Comparison of Seabed Features within the Richardson Ridge Complex, Blake Plateau

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ABSTRACT

As part of the *Windows to the Deep 2018* expedition, scientists from the NOAA Office of Ocean Exploration and Research, US Geological Survey, Smithsonian Institution, and College of Charleston collected multibeam sonar data and high definition video of the seafloor off the Southeast U.S. Continental Margin between May and July of 2018. Bathymetric data were obtained and high definition video was used to ground truth bathymetric surfaces. The expedition's discovery of deep-sea coral habitat in this area and subsequent exploration by the DSV *Alvin* of adjacent expanses of similar habitat during the July *2018 Deep SEARCH* expedition have generated new ideas on the geomorphology of deep-sea coral habitat. Thus, the purpose of this study is to characterize the geomorphology of the newly discovered deep-sea coral mounds for comparison with the geomorphology of other seabed features in the area referred to here as the Richardson Ridge Complex. This area is approximately 160 miles off the coast of Charleston, SC on the eastern edge of the Blake Plateau with depths between 700 and 900 m. In order to manage and protect critical benthic habitats, we must be able to properly characterize their geomorphology. Data collected from the bathymetric surfaces revealed that there are weak to no correlations among slope, intensity, and the presence of corals in these deep-sea environments, therefore we cannot rely on the traditional markers of high slope and high intensity to indicate the presence of coral habitat. Instead, using bathymetric data to identify mound features and locate mound crests can effectively aid in finding coral habitat and live corals.

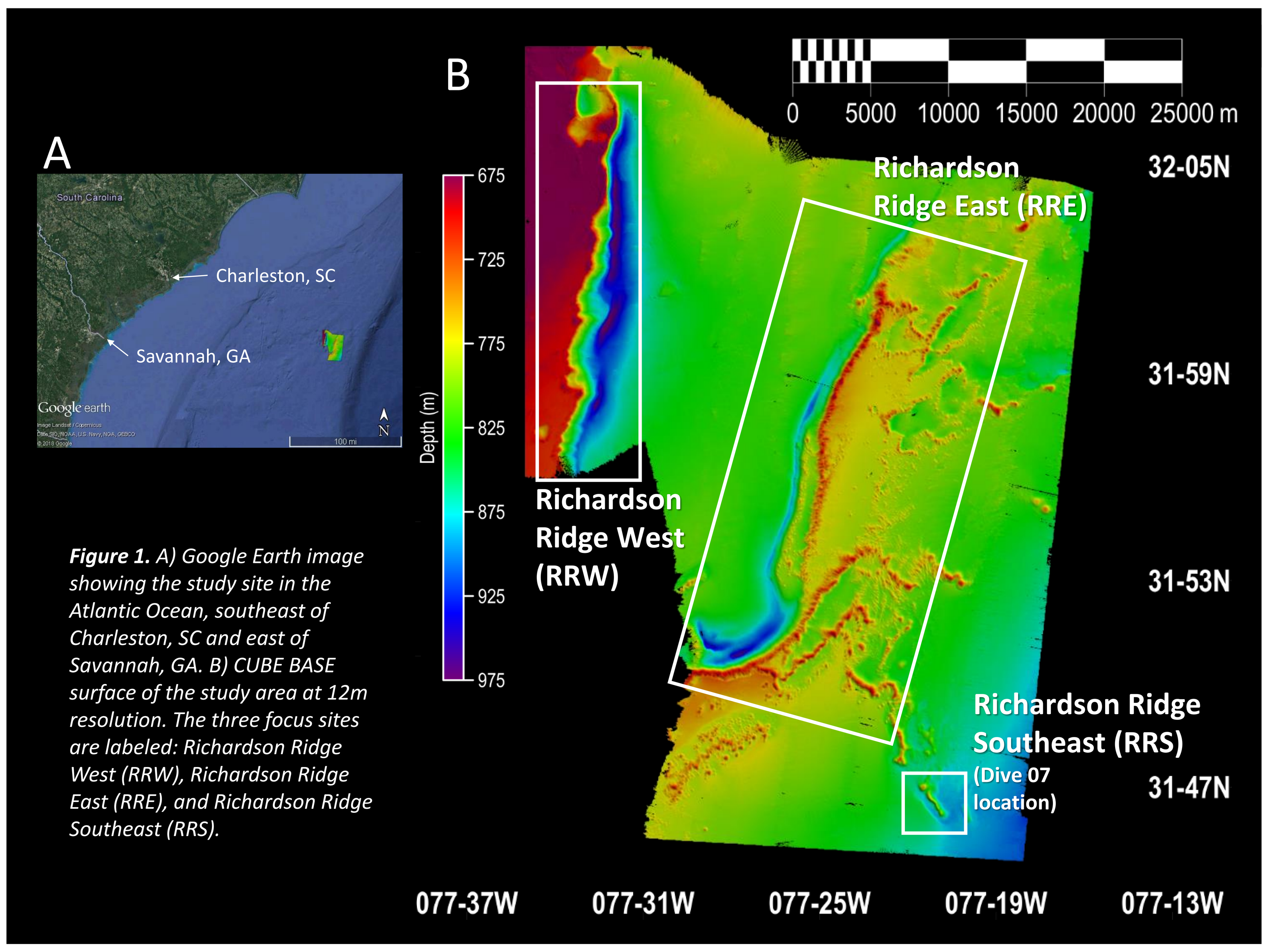
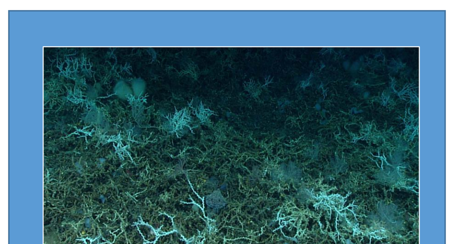


