Analysis of the Unalaska Slope, Aleutian Trench

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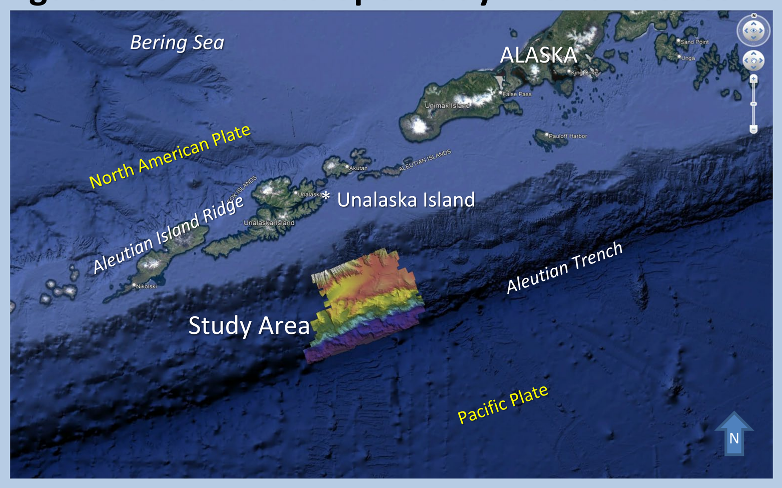
Introduction/Background

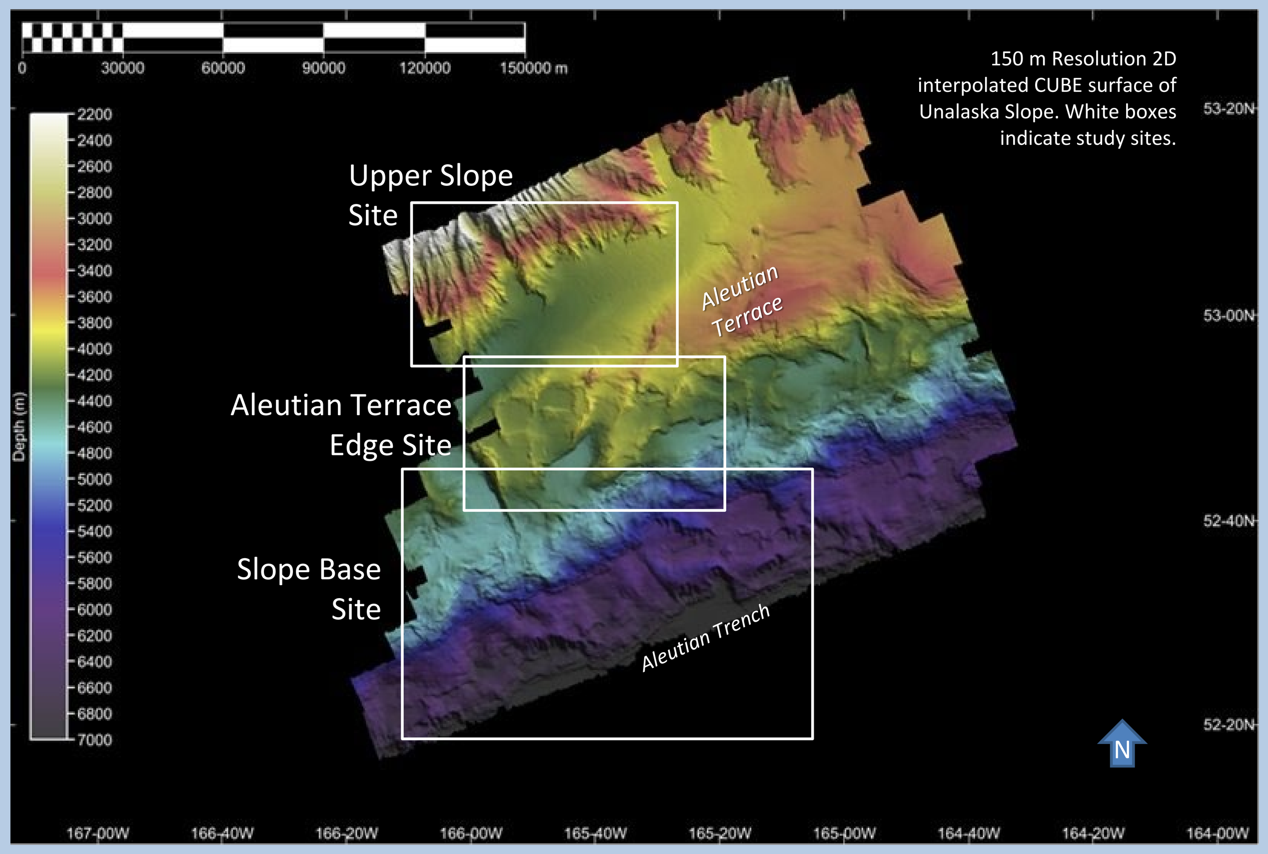
From May to September 2023, NOAA Ocean Exploration embarked on the *2023 Seascape Alaska: Gulf of Alaska Deepwater Mapping Expedition* aboard the NOAA Ship *Okeanos Explorer* to map the north slope seabed of the Aleutian Trench. The Unalaska Slope study area, mapped during the 2023 Seascape Alaska voyages 1, 2, and 3, is a segment of the Aleutian Trench located parallel to the Aleutian Island Ridge and 37.5 km south of Unalaska Island. This area features a depth range of ~2000-7000 m. Scientists aimed to piece together the geologic history of the Aleutian Trench, an area that is widely unknown to this day (NOAA OE, 2023). This trench, which lies at the base of the Unalaska Slope is located on an active margin called the Alaska-Aleutian subduction zone, the result of the Pacific Plate's subduction beneath the North American Plate. Seismic energy accumulating at the Alaska-Aleutian plate boundary has made the entire Aleutian Island chain a tectonically active zone for earthquakes and volcanoes, which cause many submarine landslides within the trench region. Unalaska Slope is one of many sites along the Aleutian Trench that features heavy sediment deposition through submarine landslides and passive sedimentation. The resulting seafloor showcases a variety of sediment characteristics.

