

Comparative Geomorphology of Axis-Parallel Ridges Along the Mid-Atlantic Ridge, Northwest of the Azores

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BACKGROUND

The area of study is located on the Mid-Atlantic Ridge (MAR) axis approximately 1100 km off Portugal's coast. In July 2022, NOAA led a cruise to this study area on the NOAA Ship *Okeanos Explorer* as a part of the expedition *Voyage to the Ridge 2022*. During this expedition, NOAA's primary objective was to gather high resolution bathymetric data and ROV dive footage along the MAR to better understand these previously unexplored regions. On Leg 2, three dives were conducted within the study area, yielding both mapping and videographic data collected by the ROV *Deep Discoverer*. EX2205-Dive 01 explored the area here referred to as South Site and analyzed an unnamed seamount west of the MAR axial valley. Deep-sea corals of *Eguchipsammia* were observed attached to the seamount's slopes, encasing deep layers of skeletal rubble of the same genus. EX2205-Dive 02 was located on the study area's North Site, where the ROV encountered extremophilic life within the Moytirra Vent Field, the only known deep hydrothermal vent located between the Azores and Reykjanes Ridge (NOAA 2022). This vent field was formed on a nearly vertical fault scarp (Wheeler et al., 2013) and is located in the study area's North Site. One type of feature is extremely common to most slow-spreading mid-ocean ridges: here referred to as axis-parallel ridges (APRs), which are commonly referred to as abyssal hills (Olive et al., 2015; Johnson 2015). APRs result from faulting associated with a divergent plate boundary and form parallel to the axial valley (Escartin et al., 2008). Another mid-ocean ridge feature is axial volcanic ridges (AVRs), which are ridges present within the axial valley itself (Wheeler et al., 2013). Further analysis of multibeam bathymetry data collected during the expedition can provide more detailed information on the unique geomorphology of this area, including variations in backscatter, slope, and vertical relief as different features and their locations relative to the MAR axis are analyzed and compared.

Figure 1. Study Area and Sites

The area of study is located on the Mid-Atlantic Ridge (MAR) axis west of Portugal and north of the Azores. The area features depths ranging 1000 to 3400 m. Three study sites were analyzed: North Site features a prominent axis-parallel ridge (APR) east of the ridge axis, and South Site also features a prominent ridge west of the axis.