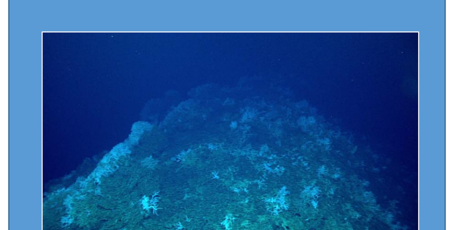
***Figure 1.** A) Google Earth image showing the study site in the Atlantic Ocean, southeast of Charleston, SC and east of Savannah, GA. B) CUBE BASE surface of the study area at 12m resolution. The three focus sites are labeled: Richardson Ridge West (RRW), Richardson Ridge East (RRE), and Richardson Ridge Southeast (RRS).*

BACKGROUND

The NOAA Ship *Okeanos Explorer* acquired data in deepwater habitats on the southeast U.S. continental margin to gain knowledge for priority science and management needs, and explore the diversity and distribution of benthic habitats as a part of NOAA's larger Deep SEARCH program. Data were collected on expedition cruises EX1805 and EX1806. Multibeam sonar data collected during this expedition showed a series of mounds and ridges in an area known as Richardson Hills, previously thought to be relatively featureless. The newly mapped area, referred to here as the Richardson Ridge Complex (Fig. 1), was initially thought to be a long, rocky ridge by EX1806 scientists. However, ROV footage from EX1806 Dive 07 showed a network of deep-sea stony corals – both dead coral skeletal framework and living corals, primarily, *Lophelia pertusa*. In this study, the dive site's area is referred to as Richardson Ridge Southeast (RRS). Further exploration was conducted in August with Woods Hole Oceanographic Institute's HOV *Alvin,* leading to the discovery of an 85-mile reef approximately 160 miles east of Charleston in the areas here referred to as Richardson Ridge East (RRE). This study aims to characterize the morphology of the mound features where live coral was found along RRE and RRS, and to further examine the area here referred to as Richardson Ridge West (RRW) to better understand where deep sea corals may occur. Both the linear nature of the mound features as well as the depth in which these coral were found were unique to this area - while mound features have been found in other deep-sea coral, they have typically been stand-alone mounds. Because the area was not known to have coral, it has not yet been included in a nearby special, protected area for deepwater corals established by the Mid-Atlantic Fishery Management Council.



Live *Lophelia pertusa* is white in color, making it easily discernible from the skeletal framework.



A view of both sides of the ridge show the increased amount of live *Lophelia* on the current-facing side, at left.

The DSV *Alvin* collecting a sample of *Lophelia pertusa* from a coral mound (Image courtesy of Woods Hole Oceanographic Institution).