The purpose of this research is to explore the geomorphology and seabed characteristics of Unalaska Slope and to identify future areas of exploration.

Figure 1. Unalaska Slope Study Area and Sites

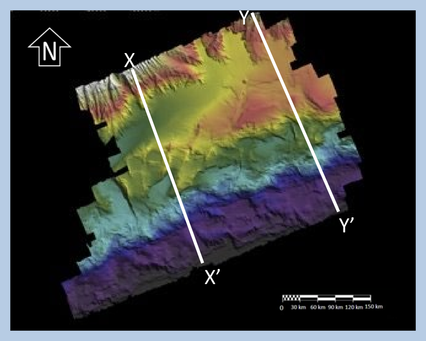


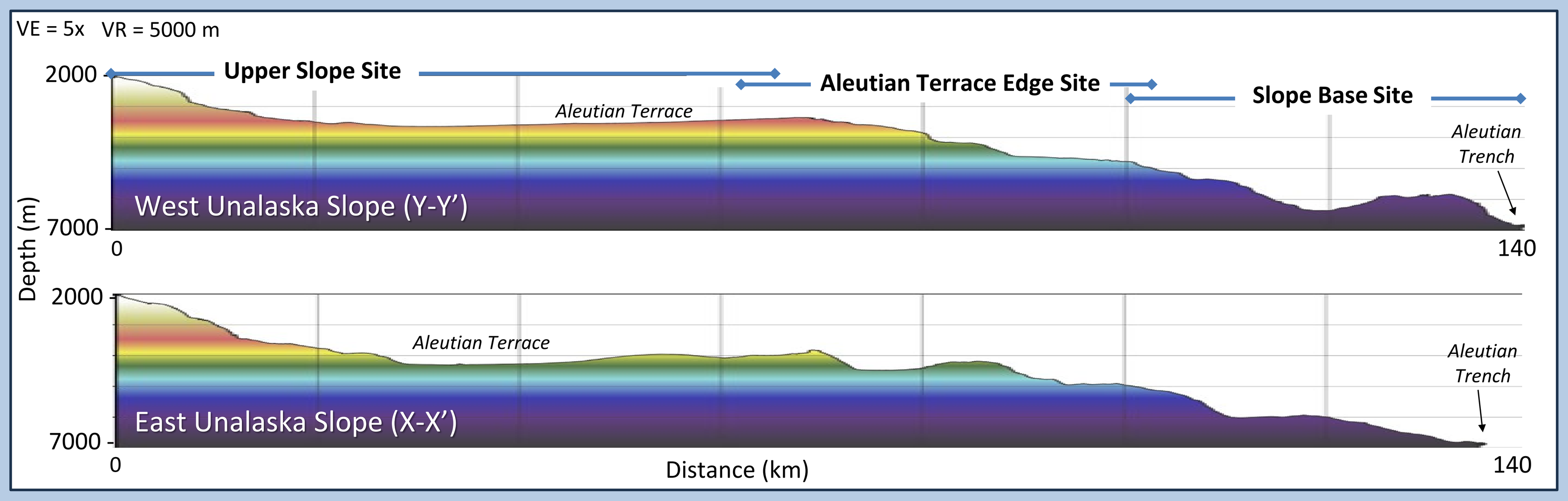
(above) Unalaska Slope is located parallel to the Aleutian Island Ridge in Alaska and directly south of Unalaska Island.



(right) The Unalaska Slope Study Area ranges in depth from approximately 2000 to 7000 m. The Upper Slope Site is the northernmost study area and has depth ranges from 2200 to 4000 m. The Terrace Edge Site (depths 3600-4600) lies on the south edge of the broad Aleutian Terrace. The Terrace Region focuses on the change in gradient from the Aleutian Terrace to the Slope Base at Trench. The Slope Base Site which lies just above and adjacent to the Aleutian Trench, has a depth range of 5400 - 7000 m.

(right and below) Depth profiles drawn across the entire slope show the bathymetry for the three study sites. The Aleutian Terrace and Aleutian Trench are indicated.



