The Santa Cruz Basin: A Study of Slope-Origin and Shelf-Origin Canyons

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NOAA Ship Okeanos Explorer

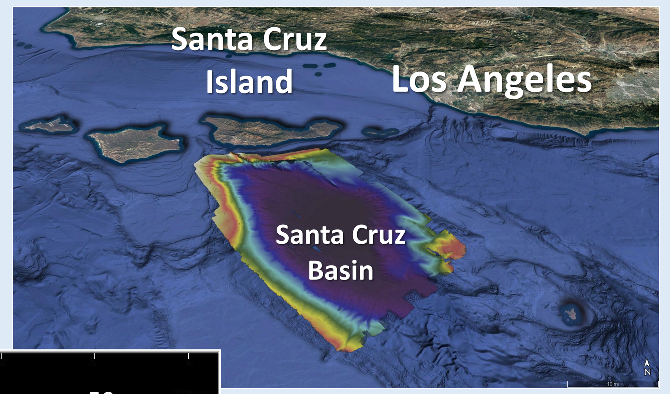
BACKGROUND

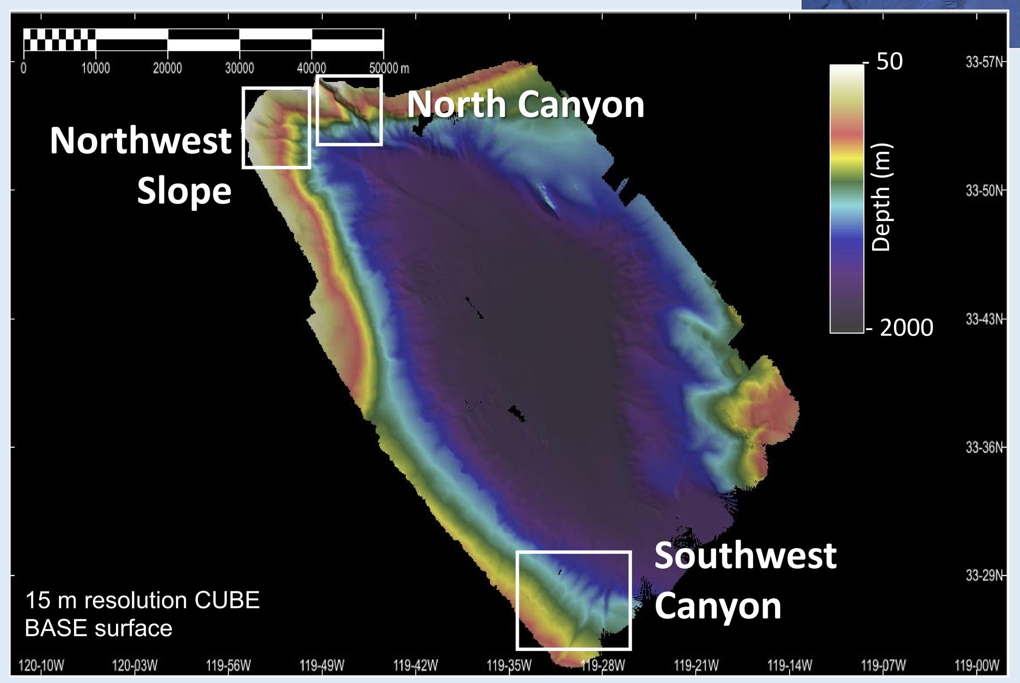
The Santa Cruz Basin is located approximately 87 km off the coast of Los Angeles, CA, directly off the south coast of Santa Cruz Island. The basin acts as a sediment depositional site for the island. In March 2011, the NOAA Ship *Okeanos Explorer* collected multibeam sonar data to support other NOAA offices' work and select specific ROV dive sites. Previous studies of the basin's geology (Chaytor et al., 2018) determined that the basin is a depositional area with varying sediment delivery paths around its perimeter. Numerous slope-origin submarine canyons are located along the basin's east and west sides. Two shelf-origin canyons are situated on the north and southwest walls of the elongated northwest-southeast-oriented basin. At the basin's northernmost point is a shelf-origin canyon, referred to as North Canyon. The head of North Canyon lies between Santa Cruz Island and Santa Rosa Island, where a large source of bottom water enters from the north due to the consistent northwest winds that bring the water mass in from the neighboring Santa Barbara Basin (Shepard et al., 1974). This constant influx of current creates the geomorphology of the northern wall, which is steep and rugged. The remaining basin perimeter has mostly slope-origin submarine canyons.