RICHARDSON RIDGE WEST

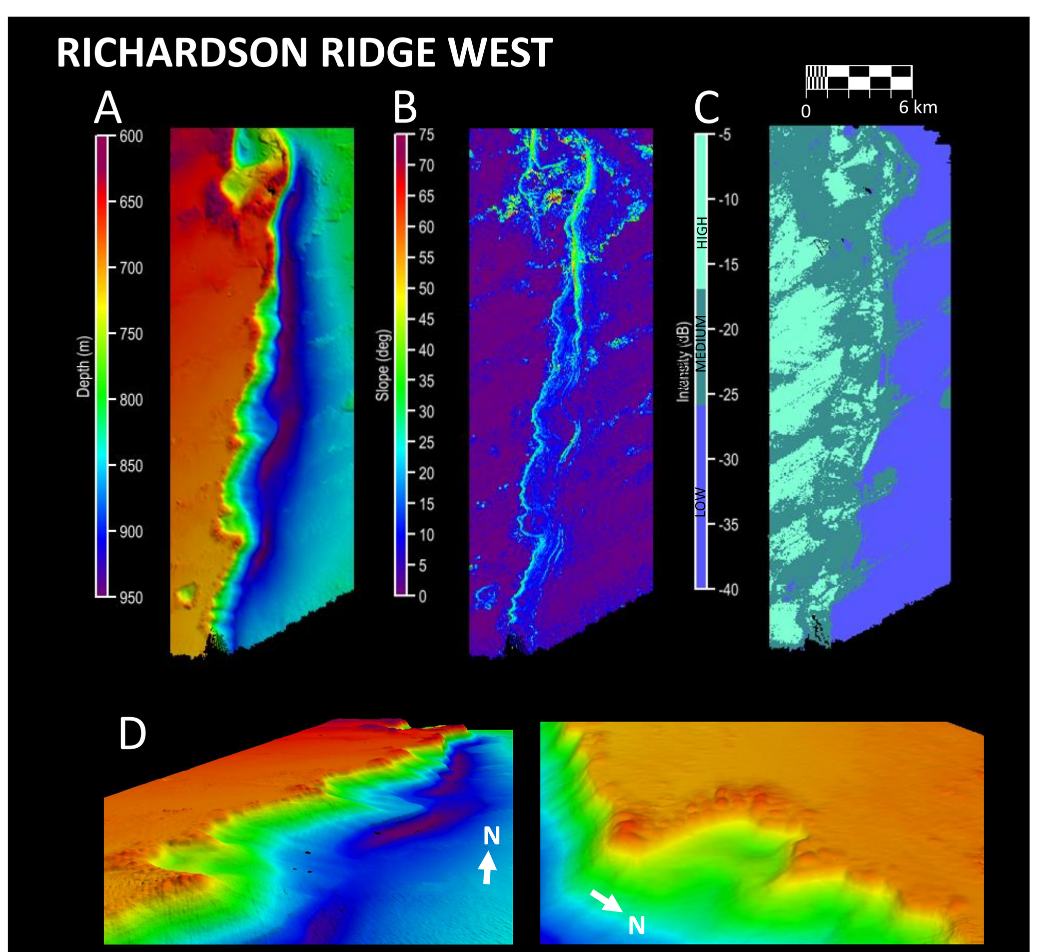


Figure 2: A) Unclassified bathymetric surface, B) Bathymetric surface draped with slope surface, C) Backscatter surface classified by high, medium, and low intensities, and D) 3D bathymetric images showing the relief of the ridge scarp and details of possible mounds. (all 3D images VE=2X)