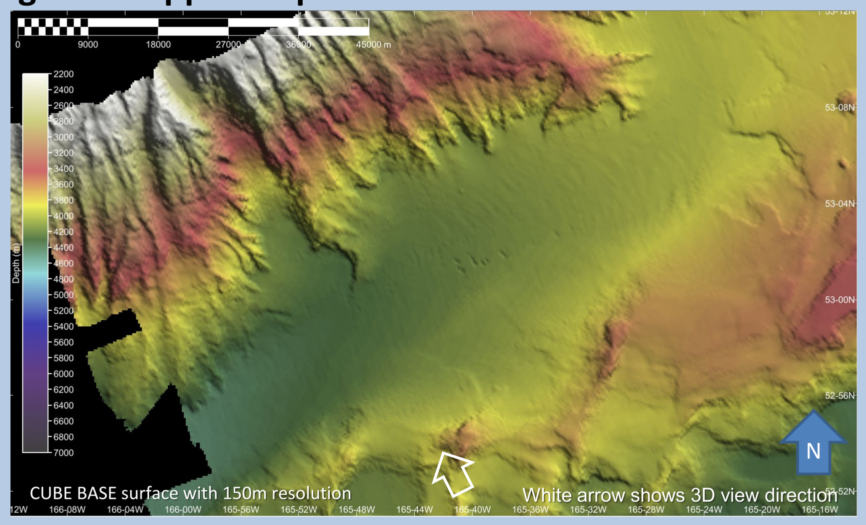


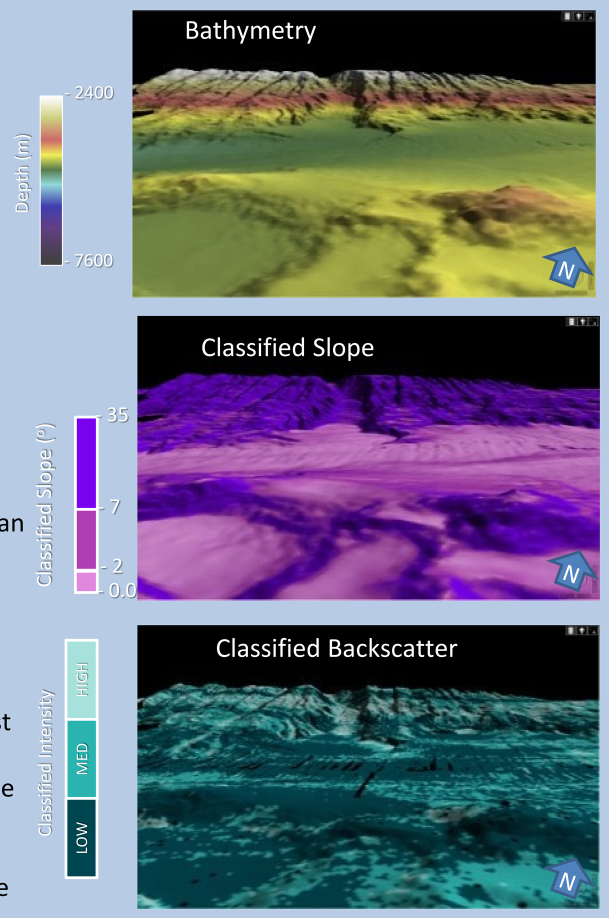
METHODS

- The NOAA Ship *Okeanos Explorer* using Kongsberg EM304 collected multibeam sonar data along the Aleutian Island Chain from May to September 2023 during expedition EX2304, "Seascape Alaska 3".

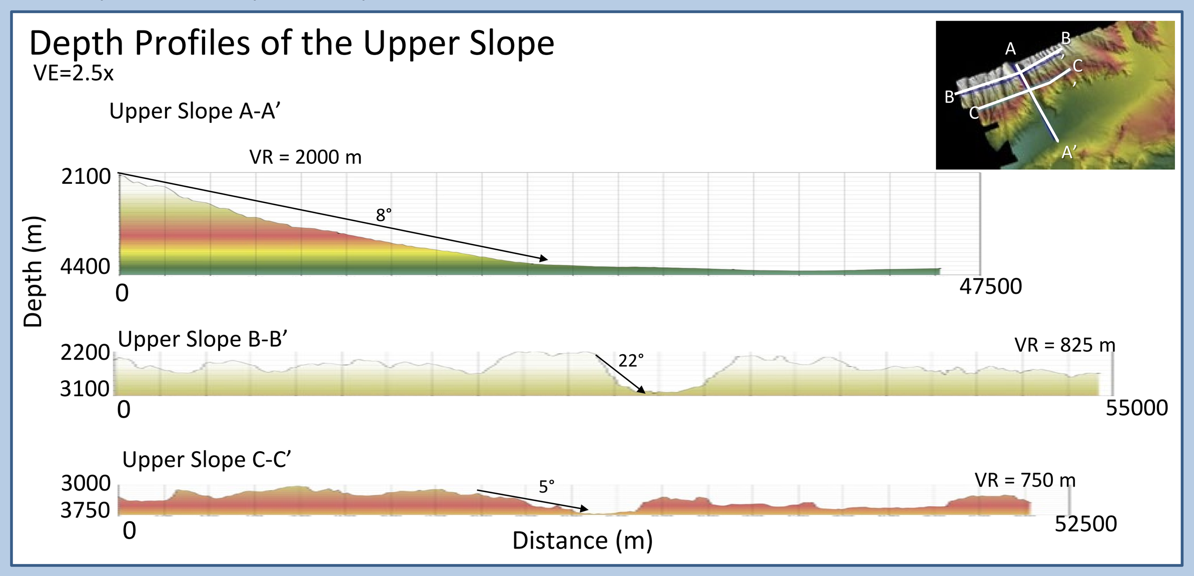
- A nearby ROV *Deep Discoverer* dive, EX2304-Dive 05 was used to provide ground-truth for the Unalaska Upper slope.
- High-resolution bathymetric CUBE surfaces were made using CARIS HIPS & SIPS 11.4.
- Three study sites were designated: Upper Slope, Aleutian Terrace Edge, and Slope Base.
- For each site, depth, slope, and backscatter intensity were analyzed in 3D with a vertical exaggeration of 3x.
- Depth profiles were created at all sites to compare depth range and slope angle with a vertical exaggeration of 3-5x.

