Comparison of Ridge Scarp Edge Geomorphology and Associated Benthic Habitats on the Southeast U.S. Continental Margin

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ABSTRACT

As part of the East Coast Mapping Expedition (EX1403) in 2014 and the *Windows to the Deep* expeditions in 2018 and 2019 (EX1805, EX1806 and EX1903), scientists from NOAA's Office of Ocean Exploration Research (OER) aboard the NOAA Ship *Okeanos Explorer* mapped portions of the Blake Plateau on the southeast U.S. continental margin using multibeam sonar data. During expeditions EX1806 and EX1903, the ROV *Deep Discoverer* (D2) conducted multiple dives on the edges of at least seven ridge scarps and collected high definition video of deep-sea coral habitat. A recent study classified deep-sea coral mounds from this area into distinct morphological categories. This study focuses on the geomorphologic features referred to as ridge scarp mounds and examines them as potentially favorable habitat for benthic communities, including deep-sea corals. Ridge scarp edges were examined on the Stetson Mesa, a feature located on the western Blake Plateau with depths ranging from 600 to 900 m. Situated under the Gulf Stream, water temperature, current velocity, and nutrient abundance are high in this area. High resolution bathymetry and subsequent exploration of these areas has revealed hundreds of mound features, suggesting that these mounds may well host significant deep-sea coral populations. Ridge scarp mound features within the Stetson Mesa were studied to understand relationships between geomorphology and associated biota. Findings were compared to ridge scarp edges in the Central Plateau and the Richardson Hills region of the Blake Plateau, both of which are located northeast of the mesa with depths ranging from 700 to 900 m. Footage from ROV dives was used to compare resident biota in each of the three study sites. Results from this study indicate that ridge scarp mound morphology near scarp edges appears to be a result of dead coral rubble over which live coral has grown. Rather than the traditional markers of high slope and high intensity backscatter, bathymetric data should be used to identify ridge scarp mound features and locate deep-sea coral populations. Recognizing types of morphological features that promote deep-sea coral growth is critical to assessing potential distribution of organisms on the Blake Plateau as well as managing and protecting their essential habitats.

METHODS

- Multibeam sonar data were collected during May 2014 on EX1403, June 2018 on EX1806 and June 2019 on EX1903 by NOAA Ship *Okeanos Explorer*, using a Kongsberg EM302.
- Survey areas from EX1403, EX1806 and EX1903 included the Stetson Mesa, Richardson Hills, and Central Plateau regions, respectively.
- CARIS HIPS and SIPS 11.2 was used to generate high resolution bathymetric (CUBE), classified backscatter intensity and classified slope surfaces at 20 to 40 m resolutions.
- 3D images and bathymetric profiles were generated for all four sites.
- Intensity and slope data were collected at random points along profiles within each study area to understand the relationship between slope and intensity.
- High definition videos from the ROV *Deep Discoverer* were used to compare resident biota among study sites.

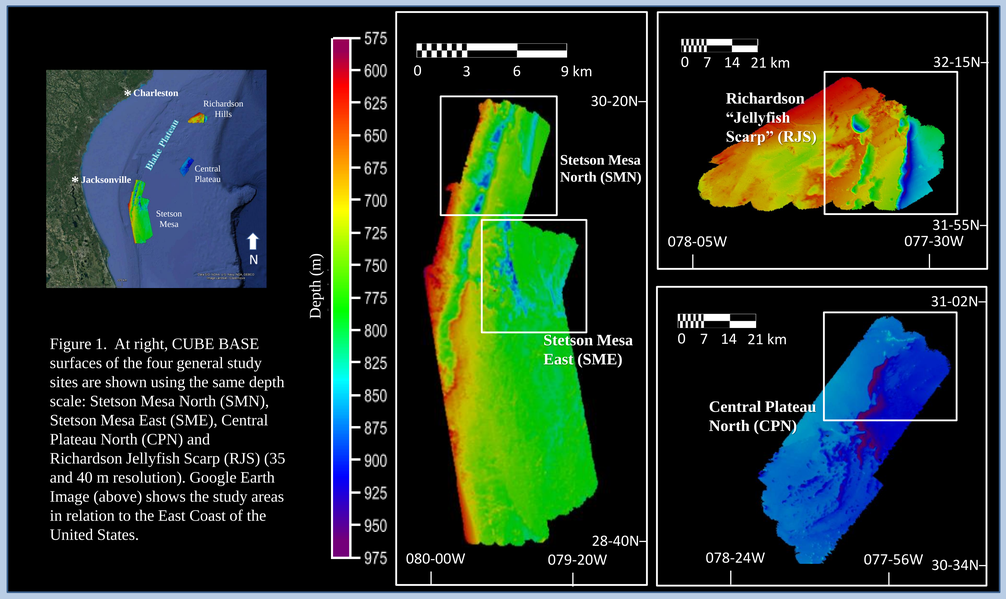

Figure 1. At right, CUBE BASE surfaces of the four general study sites are shown using the same depth scale: Stetson Mesa North (SMN), Stetson Mesa East (SME), Central Plateau North (CPN) and Richardson Jellyfish Scarp (RJS) (35 and 40 m resolution). Google Earth Image (above) shows the study areas in relation to the East Coast of the United States.

