Geomorphological Analysis of the Bogoslof Seamount & Surrounding Region

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Background

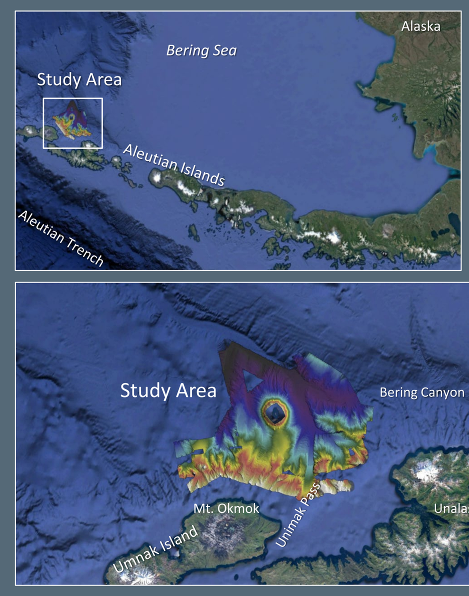
Seafloor topography and deep-water environments off the Aleutian Islands and within the Aleutian Trench are poorly understood. Throughout May to July 2023, NOAA Ocean Exploration conducted the 2023 Seascape Alaska Expedition aboard the NOAA Ship *Okeanos Explorer* to obtain geomorphological information of the southern Bering Sea and Aleutian Trench seafloor. Multibeam sonar bathymetry and backscatter data were collected off the north coast of Mount Okmok located on Umnak Island, and include the Bering Canyon and Bogoslof Seamount. From 1927 to 1953 Bogoslof steadily reduced in size by marine erosion (*Byers*, 1961). Bering Canyon lies at the edge of Alaska's continental shelf, where sediments are transported from the Aleutian North Slope Current to the deep Bering Sea. Mount Okmok is part of the Aleutian Ridge and is constructed of sedimentary and igneous rock (*Scholl et al., 1970).* Mount Okmok, a historic caldera lying on the northeastern part of Umnak Island, contains Tertiary and Quaternary rock layers.

Backscatter intensity mosaics were used to characterize variations in seafloor substrate character. Information documented from this study will provide insight to understand the topography off Mount Okmok. These analyses will be useful in support of future research and exploration to improve knowledge of commercially significant biological communities and resources.

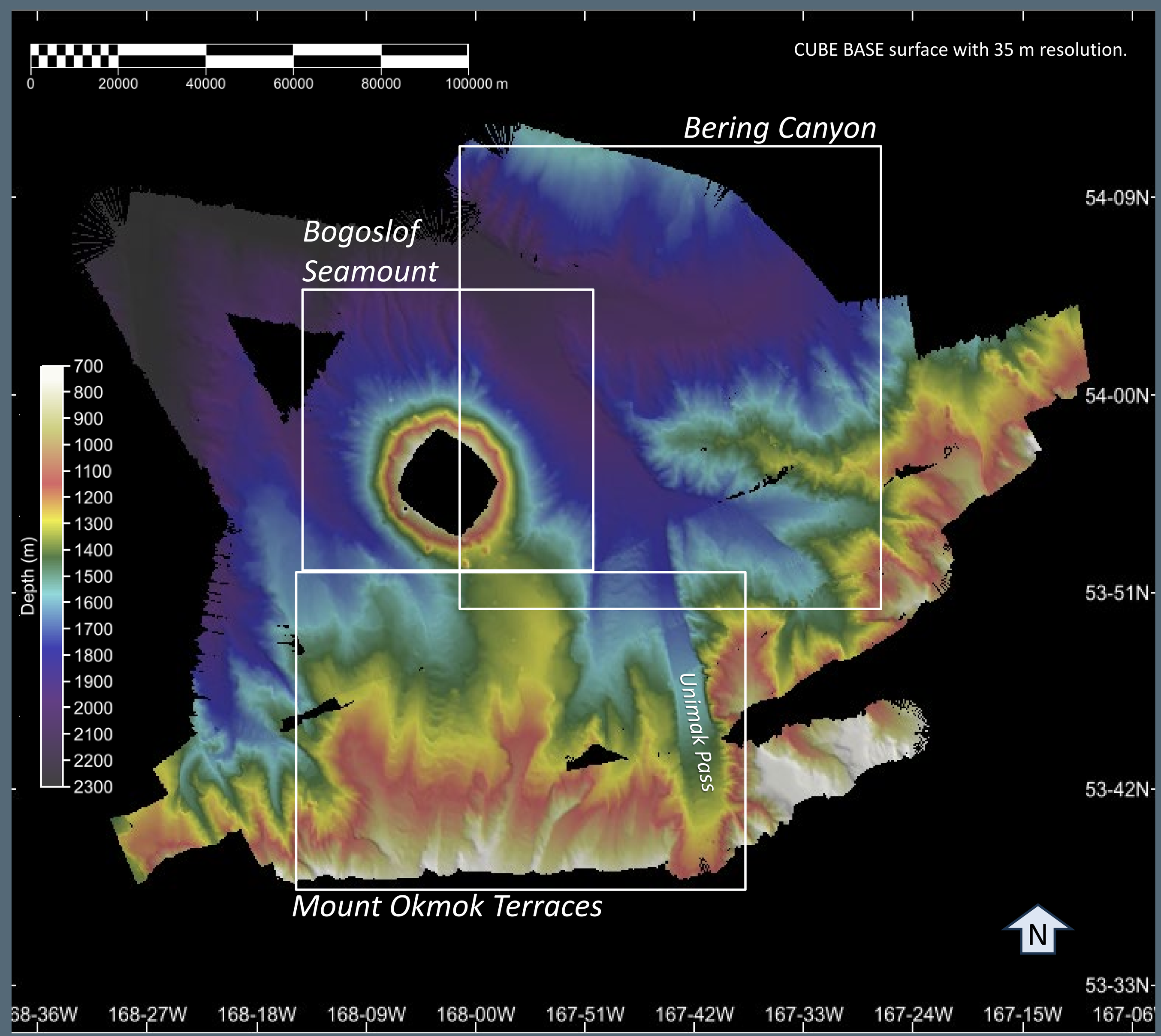
(Right) NOAA Ship *Okeanos Explorer* led the expeditions in 2023.

