Geomorphologic Characterization of the Charlie-Gibbs Fracture Zone, Mid-Atlantic Ridge

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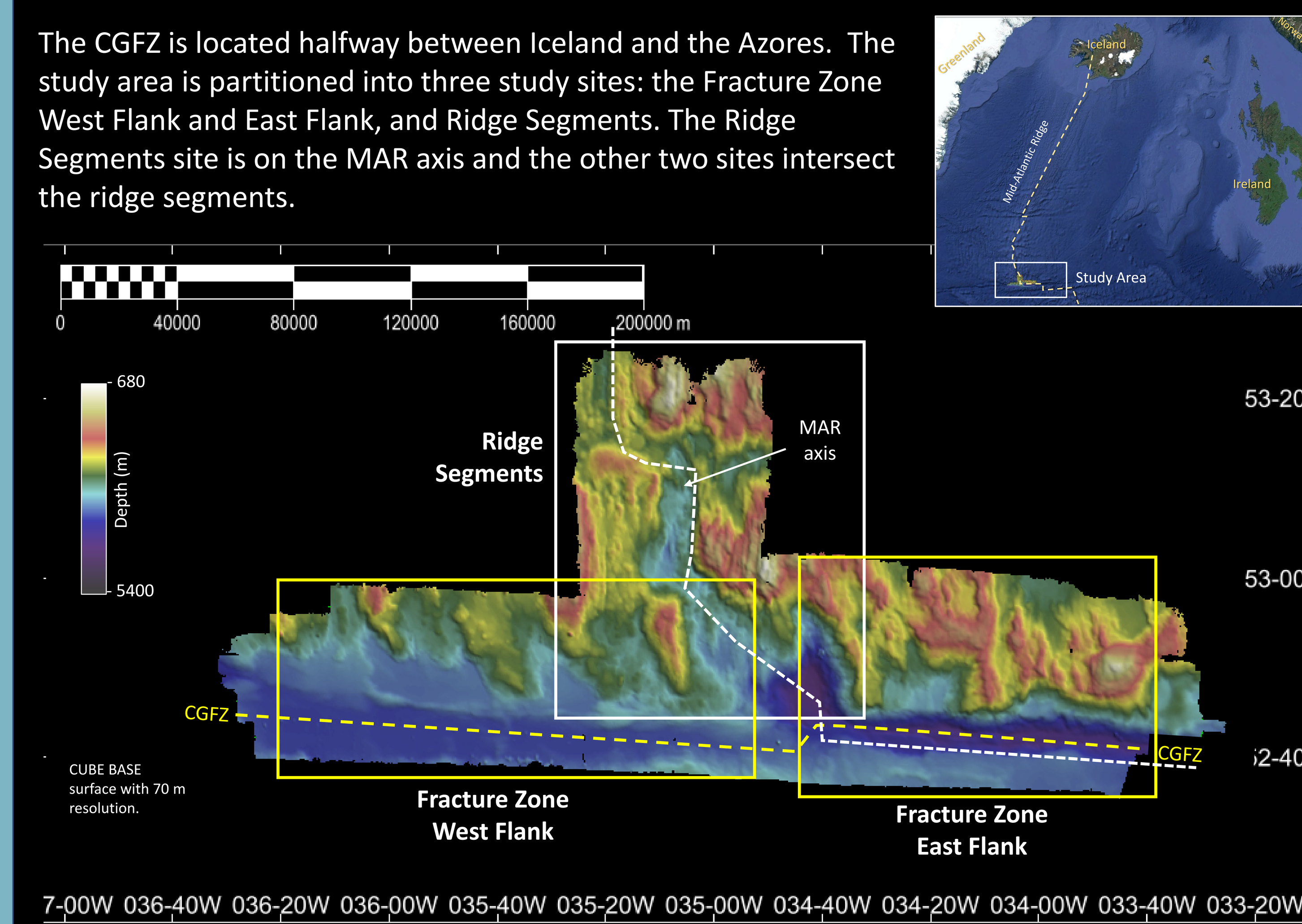
BACKGROUND