RICHARDSON RIDGE EAST

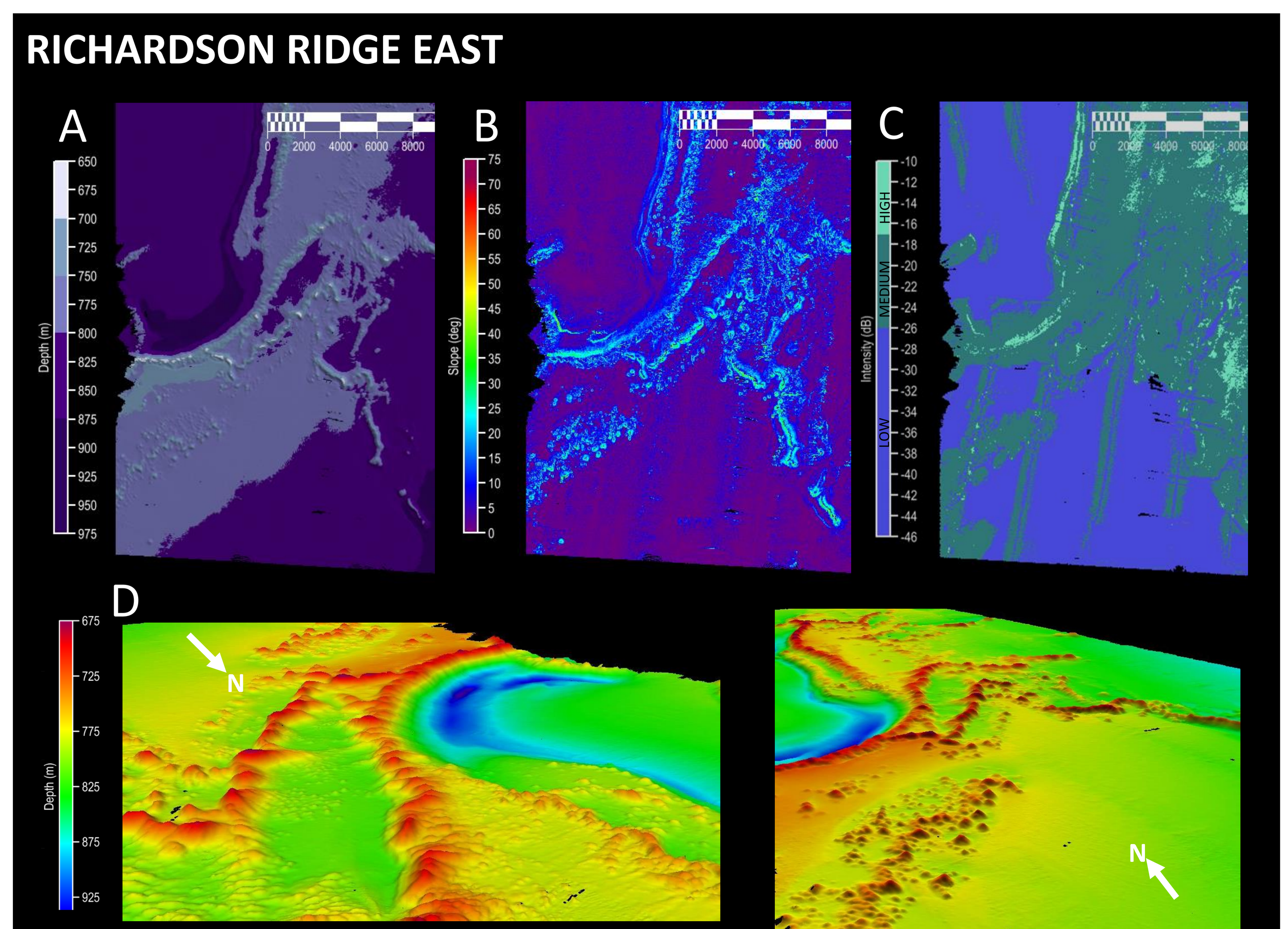


Figure 3: A) Bathymetric surface classified by depth to highlight mound crests, B) Bathymetric surface draped with slope surface, C) Backscatter surface classified by high, medium, and low intensities, and D) 3D images of the bathymetric surface, clearly showing the presence of many mounds along the ridge. (all 3D images VE=2X)

METHODS

- Bathymetric surveys were conducted by NOAA OER on the NOAA Ship *Okeanos Explorer* with a Kongsberg EM302.
- High definition video frame-grabs from the ROV *Deep Discoverer* were used to ground truth locations along the dive track.
- CARIS HIPS 10.4 was used to post-process raw multibeam sonar data and render CUBE BASE surfaces at 12 m resolution.
- 3D images and profiles were generated, slopes and distances were measured, and backscatter intensity was classified.
- RRE and RRW surfaces were classified both by depth and by intensity. Intensity and slope data were collected at random points within each depth and intensity range to represent the slope and intensity associated with each focus area.