Figure 2. Upper Slope





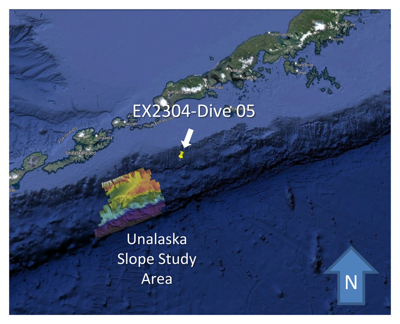
Unalaska's Upper Slope Site is a series of steep slopes that lie at the edge of the Aleutian Island Ridge. This area features submarine canyons with an observed depth range of approximately 1950 to 4300 m. The slope of this area has high variation, with a maximum slope of 40° and a minimum slope of <1°. However, most of the study area has slope ranging between 15° and 20°. The site mostly consists of low and medium intensity backscatter, with high intensities focused on a stretch of the site at a depth range of about 2500 to 3500 m. Despite the presence of rough terrain throughout most of the Upper Slope, high intensity within this study area likely indicates areas of consolidated sediments. High intensity backscatter is also present within the submarine canyons, which run down the Upper Slope. Massive erosional events, such as earthquakes and volcanism along the Alaska-Aleutian subduction zone, exposes the underlying bedrock and is likely the cause for high intensity backscatter throughout the canyon. As a result, areas at the bottom of the canyon that lead into the Aleutian Terrace feature low intensity backscatter because this is where eroded sediments from the canyon have likely been deposited.



The Upper Slope was first profiled along the length of the largest canyon (A-A') and then across the numerous canyons at the steeper part of the slope (B-B') and the flatter part of the slope (C-C'). Profile A-A' features a vertical relief of 2000 m with a slope of 8°. Profile B-B' features a VR of 825 m with a slope of 22°. Finally, profile C-C' features a VR of 750m with a slope of 5°. The measurements for B-B' and C-C' represent the western sides of the canyon wall down to the thalweg.

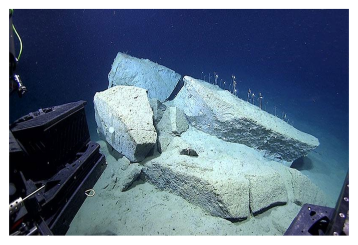
ROV DIVE EX2304-Dive05 - Lone Knoll Scarp

Lat: 53.291528°, Long: -164.170062°
Depth range: 2,806-2,100 m



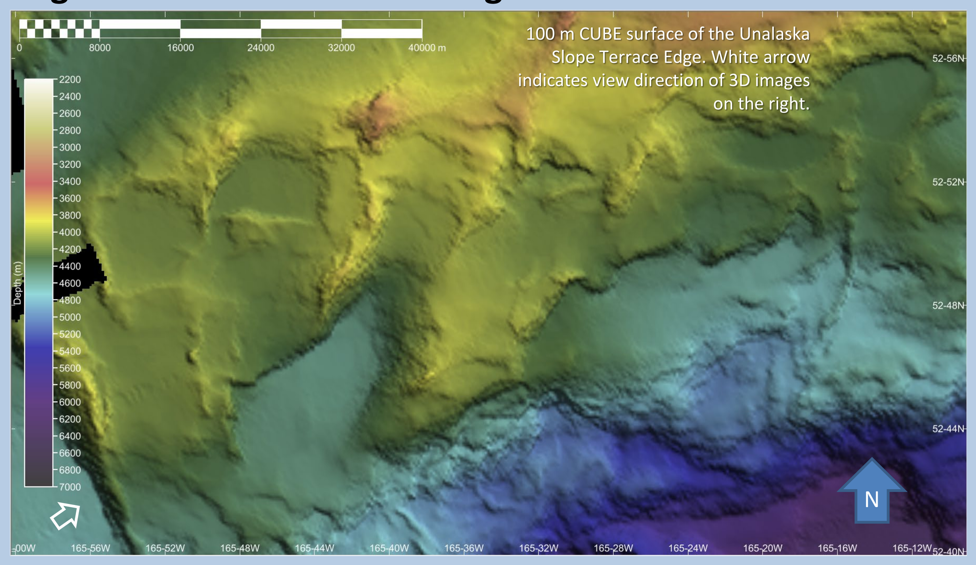
(Left) The Lone Knoll Scarp is located directly east of the Unalaska Slope Study Area (shown by the yellow marker at the white arrow). The depth of the dive was similar to depths within Unalaska's Upper Slope Site.
The goal of the dive was to observe Lone Knoll Scarp, a submarine landslide that is possibly linked to a 1946 earthquake and tsunami on Unimak Island. These images show seafloor variation which can help support the backscatter intensity results from Figure 2.