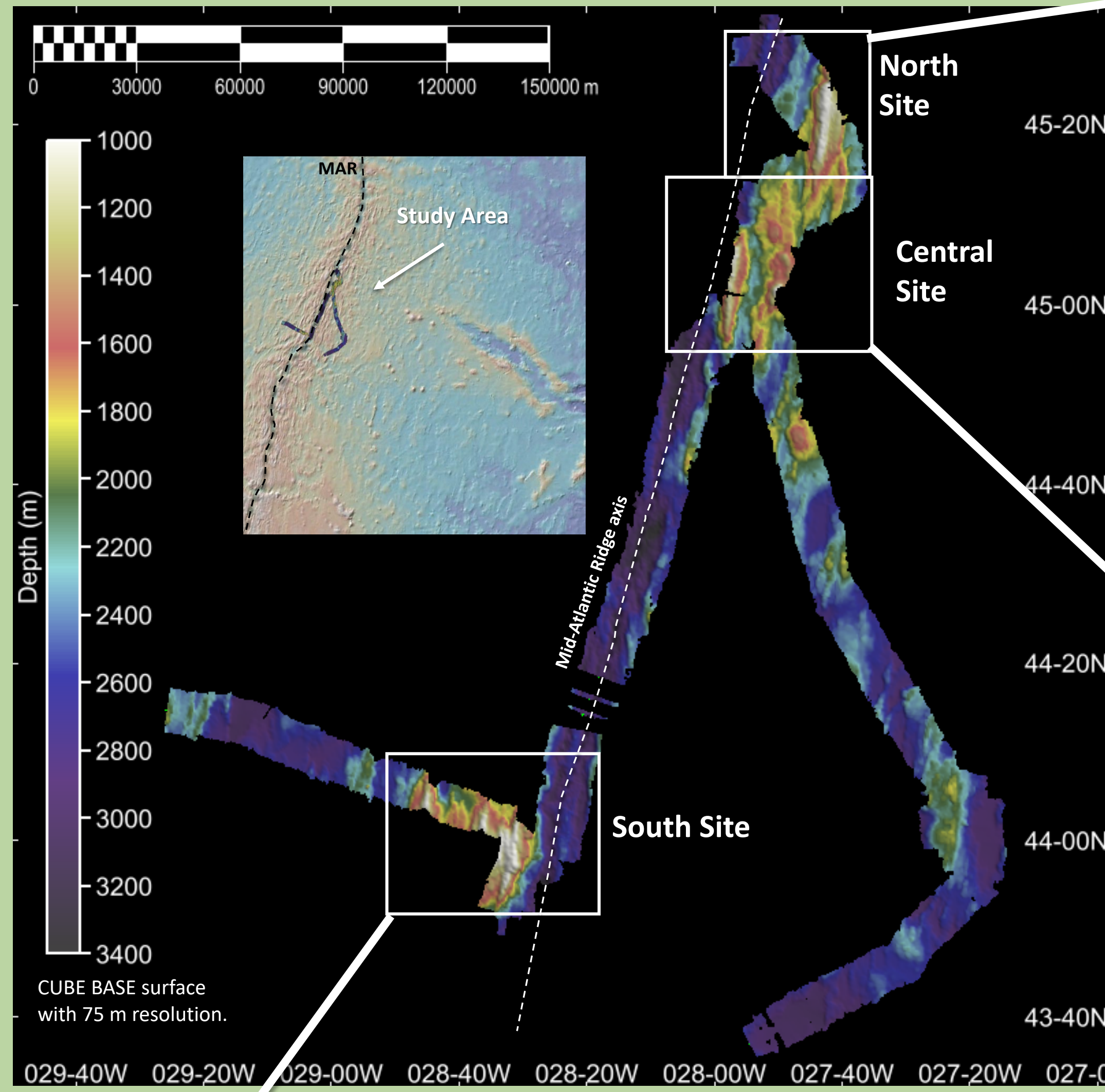
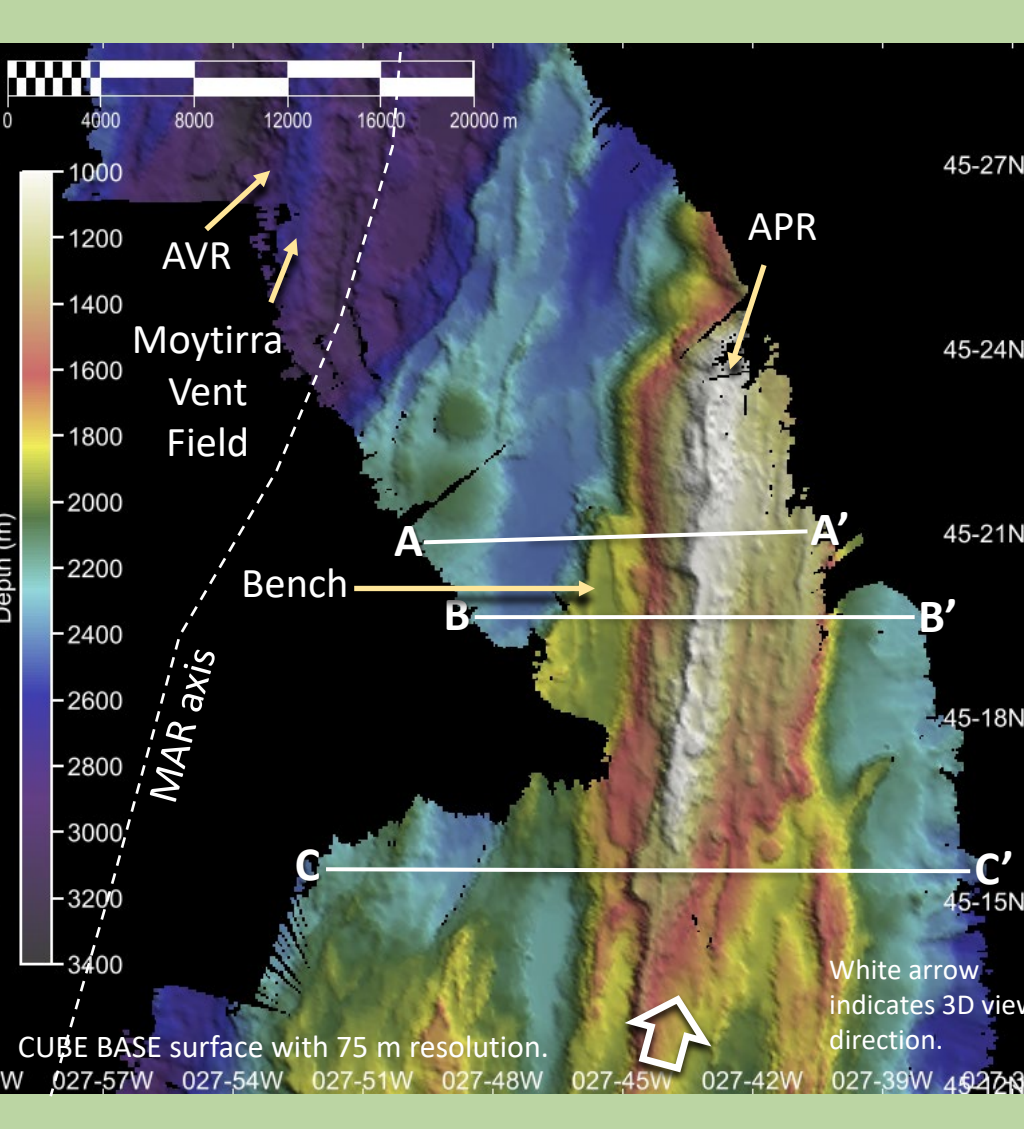
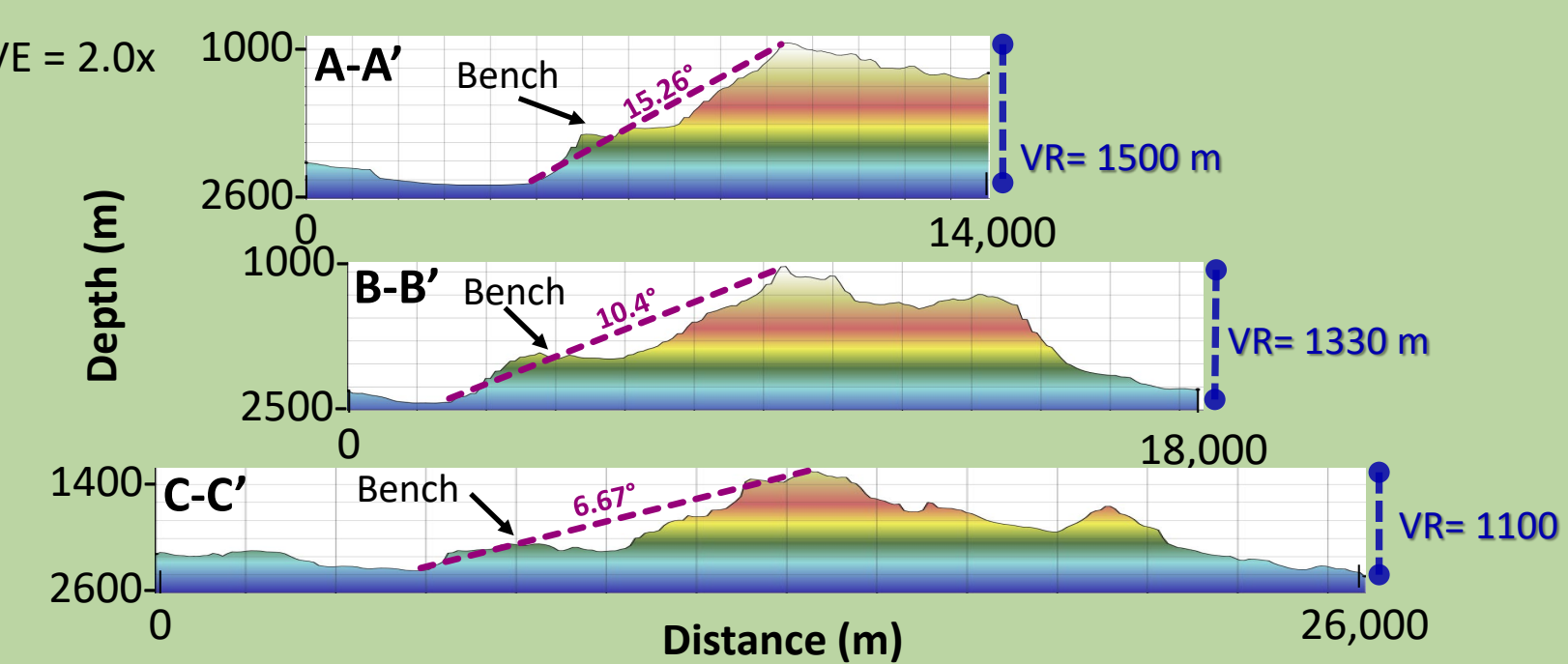