The purpose of this study is to examine bathymetric and slope surfaces and canyon axial and cross-section profiles to examine the geomorphology of three submarine canyons along the basin wall. Canyon slope profiles and sinuosity were used to compare the two shelf-origin and one slope-origin canyon to observe the relationship between canyon slope and sinuosity. Classified backscatter was used to explain the canyon geomorphologies and substrate lining the canyon thalwegs.

Figure 1. Study Area and Site Locations

Shelf-origin and slope-origin submarine canyons are found around the basin's perimeter. Three sites were examined.



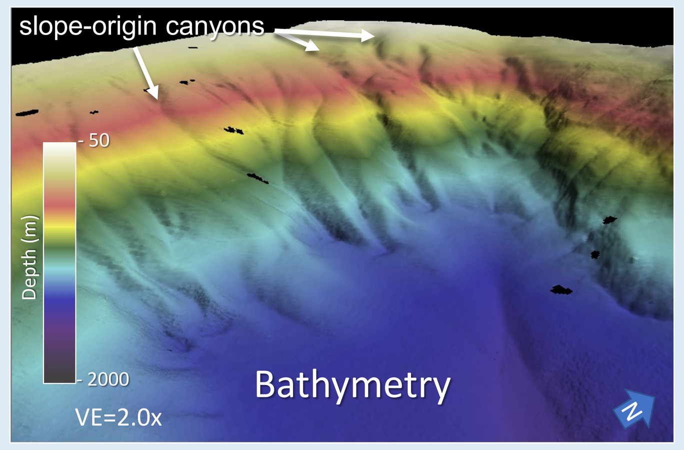


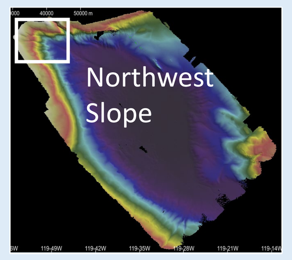
Two sites (North Canyon and Southwest Canyon) are shelf-origin, whereas Northwest Slope is one of many slope-origin canyons that line the basin perimeter.

METHODS

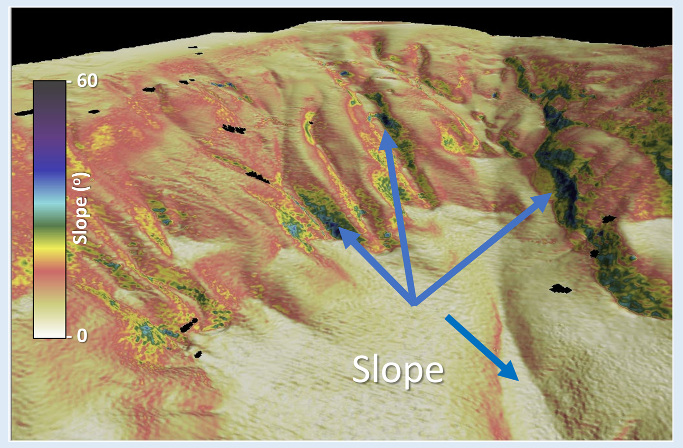
- The NOAA Ship *Okeanos Explorer* served as sonar platform, using an EM302 multibeam sonar.
- Raw multibeam sonar data were collected during expedition EX1101, surveyed in March 2011.
- Sonar data were post-processed using CARIS HIPS and SIPS 11.3.
- Bathymetric surfaces were made with 15 m resolution and bathymetry, slope, and classified backscatter surfaces were created to study individual canyon sites.
- Depth profiles of canyon thalwegs were compared to highlight slope and sinuosity.
- Canyon sinuosity were calculated by taking the distance along the canyon thalweg and dividing it by straight line distance from beginning point to end point, "distance to home".