RICHARDSON RIDGE SOUTHEAST

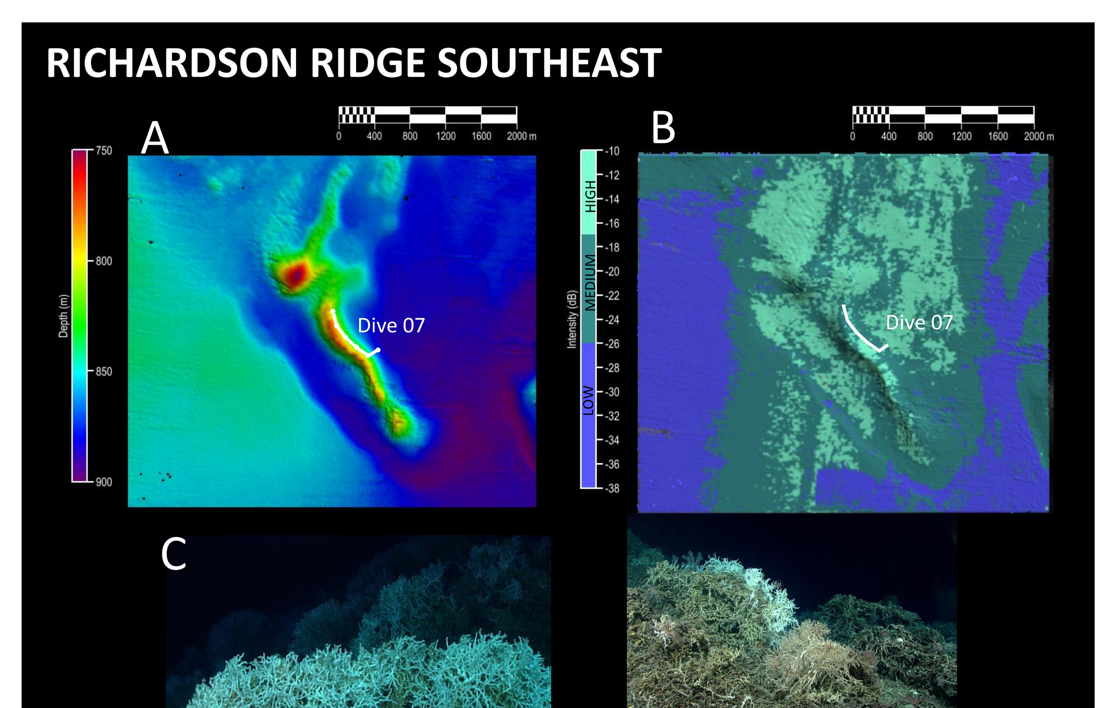


Figure 4: A) Bathymetric surface with 12 m resolution and overlay of Dive 07 path, B) Classified intensity draped over the bathymetric surface with VE=1x, C) Video frame grabs captured by ROV Deep Discoverer showing the living coral found along the dive track, at the mound crest.