Figure 2. North Site

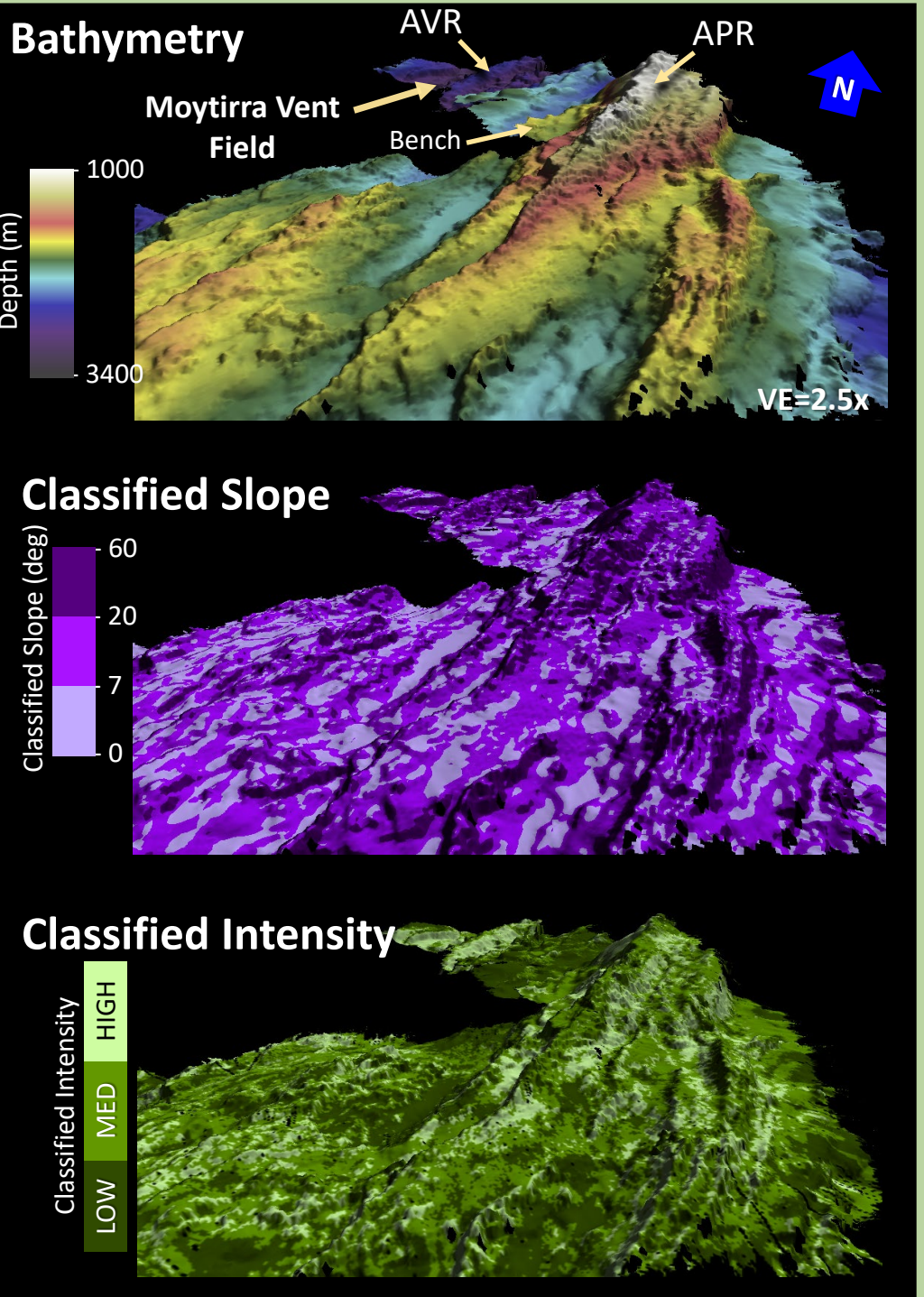


North Site (800 to 3200 m) features a prominent axis-parallel ridge (APR) east of the ridge axis. An axial volcanic ridge (AVR) lies within the ridge axial valley where the Moytirra Vent Field is located.

Slopes range 0 to 56°, with highest slopes present on the APR walls.