(Left) Google Earth image showing the volcanic island top of Bogoslof Seamount.

Figure 1. Study Area

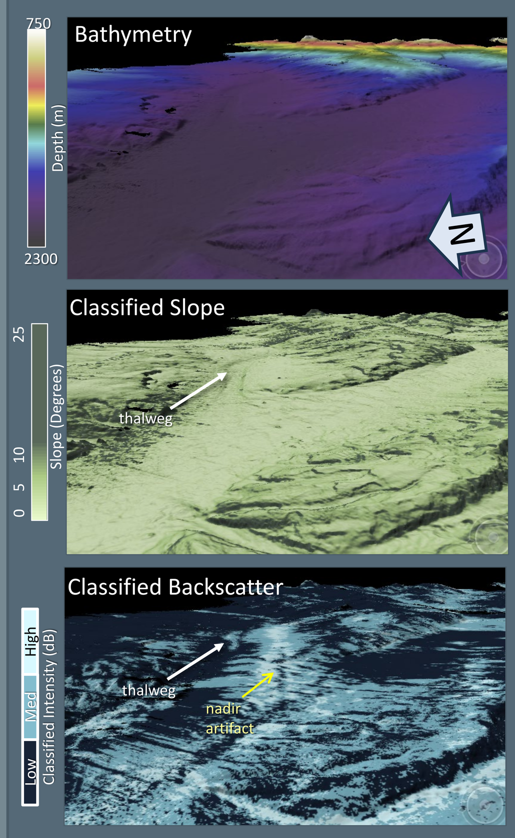


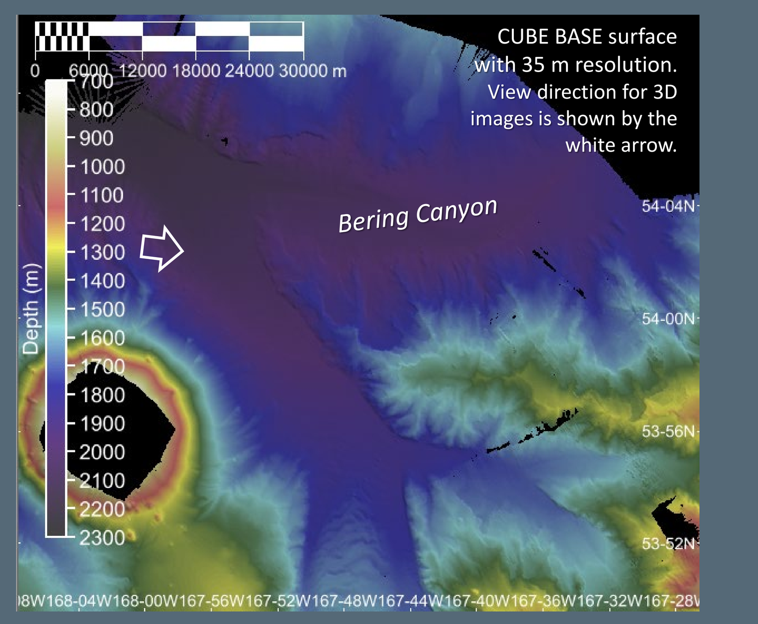
The study area is located approximately 42 km north of Mount Okmok, 32 km south of Alaska's continental margin.

