

BACKGROUND

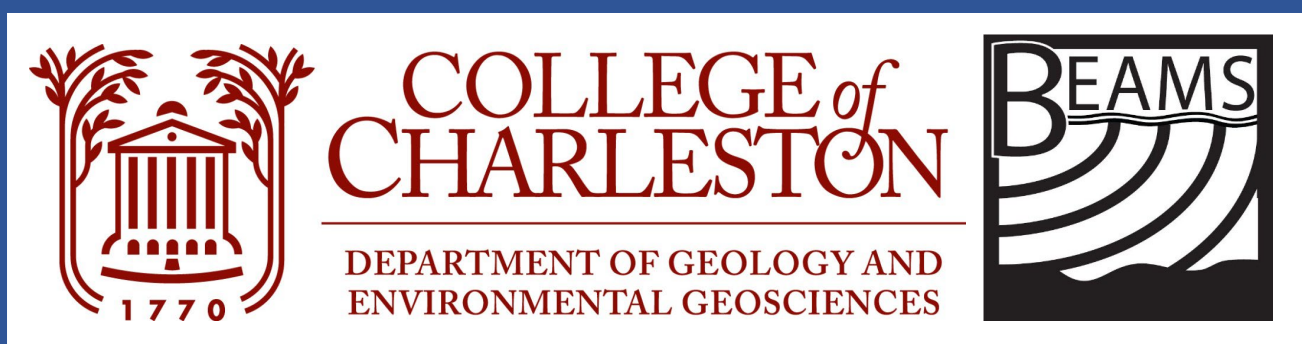
NOAA Ocean Exploration and partners conducted the *Voyage to the Ridge* expedition in May-September 2022 on the NOAA Ship *Okeanos Explorer*. This expedition focused on getting a better understanding of the Mid-Atlantic Ridge (MAR) and Azores Plateau, including deep-water features such as hydrothermal vents, seamounts, diverse chemosynthetic biota, and seafloor tectonic features (NOAA Expedition). Multibeam sonar data were collected, mapping the seabed in high resolution and using ROV *Deep Discoverer* video to examine benthic communities. Upwelling of magma from within the earth causes the North American and Eurasian Plates to diverge at the MAR at rates between 2 and 5 cm/year, forming a rift valley ranging in depth 1 to 3 km (MacDonald,2010). This spreading does not occur in a linear fashion due to lateral offsets from transform faults and volcanoes.

Zenith Seamount is located at 42.5° N on the MAR. This seamount was explored during expedition EX2205 to compare how different habitats are connected, known as habitat conductivity, along the MAR. Which is important for maintaining healthy populations of organisms, throughout sites along the MAR. This study examines a section of the MAR north of the Azores Plateau, west of Portugal, using data collected during EX2205. The purpose of this study is to characterize the seafloor geomorphology adjacent to this previously unmapped section of the Mid-Atlantic Ridge, and examine benthic habitat observed from EX2205-Dives 04 and 05.

Geomorphic Characterization Along the Mid-Atlantic Ridge North of the Azores Plateau

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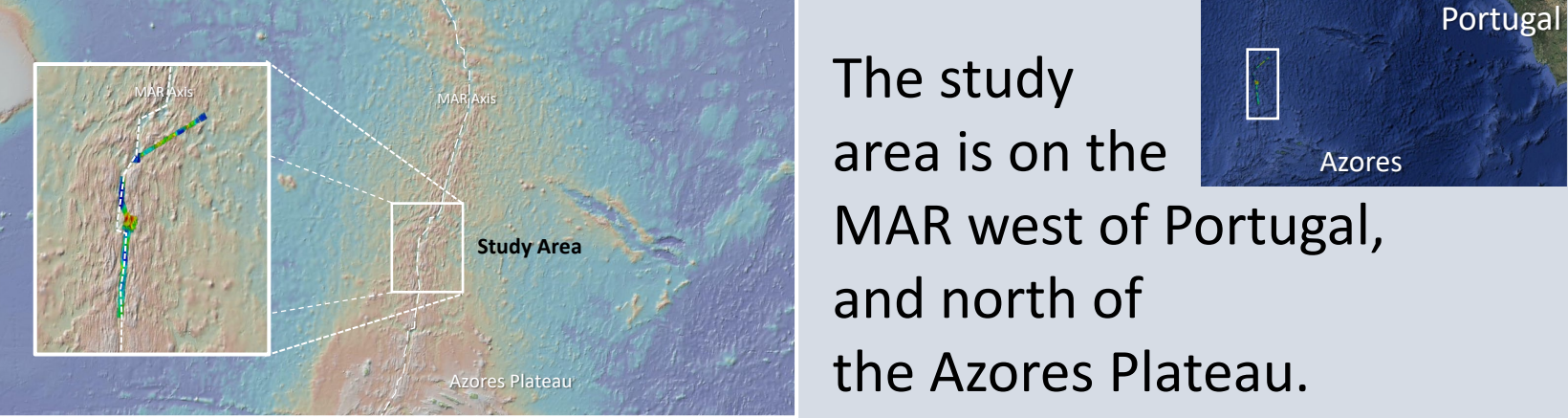


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METHODS

- The NOAA Ship *Okeanos Explorer* on Voyage to the Ridge 2022 (May-September 2022), collected multibeam data using the deep-water Kongsberg EM304 multibeam echosounder.
- Ran sonar data through CARIS HIPS & SIPS 11.4 to compute surfaces.
- 2D and 3D CUBE surfaces of bathymetry, slope, and mosaic backscatter with 60 m resolution were used to compare features along sites.
- Depth profiles were made to compare geomorphological features of vertical relief and slope along the MAR.
- Expedition 2 dives with remotely operated vehicle (ROV) used to observe and compare substrate of the seafloor.