From May 11- June 7, the NOAA Ship *Okeanos Explorer* collected acoustic data of the seafloor and sub-seafloor geomorphology of the Charlie-Gibbs Fracture Zone (CGFZ) which lies approximately halfway between Iceland and the Azores, west of Portugal. Geologically, the fracture zone consists of two parallel transform faults, 'Charlie' and 'Gibbs', and is currently recognized as the largest geological fault on the northern Mid-Atlantic Ridge (MAR). The fracture intersects the MAR on an east-west orientation for 2000 km, with two parallel valleys and ridges. Notably, the CGFZ represents the sole deep-water and faunal exchange in the middle of the northeast and northwest Atlantic (Charlie-Gibbs Marine Protected Area). The area is located at the convergence of warm, nutrient-poor water from the south and cold, nutrient-rich water from the north. This convergence strengthens the area's biological productivity, biomass, and species pool. Seafloor abyssal hills, here referred to as an axial-parallel ridges (APRs), are the result of volcanism and block faulting (Olive et al., 2015). Axial valleys form where faulting is most centralized (Buck et al., 1998). Profiles of each locality were created to analyze any differences in geomorphological features among site locations.

The primary objective of this expedition was to ameliorate knowledge of the Charlie-Gibbs Fracture Zone, with the goal of better informing habitat and resource management, better understanding potential future geohazards, and further exploring biogeographic patterns of deep-sea ecosystems (NOAA Ocean Exploration, 2022). Prior to this expedition, the CGFZ had not been mapped in high resolution. Doing so leads to better geomorphologic characterization of the MAR and tectonic features.

Figure 1. Charlie-Gibbs Fracture Zone Study Area and Site Locations

The CGFZ is located halfway between Iceland and the Azores. The study area is partitioned into three study sites: the Fracture Zone West Flank and East Flank, and Ridge Segments. The Ridge Segments site is on the MAR axis and the other two sites intersect the ridge segments.



NOAA Ship *Okeanos Explorer*

METHODS

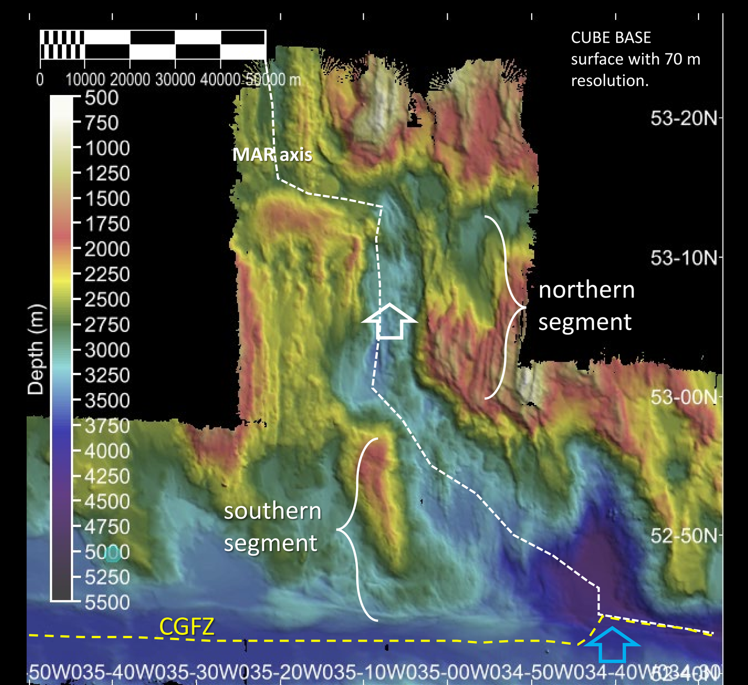
- Raw multibeam sonar data were collected aboard the NOAA Ship *Okeanos Explorer* using a Kongsberg EM304 multibeam echo sounder.
- Acquired data were processed using CARIS HIPS and SIPS 11.4.
- 2D and 3D bathymetry, classified slope, and classified backscatter intensity mosaics were constructed with a 70 m resolution.
- Profiles of each site location were constructed to compare the vertical relief as well as geomorphological features throughout the study area.