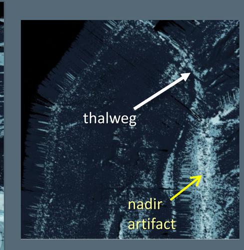


(Right) The study area includes three sites studied: Bogoslof Seamount, Bering Canyon, and Terraces of Mount Okmok's north flanks. Bogoslof Seamount is situated 42 km north of Mount Okmok. Bathymetric features are included, with a depth range of ~700- 2400 m.

Figure 2. Bering Canyon







The deepest site of the study region, the flat canyon (1-2°) is located northeast of Bogoslof Seamount and lies at a depth of 1400-2222 m. Classified backscatter indicates regions of the canyon with relatively high to low intensity. The canyon is characterized by its flat seabed and scarp–like features (18°). However, the intensity values from the canyon thalweg are somewhat obscured by the nadir artifact.

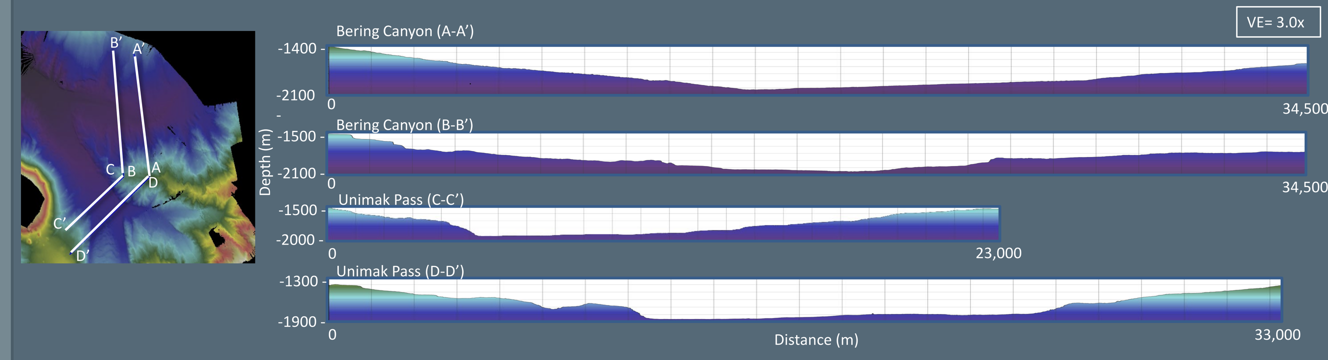
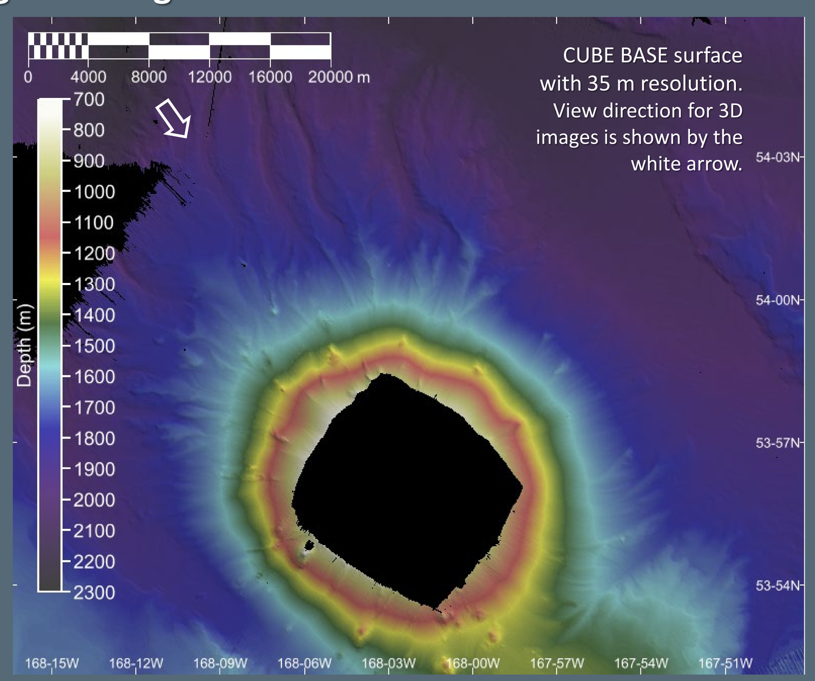
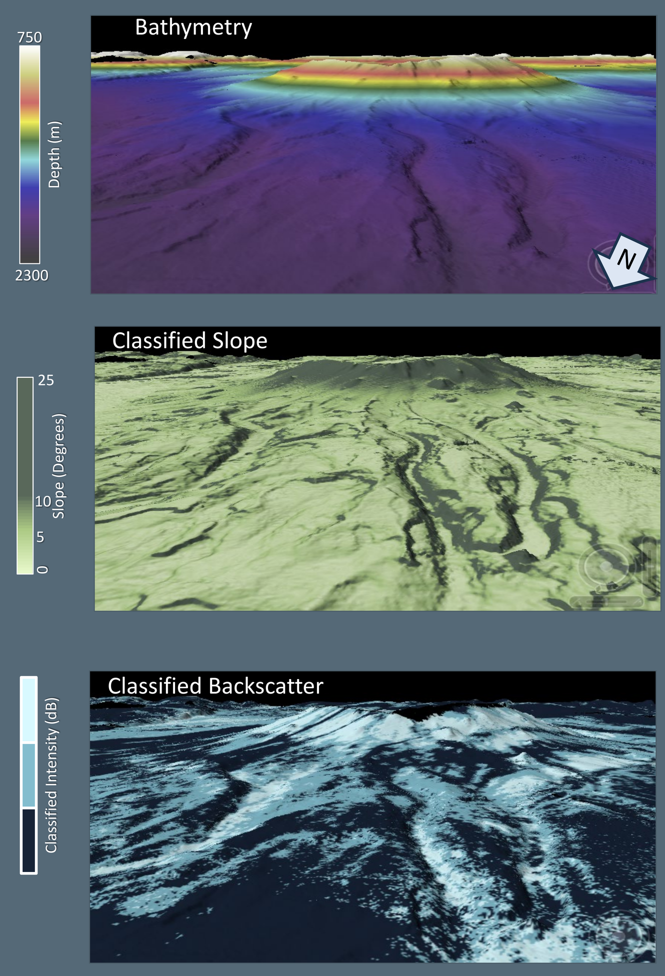
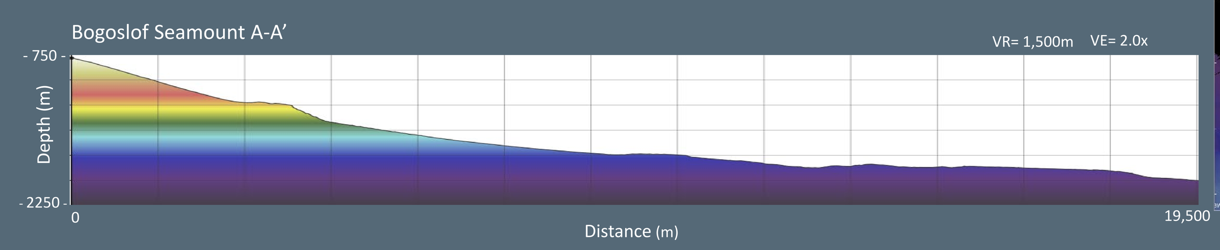