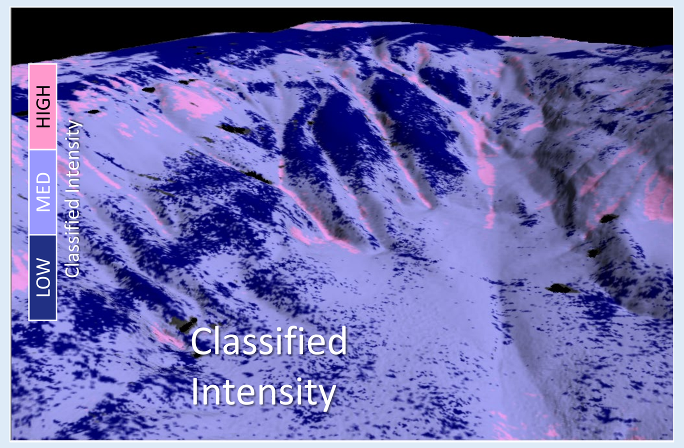
Figure 2. Northwest Slope Site: Slope-Origin Canyons





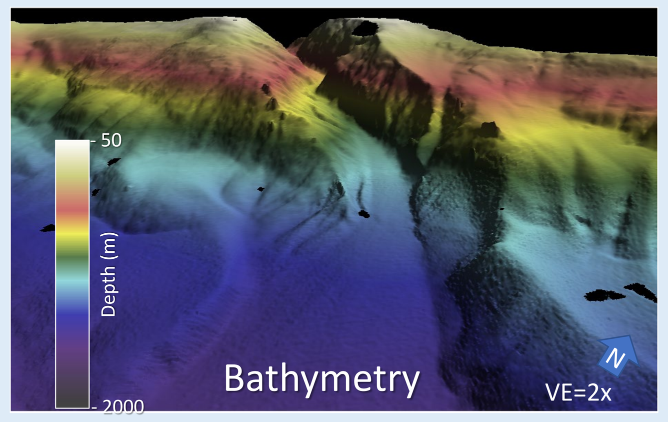
The Northwest Slope Site is a collection of smaller slope-origin canyons (white arrows). Steep canyon walls create inter-canyon ridges. Canyon wall slopes are greatest (up to 40°) on the north side of several channels, indicated by the black arrows in the slope image. These channels lead into a canyon tributary system which contributes to a single channel (blue arrow on Slope image).