Figure 2. Ridge Segments

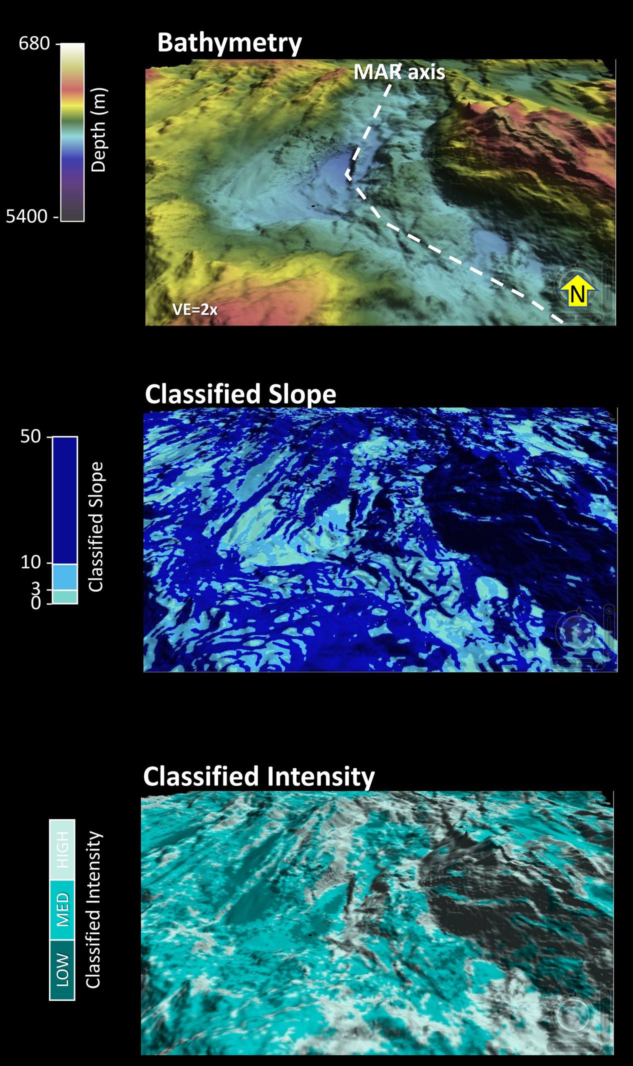
The Ridge Segment study site is on the northern side of the Charlie-Gibbs Fracture Zone. The depth range is between 680 and 5400 m, with the deepest area occurring within the MAR axial valley' southern portion adjacent to the CGFZ.

The northern segment ranges in depth from 1500 to 3250 m, whereas the southern segment ranges 1500 to 5400 m. The axial valley's deepest portion for the northern and southern segments are at 3500 m and 5400 m, respectively.

The white arrow on the 2D surface (at right) shows the viewpoint for the northern segment's 3D images, shown below. The blue arrow shows the southern segment view.



Northern Segment



Valley walls of the southern segment are significantly steeper than those of the northern segment, with a greater vertical relief of 2324 m, compared to 2123 m. The southern segment also features the deeper axial valley.

The slope range is 0 to 50º, with maximum slopes found primarily on the axis valley walls. In contrast, the seafloor in the axis valley is nearly flat with a slope <10º.

Classified intensity shows that higher intensity areas are concentrated on the valley wall crests.

