric functions.
- Channel symmetry (S) was determined by the ratio of the distance from canyon axis to the left wall to the distance from axis to the right wall.

Figure 4: Example profile with methods of measurement (Table 1).



Channel symmetry (S) was calculated using the equation below. Values greater than one indicate left-skewed channels, right-skewed channels have an S value less than 1, and symmetric canyons have an S value of 1. All cross-channel profiles are shown as if viewed from the canyon base looking towards the canyon head.

$$S = \frac{\text{Distance Left of Axis}}{\text{Distance Right of Axis}}$$

Table 1. Profile measurements for Canyons A, B, and C. Methods of measurements in Figure 4.

Site	Profile Line	Width: 200m Above Thalweg (m)	Width: 400m Above Thalweg (m)	Width: 600m Above Thalweg (m)	Width: 800m Above Thalweg (m)	Channel Symmetry: 200m Above Thalweg	Channel Symmetry: 400m Above Thalweg	Channel Symmetry: 600m Above Thalweg	Channel Symmetry: 800m Above Thalweg	Wall Slope: Left Wall Slope (°)	Wall Slope: Right Wall Slope (°)	Canyon Wall Symmetry
Canyon A	A-A'	1722	2049	2833	4068	1.345	1.371	1.579	1.072	30.7	28.6	1.072
	B-B'	1561	2276	3418	4388	1.013	1.027	0.914	0.903	25.1	21.9	1.147
	C-C'	5710	6516	7419	7224	1.034	1.046	1.034	1.057	25.2	27.6	0.915
Canyon B	D-D'	1684	1935	2352	2852	1.145	1.092	1.064	1.080	45.6	44.3	1.029
	E-E'	2183	3357	4794	5810	1.434	0.831	0.706	0.781	25.3	14.1	1.793
	F-F'	3750	5296	7213	8139	1.755	1.520	0.859	0.824	25.2	11.0	2.282
Canyon C	G-G'	5468	5974	9000	13416	1.965	1.840	1.056	0.688	18.0	5.5	3.253
	H-H'	3310	4524	9262	11738	1.482	0.959	0.594	0.793	10.6	6.6	1.591
	I-I'	7737	8667	10456	12702	1.005	1.120	1.113	1.099	9.2	11.6	0.795

Results

- Canyon profiling shows Canyon C to be significantly wider than Canyon A and Canyon B (Fig. 5).
- The width of Canyon B was found to increase at all depths above the thalweg as distance from the canyon head increased. Canyons A and C had widths that fluctuated with distance from the canyon head (Fig 6).
- The largest canyon width (13,416 km) was found in Canyon C 800 m above the thalweg and 7.5 km from the head (Table 1).
- Canyon C showed greatest variation in width: at 200 m above the thalweg, width decreased by 2158 m between 7.5 and 15.0 km, and increased by 4427 m between 15.0 and 22.5 km from the head.
- Channel symmetry varied among canyons (Fig. 7); however, all canyons showed a left-skew preference in symmetry: Average symmetries of 1.12, 1.09, 1.14 were calculated for Canyons A, B, and C, respectively. Canyon C had the largest amount of asymmetry (Table 1).
- Wall slope varied among the three canyons. Canyon C's right wall slope increased with distance from head while the left wall slope decreased.

Figure 6. Channel width for each canyon at 200, 400, 600, and 800 m above the thalweg, along increasing distance from the canyon head. Darker lines are measurements furthest from thalweg (Table 1). Refer to Figure 4 for methods of measurement.