Figure 1. Study Area and Site Locations



North Ridge, Central Ridge, and South Ridge are located on the Mid-Atlantic Ridge axis. Zenith Seamount is offset to the east of the axis. The North site is a part of an axial volcanic ridge.

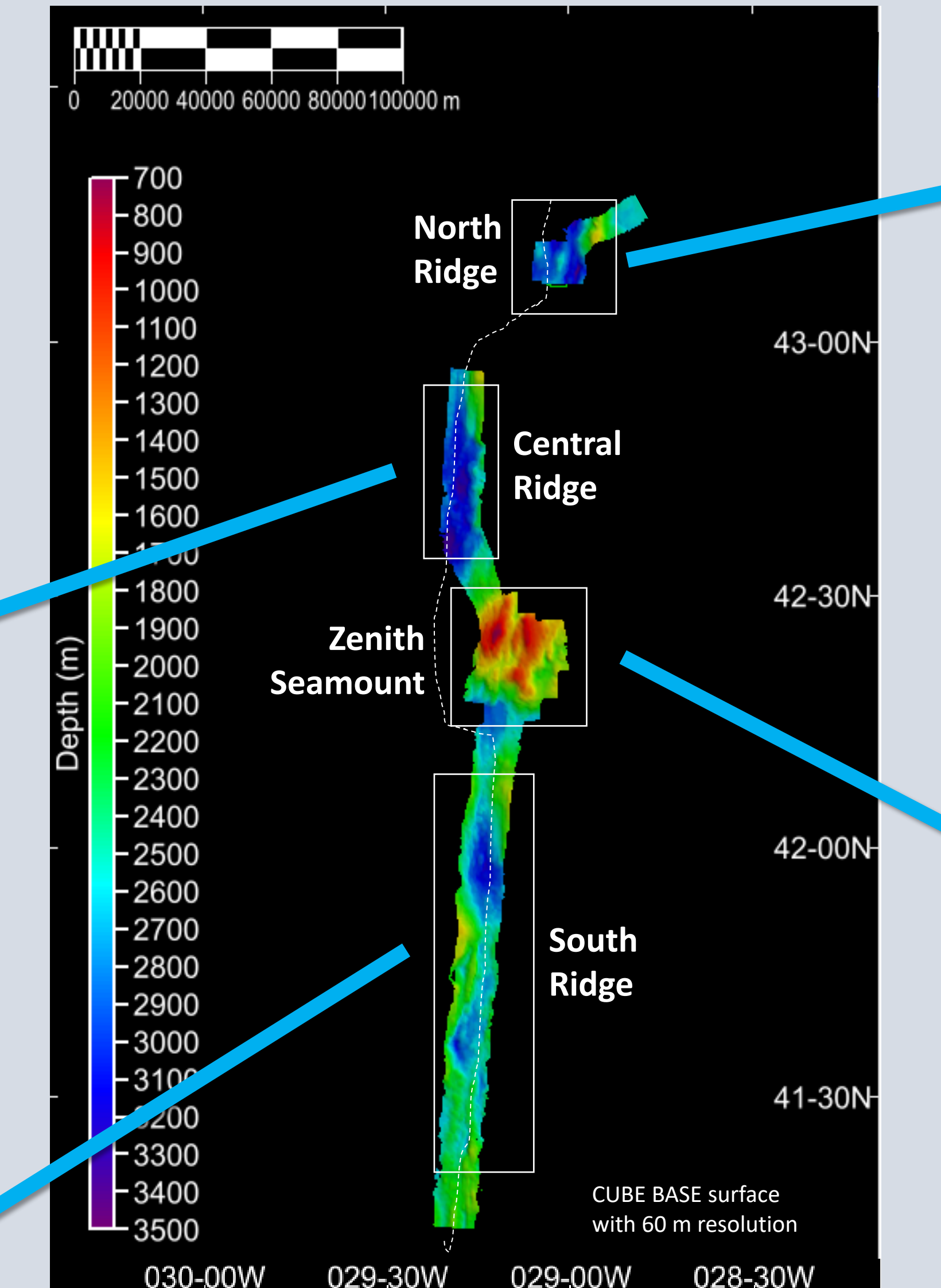
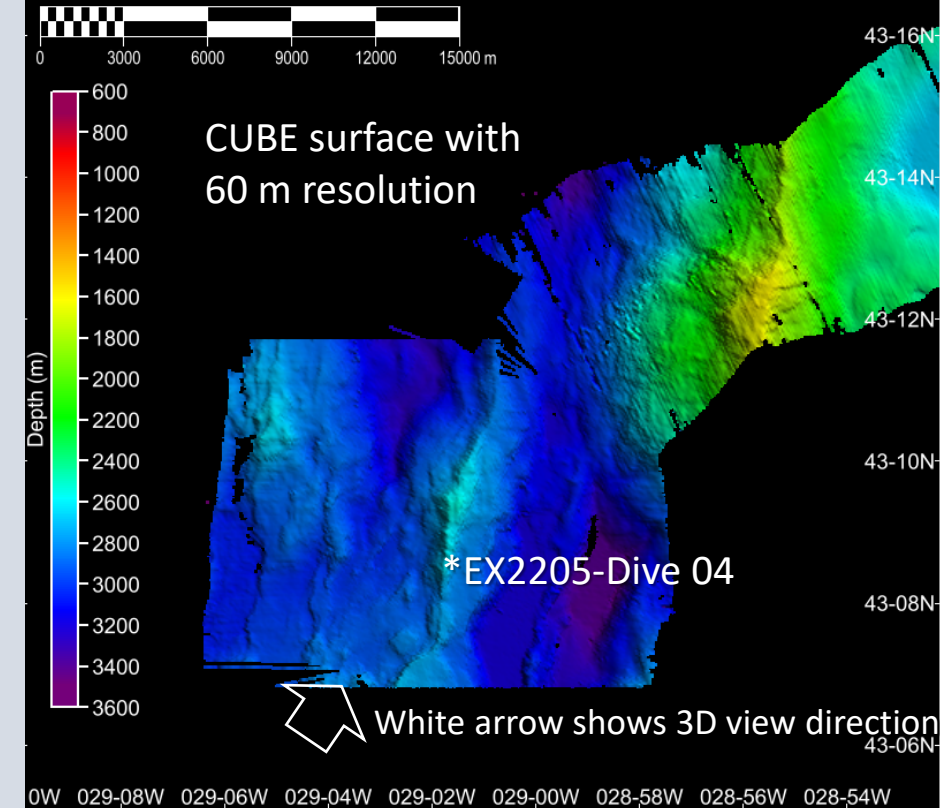