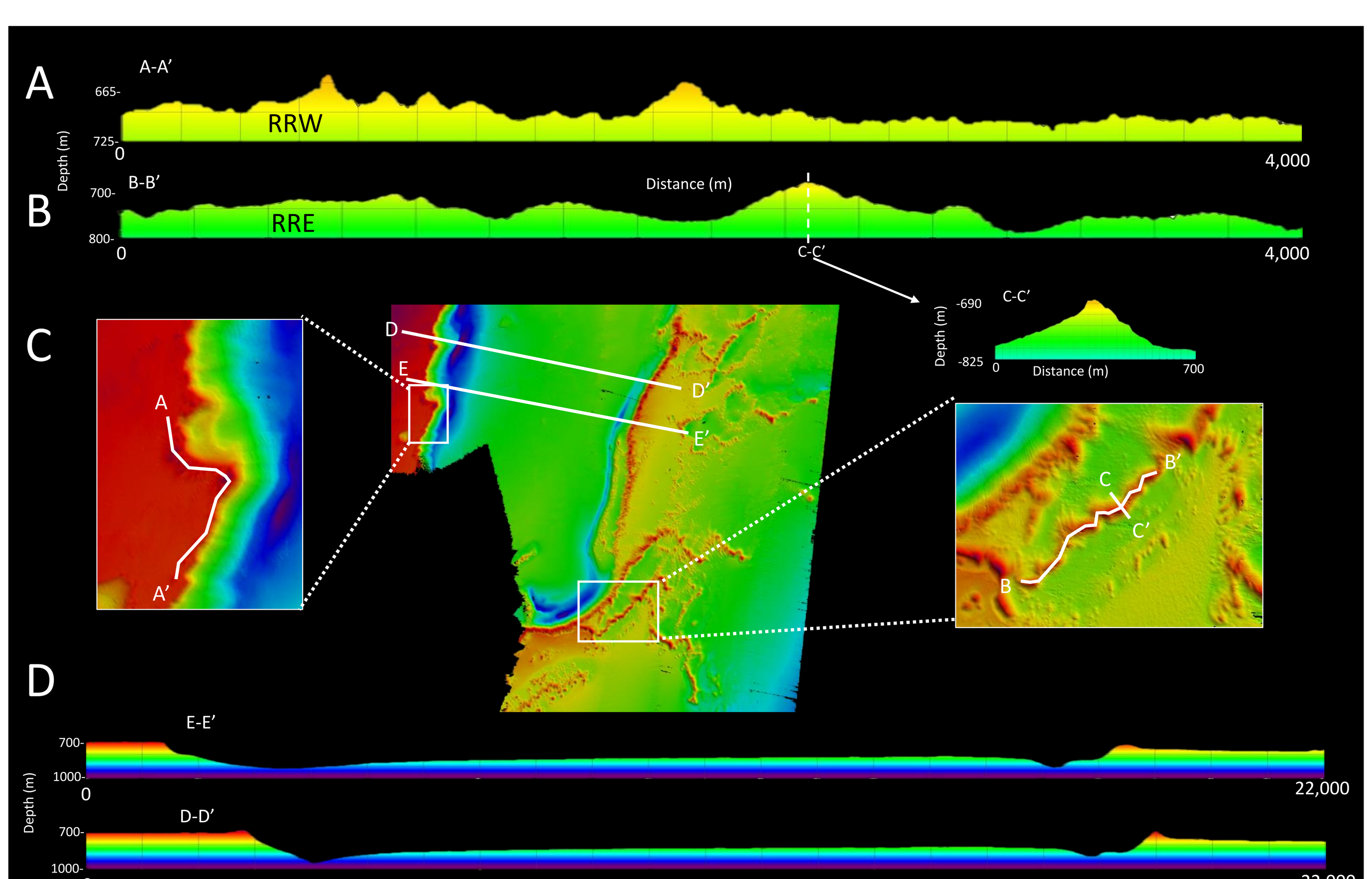


Figure 5: A) Profile of possible mound features along the edge of RRW, B) Profile of a series of coral mounds in RRE, C) Bathymetric surface with all profile locations, D) Profiles across the entire study area. (all profiles VE=2.5x)

RESULTS

- There are similar slope values on both sides of the large, U-shaped scarp/ridge feature that runs across the Richardson Ridge Complex.
- On the Western side of the U-shaped feature, the aspect values are oriented to the East, and on the Eastern side of the feature, aspect values are oriented to the West.
- Across the entire study area, there was weak to no correlation between slope and backscatter intensity (Fig. 6).

Richardson Ridge West:

- There is a steeply sloping, >100 m scarp on the edge of the ridge.
- Profiles along the ridge edge show a strong similarity to the mound features of Richardson Ridge East (Figs. 6A and 6B and 2D).
- A weak positive correlation exists between slope and intensity in the deep depth series. In both the medium and shallow depth series, there is no correlation between depth and intensity (Fig. 6A).
- There is a weak negative relationship between slope and intensity in areas with medium and low intensity returns. There is no relationship in areas with high intensity returns (Fig . 6C)

Richardson Ridge East:

- The mound features have very similar geomorphology across the entire study area (Fig. 5A).
- A weak positive relationship between slope and intensity is found in the shallow depth series. In the medium and deep series, there is no relationship between slope and intensity (Fig. 6B).
- A weak negative relationship exists between slope and intensity in all three depth ranges (Fig 6D).