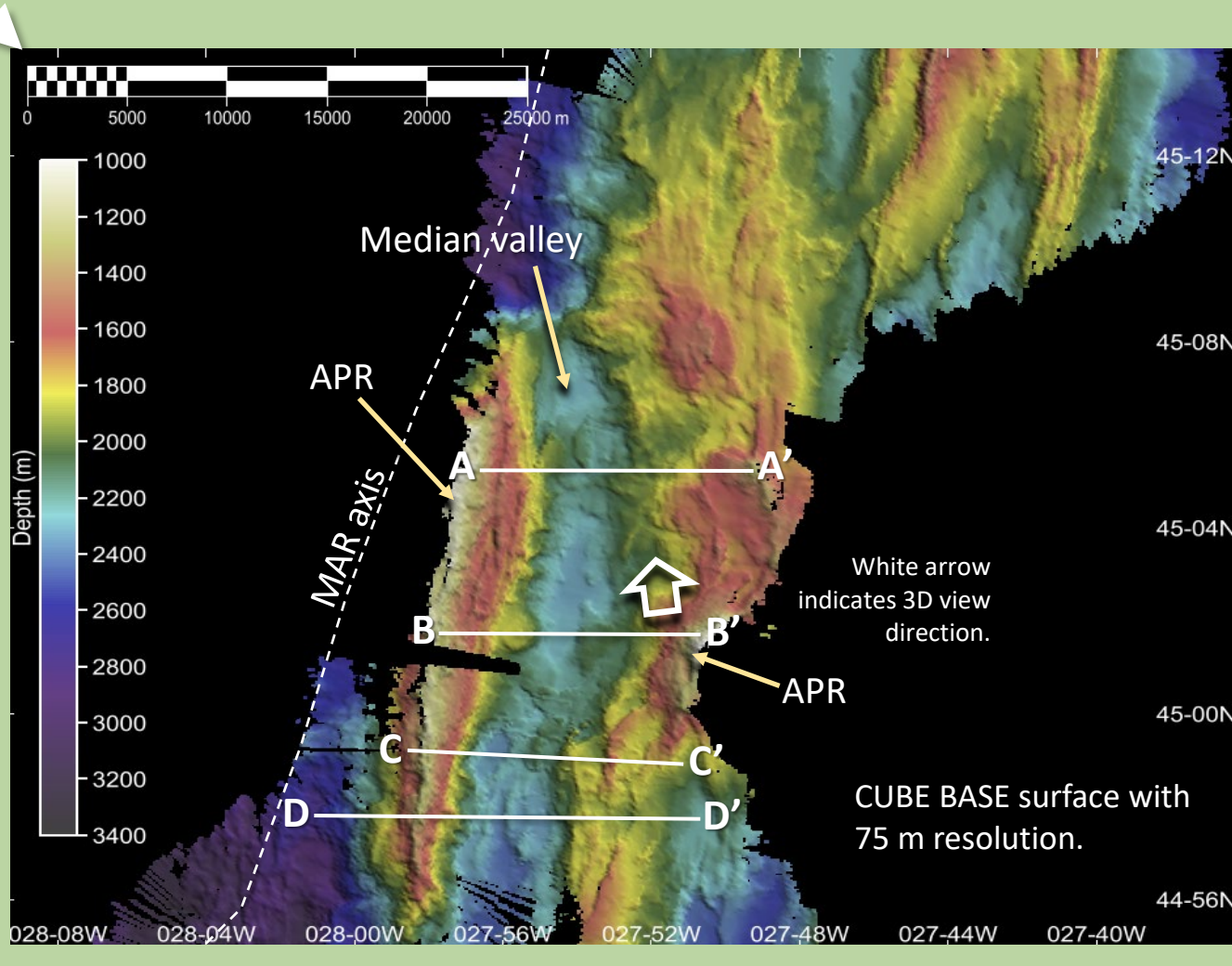


(above) Vertical relief (VR) and overall slope of the prominent APR decreases substantially north to south; 1500 to 1100 m and 15.26 to 6.67°, respectively. A bench occurs to the west of the APR in profiles A-A' and B-B', indicating the presence of an AVR west of the axial valley.



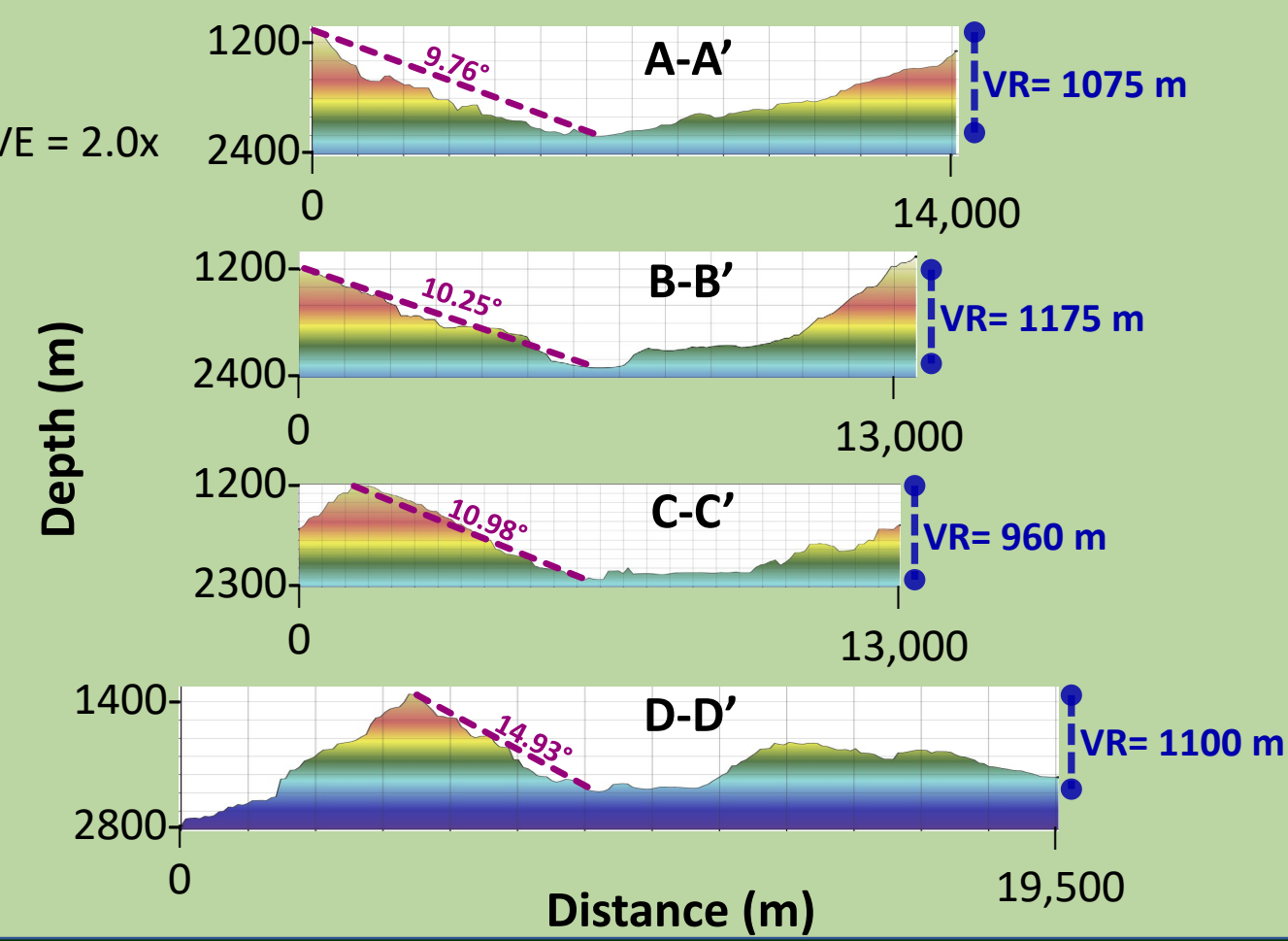
(above) Low slope areas display the lowest intensity, while the APRs display higher intensity return, suggesting exposed rock substrate.