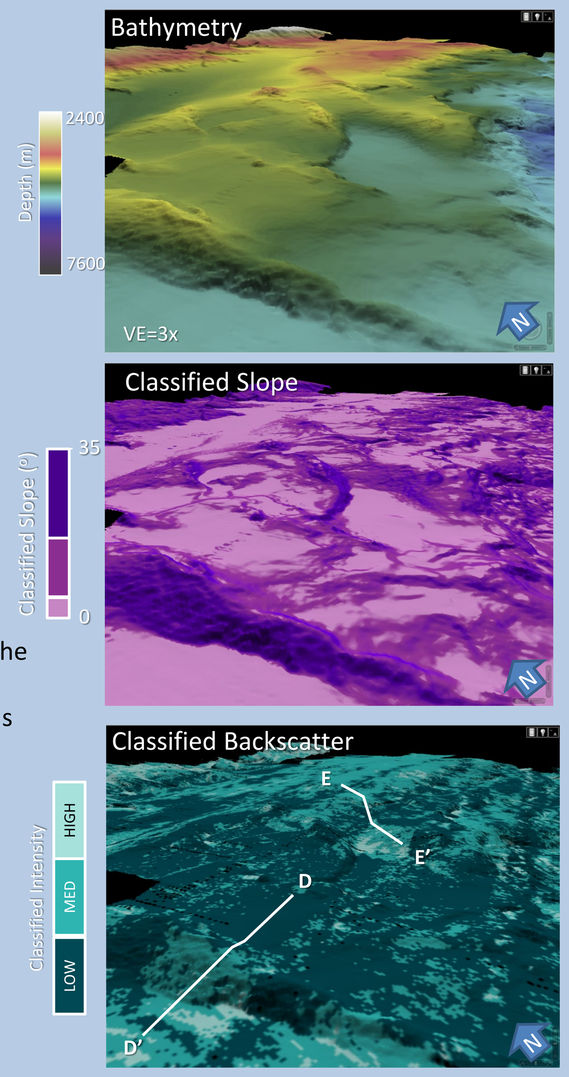
(Left) ROV image of the base of Lone Knoll Scarp (EX2304-05) at a depth of ~2800 m. This image displays, soft, unconsolidated sediment that is made of low-density organic matter (NOAA OE 2023).



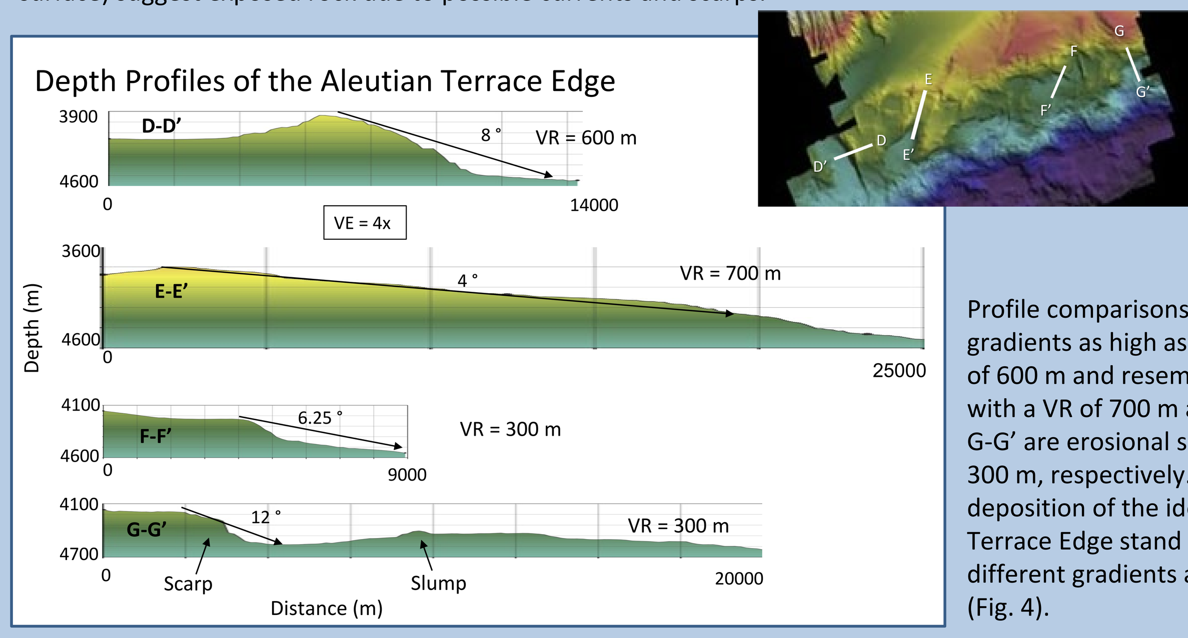
(Right) ROV image of boulder fragments found at the base of the Lone Knoll Scarp. These boulders were most likely deposited during a submarine landslide event (NOAA OE, 2023).