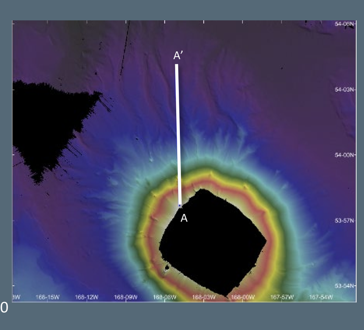
Figure 3. Bogoslof Seamount





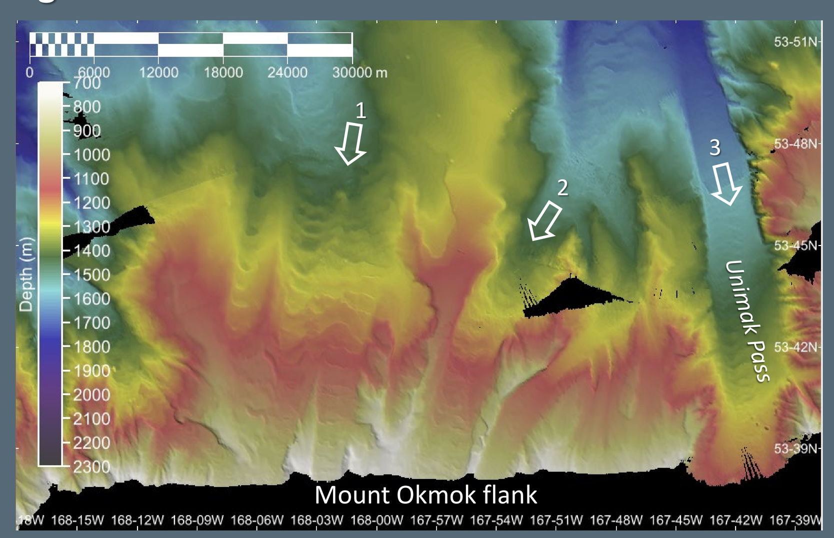
Bogoslof Seamount is 29 km wide and has a depth range of 0 - 1800 m, with flanks of varying morphology. The maximal height of this stravavolcano extends 300 m above sea level to Bogoslof Island, which explains the absence of data at the seamount's center. The northern flank has multiple canyon channels extending to the seamount's base. The classified slope of the seamount's northern face has a slope range of 2-20°. The southern end of the seamount is moderately more steep, with slopes ranging 3-25°. Classified backscatter indicates the possibility of active volcanic slumps flowing from the peak of this seamount. This interpretation is observed on the little mounds surrounding the volcano, which are indicative of magma plumes. Profile A-A', is shown below, with a vertical relief of 1,500 m.