Figure 3. Central Site



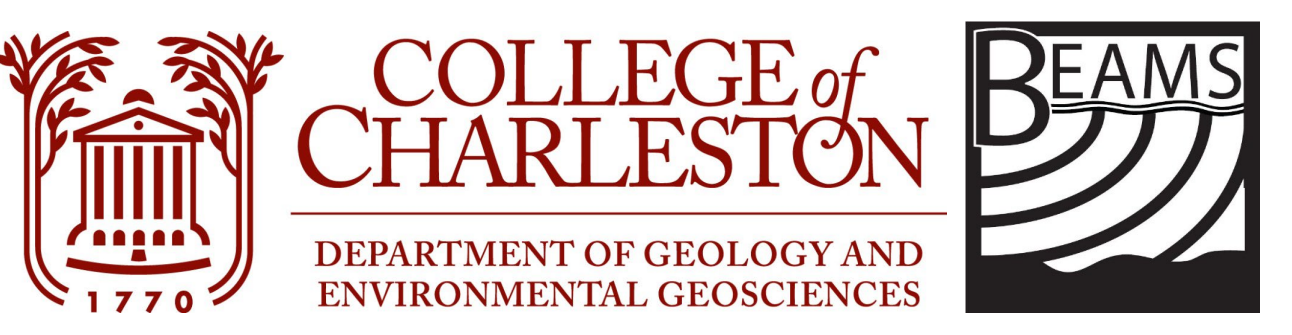
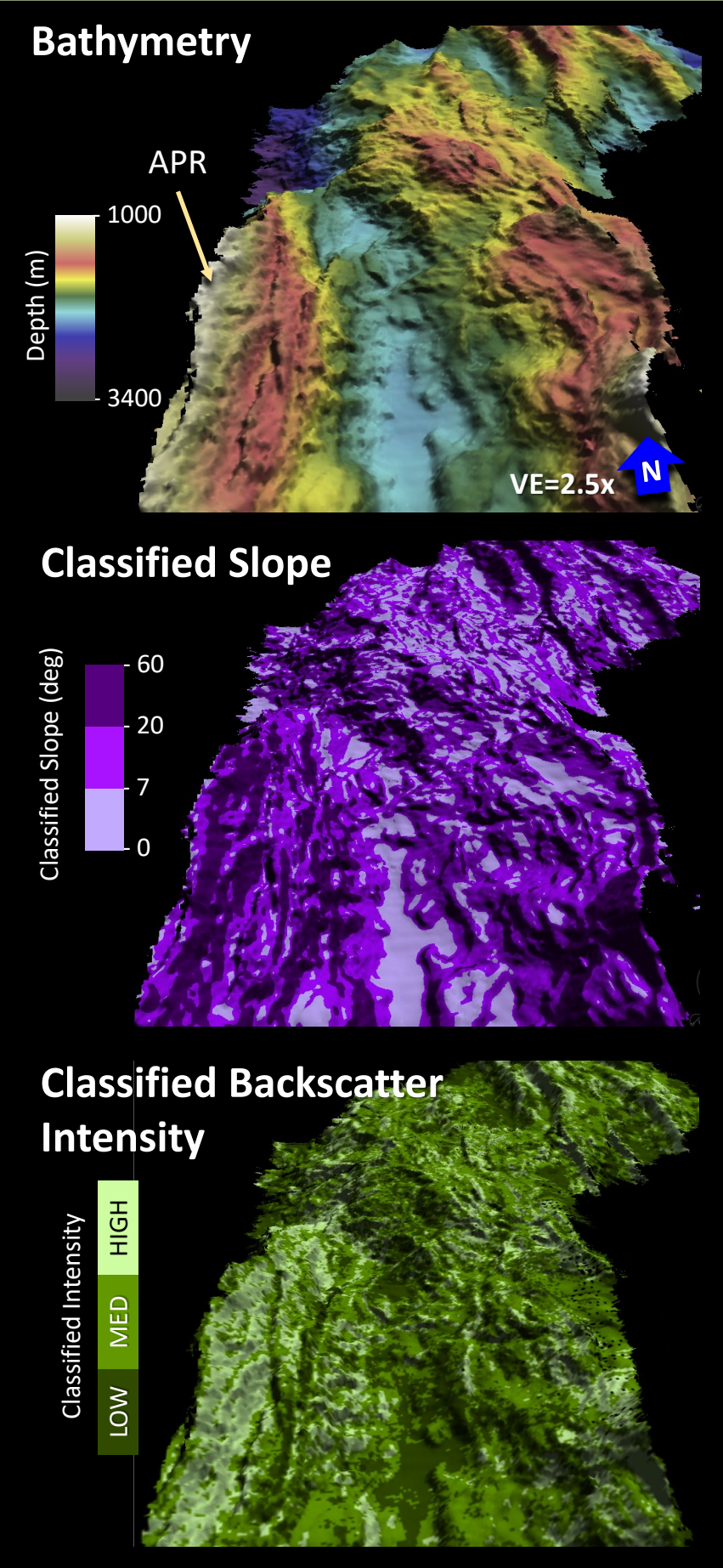
Central Site has a depth range of 1100 to 3100 m and lies east of the MAR axis. This site displays a prominent median valley and two APRs. The western APR was only partially mapped.

Slopes range 0 to 54° and are highest on the walls of the APRs.



The western APR featured high intensity, suggesting the presence of exposed rock. Intensity decreased sharply in the low-slope median valley.