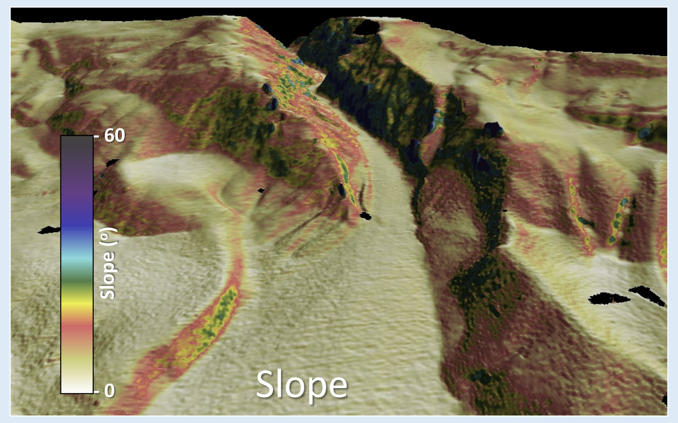


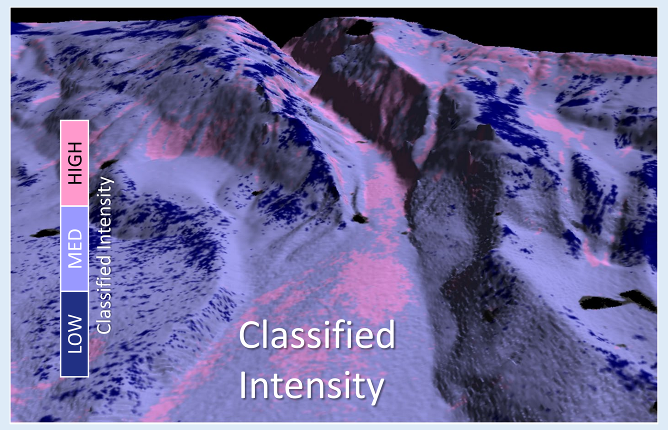


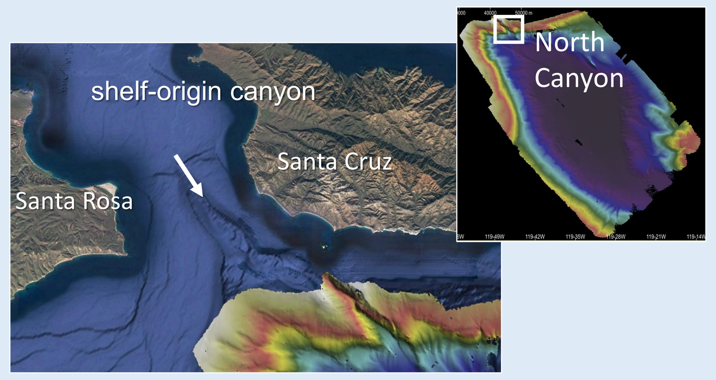
Classified Backscatter Intensity shows high intensity (pink) finger-like paths down individual canyon channels, suggesting hard substrate, possibly rock exposure or consolidated sediments along the thalwegs.

Figure 3. North Canyon Site: Shelf-Origin Canyon





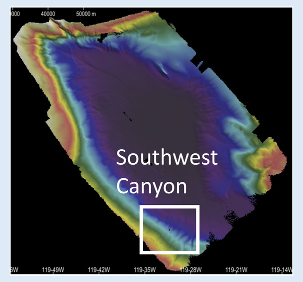


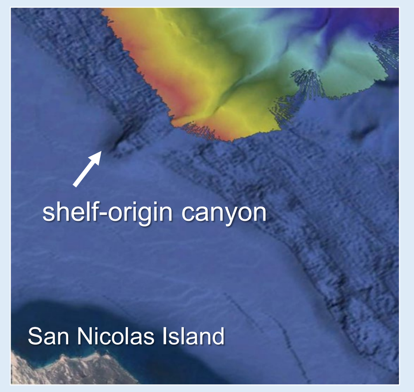


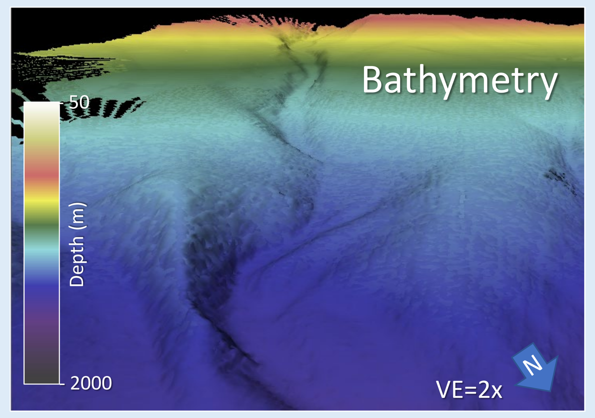
North Canyon Site is located off the south coast of Santa Cruz Island and southeast of Santa Rosa Island. This shelf-origin canyon's head is located between the two islands (see the Google Earth image, above). North Canyon extends from the shelf, between the two islands to the basin floor. This canyon meanders at the head and grows straighter towards the base. North Canyon has extremely steep canyon walls (up to 61°) on its east side, with walls of only 45° on the west side. It is the most pronounced canyon in the basin.