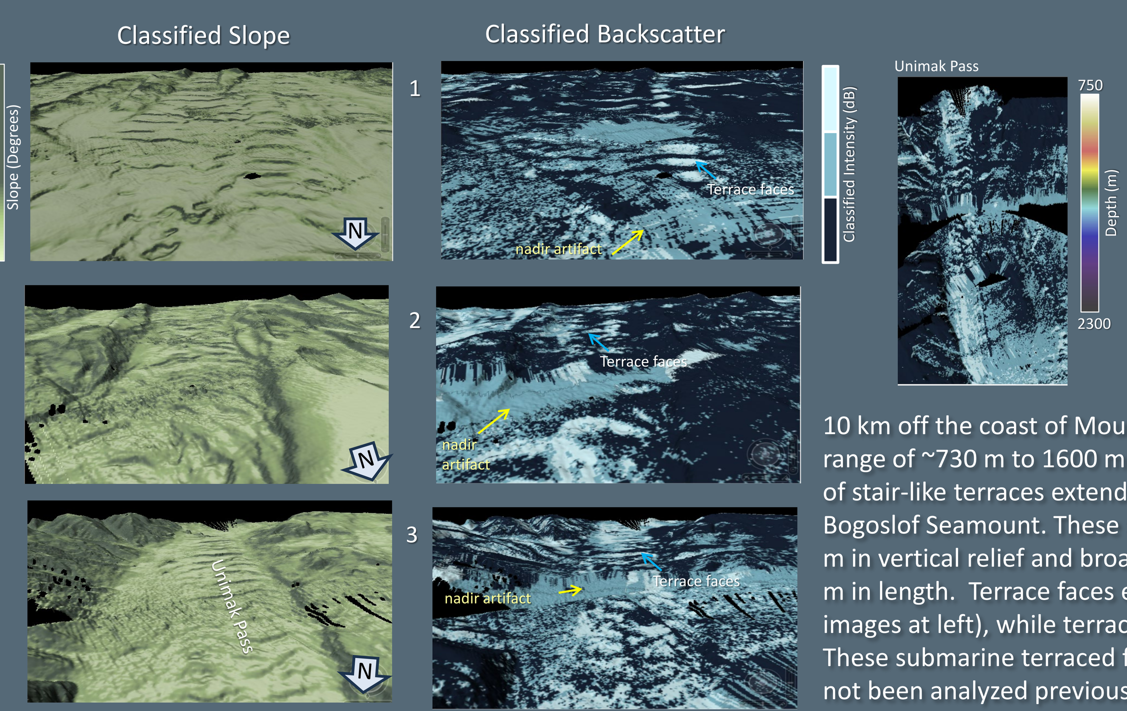


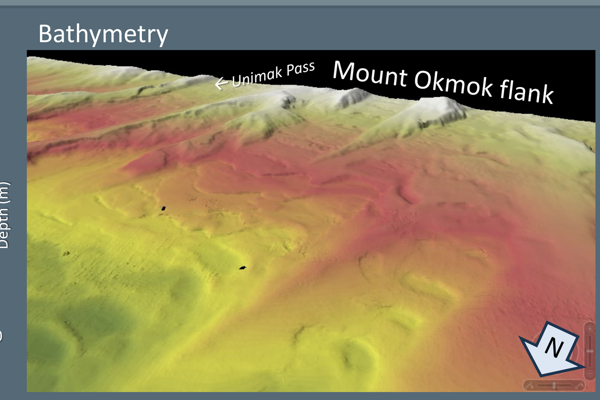
Profile A-A' (above) was taken along the northern seamount flank where slopes are ~10°, whereas the steepest slope of the seamount averaged ~23-35°. The bump may indicate the presence of a magma plume.

Figure 4. Mount Okmok Terraces

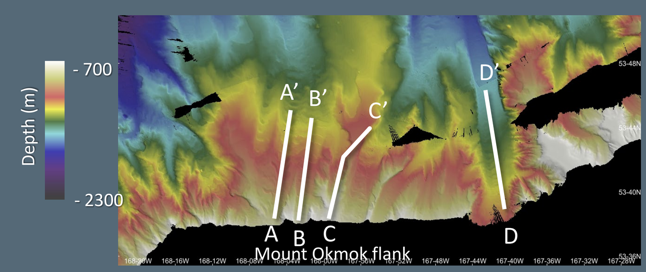


CUBE BASE surface with 35 m resolution.
View direction for 3D images is shown by the white arrows.