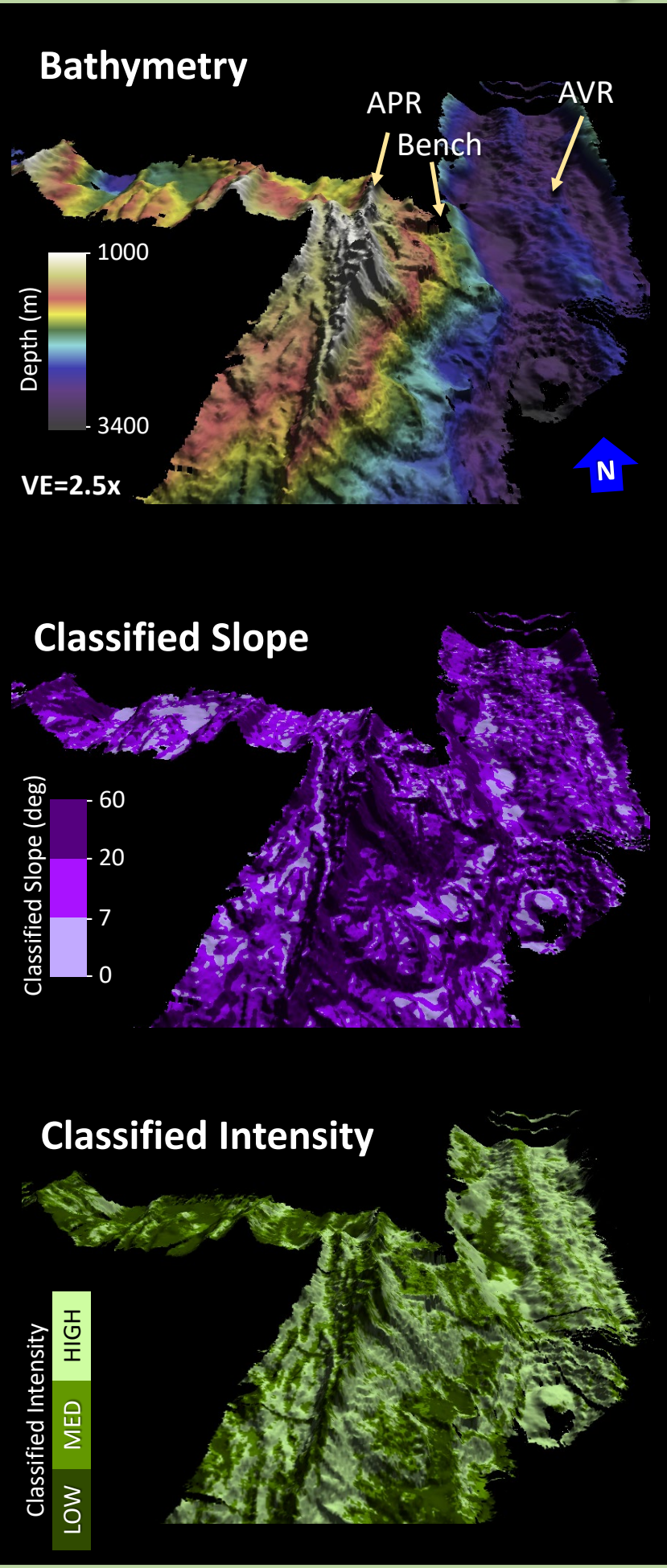
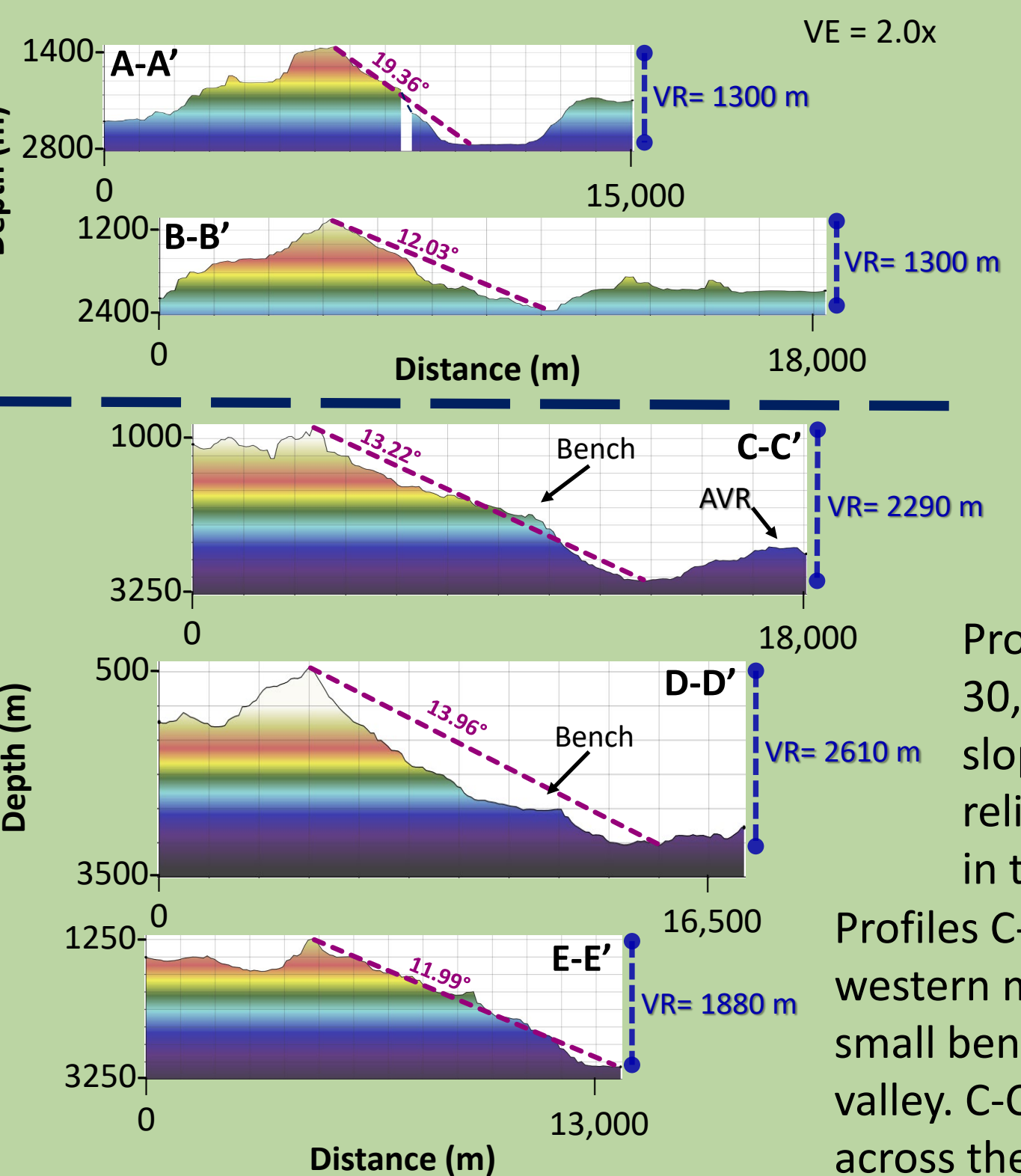
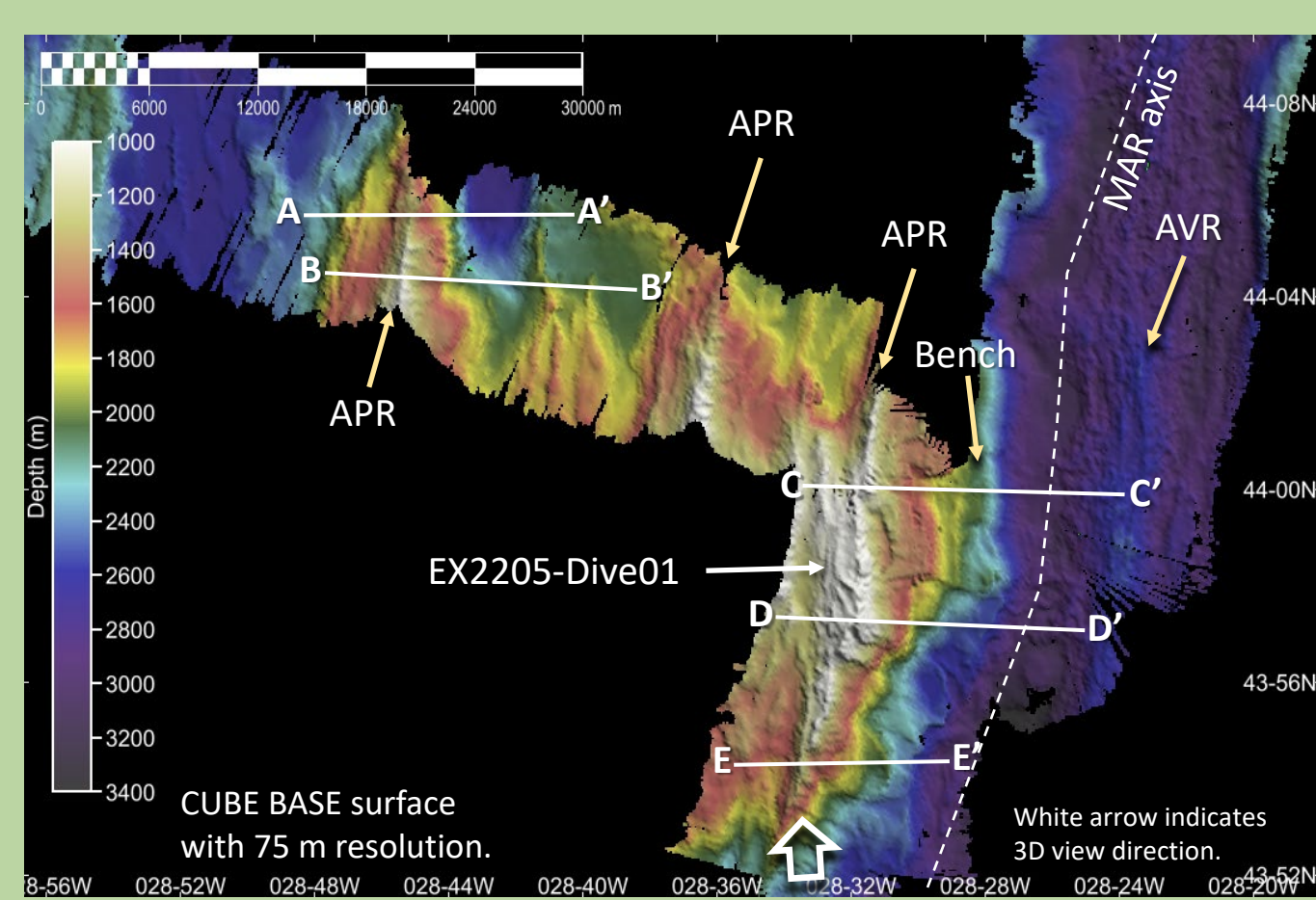
(left) North to south, the median valley's slopes gradually increase from 9.76 to 14.93°, while the vertical relief remains fairly consistent at 960 to 1175 m with little variation.