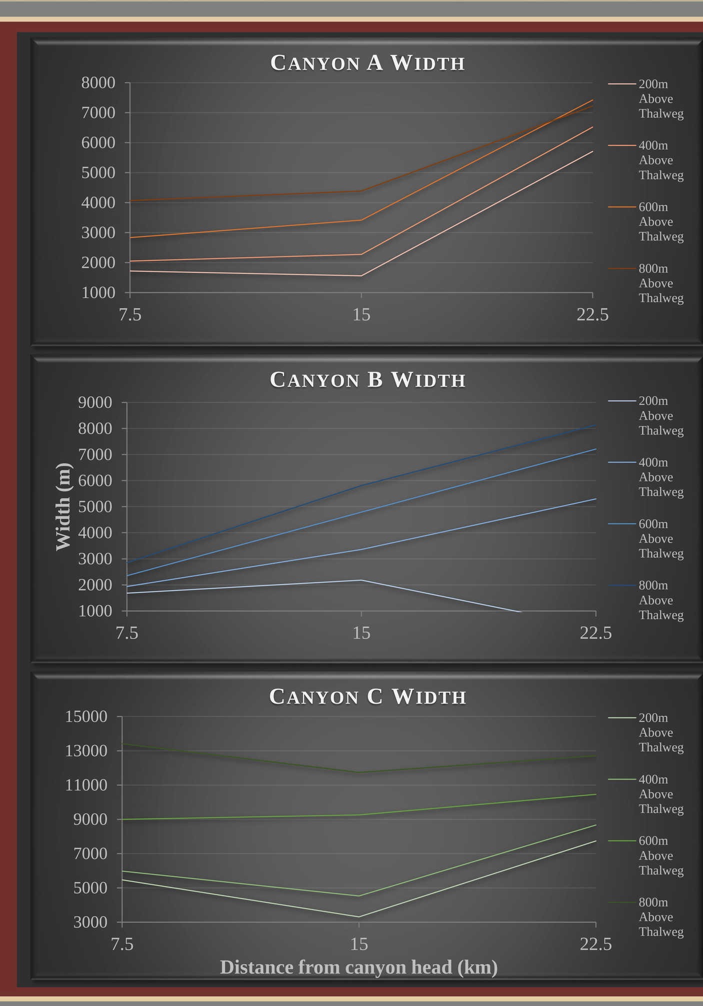
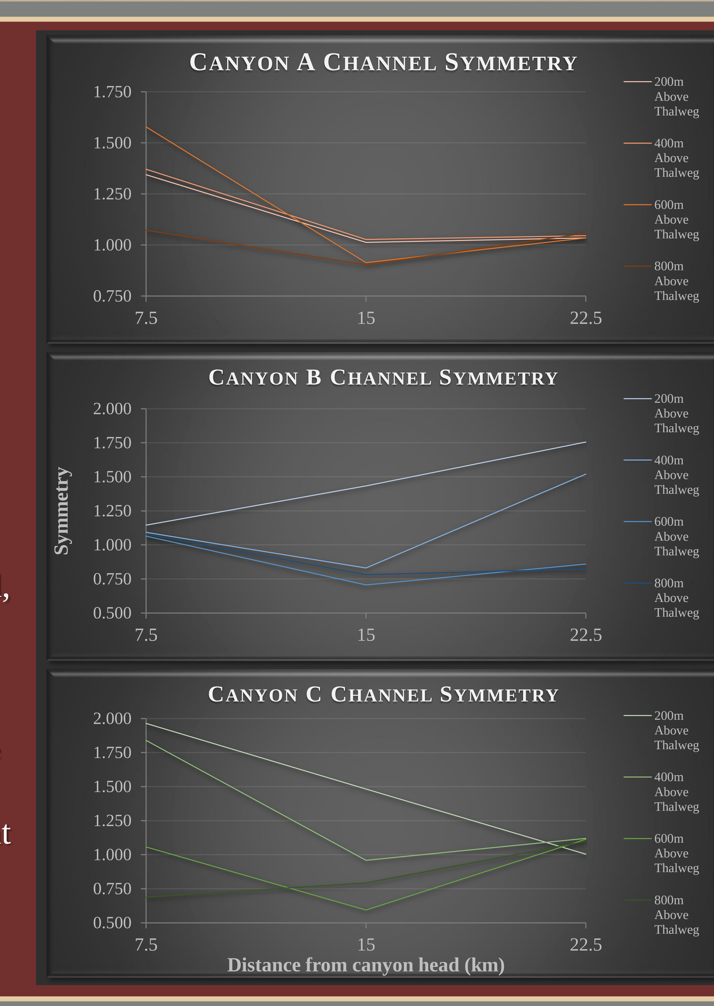


Figure 7. Channel symmetry at 200, 400, 600, and 800 m above the thalweg along increasing distance from the canyon head. Values greater than 1 are left-skewed, and less than one are right-skewed. Refer to Figure 4 for methods of measurement and Table 1 for data.



Discussion & Conclusion

Campeche Escarpment offers a unique opportunity to study a large number of morphologically unique submarine canyons along a single stretch of continental shelf. The relative flatness of the floors of Canyons A and C seen in 3D images (Fig. 5a-c) are misleading representations of morphologies, as the difference steepness of the canyon walls and along-axis slope were relatively high (Fig. 5g and 5i; Fig. 3). The method of submarine canyon characterization used here highlights the uniqueness of these canyons by placing constraints on the location of measurements, and thus, removing superfluous values normally associated with canyon characterization. Further characterization of Campeche Escarpment submarine canyons would provide insight into the fascinating geologic history of the region.

References

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