Figure 3. Aleutian Terrace Edge Site



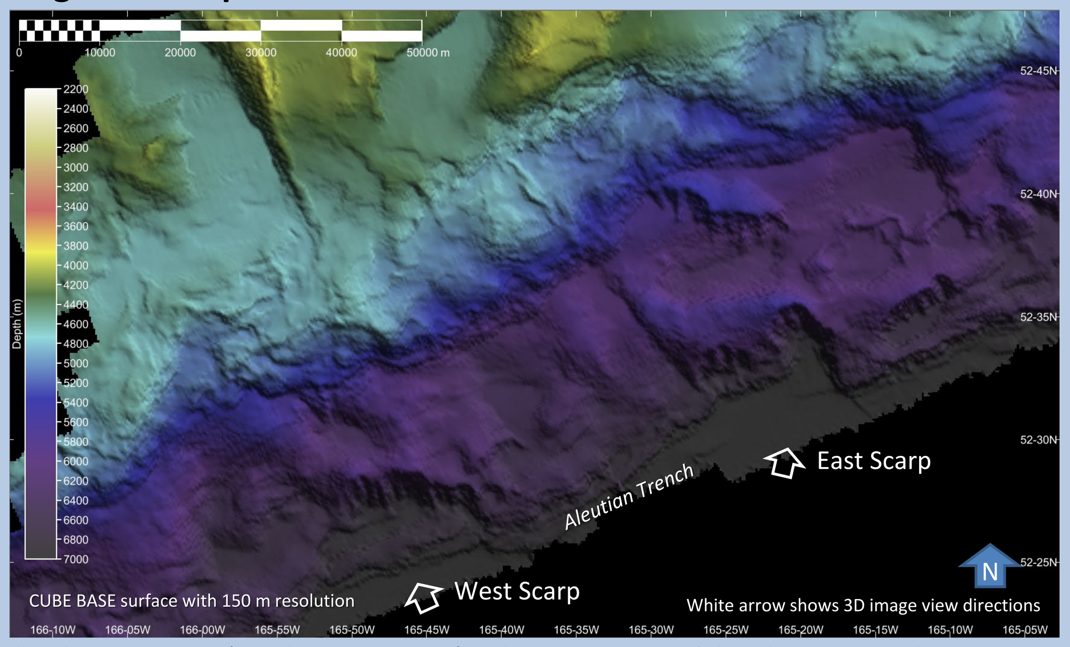


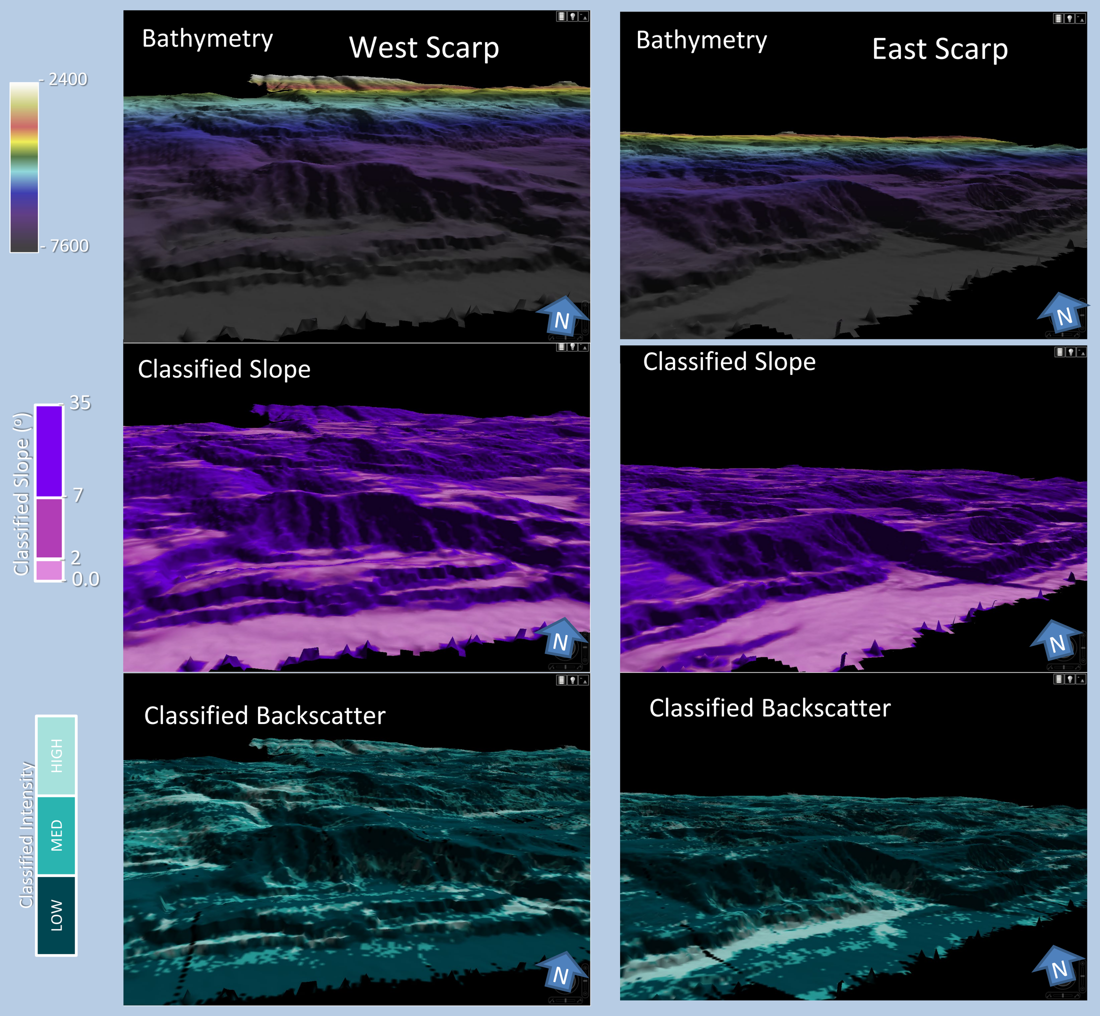
The bathymetric range of the Aleutian Terrace Edge site is 3400 to 5000 m and lies above the Slope Base. Terraces consist of slumps and scarps and a canyon feature. Classified slope shows ranges of 0-15° within the Aleutian Terrace, and as high as 35º at the terrace edge. Backscatter intensity shows much of the Aleutian Terrace has medium to low intensity, suggesting passive sedimentation while the Aleutian Terrace Edge has high intensity along the steep portion of profile D-D' and within the channel of E-E' (overlain on the 3D surface) suggest exposed rock due to possible currents and scarps.