METHODS

- The NOAA Ship *Okeanos Explorer* collected high resolution multibeam sonar data using the Kongsberg EM304 multibeam echosounder, as well as HD video using the ROV *Deep Discoverer* during EX2205 (July 20-22, 2022).
- CARIS HIPS and SIPS 11.4 software was used to post-process raw multibeam data.
- A 2D CUBE BASE bathymetric surface was generated, from which all 2D and 3D bathymetric surfaces, aspect bands, slope bands, and classified backscatter intensity mosaics were created.
- For each site, depth profiles were made in order to measure and further analyze slope and vertical relief (VR) variations within the study site.
- All slopes were graphed for further comparison.

Figure 4. South Site



Profiles A-A' and B-B' (approximately 30,000 m west of the MAR) show high slopes of 19.36 to 12.03°, and vertical reliefs of 1300 m. Small APRs are displayed in these profiles.

Profiles C-C', D-D', and E-E' show the ridge's western median valley wall which also has a small bench (2300 m depth) adjacent to the axial valley. C-C' is drawn from the prominent APR, across the MAR axis to the AVR.

South Site ranges in depth from 500 to 3400 m and includes several prominent APRs west of the ridge axis. An axial valley ridge (AVR) also occurs, with a prominent APR immediately west of the axis. This APR also displays a bench feature before descending into the ridge valley. EX2205-Dive01 explored this APR and discovered a deep-sea coral reef on both its summit and median walls.

Slopes range from 0 to 56° and are highest on the prominent APR.

Median valley walls display relatively low intensity, while the ridge axis itself has much higher intensity, suggesting the presence of exposed rock.

Figure 6. Comparative Geomorphology of Each Sites' Prominent APR

A representative profile at each site was selected for comparison. All are shown at the same scale. North Site has the lowest slope (10.4°), while Central Site and South Site slopes are only somewhat greater at 14.93° and 13.96°, respectively. South Site's VR of 2610 m was double that of North Site (1330 m) and Central Site (1100 m).

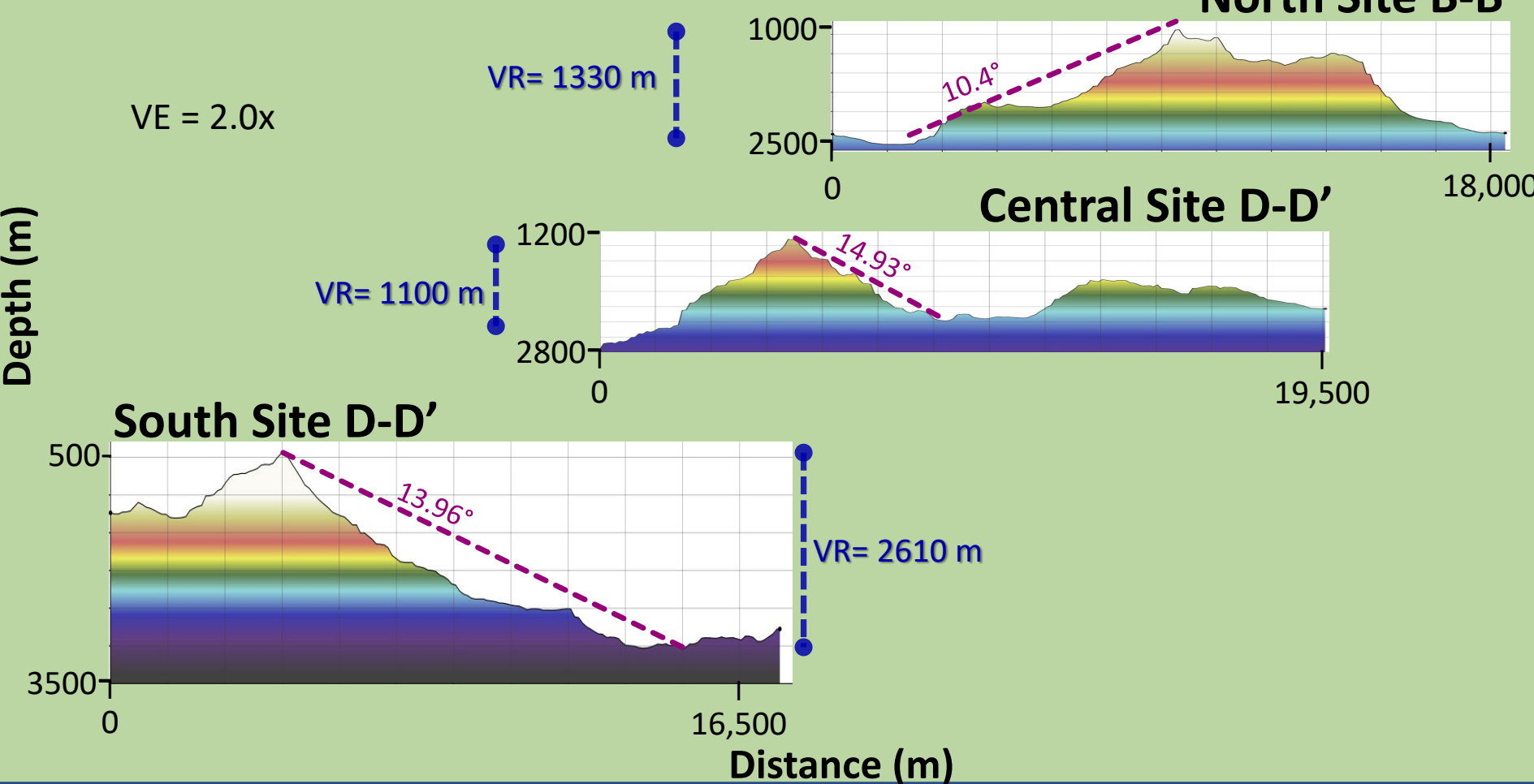
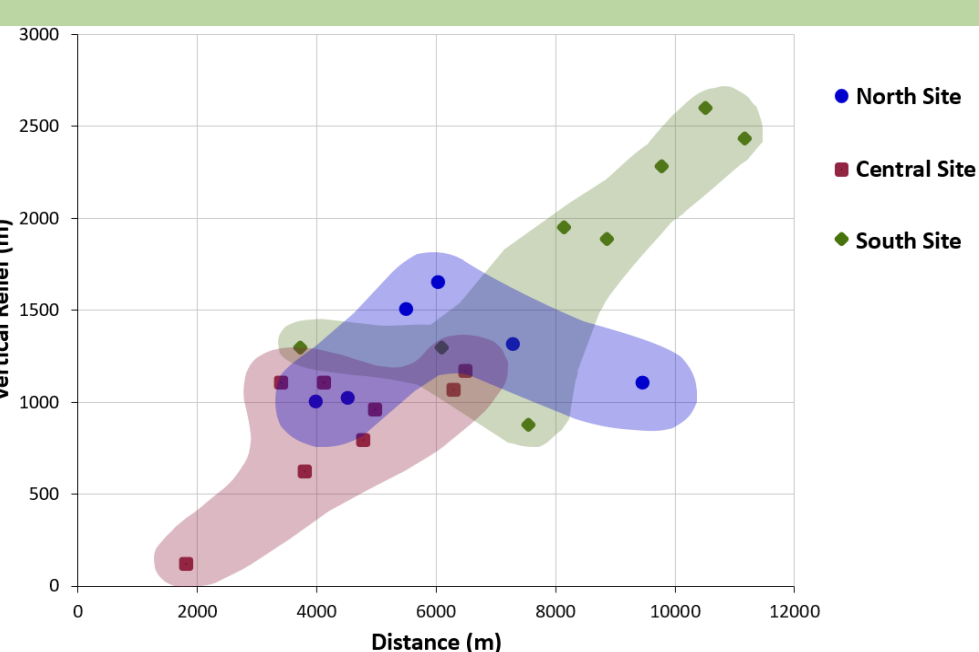


