Geomorphology and Substrate Characteristics at the Intersection of Bowers Ridge and Aleutian Island Ridge, South-Central Bering Sea

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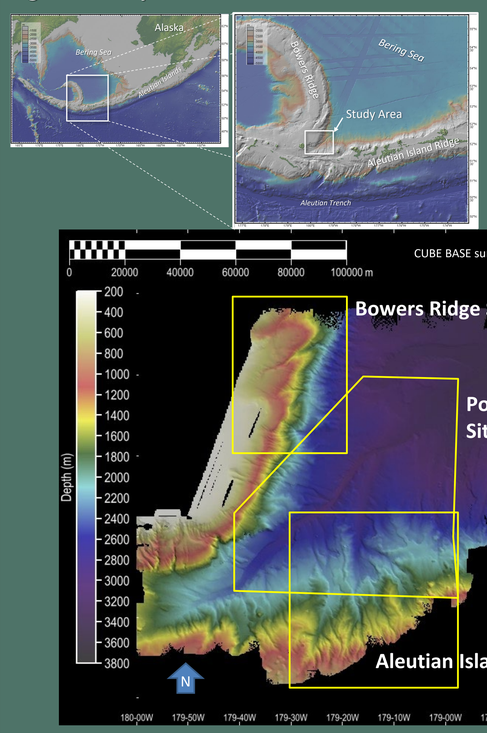
Introduction and Background

In May 2023, NOAA Ocean Exploration conducted the first leg of *Seascape Alaska: Aleutians Deepwater Mapping Expedition*. This cruise, EX2302, focused on increasing deep water mapping coverage of areas off the coast of Alaska, including portions of the southern Bering Sea. Multibeam sonar bathymetric and backscatter intensity data collected by NOAA Ship *Okeanos Explorer* were used to examine an ~7,700 km² area - where depths range 280 to 3600 m (Fig. 1). This study area is located at the intersection of the southeastern edge of Bowers Ridge with the central Aleutian Island Ridge. Bowers Ridge is a ~900 km north-south oriented tectonically inactive arced volcanic ridge that runs nearly perpendicular to the Aleutian Island Ridge in the south-central Bering Sea.

The Aleutian Island Ridge is an active volcanic arc resulting from the subduction of the Pacific Plate beneath the North American Plate, with convergence occurring at an average rate between 5.6 and 8.1 cm/yr (Carver and Plafker, 2008). Aleutian Island Ridge dates to the Early Eocene. Bowers Ridge was likely formed through subduction and island arc volcanism, though there is currently no active subduction nor volcanism. Geochemical data dates the formation of Bowers Ridge to the Oligocene – making it younger than the Aleutian Island Ridge (Wanke et al. 2012). Volcanic rocks sampled from previous expeditions and a geothermal gradient that shows residual heat support the hypothesis of a subductive origin for Bowers Ridge (Expedition 323 Scientists, 2010). The study area also includes a major submarine canyon, Pochnoi Canyon located ~12 km east of Bowers Ridge's crest and stretches ~60 km northeastward from a depth of ~2000 to ~3600 m, running between Bowers Ridge and the Aleutian Island Ridge. Sediment samples collected from depths 750 to 900 m in the canyon contain volcanic siltstone, volcanic debris, and feldspar (Wanke et al. 2012).

Bathymetry, slope, backscatter intensity surfaces, and depth profiles were generated to compare ridge and canyon geomorphology and substrate characteristics. The purpose of this study is to further expand our knowledge of a remote, unexplored region of the seafloor and its geologic features, and to identify areas for potential future exploration.

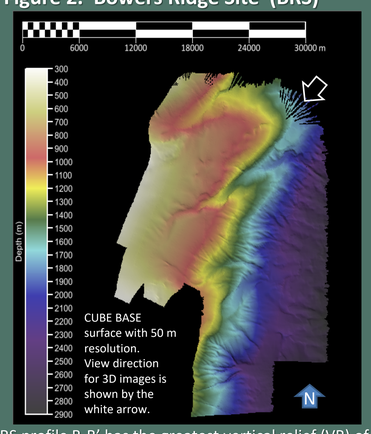
Figure 1. Study Area and Site Locations



(left) The study area is located in the South-Central Bering Sea, 1300 km off the west coast of Alaska, at the intersection of Bowers Ridge and the Aleutian Island Ridge.

(below) Overview of the study area with depth ranging from 280 to 3600 m. Three study sites are identified.