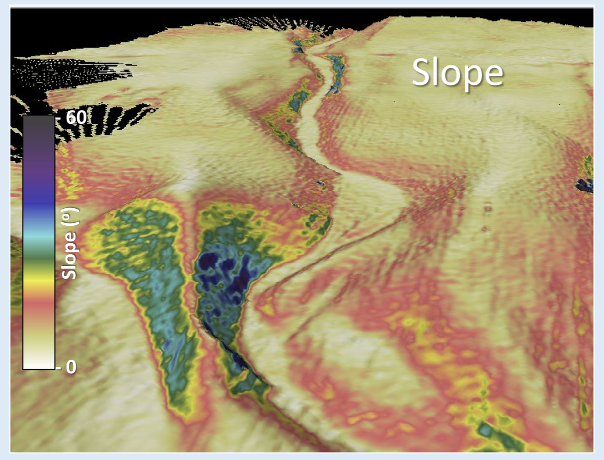
Backscatter intensity suggests hard substrate (high intensity) for much of the channel.

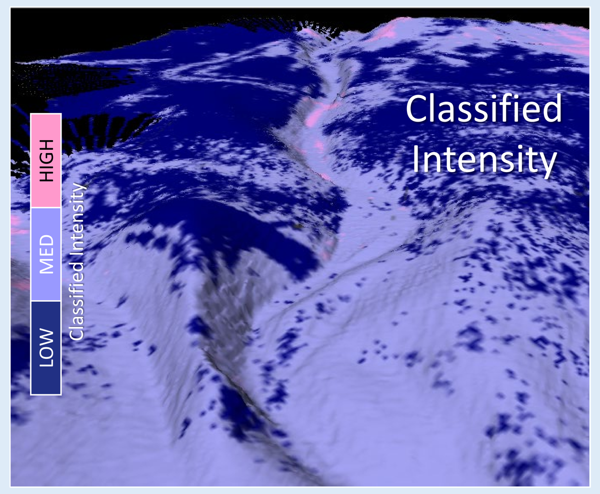
Figure 4. Southwest Canyon Site: Shelf-Origin Canyon