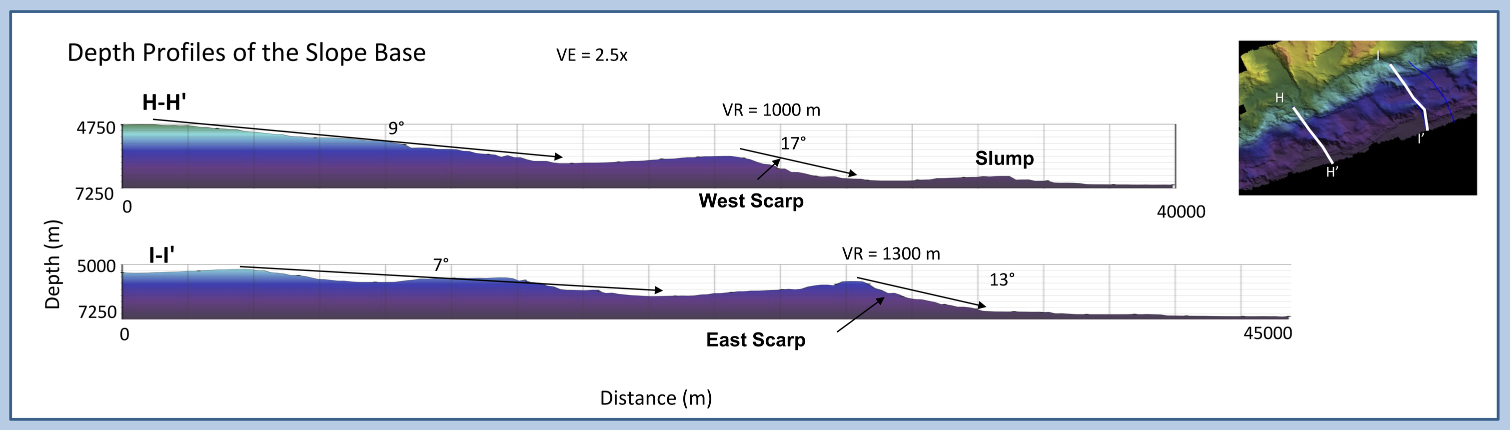
Profile comparisons of the Aleutian Terrace Edge Site show edge gradients as high as 12°. Profile D-D' has an 8° slope with a vertical relief of 600 m and resembles an erosional scarp. Profile E-E' canyon feature with a VR of 700 m and 4° slope, displaying high intensity. Both F-F' and G-G' are erosional scarps, with slopes of 6.25 and 12 ° and VR of 700 and 300 m, respectively. G-G' also showcases a slump as a result of sediment deposition of the identified scarp. These four profiles of the Aleutian Terrace Edge stand out amongst the Aleutian Terrace as they show different gradients and scarps nearing the trench and subduction zone (Fig. 4).