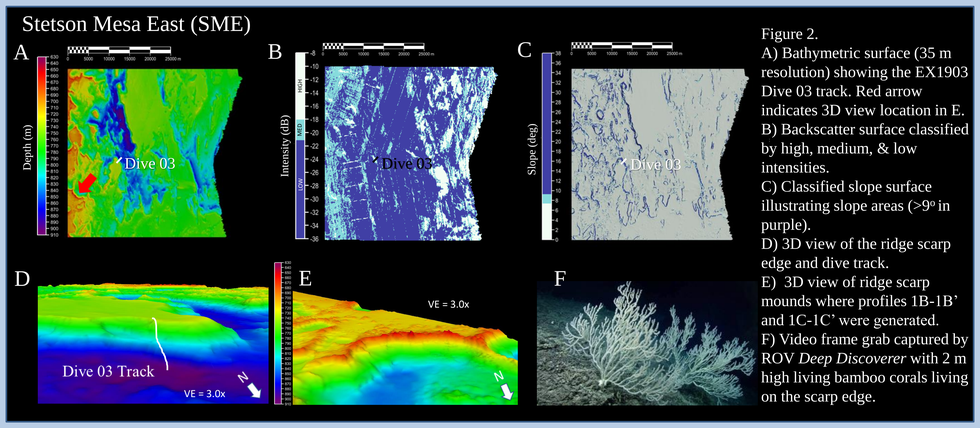

Figure 2.
A) Bathymetric surface (35 m resolution) showing the EX1903 Dive 03 track. Red arrow indicates 3D view location in E.
B) Backscatter surface classified by high, medium, & low intensities.
C) Classified slope surface illustrating slope areas (>9° in purple).
D) 3D view of the ridge scarp edge and dive track.
E) 3D view of ridge scarp mounds where profiles 1B-1B' and 1C-1C' were generated.
F) Video frame grab captured by ROV *Deep Discoverer* with 2 m high living bamboo corals living on the scarp edge.

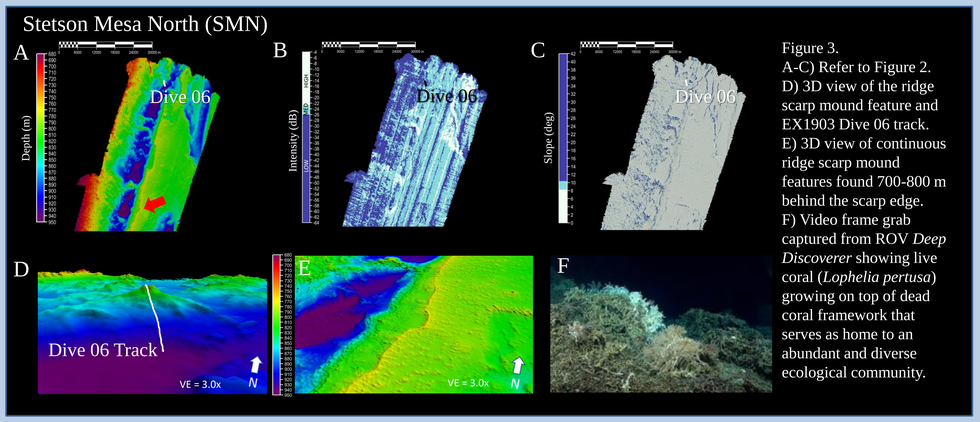

Figure 3.
A-C) Refer to Figure 2.
D) 3D view of the ridge scarp mound feature and EX1903 Dive 06 track.
E) 3D view of continuous ridge scarp mound features found 700-800 m behind the scarp edge.
F) Video frame grab captured from ROV *Deep Discoverer* showing live coral (*Lophelia pertusa*) growing on top of dead coral framework that serves as home to an abundant and diverse ecological community.