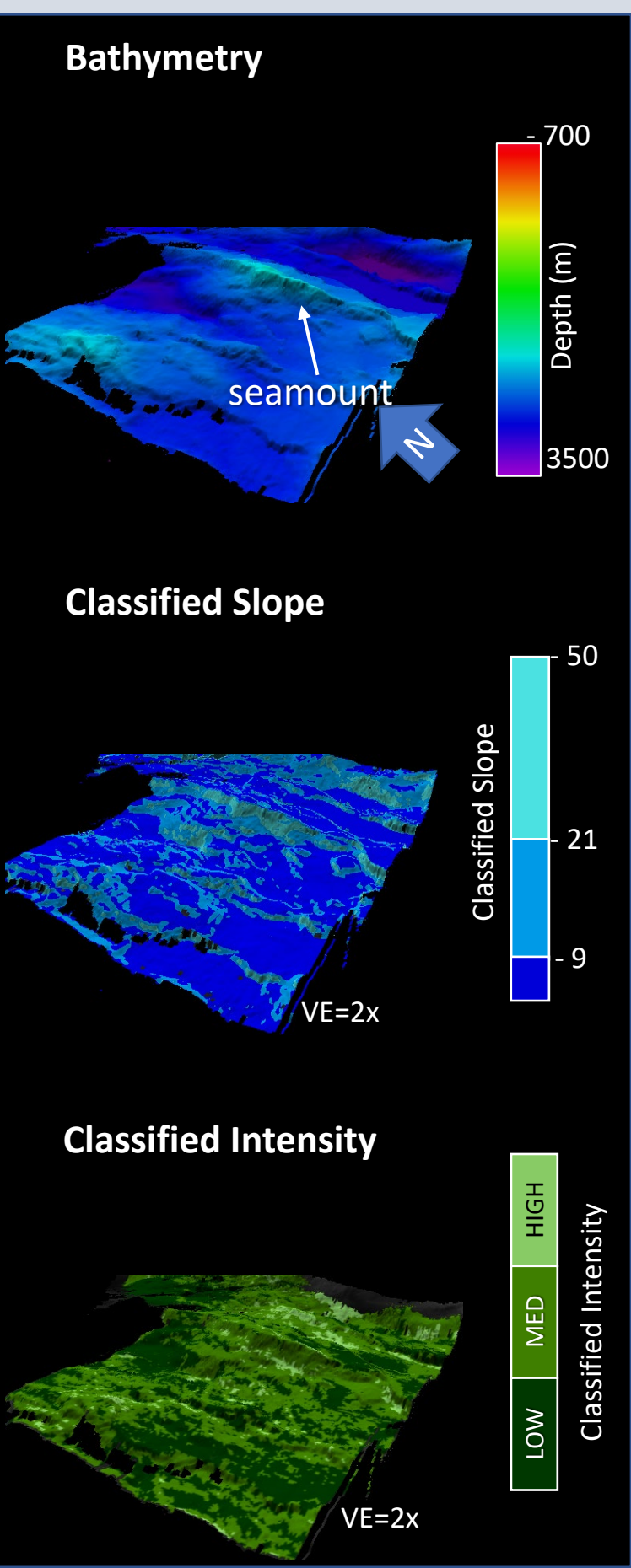
Figure 2. North Ridge



On EX2205-Dive 04 the ROV explored an elongated volcano, along a volcanic ridge formed from magma pushing up from the earth's mantle.

Several sublinear sets of holes in the seafloor sediment were found at a depth of 2,540 m (below). The origin of the holes remains unknown but scientists have concluded they are a type of lebensspuren (translates to 'life traces').

EX2205-Dive09 4 more sets of holes were found ranging in depth from 1,440 to 1500 m. Dive 9 of Cachalote Guyot took place west of the Azores of Portugal.