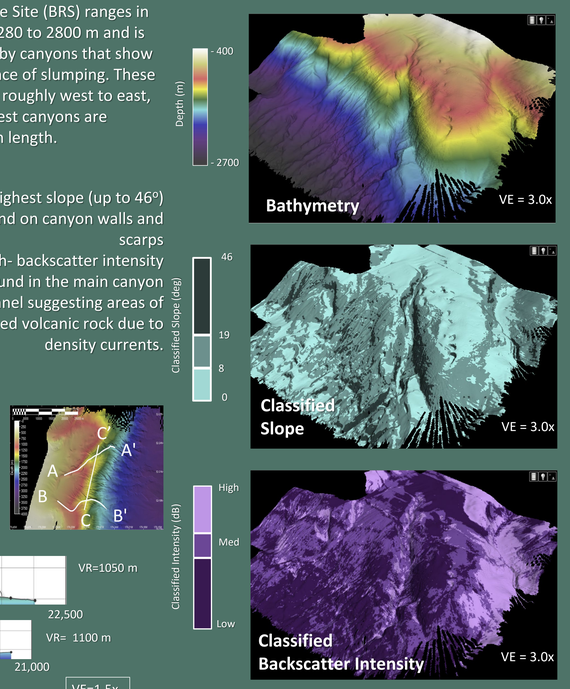
Figure 2. Bowers Ridge Site (BRS)



Bowers Ridge Site (BRS) ranges in depth from 280 to 2800 m and is cut through by canyons that show some evidence of slumping. These canyons run roughly west to east, and the largest canyons are ~18,000 m in length.

Areas of highest slope (up to 46°) are found on canyon walls and scarps

Mid- to high- backscatter intensity is found in the main canyon channel suggesting areas of exposed volcanic rock due to density currents.



BRS profile B-B′ has the greatest vertical relief (VR) of the canyon thalwegs (1100 m), and it is the steepest (4.24°). BRS C-C′ demonstrates that canyon walls of Canyon B-B′ (350 m) have a greater VR than those of Canyon A-A′ (180 m) but the slopes of the canyon walls are similar, 5.33° vs. 5.14° respectively.

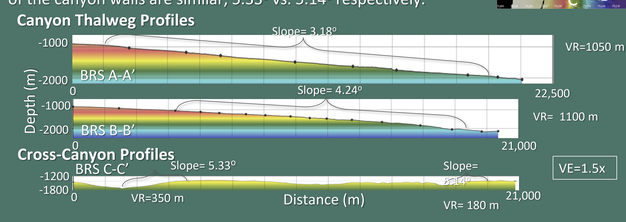
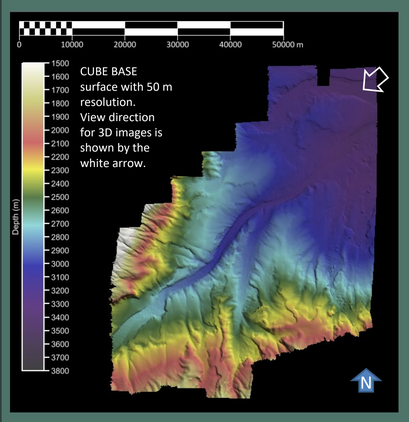


Figure 3. Pochnoi Canyon Site (PCS)

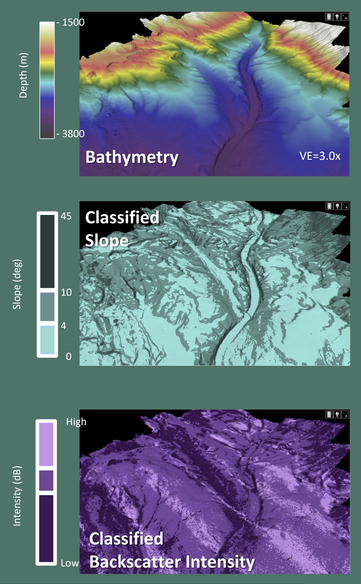


Note that the depth scale has been changed from Fig. 1 to show canyon details.

Pochnoi Canyon Site (PCS) is a submarine canyon complex measuring more than 55 km in length and 3 km at the widest point of the channel. Pochnoi Canyon runs southwest to northeast and has a major AIRS origin tributary canyon converging at ~3,250 m depth Abundant small canyons from both BRS and AIRS discharge into PCS.

Areas of highest slope (45°) occur along the canyon's walls, and lowest slope is seen in the channel.

Low- mid- backscatter intensity is seen in canyon channels, indicating a low energy environment and unconsolidated sediments. (Striped areas of high intensity are likely nadir artifacts.)



PCS B-B′ had the greater vertical relief (VR) (1025 m) of the canyon thalwegs, though PCS A-A′ and B-B′ are of similar slope, 1.27° vs. 1.64°, respectively. PCS C-C′ had the greater vertical relief (500 m) and slope (4.76°) of the cross-canyon profiles. The steeper canyon thalweg does not correspond with the steeper canyon walls.