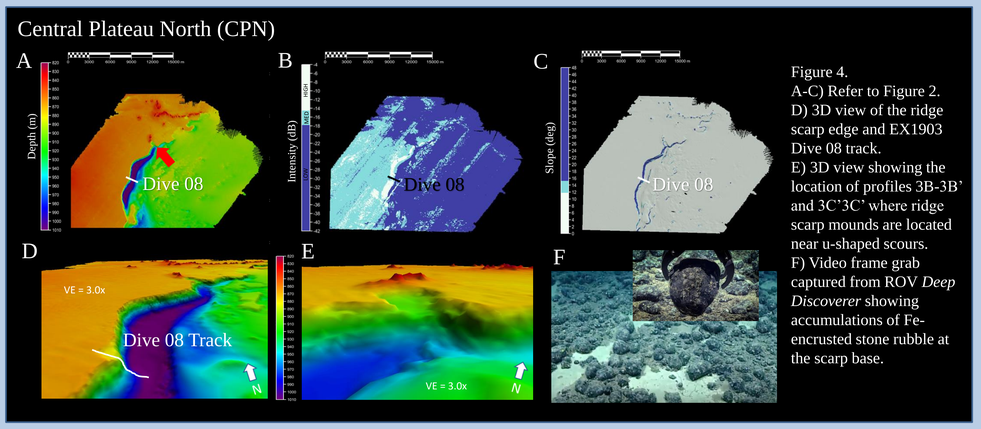

Figure 4.
A-C) Refer to Figure 2.
D) 3D view of the ridge scarp edge and EX1903 Dive 08 track.
E) 3D view showing the location of profiles 3B-3B' and 3C'3C' where ridge scarp mounds are located near u-shaped scours.
F) Video frame grab captured from ROV *Deep Discoverer* showing accumulations of Fe-encrusted stone rubble at the scarp base.

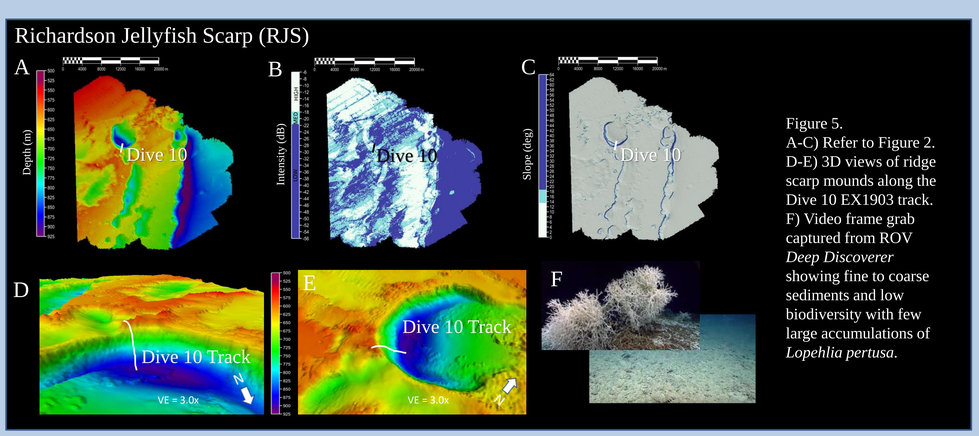

Figure 5.
A-C) Refer to Figure 2.
D-E) 3D views of ridge scarp mounds along the Dive 10 EX1903 track.
F) Video frame grab captured from ROV *Deep Discoverer* showing fine to coarse sediments and low biodiversity with few large accumulations of *Lopehlia pertusa*.