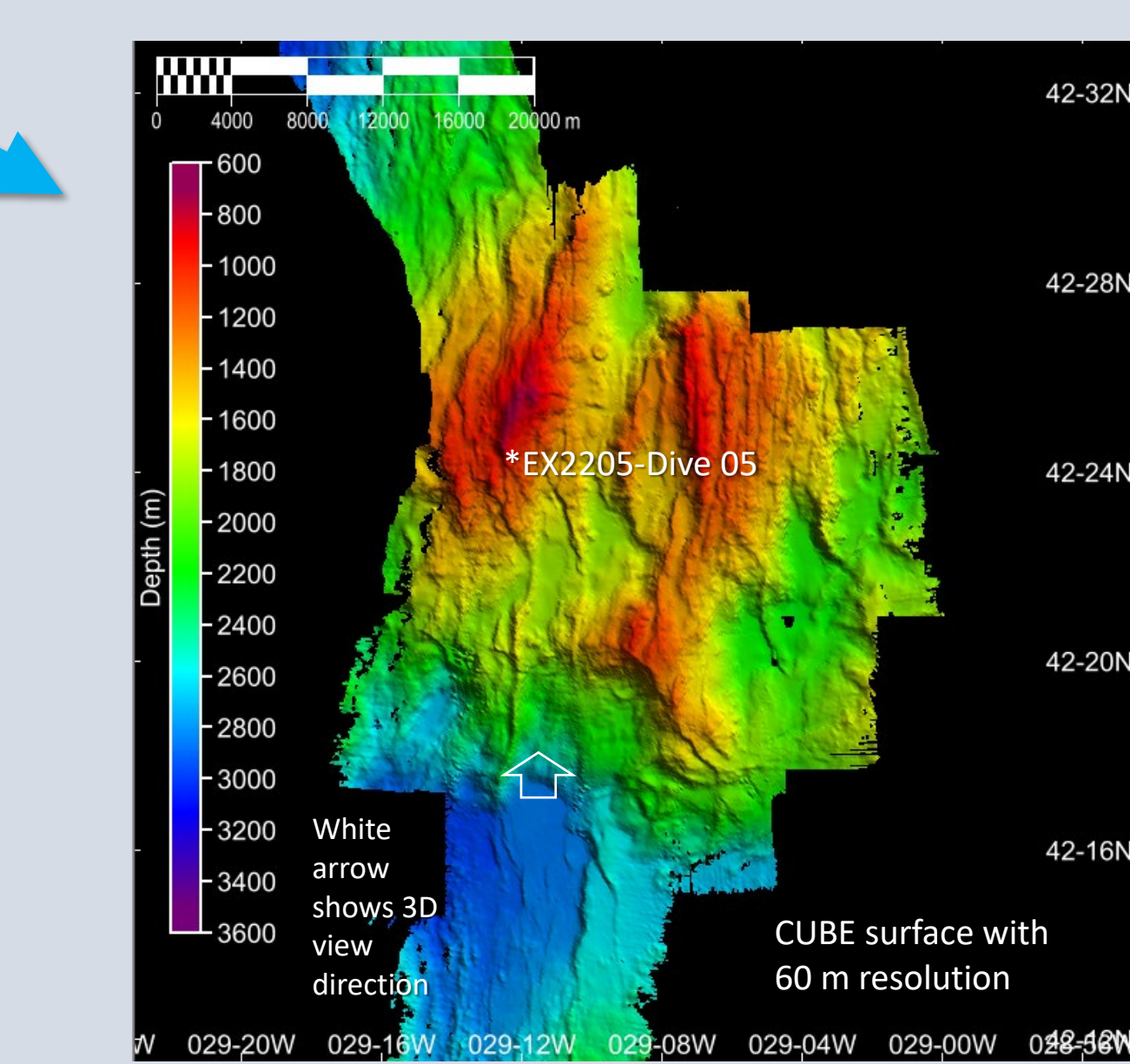
North Ridge has a depth range of 3500 to 1600 m. The site has an unnamed seamount, with a peak at ~ 2600 m. The ROV Deep Discoverer explored this seamount during EX2205-Dive04.

The seamount's peak has higher slopes, with a maximum of 30.9° (light blue). Low slope areas range 1 to 6°.