Figure 4. Slope Base Site





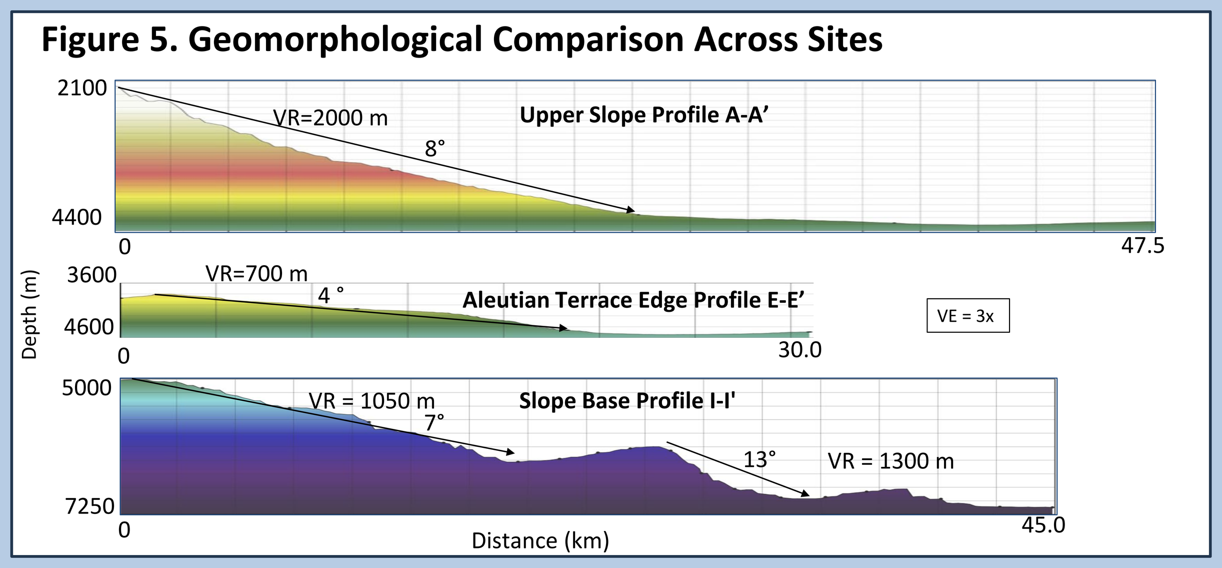
The Slope Base Site (depth 4750-7250 m) includes a portion of the Aleutian Trench and is comprised of several steep scarped features that are flat at their base. These scarps are remnants of a previous erosional event which has most likely deposited sediment further south of the Slope Base site. This site has a minimum slope of <1°, and steeper parts ranging between 15-25°. The majority of this area, including the steep scarps, have low intensity backscatter compared to the Upper Slope and the Aleutian Terrace Edge, suggesting that this portion of the slope might have extremely rough terrain and is composed of unconsolidated sediments that scatter or absorb the acoustic signal. However the site's great depth range exceeding 7 km possibly causes the backscatter signal to return with less intensity than study sites at shallower depths. On the East scarp's classified backscatter, high intensity can be identified below the scarp, suggesting exposed bedrock that may have been revealed as sediment moves down the slope.



Three main scarp features occur within the Slope Base area ranging in depth from about 4750 to 7250 m displayed on depth profiles H-H' and I-I'. Shallower portions of the profiles have more gradual change in depth (7-9º slope) than at the scarps, which feature slopes ranging 13 to 17º. Below the Western Scarp, there is an increase in elevation which is evidence of a slump that originated from the scarp. The upward slopes before the scarps could be accumulated sediment from the moderately terraced, downward sloping area above the scarps.

DISCUSSION and CONCLUSIONS

Figure 5. Geomorphological Comparison Across Sites



The Upper Slope, Aleutian Terrace Edge, and Slope Base show varying geomorphology which can be visualized in these representative profiles. The Upper Slope (profile A-A') is characterized by a depth range of 2100-4400 m and slope of 8° and features a submarine canyon, which may be evidence of a submarine landslide caused by megathrust earthquakes (NOAA OE, 2023) from the converging Pacific Plate subducting under the North American Plate (Alaska-Aleutian subduction zone). In this Upper Slope canyon, high intensity is associated with possible turbidity currents that traveled through the canyon revealing exposed bedrock. ROV *Deep Discoverer* footage from EX2304-Dive05 provides ground-truth for the Upper Slope region's scarp features. Although the footage is not from this study area, similarities of the unconsolidated sediment and boulder fragments can be associated with low and medium backscatter intensity (Fig. 2). The Aleutian Terrace is extremely flat with slopes of <1°, however, the terrace edges are significantly steeper.The Aleutian Terrace Edge (profile E-E'), is characterized by a depth range of 3600-4600 m and a slope of 4°. Throughout the Aleutian Terrace, low and medium backscatter intensity indicates passive pelagic sedimentation from eolian transported volcanic ash related to nearby volcanic activity and is influenced by the Makushin Volcano to the north of Unalaska Island (Boyd and Jacob 1986), contributing terrigenous-volcanic and volcanic deposits (Brown *et al.,* 2013). The Aleutian Terrace Edge, where slopes are steeper and scarps are present, displays high and low backscatter intensity. Within the Aleutian Terrace, depositional slumps with low backscatter intensity may be identified as the terrain's gradient decreases from the Upper Slope from where slumping occurred during submarine landslides, which could be evidence of how the Aleutian Terrace formed. The Slope Base, ranging from 5000-7250 m with a slope of 7°, showcases significant erosion, as indicated by a series of scarps (profile I-I'). High backscatter at the base of the Slope Base both East and West Scarps (Fig. 4) suggests slumping has occurred due to tectonic activity and has left erosional remnants of the bedrock exposed.

In light of these findings and considering the influence of tectonic activity along the Alaska-Aleutian Subduction Zone, further exploration in the Upper Slope, Aleutian Terrace Edge, and the Slope Base areas is recommended. Field surveys, sediment sampling, ROV dives, and advanced mapping techniques are essential for exploring the variations in geomorphology along the Unalaska Slope with regards to seismic activity within the Alaska-Aleutian Subduction Zone and its resulting earthquakes and submarine landslides.

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