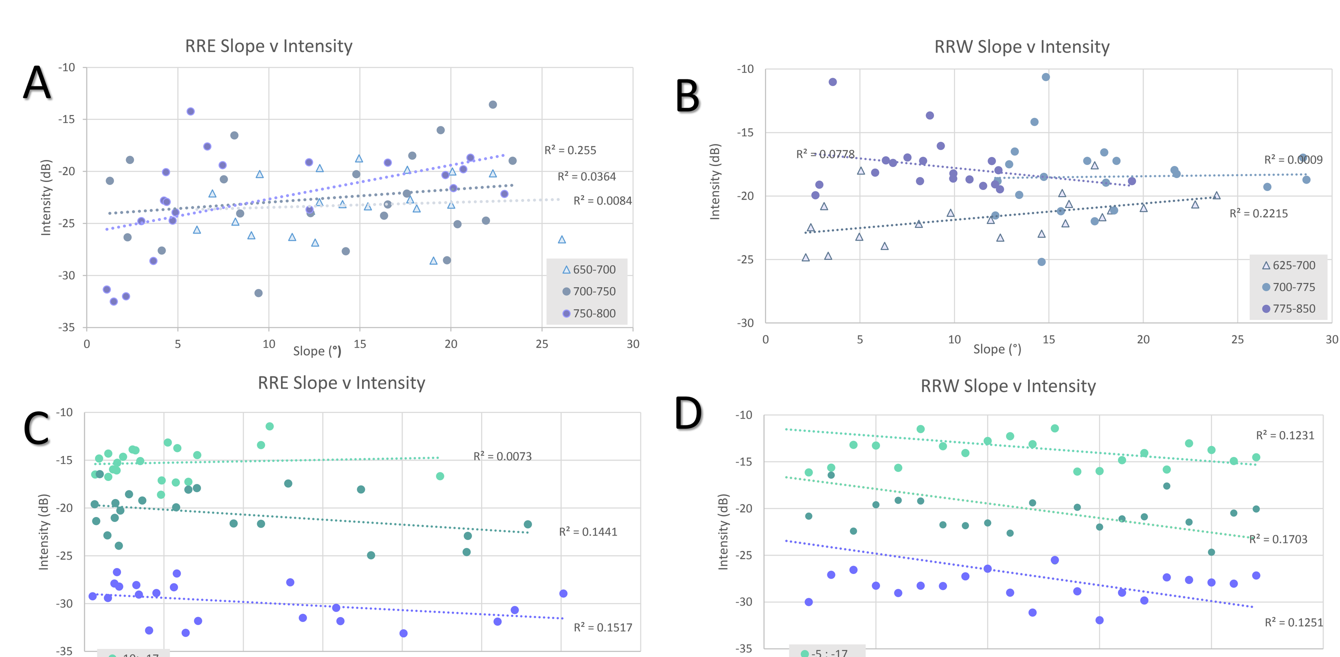


Figure 6: All graphs show slope and intensity. A & B) Data points were chosen in RRE and RRW based on three depth categories. C & D) Data points were chosen in RRE and RRW, based on three backscatter classifications.

Table 1: Slope and intensity chosen by A) depth range and B) backscatter intensity in Richardson Ridge West.

625-700 m		700-775 m		775-850 m		-5: -17		-17: -26		-26 : -40	
Slope (degrees)	Intensity (dB)	Slope (degrees)	Intensity (dB)	Slope (degrees)	Intensity (dB)	Slope (degrees)	Intensity (dB)	Slope (degrees)	Intensity (dB)	Slope (degrees)	Intensity (dB)
18.295	-21.129	13.425	-19.908	19.404	-18.821	0.335	-16.139	1.191	-20.824	12.486	-29.995
17.837	-21.657	26.574	-19.279	6.741	-17.384	1.450	-15.628	3.549	-16.429	12.484	-27.086
12.430	-23.274	18.458	-21.124	10.796	-18.685	2.126	-13.191	4.48	-22.420	4.187	-26.564
14.613	-22.964	14.240	-14.162	10.532	-18.732	18.790	-13.265	6.3603	-19.602	1.020	-28.250
2.392	-22.454	13.194	-16.496	7.513	-16.953	6.347	-15.645	11.018	-19.119	4.361	-29.034
9.794	-21.317	18.022	-18.944	6.364	-17.182	7.004	-11.503	12.374	-19.196	1.977	-28.250
3.314	-24.702	28.458	-16.971	2.843	-19.105	5.273	-13.343	3.788	-21.742	5.577	-28.298
11.925	-21.872	21.653	-17.949	9.276	-16.052	1.269	-14.065	3.132	-21.830	3.656	-27.248
16.068	-20.622	17.030	-17.222	8.337	-17.227	3.643	-12.779	0.854	-21.544	8.537	-26.432
15.878	-22.141	12.893	-17.491	5.797	-18.146	7.051	-12.273	6.834	-22.642	0.731	-29.007
17.429	-17.572	14.840	-10.618	3.553	-11.013	6.829	-13.128	13.030	-19.392	4.215	-31.130
6.306	-23.930	18.582	-17.222	9.940	-18.219	5.377	-11.432	18.364	-25.605	1.564	-25.510
22.752	-20.651	14.736	-18.484	9.935	-18.619	5.208	-16.059	10.925	-19.866	7.030	-28.864
8.114	-22.186	17.933	-16.559	8.179	-18.821	2.290	-16.003	3.710	-21.989	2.355	-31.946
3.093	-20.794	17.426	-21.989	11.518	-19.194	5.129	-14.836	7.054	-21.109	5.825	-28.997
23.89	-19.940	12.165	-21.527	12.324	-17.961	11.689	-14.062	1.761	-20.881	8.947	-29.845
2.118	-24.828	15.636	-21.198	8.695	-13.644	10.829	-15.830	4.427	-17.595	6.061	-27.370
4.959	-23.208	14.621	-25.179	12.413	-19.458	2.471	-13.039	20.325	-21.449	1.046	-27.638
5.050	-17.989	28.642	-18.715	12.147	-19.079	0.850	-13.740	1.871	-24.677	10.476	-27.902
20.019	-20.940	12.280	-18.822	2.640	-19.932	0.763	-14.917	10.520	-20.484	4.574	-28.038
15.711	-19.759	21.768	-18.260	11.981	-17.247	2.771	-14.519	3.937	-20.046	8.042	-27.157

Table 2: Slope and intensity chosen by A) depth range and B) backscatter intensity in Richardson Ridge East.