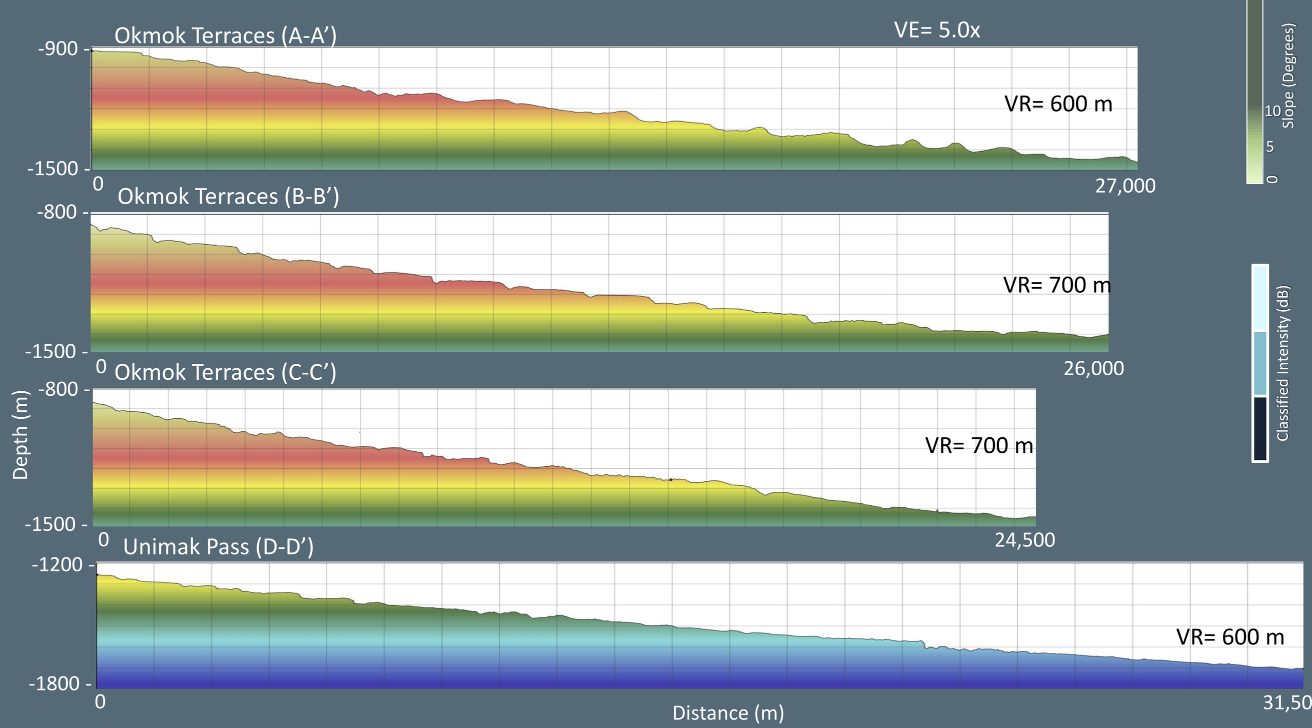


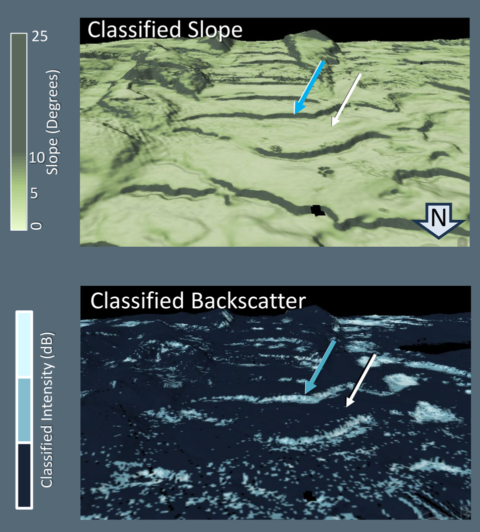


10 km off the coast of Mount Okmok, the Okmok Terraces have a depth range of ~730 m to 1600 m. Numerous channels with a considerable variety of stair-like terraces extend 40 km from Mount Okmok to the base of Bogoslof Seamount. These steep-sloped terrace faces (6-15°) range 10 to 20 m in vertical relief and broad, low-sloped (<3°) terrace tops are up to ~1000 m in length. Terrace faces exhibit high intensity backscatter (blue arrows, images at left), while terrace tops show areas of low intensity backscatter. These submarine terraced features of the island's northeastern flank have not been analyzed previously.



Okmok Terrace profiles A-A', B-B', and C-C' begin at an 800 m depth, while D-D' begins at a depth of 1200 m. All profiles display a significant amount of uniform terracing along the volcano's flank. Terrace tops display an average slope of ~4°, while the terrace faces exhibit slopes of 10-20°. Backscatter intensity readings show high intensity backscatter on terrace faces, and low intensity on their flat tops. The Unimak Pass profile (D-D') also shows the stair-step terracing.





(above) Blue arrows indicate areas of high slope and high intensity of terrace faces, whereas white arrows indicate areas of low slope and low intensity of terrace steps.