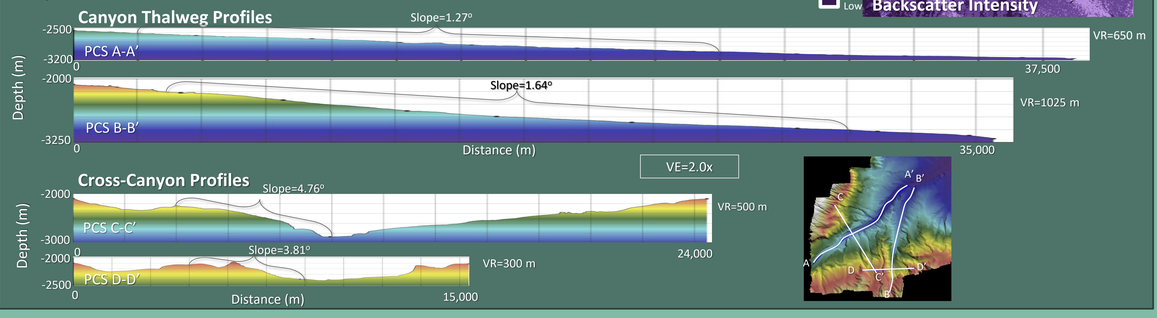
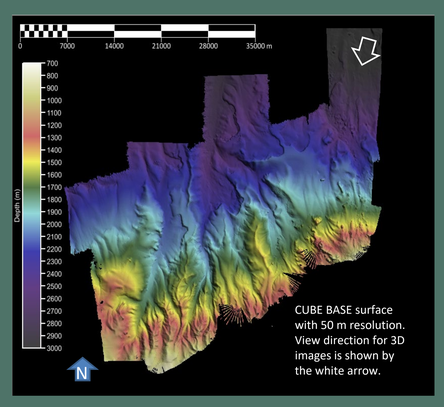


Figure 4. Aleutian Island Ridge Site (AIRS)

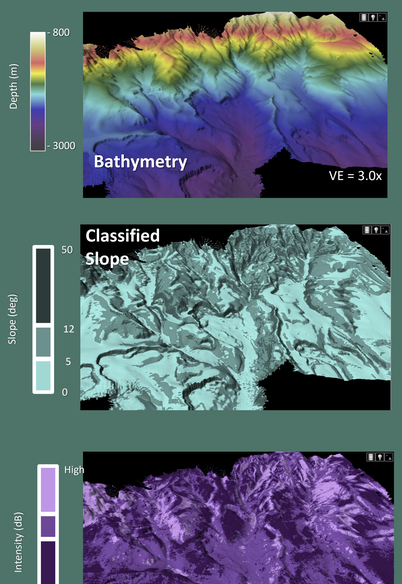


Note that the depth scale has been changed from Fig. 1 to show canyon details.

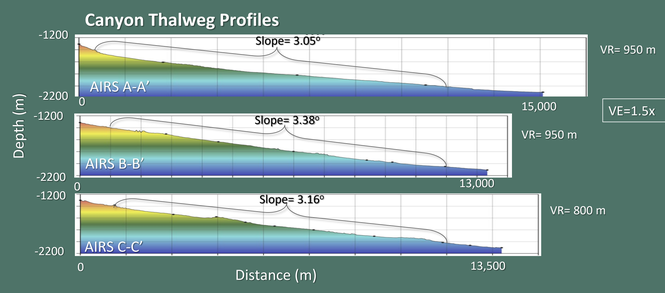
The Aleutian Island Ridge Site (AIRS) has a depth range of 750 to 3000 m. It is cut through by abundant canyons and shows widespread evidence of scarps and slumping. These features may be due to earthquakes and subduction as AIRS is tectonically active.

Areas of highest slope (up to 50°) and high backscatter intensity are seen on canyon walls and scarp areas.

Low slope (<5°) and mid-range backscatter intensity are visible in canyon channels, suggesting weak-moderate water flow and unconsolidated sediments.



All of the canyons examined display similar slope of approximately 3°, and similar vertical relief, from 800 to 950 m.