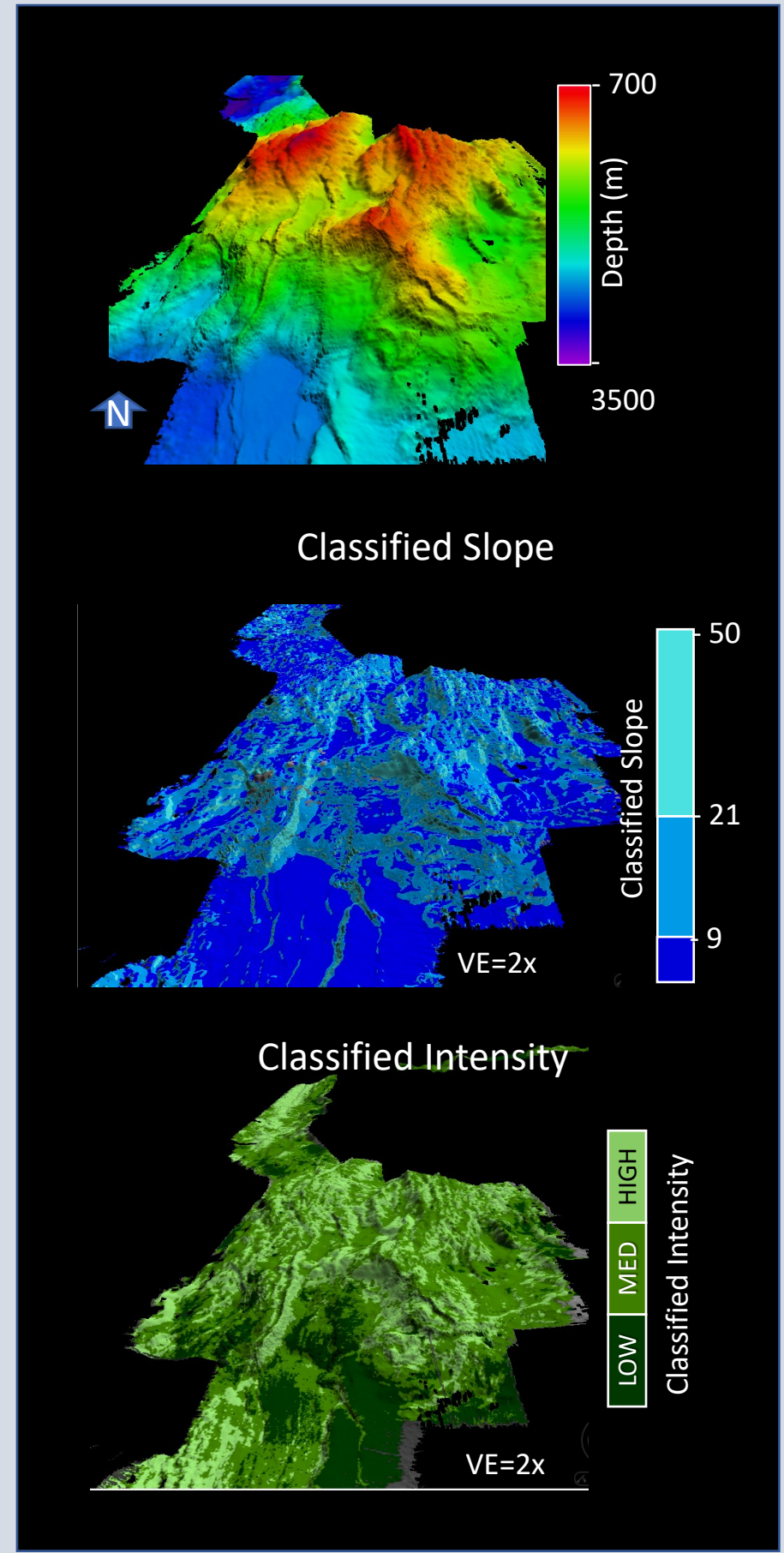
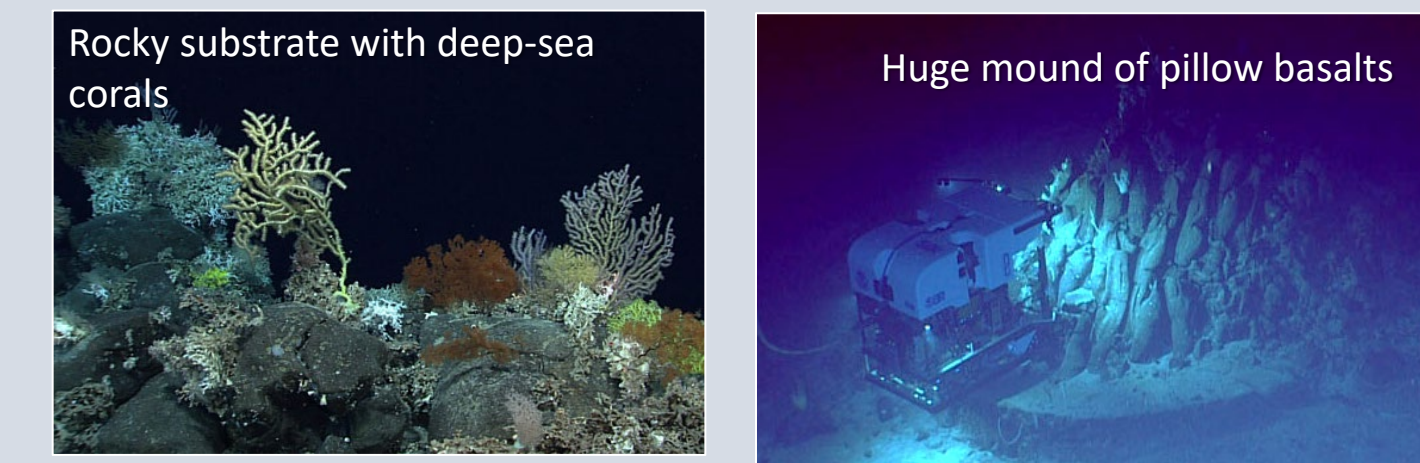
Between the seamount's volcanic peaks there is a lower intensity backscatter.

Sediments recovered on the ROV dive had abundant pteropod shells, some of which were encrusted with black mineral. Unconsolidated sediments scatter and absorb sound waves, causing a low backscatter intensity.

Figure 4. Zenith Seamount



Throughout EX2205-Dive05 the seafloor substrate observed was rocky with a variety of corals (below, left). Nutrient-rich water makes a good environment for deep-sea organisms.



Zenith has a depth ranging 600 to 3000 m and has two peaks with depths at 600 and 1000 m. The linear features on the seamount are axis-parallel ridges, from new sea floor being creating pushing the older one back.

The high slope areas on Zenith have a slope ranging from 19.0 to 42.6°. The east ridge has the greatest slope 42.6°.

Higher backscatter rates occurs on areas of higher slope. (slope between 21 and 50°). The crest of Zenith has high backscatter and moving along to the bottom of the seamount the rate of backscatter lessens.