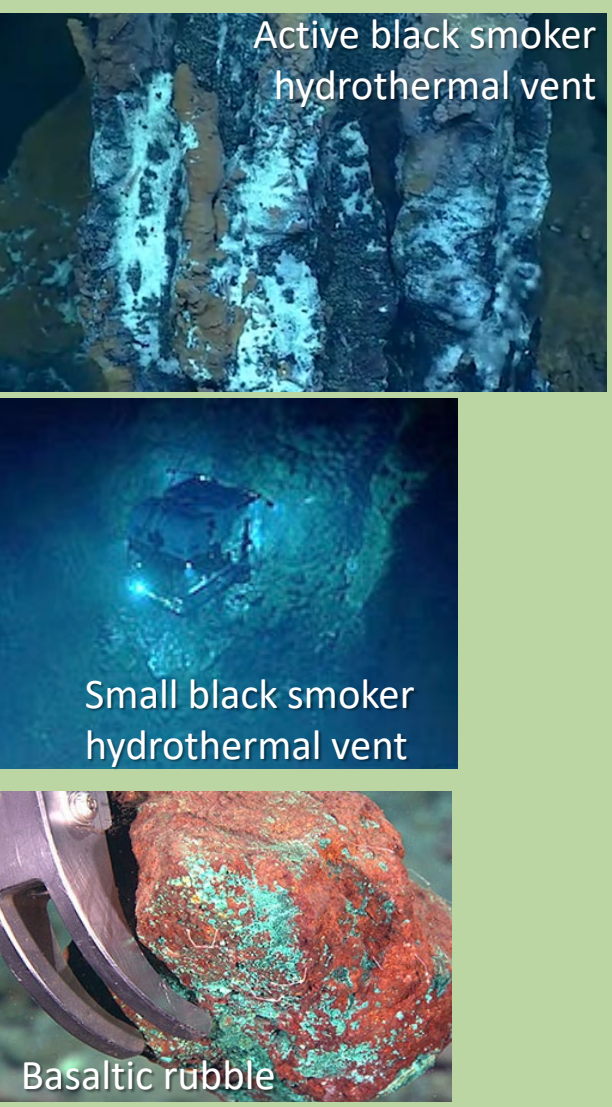
Figure 7. Comparison of APR Geomorphology



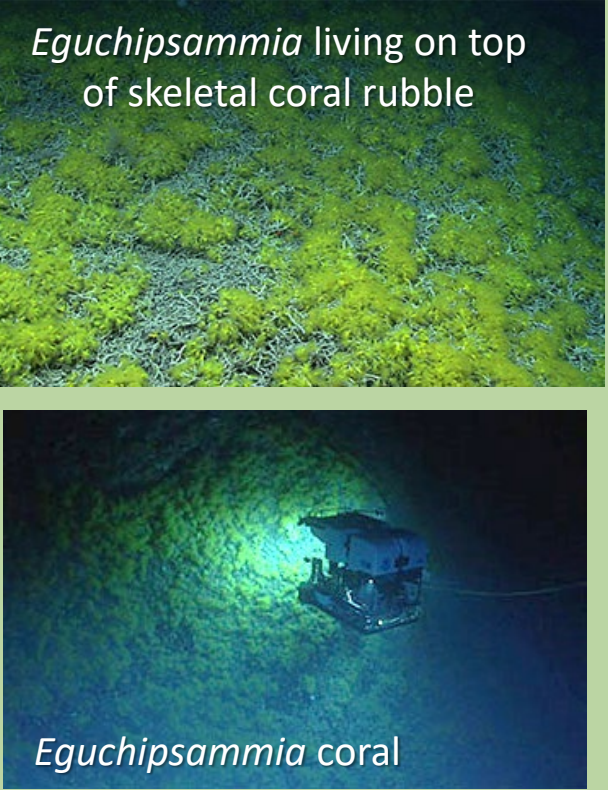
(above) Data collected from numerous profiles (not shown) of each sites' most prominent APR indicate South Site has the greatest VR and extent (distance). Central Site had the smallest VR and extent. North Site's VR and extent were between South Site's and Central Site's.

Figure 5. Images from ROV *Deep Discoverer* dives.

North Site



South Site



EX2205-Dive01: An entire deep-sea reef of *Eguchipsammia* lives on a large seamount's summit, growing on a mix of dead coral rubble and exposed basalt.

EX2205-Dive02: Black smoker hydrothermal vents were encountered within the Moytirra Vent Field. The substrate was mostly exposed basalt, of which some samples were collected.

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