BACKGROUND

In an effort to prioritize scientific studies, support resource management decisions and understand the diversity and distribution of benthic habitats, expeditions aboard the NOAA Ship *Okeanos Explorer* collected critical information regarding the poorly understood deep water areas of the Southeastern continental margin during the summers of 2014, 2018 and 2019 (NOAA OER 2019). During expedition cruises EX1403, EX1805, EX1806 and EX1903 multibeam sonar data were used to map areas of the Blake Plateau, a broad, flat region with 500 m average depth extending 145 km east of the southeastern United States' coast (Dillon, 1988). NOAA's ROV *Deep Discoverer* was used for high-resolution visual surveying and biologic and geologic sampling to investigate coral Habitat Areas of Particular Concern by the South Atlantic Fisheries Management Council (SAFMC) (NOAA OER, 2014). This study concentrates on several areas within the Blake Plateau, including the Stetson Mesa (Fig. 1). Stetson Mesa, a broad feature located approximately 184 km east of and parallel to Florida's coastline lies directly beneath the Gulf Stream and is known for containing countless numbers of coral mounds. The mesa has been designated as a Marine Protected Area (MPA) by the SAFMC because of its potential deep-sea coral habitat (NOAA OER, 2018). The mesa's proximity to the Gulf Stream's high velocity flow provides abundant food suitable for deep coral growth and subsequent bioherm, or mound development. A recent study by Horn and Sautter (2019) classified deep-sea coral mounds from this area into three distinct morphological categories: ridge scarp mounds, connected mounds and individual mounds. The purpose of this study is to determine characteristics of ridge scarp mounds that make for a favorable deep-sea coral habitat through comparison amongst sites throughout the Blake Plateau. Two sites within the Stetson Mesa, here referred to as Stetson Mesa East (SME) and Stetson Mesa North (SMN) (Fig. 1), were chosen to examine ridge scarp mounds. NOAA OER EX1903 Dive 03 and EX1806 Dive 06 on the Stetson Mesa confirmed the existence of thick accumulations of dead coral rubble on mound crests serving as habitat for living deep sea stony coral *Lophelia pertusa* as well as bamboo coral communities (NOAA OER, 2018 and 2019). Two additional sites located northeast of the mesa, here referred to as Central Plateau North (CPN) and Richardson Jellyfish Scarp (RJS) (Fig. 1), were chosen to allow for comparison of ridge scarp mound features. These newly mapped areas, previously thought to be flat and featureless, revealed hundreds of mounded features (NOAA OER, 2019). While EX1903 Dive 10 on the Richardson Jellyfish Scarp documented large amounts of fine to coarse sediment and some living and dead coral, Dive 08 on the Central Plateau revealed accumulations of stone rubble and no coral. Both EX1903 Dives 10 and 08 showed low species abundance and diversity, likely due to the absence of the necessary coral habitat structure.

RESULTS

Stetson Mesa East (SME)

- Continuous ridge scarp mounds are found near to the scarp edge at 700-800m (Fig. 2).
- No ridge scarp mound features were found on this portion of the ridge scarp where EX1903 Dive 03 was conducted.
- High definition videos from EX1903 Dive 03 revealed abundant coral rubble that serves as habitat for a complex ecological community (Fig. 2).
- High backscatter intensities were observed nearest to ridge scarp mounds on profiles 1B-1B' and 1C-1C'. High return was observed nearest to scarp edges on profile 1A-1A' (Fig. 6B).
- For all profiles within SME, a positive relationship was observed between slope and backscatter intensity (Fig. 6B). Profile 1B-1B' showed the greatest relationship between slope and backscatter intensity ($R^2 = 0.554$).

Stetson Mesa North (SMN)

- Continuous ridge scarp mound features are found 700-800 m behind the edge of the 12° scarp at 700-800 m (Fig. 3).
- High definition videos from EX1903 Dive 06 revealed a coral framework that serves as habitat for an abundant and diverse community (Fig. 3).
- A single ridge scarp mound occurs at the dive site, located on the scarp edge.
- SMN profiles show weak to no correlation between slope and backscatter intensity (Fig. 6B), however profiles 2A-2A' and 2B-2B' showed high backscatter intensities nearest to the ridge scarp edges (Fig. 6A).

Central Plateau North (CPN)

- No ridge scarp mound features were present at the EX1903 Dive 08 site, however ridge scarp mounds are located near u-shaped scours in CPN at 800-900 m (Fig. 4).
- High definition videos from EX1903 Dive 08 revealed abundant stone rubble at the scarp base and some live corals on the scarp wall (Fig. 4).
- CPN profiles show weak to no correlation between slope and backscatter intensity (Fig. 6B).

Richardson Jellyfish Scarp (RJS)

- Ridge scarp mound features occur on the edge of the 700 m wide u-shaped scour at 550-650 m (Fig. 5).
- High definition videos from EX1903 Dive 10 revealed fine to coarse sediments, coral rubble and little biodiversity at this site (Fig. 5).
- RJS profiles show weak to no correlation between slope and backscatter intensity (Fig. 6B).

DISCUSSIONS and CONCLUSIONS

Ridge scarp mound morphology near scarp edges appears to be the result of dead coral rubble over which live coral has grown. These structures create frictional drag on fast-moving currents and allow for the deposition of food particles containing nutrients that deep-sea corals need to survive.

While ridge scarp mounds in Stetson Mesa East, Central Plateau North and the Richardson Jellyfish Scarp occur at the scarp edge, at Stetson Mesa North these features are located several hundred meters from the scarp edge. These features occur around u-shaped scours at Central Plateau North and Richardson Jellyfish Scarp and occurred parallel to ridge scarp edges in the two Stetson Mesa study sites.

High definition video from ROV D2 revealed dead and living corals in a complex ecological community at the Stetson Mesa East and North dive sites. The ROV documented little abundance and biodiversity at the Central Plateau North and Richardson Jellyfish Scarp dives sites, probably due to the lack of ridge scarp mound features in these areas.