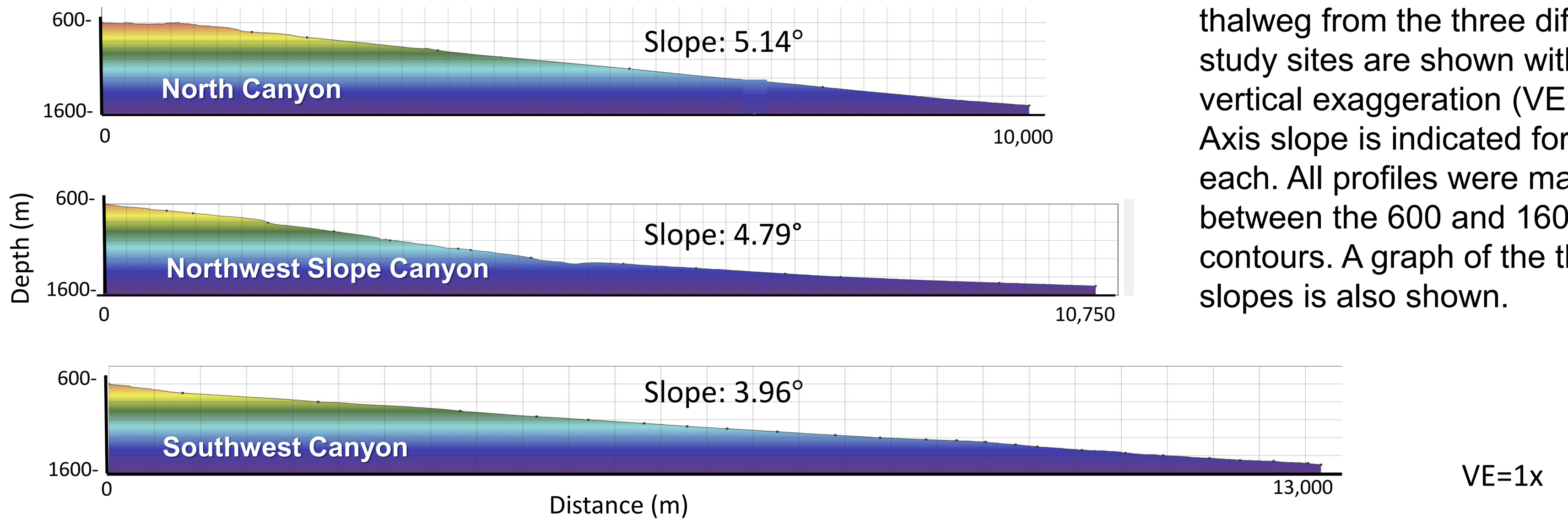






At the southwest edge of the basin, Southwest Canyon is a shelf-origin canyon with the canyon head lying off the coast of San Nicolas Island (see the Google Earth image white arrow, above). Unlike North Canyon, it is straighter at the canyon head and grows increasingly more sinuous towards the base. Southwest Canyon is not as steep as North Canyon, with the steepest section having a slope of approximately 45°. This canyon also does not have high intensity located along thalweg near the base, likely due to the higher sinuosity and lower slope when compared to the canyon head, allowing for more sediment build up along thalweg. High intensity is found only in the steeper portion of the canyon channel.

Figure 5. Canyon Thalweg Axis Profiles



Axis profiles made along the thalweg from the three different study sites are shown with no vertical exaggeration (VE=1x). Axis slope is indicated for each. All profiles were made between the 600 and 1600 m contours. A graph of the three slopes is also shown.

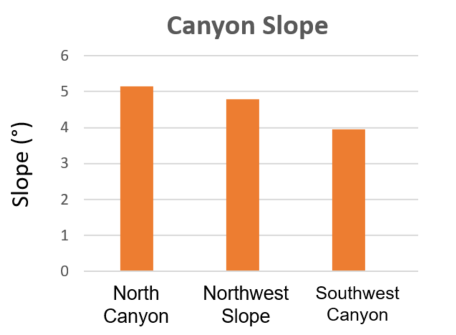
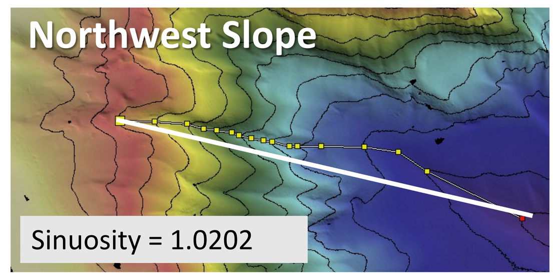


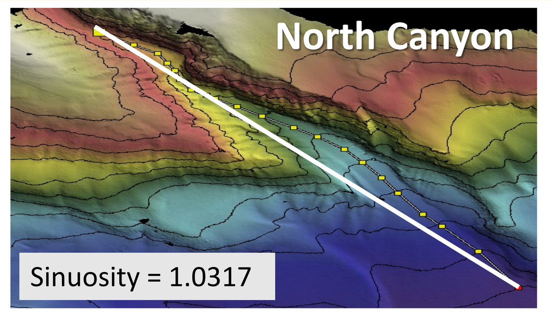
Figure 6. Canyon Sinuosity

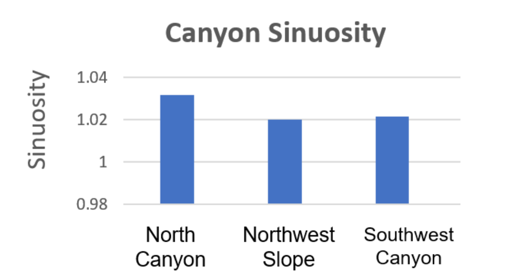
Sinuosity was measured between the 600 and 1500 m contours to assess each channel's departure from linear. These three canyons have similar sinuosity despite their different geomorphologies.