Southern Segment

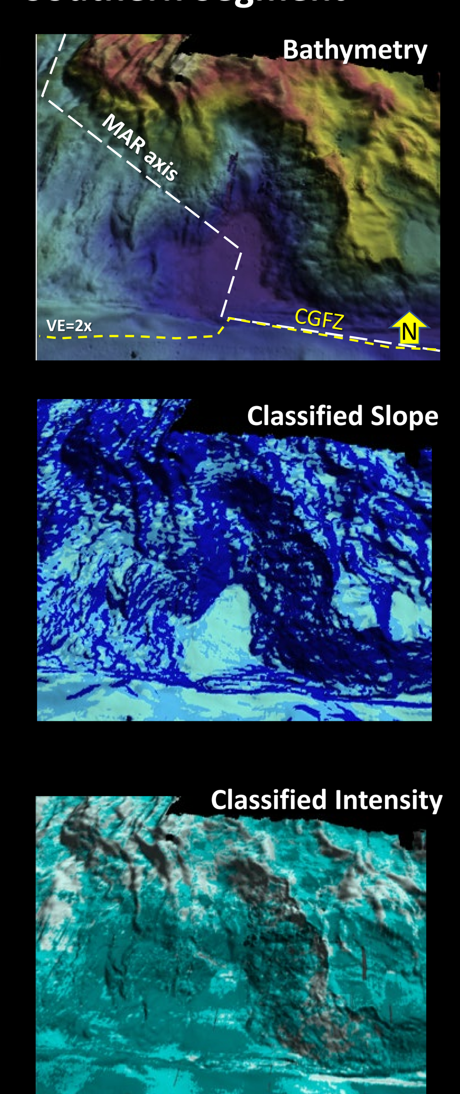
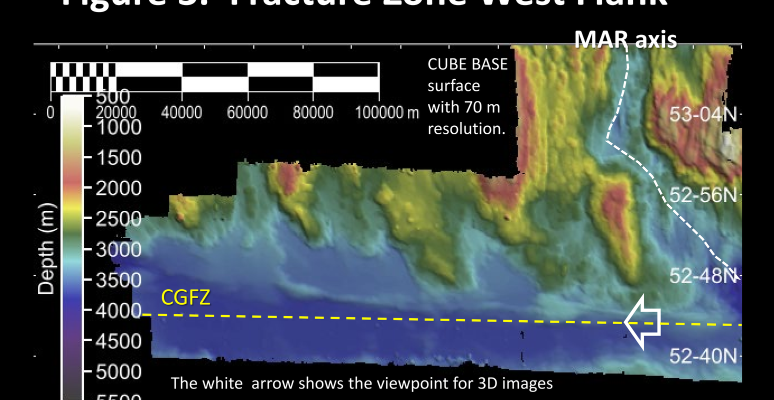
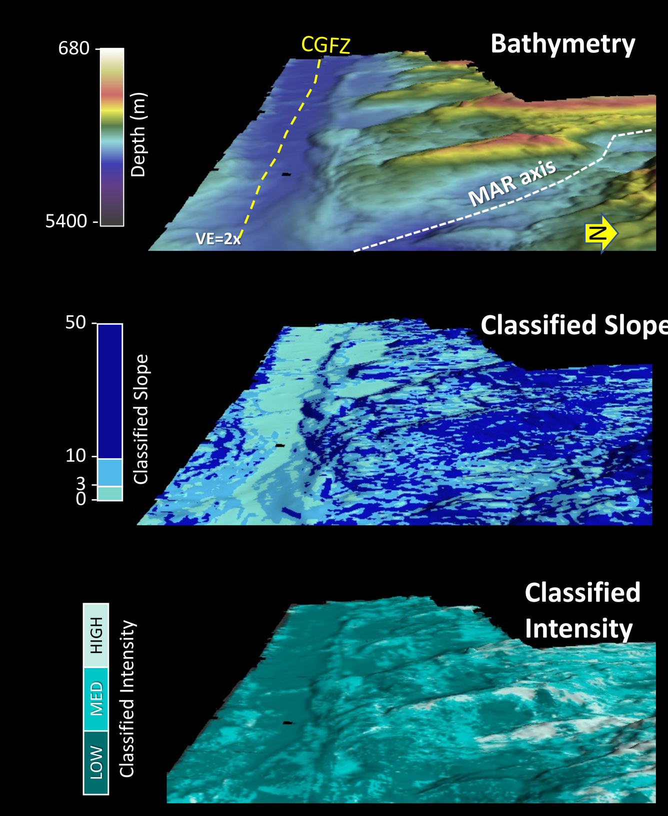