650-700 m		700-750 m		750-800 m		-10: -17		-17: -26		-26: -35	
Slope (degrees)	Intensity (dB)	Slope (degrees)	Intensity (dB)	Slope (degrees)	Intensity (dB)	Slope (degrees)	Intensity (dB)	Slope (degrees)	Intensity (dB)	Slope (degrees)	Intensity (dB)
6.049	-25.593	1.262	-20.898	1.099	-31.346	2.030	-16.054	2.808	-18.548	6.366	-33.047
6.899	-22.109	2.234	-26.325	1.483	-32.503	3.509	-15.080	24.058	-24.594	2.049	-26.694
8.164	-24.824	2.368	-18.889	2.151	-31.990	5.752	-17.333	27.907	-21.696	5.813	-26.843
9.040	-26.129	4.120	-27.604	2.995	-24.768	7.094	-14.454	17.406	-18.048	3.431	-29.051
9.496	-20.234	7.530	-20.743	3.662	-28.599	22.385	-16.671	0.642	-19.600	15.848	-30.447
11.279	-26.292	8.105	-16.537	4.236	-22.788	5.843	-13.732	6.540	-18.063	7.149	-31.807
12.319	-23.771	8.422	-24.040	4.349	-20.058	3.213	-13.969	0.963	-16.449	2.186	-28.220
12.542	-26.825	9.432	-31.691	4.388	-22.929	3.030	-13.870	5.767	-19.930	4.532	-28.884
12.776	-22.942	12.287	-24.001	4.714	-24.714	6.541	-17.260	0.736	-21.363	1.885	-27.900
12.791	-19.670	14.228	-27.661	4.870	-23.941	5.250	-13.138	1.950	-19.481	3.269	-28.056
14.049	-23.141	14.806	-20.258	5.706	-14.226	11.111	-13.406	9.389	-21.619	4.068	-32.798
14.954	-18.744	16.323	-24.240	6.619	-17.595	11.662	-11.448	18.038	-24.946	0.519	-29.223
15.438	-23.350	16.535	-23.162	7.456	-19.399	0.926	-14.809	3.638	-19.213	1.481	-29.406
17.602	-19.833	17.573	-22.123	12.207	-19.115	0.681	-16.485	11.114	-21.643	30.146	-28.944
17.762	-22.676	17.873	-18.470	12.232	-23.665	2.428	-14.645	2.265	-20.258	20.078	-33.102
18.121	-23.550	19.435	-16.022	16.535	-19.145	1.503	-16.742	7.080	-17.912	16.110	-31.823
19.044	-28.564	19.782	-28.524	19.702	-20.342	4.823	-18.605	2.165	-23.952	27.082	-30.669
20.015	-23.184	20.363	-25.072	20.139	-21.595	4.864	-17.119	1.451	-22.852	26.003	-31.886
20.082	-19.990	21.922	-24.727	20.676	-19.788	1.798	-15.951	12.830	-17.431	5.630	-28.292
22.301	-20.173	22.301	-13.569	21.068	-18.670	2.069	-15.260	24.127	-22.910	13.744	-31.483
26.099	-26.513	23.388	-18.973	22.944	-22.160	1.498	-14.294	1.907	-21.029	12.949	-27.763

DISCUSSION and CONCLUSIONS

The large U-shaped ridge feature that extends across the entire study area appears to be one continuous feature. This feature may be the result of subsidence in the area, forming a flat, broad basin which was impacted differently on either side as the current interacted with the substrate. The scour-like dips at the base of the ridge scarps on both sides of the basin are also of interest (Fig 6D).

The shape of the coral mounds appears to be the result of live coral growing on top of the skeletons of dead coral. The framework developed by the rugose, stony coral skeleton creates frictional drag, which slows the current and allows for the deposition of suspended particles. These deep sea corals grow upwards in order to be in the midst of the current, which contains suspended particles they consume.

The edge of the scarp in Richardson Ridge West has features with similar morphology and structure to the coral mounds of Richardson Ridge East (Figs 5A & 5B). The evidence from the profiles, as well as from visual observations of the similar features along RRW lend themselves to the conclusion that there are also coral mounds and pinnacles in this focus area.

Data collected from the bathymetric surfaces revealed that there are weak to no correlations among slope, intensity, and the presence of corals in these deep-sea environments. Thus, we cannot rely on the traditional markers of high slope and high intensity backscatter to indicate the presence of coral habitat in areas with mound-like geomorphology. Instead, using bathymetric data to identify mound features and locate the mound crests can be useful in discovering potential deep-sea coral habitat.

Previous discoveries of *Lophelia* reefs between Florida and North Carolina were in the depth range of 350-600m and were much closer to the shore. Thus, the discovery of the vast reef network in this depth range (700-900m) and a greater distance from the shore opens new possibilities as to where we can locate mounds and subsequently, live coral.

ACKNOWLEDGEMENTS

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