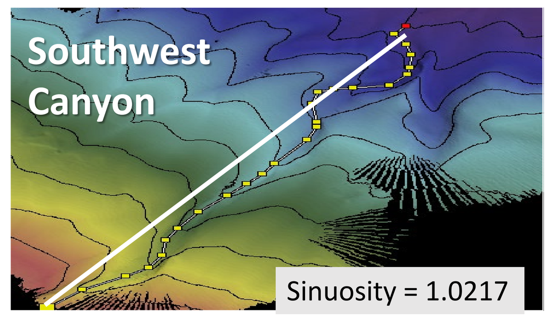
North Canyon and Northwest Slope Canyon are two branches of a single depositional path to the basin floor. North Canyon, a shelf-origin canyon, is slightly more sinuous.

The other shelf-origin canyon, Southwest Canyon differs from the others, as it has a fairly straight canyon head and a sinuous base.









DISCUSSION and CONCLUSIONS

This study examines two shelf-origin and one slope-origin canyons in the Santa Cruz Basin. Slope-origin canyons are limited to canyons that start on the incline of the basin wall. In contrast, shelf-origin canyons have their origin above the basin wall in shallower waters. The three observed canyon systems show similar sinuosities and canyon-axis slopes, though they have geomorphological differences.

Of the three canyons studied, **North Canyon**, a shelf-origin canyon (Fig. 3), has the steepest slope (5.14°), and highest sinuosity (1.0317) (Figs. 5 and 6). This canyon also has the steepest canyon walls (61°) and is more sinuous at the canyon head, becoming increasingly less sinuous descending to base. The other shelf-origin canyon, **Southwest Canyon** (Fig. 4.) has a lower slope and sinuosity (3.96° and 1.0217, respectively). Unlike North Canyon, **Southwest Canyon** is straighter at the canyon head and becomes increasingly more sinuous towards the base. This difference is likely due to the steeper basin rim directly off the shelf at the canyon's head compared to the lower gradient at the bottom (Fig. 5). The slope-origin canyon, **Northwest Canyon**, has a slope intermediate between the other canyons (4.79°) and sinuosity (1.0202) similar to Southwest Canyon. Its low sinuosity is likely due to its relatively steep slope, allowing for less variability in the depositional path into the basin.

Varying backscatter intensity indicates, that all canyons have harder substrate in their channels, where turbidity and other bottom-flowing currents would potentially prevent sedimentation and may expose underlying rock substrate. **Southwest Canyon** differs slightly as it has high intensity only in the upper, steeper portion of the channel and low intensity near the base where higher sinuosity and lower slope occurs, allowing for more sediment build up along thalweg (Fig 4.).

These study sites represent the different delivery paths sediments take to enter the Santa Cruz Basin. Several additional canyons will be measured in future work in order to make statistical comparisons.

REFERENCES

Chaytor, J. D., Conrad, J. E., Brothers, D. S., Maier, K. L., Kluesner, J. W., (2018). The Santa Cruz Basin Submarine Landslide Complex, Southern California: repeated failure of uplifted basin sediment. Pacific Coastal and Marine Science Center, US Geologic Survey, p. 1-10.

Loebecker, M. (2011) "California shakedown cruise 2011: Exploring California's National Marine Sanctuaries." California shakedown cruise, NOAA Office of Ocean Exploration and Research, p. 1-4.

Shepard, F. P., Marshall, N.F., McLoughlin, P.A., (1974). Internal waves advancing along submarine canyons, Elsevier Scientific Publishing Company, p.195-198.

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