Figure 3. Fracture Zone West Flank



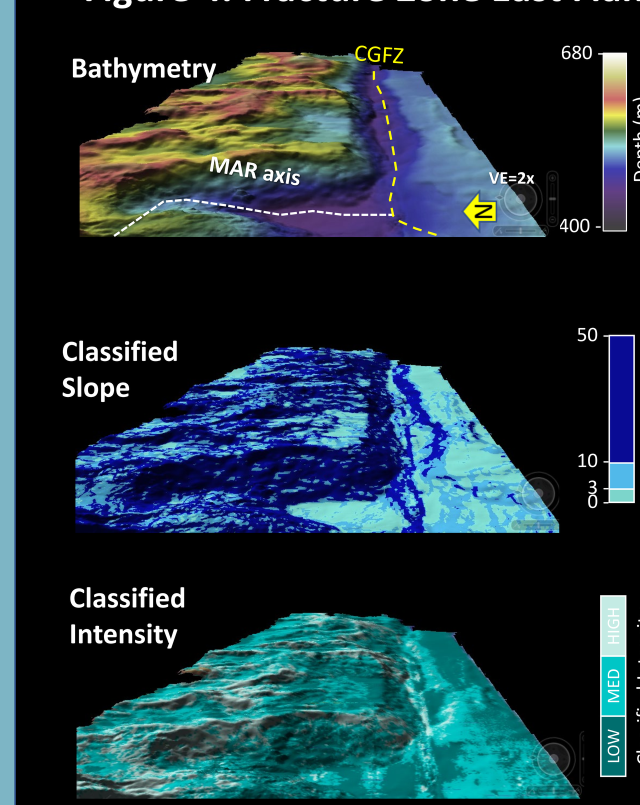


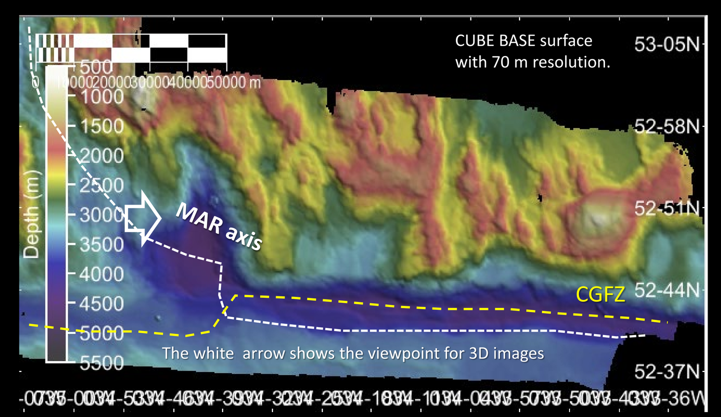
West Flank has less variation than the East Flank with regard to depth range and geomorphological features. The depth range is between 680 and 4000 m. Axis-parallel ridges are present across the West Flank, ending at the fracture zone.

Slope ranges 0 to 50º, with low slope areas concentrated towards the fracture zone and APRs ranging >10º.

Higher backscatter intensity areas are concentrated on the axis-parallel ridges, whereas low intensity occurs towards the fracture zone.

Figure 4. Fracture Zone East Flank



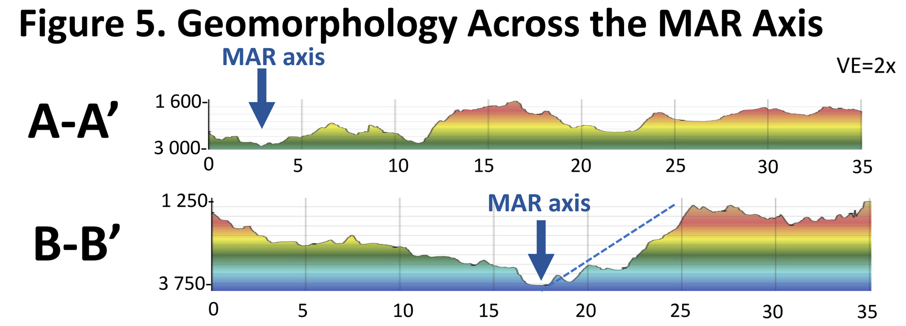


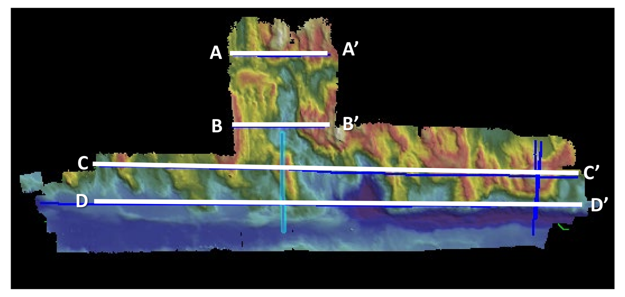
East Flank also has axis-parallel ridge features and the Charlie-Gibbs fracture zone. Here the depth range is greater (1000 to 5400 m), with the shoalest point occurring on a peak within the sites most eastward APR.

The slope range of the East Flank is comparable to that of the West Flank, though more of the APRs have steep slopes.

Higher intensity areas are concentrated on the axis-parallel ridge crests, with more moderate intensity seen across the area.

Figure 5. Geomorphology Across the MAR Axis





Profiles A-A' through D-D' are drawn across the MAR axis, north of the CGFZ and show an eastward shift of the axis (blue arrows on profiles). The axis depth increase southward from 2 800 to 4500 m. C-C' is drawn across APRs with vertical reliefs as great as 2500 m, and D-D' crosses the deeper south ends of APRS, where they meet the CGFZ.