(left) Pillow basalts, formed from lava cooling rapidly in the cold seawater, were observed in huge mounded features .

DISCUSSION

Comparing axial valleys of North, Central and South Sites allows us to understand the geomorphology along a portion of the Mid-Atlantic Ridge. These sites are less than 1 my old and lie along the ridge axis, where spreading is taking place at a rate of 20-50 mm/yr (Mueller, 2008). The MAR is a slow-spreading ridge, characterized by having steeper walls between abyssal hills, or axis-parallel ridges (APRs) (Mitchell, 2019). The difference in morphology is reflected in the ruggedness of the flanks of these APRs. Zenith Seamount is located ~ 20 km to the east of the MAR axis. The west ridge of Zenith is ~1.0 my old, whereas the seamount's older east ridge is 1.6 my old, as it is farther from the MAR axis (Mueller, 2008). The three sites on Zenith Seamount appear to share similar properties as determined using the bathymetric and backscatter surfaces computed and imaged during EX2205-Dive05. Dive 5 explored a depth of 900 m on the seamount's west crest where the slope ranged from 23 to 42°, and backscatter intensity was high, suggesting more rock exposure. Deep-sea corals were found living on the exposed pillow basalts, and hydrothermal vents are common on the seamount. In these areas ROV video revealed sponges, worms, sea cucumbers and other small benthic organisms. ROV dives show life in areas of high slope (between 21 and 50°) and areas of high backscatter and rock exposure. The boxes (right) indicate other areas on Zenith where deep-sea corals and diverse biological life might occur, identifying areas that would be potential locations for future dives. These sites have a slope greater than 30° and high intensity backscatter. Although no dives were conducted on the south ridge, the sites identified have similar slopes and backscatter intensities. Identifying deep-sea coral locations is important because corals offer habitat for other benthic organisms that live within deep-sea coral communities.

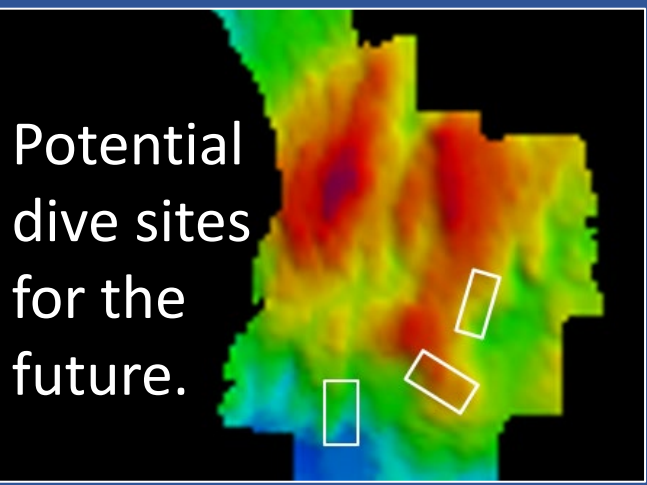


Figure 3. Central Ridge

The Central Ridge has a deep axis valley ranges from depths of 3600 to 1500m. The depths ranging from 3000 to 3600 m are part of MAR.

The highest slopes (30.1°) are found along the same areas as the high intensity (light green areas). Central Ridge overall has areas with smaller value slopes. Lower slopes (9-0°) occur along deeper sections of the site. High intensity areas occurs at areas of depths between 2600 and 3500 m. Lower intensity areas are older sections of the MAR which are now part of the median valley.