Bathymetric data of Stetson Mesa East and Stetson Mesa North revealed positive correlations between slope and intensity, and deep-sea coral communities were found in areas with high intensity and steep slopes. Conversely, bathymetric surfaces of Central Plateau North and Richardson Jellyfish Scarp showed weak to no correlation between slope and intensity. According to these results, traditional markers of high slope and high intensity backscatter cannot always be used to pinpoint coral habitat in areas with mound-like geomorphology. Instead, bathymetric data can aid in the identification of ridge scarp mound features and the location of deep-sea coral populations.

Figure 6A (below). Profiles of possible ridge scarp mound features and dive sites in each study area (all profiles VE = 1.3x). Classified backscatter intensity was generated along all profiles and is represented by the bar beneath each profile (scale at right). The ROV *Deep Discoverer* icon indicates a dive site profile.

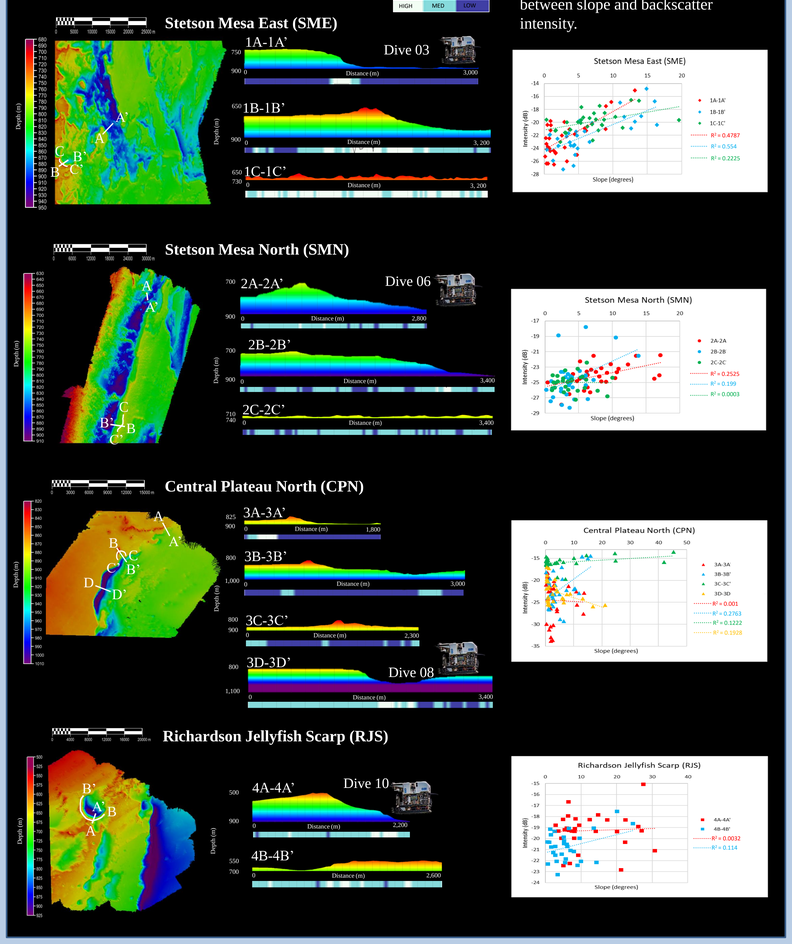

Figure 6B (below). Plots of random points chosen along profiles at each site showing the relationship (if any) between slope and backscatter intensity.

Table 1. Average intensity, standard deviation of intensity and average slope of profiles at each site (green text indicates along-edge profiles).

		Average Intensity (dB)	Standard Deviation Intensity (dB)	Average Slope (deg)	Standard Deviation Slope (deg)
SME	1A-1A'	-22.43	2.88	3.05	3.37
	1B-1B'	-21.93	2.81	6.29	4.83
	1C-1C'	-19.92	1.56	6.86	4.04
SMN	2A-2A'	-24.06	1.51	8.09	4.12
	2B-2B'	-24.59	2.53	4.14	2.82
	2C-2C'	-24.98	1.05	3.91	2.35
CPN	3A-3A'	-24.56	4.72	3.46	3.87
	3B-3B'	-21.82	4.08	5.53	4.55
	3C-3C'	-15.86	1.25	7.23	11.87
	3D-3D'	-22.67	2.48	4.02	5.11
RJS	4A-4A'	-19.27	1.62	12.45	8.33
	4B-4B'	-20.75	1.33	6.41	5.55

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