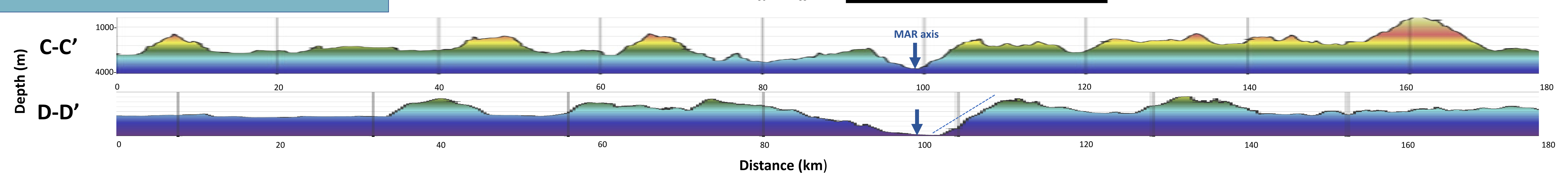
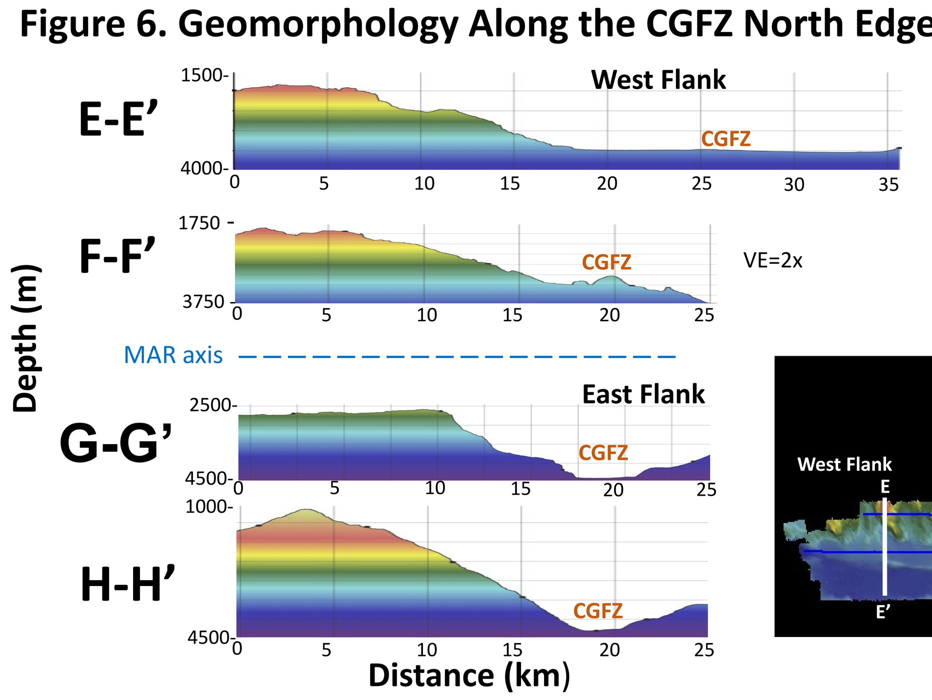
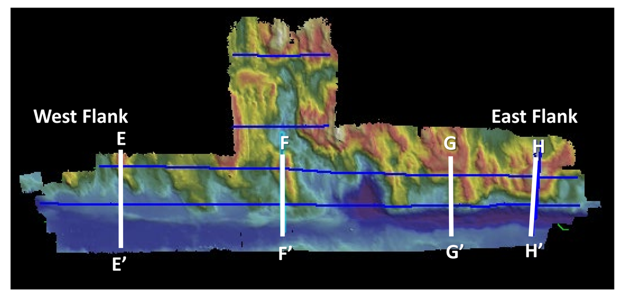


Figure 6. Geomorphology Along the CGFZ North Edge



Shown at the same scale as Fig. 5 profiles, variation in geomorphology along the north edge of the CGFZ is illustrated by profiles E-E' through H-H'. Maximum depth of the CGFZ at E-E', F-F', G-G', and H-H' is 3765, 3705, 4390, and 4296 m, respectively.



DISCUSSION and SUMMARY

Geomorphologic features of the Charlie-Gibbs Fracture Zone include axis-parallel ridges (APRs), axial valleys, and other volcanic features which are the result of volcanism, block faulting, rifting and spreading (Smoot et al., 1985). This area has not been explored in detail prior to the 2022 NOAA expedition. The area's geomorphology varies both across the Mid-Atlantic Ridge axis (Fig. 5) and across the north edge of the CGFZ (Fig. 6.).