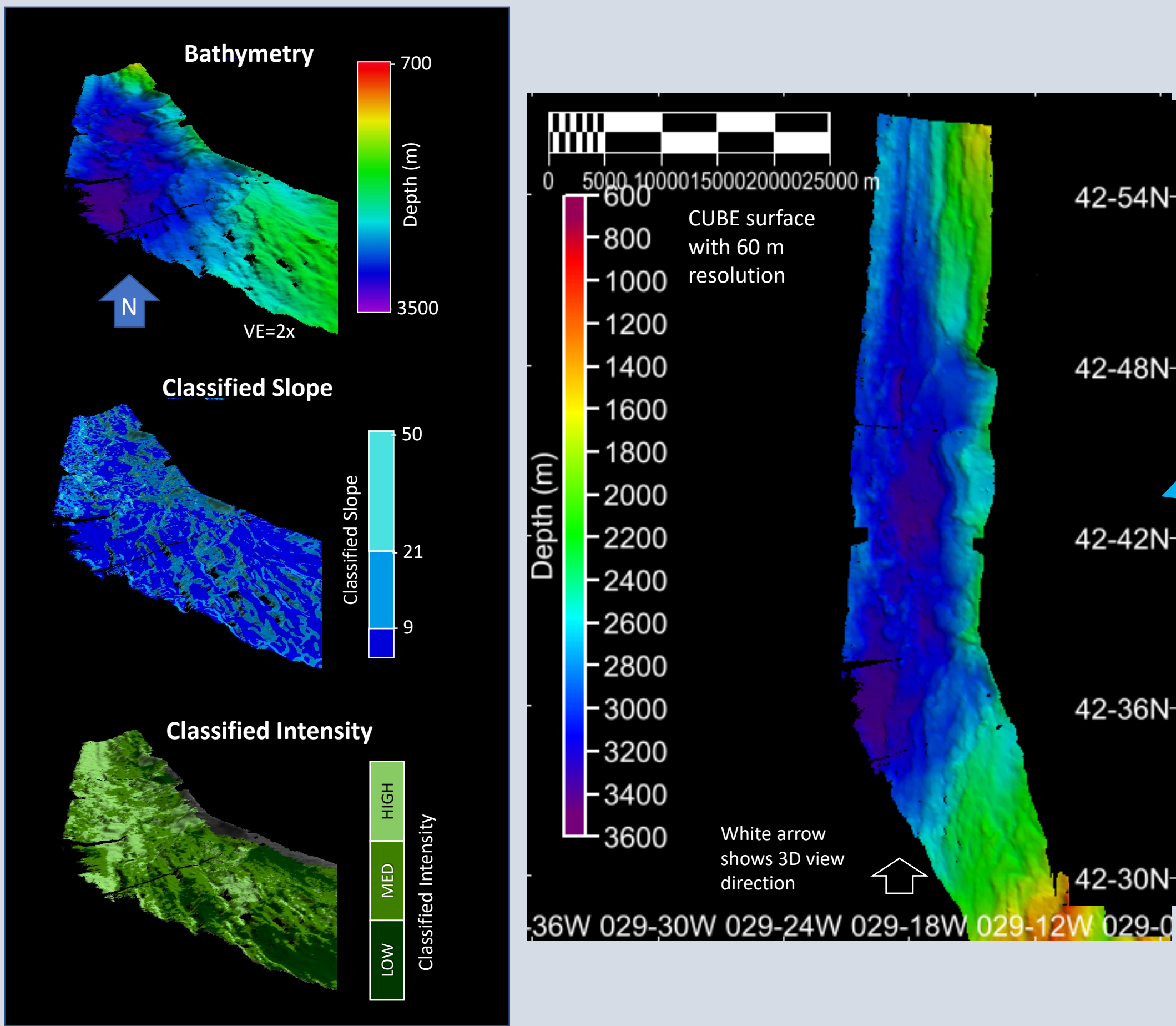


Figure 5. South Ridge

South Ridge depth ranges from 1400 to 3200 m. Portions of two seamounts are shown. The south section of the ridge is a series of axis-parallel faults. The deepest sections (represented by dark blue) are part of MAR axis.

The highest slope value is 56.1°. The axis parallels on the southern point of South Ridge have slopes ranging from 14 to 30°.

South Ridge has a high intensity backscatter. An axis parallel fault is formed, the two oceanic crust are diverging apart, as magma pushing up, forming basalt rock. South site has the largest area of high intensity (area with the most exposed rock).