Methods

- Multibeam sonar data were collected from and surveyed from May-July 2023 aboard NOAA Ship *Okeanos Explorer* using a Kongsberg EM302 multibeam echosounder during expeditions EX2302, EX2303, and EX2304 from the 2023 *Seascape Alaska* Expeditions
- CARIS HIPS & SIPS 11.4 was used to generate CUBE bathymetric and slope surfaces from the raw multibeam sonar data, using a 35 m resolution.
- Depth profiles and slope surfaces were rendered to further analyze geomorphologies and collect quantitative measurements for depth and slope comparisons.
- Classified backscatter intensity mosaics were created to compare benthic substrates of the entire study region.

Figure 5. Linear Regression Analysis Slope vs Backscatter (Fig. 4 Profile B-B')

Statistical analysis of the Okmok Terraces from Profile B-B' was performed to determine if a correlation exists between slope and backscatter at the Okmok Terraces. Red data represents the Terrace flat, whereas the blue represents the terrace face. There is a weak positive correlation of the terrace face (R^2=0.2582). However, there is no correlation for the terrace flats (R^2=0.0021). These results suggest that within the terrace features, higher intensities weakly correlate to higher slopes.

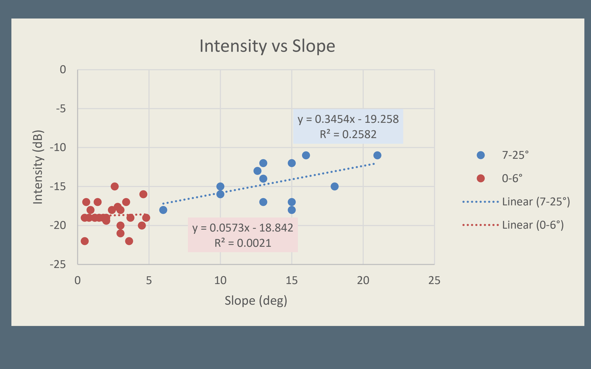
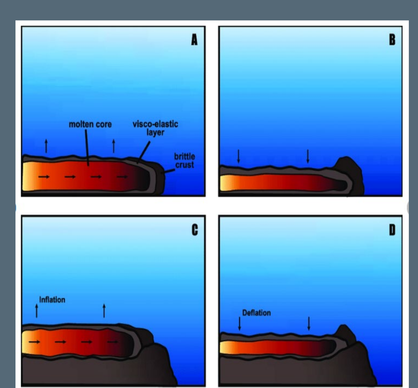
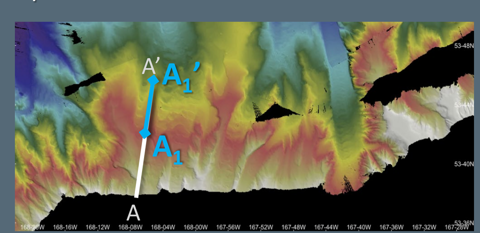