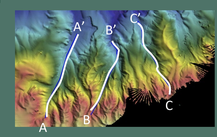
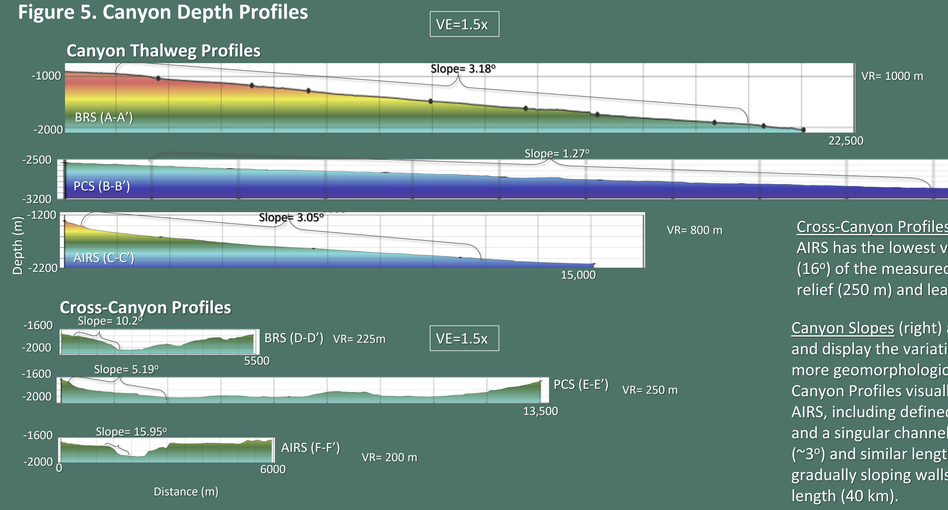
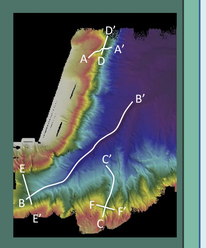


Figure 5. Canyon Depth Profiles

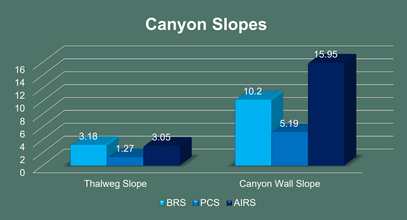


Thalweg Profiles: BRS displayed the greatest vertical relief (1000 m) and slope (3.18°) of the 3 canyons. PCS has the lowest vertical relief (600 m) and slope (1.27°).



Cross-Canyon Profiles were taken at a thalweg depth of 1500 m. AIRS has the lowest vertical relief (200 m) but greatest slope (16°) of the measured canyon walls. PCS has the greatest vertical relief (250 m) and least slope (5°) of the measured canyon walls.

Canyon Slopes (right) are compared for thalwegs and canyon walls and display the variation among the three sites. BRS and AIRS are more geomorphologically similar to each other than to PCS. Cross Canyon Profiles visually portray similar canyon structures in BRS and AIRS, including defined canyon walls with slopes greater than 10° and a singular channel. BRS and AIRS share similar thalweg slopes (~3°) and similar lengths (~20 km). PCS displays multiple channels, gradually sloping walls (~5°), a low thalweg slope (~1°), and great length (40 km).



Methods

- Bathymetric surveys were conducted by NOAA OER on the NOAA Ship *Okeanos Explorer* using a Kongsberg EM304 multibeam echosounder
- Teledyne CARIS HIPS& SIPS 11.4 was used for post processing of raw multibeam data to generate CUBE BASE surfaces at 50 m resolution
- 3D surfaces, backscatter mosaic, and profiles were generated.
- Slope and backscatter mosaics were classified.
- Profiles were made of each site, then scaled.
- GeoMapApp used for geographic overview figures.

Discussion and Conclusion

Both the Aleutian Island Ridge and Bowers Ridge formed as a result of subduction. However, Aleutian Island Ridge Site displays extensive areas of scarps and slumping in contrast to Bowers Ridge Site which has a notably lower quantity of erosional features. This abundance of erosional features on Aleutian Island Ridge Site compared with relatively embryonic features observed at the Bowers Ridge Site supports Bowers Ridge being younger than the Aleutian Island Ridge and tectonically inactive.

Figures 2-4 display canyons at various depths. Submarine canyons of Bowers Ridge and Aleutian Island Ridge have depths extending to 2800 and 3000 m, respectively, similar thalweg slopes (~3°), and mid- to high canyon channel backscatter intensities. In comparison, the largest canyon, Pochnoi, extends over 55 km to a depth of ~3,250 m, with a slope of 1.27° and low- to mid-backscatter intensity in the canyon channel. These data indicate that deeper canyons in this region have lower backscatter intensity in their channel. Low backscatter intensity in Pochnoi Canyon may be indicative of turbidite deposition as density currents lose strength with depth. Pochnoi Canyon's meandering geomorphology indicates low current strength as well. Density currents originating from Bowers Ridge and Aleutian Island Ridge channelize into Pochnoi Canyon to form the canyon.

Based on geomorphological analysis of this research, existing data supporting Bowers Ridge's younger origin compared to the Aleutian Island Ridge is supported. Additionally, the origin of Pochnoi Canyon has been identified as the result of channelized density currents coming from the flanking ridges. Furthermore, exploration should be considered to map additional areas on the north-eastern flank of Bowers Ridge to conduct a geomorphological comparison and analysis of the region.

ACKNOWLEDGEMENTS

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