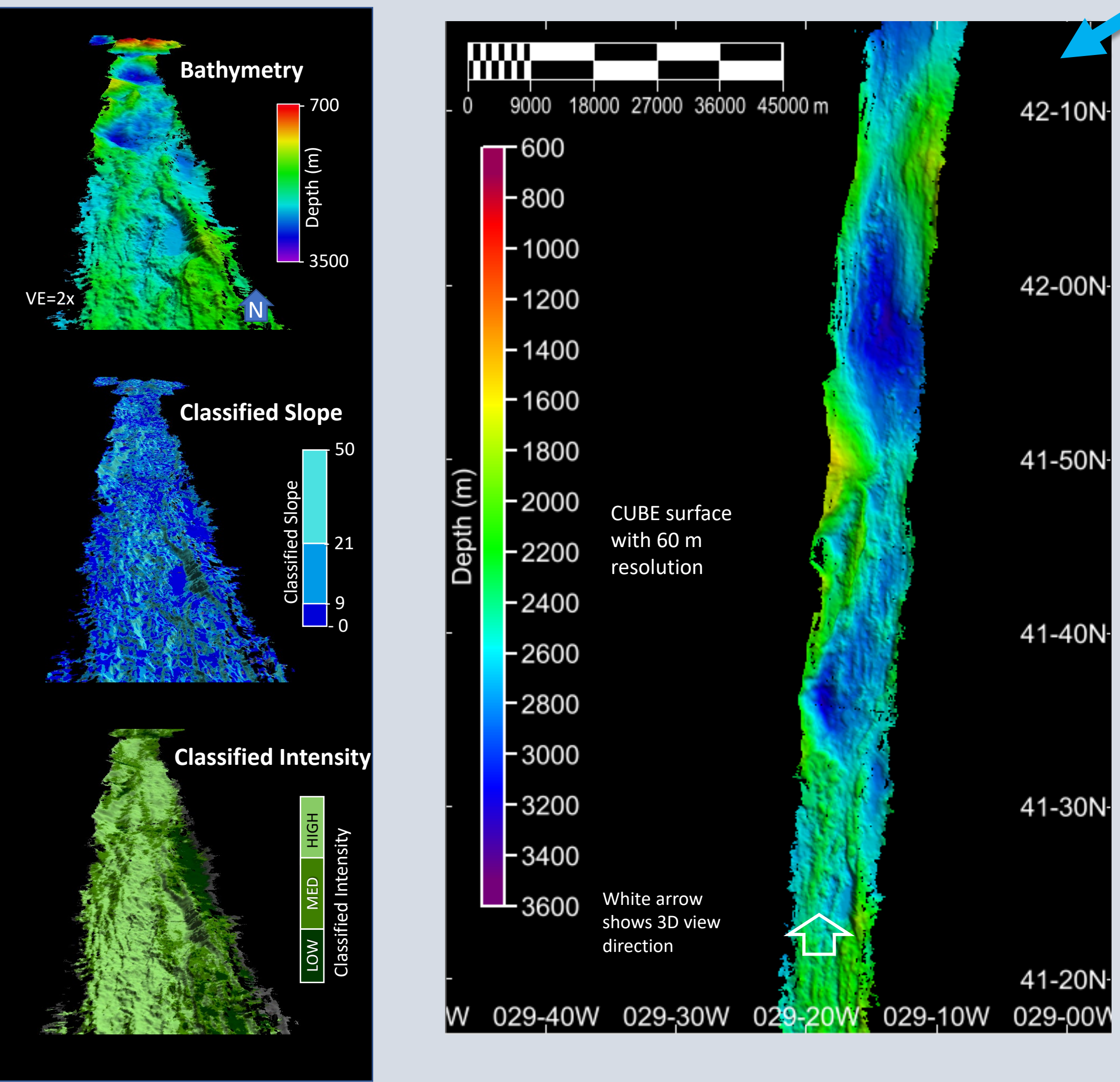
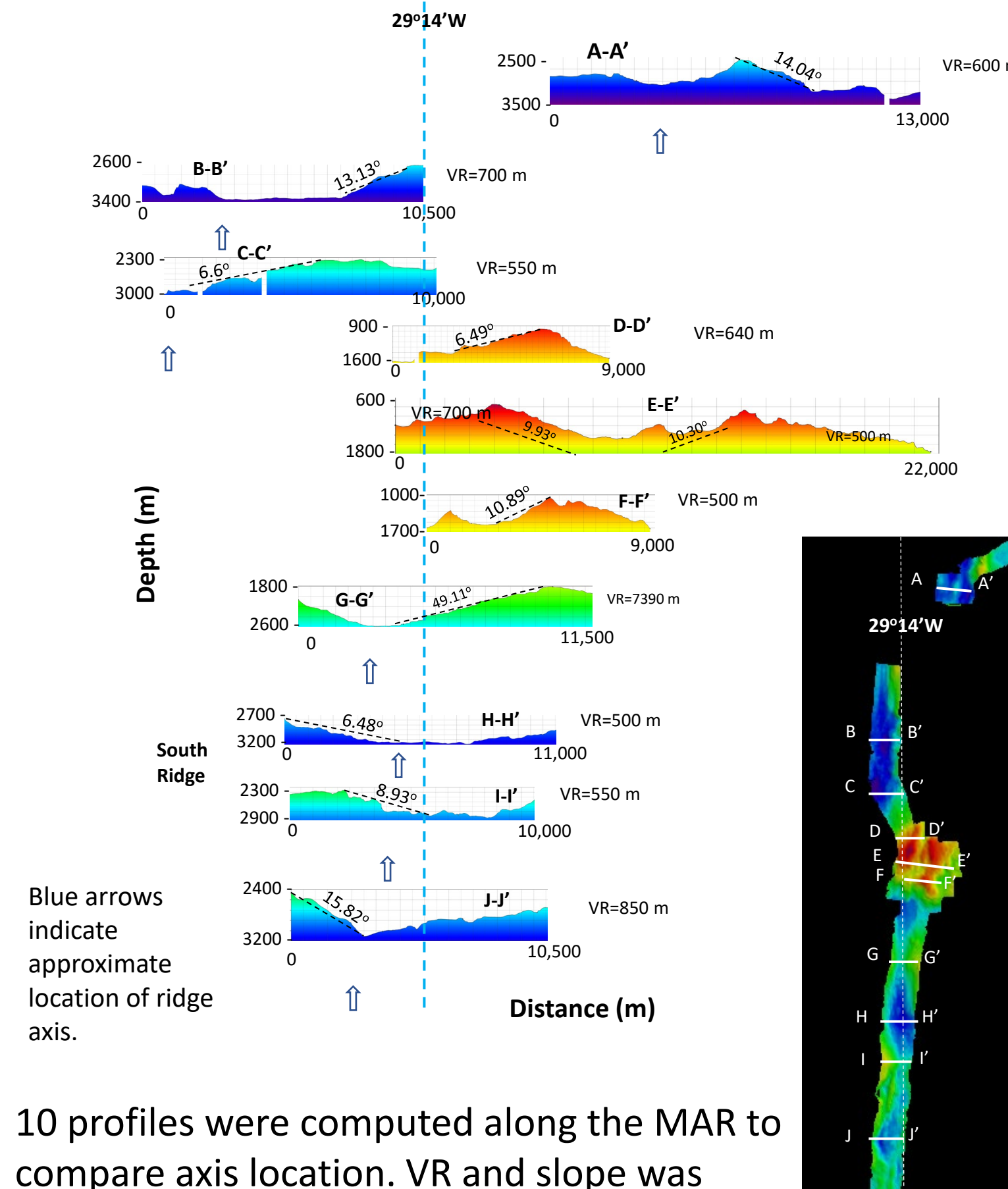


Figure 6. Comparative Profiles



10 profiles were computed along the MAR to compare axis location. VR and slope was calculated to compare geomorphology. Throughout the sites VR ranges from 500 to 850 m, and slopes ranges 6.48 to 49.11°. Zenith Seamount has the greatest VR (700m) and slope range of 6.49 to 10.89°. The east peak, father away from the MAR axis has a smaller VR (500 m) but greater slope compared to the west peak. West peak has a VR of 700 m and a less steep slope at 9.93°.

Abyssal hills, or axis-parallel ridges are part of the median valley. The location of the highest slope is south of Zenith on the G-G' profile. The high slope is 49.11°

ACKNOWLEDGEMENTS

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