The MAR axis north of the fracture zone has two ridge segments, both of which display APRs east and west of the MAR axis. The southern segment has a greater vertical relief (2324 m) and greater axial valley depth (5400 m).

Both the West Flank and East Flank fracture zone sites have axis-parallel ridges that terminate to the south at the CGFZ, however vertical relief (VR) and slope characteristics of each flank vary. East Flank APRs have greater VR compared to those of the West Flank (4400 m and 3320 m, respectively), and steeper slopes. East Flank APRs are larger and steeper, and include an isolated seamount peak with VR of 1500 m.

Potential future areas of interest for ROV dive exploration include the axial valley of the southern ridge segment, the East Flank's' isolated peak, and the volcanic features found in the northern ridge segment.

ACKNOWLEDGEMENTS

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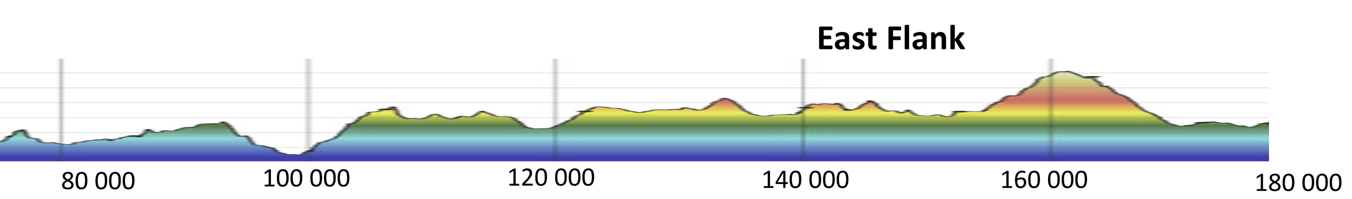
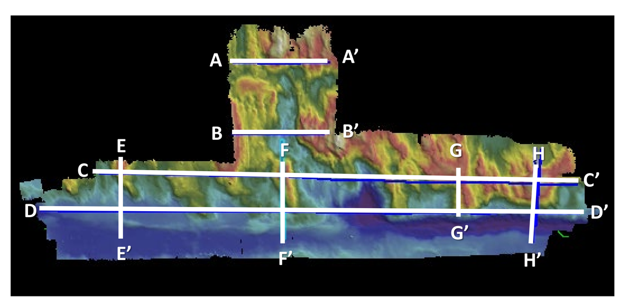


Figure 6. Comparative profiles (?)

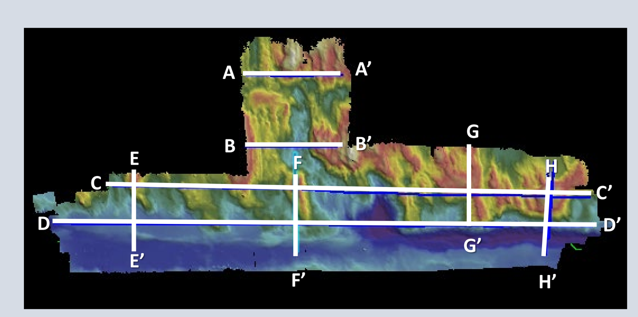


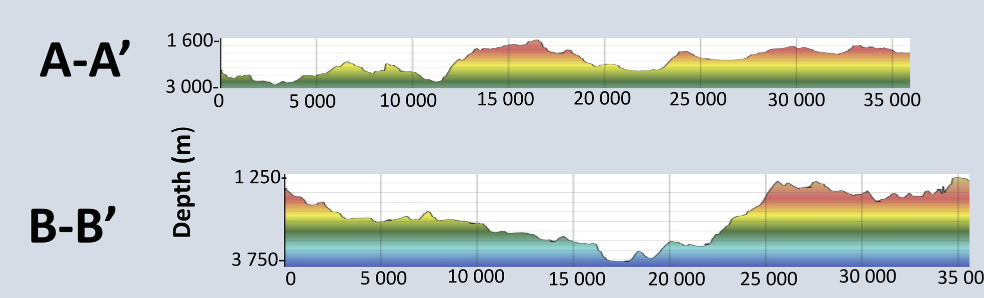
VE = 2x

Distance (km)

Distanc

Figure 6. Comparative profiles (?)





Locations of profiles drawn across the Charlie-Gibbs Fracture Zone. Profile sites were chosen to include either side of the Mid-Atlantic Ridge Axis, as well as intersecting any remarkable features.