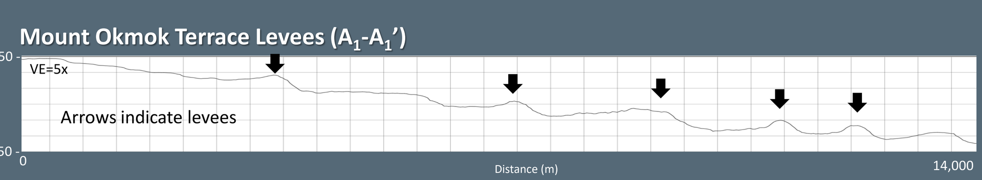
Figure 6. Levee Terrace Formation

(below, left) The figure below (from *Geist et al.,* 2008) summarizes the formation of a levee formed by a truncated lava flow. The basaltic lava flowing from volcanic activity is slowed by cold seawater and, due to hydrostatic pressure deflates simultaneously. Over long periods of time, lava flows will continuously layer on top of each other, with the levees acting as a border or barrier to contain the lava flow. These levees result in stair-step terrace formations observed on Okmok's north flank.





Segment A_1-A_1' (in blue) of profile A-A' was rendered with a VE=5x to emphasize levee formation within the terraces.



Discussion & Conclusion

Distinctive geomorphologies observed at each site within this study region are presented for comparison, highlighting the unique characteristics of each region. The flanks of the northern region of **Bogoslof Seamount** (Fig. 2) indicate past eruptions of lava that flowed down the seamount's flanks. Classified backscatter (Fig.2) shows consolidated sediments present in the northern flanks, which may be suggestive of turbidity currents. The characteristic of **Bering Canyon** (Fig. 3) that sediment accumulation has occurred, supports the work of Scholl et al. (1970) who suggest accumulation throughout the Tertiary and Quaternary periods. The sediment accumulation supports the backscatter data for the Canyon with high intensity on the thalweg, however most of the central region of the canyon is obscured by nadir artifact. Unique terracing along flank canyons emanates from **Umnak Island's Mount Okmok.** This terrace morphology found on Mount Okmok's north flank has high definition features, especially compared Umnak Pass. The terracing on Umnak Pass is less consistent, likely due to the Alaska Coastal Current (ACC) acting as a high-velocity highway system for sediment transportation. Although the ACC is a coastal current, Umnak Pass is relatively shallow, allowing the ACC to affect the seafloor.

The primary and most cogent argument regarding the terracing off northern Okmok is based on how basaltic lava flow was formed. A study conducted by (*Geist et al.,* 2008) suggests that this process is due to levee formation based on truncated lava flow (Fig. 6). Levee formation continues over long periods of time, creating stair-like terraces visible off the north coast of Umnak Island. Low backscatter intensities found on flat terraces (Fig. 4) may indicate pelagic sediment accumulation, possibly of ash, biogenic material, or eolian transported dust. Low intensities could also be due to deposition of ash from pyroclastic density currents resulting from past eruptions off Mount Okmok. Ocean currents flowing through Unimak Pass may be partially obstructed by Bogoslof Seamount and Umnak Island which act as boundaries against incoming currents. Unimak Pass acts as a transportation system between the Bering Sea and Pacific Ocean, with currents up to 200 cm/s (*Stabeno et al., 1999).*

Future research is recommended to fully understand these stair-step terraces which could provide useful information of the historical record of Mount Okmok eruptions, as well as comprehending ground truth in this region. Along with these interpretations made from seafloor mapping, deep-sea environments around this area could also be recognized. The deep-sea and coastal ecological communities could be further analyzed from ROV dives in this study region.

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