

Geomorphology of the Blake Spur and Blake Escarpment, Southeast U.S. Continental Margin

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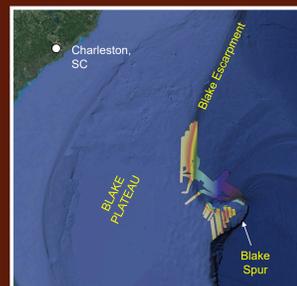
BACKGROUND:

The **Blake Plateau** is a large and flat portion of the southeast U.S. continental margin with depths ranging from 800 to 1,200 m (Fig. 1). The Plateau is bounded to the east by the **Blake Escarpment**, a very steep section of the continental margin which descends to a depth of 5,000 m. The **Blake Spur** is a promontory of the Blake Escarpment that extends more than 60 km eastward from the north-south trending Blake Escarpment and was formed from the onset of the Gulf Stream (USGS 1988). Compared to the Escarpment, the Blake Spur is significantly steeper, descending nearly vertically to a depth of over 5 km. Multibeam sonar data were collected by NOAA Ship *Okeanos Explorer* (EX2107) and R/V *Pathfinder* (PF0501) in 2021 and 2005, respectively. Three study sites along the Blake Escarpment (including the Blake Spur) were examined (Fig. 1) to compare and analyze variations in the region's geomorphology and to characterize the stark contrast of depth, slope, and backscatter intensity among the sites. Two of the study sites (Escarpment North and Escarpment South) range from 800 to 2,500 m water depth and the third site (Blake Spur) ranges from 2,500 to 5,000 m. To ground truth the geomorphology of two areas within the Blake Spur study site, HD video footage collected by the ROV *Deep Discoverer* (EX2107-Dive06 and EX2107-Dive07) was analyzed and compared. The ROV dives (4,000-2,800 m) explored features of the Blake Spur, an enormous collapsed section of the Spur's wall was encountered, revealing large carbonate slabs, boulders/rubble, and sandy/silty channels.

After analyzing depth, slope, vertical relief, and HD video collected by ROV *Deep Discoverer*, the geomorphologic features and differences between the Blake Spur and Blake Escarpment were identified. The purpose of this study is to characterize the significant geomorphological variability among these three sites along the eastern edge of the Blake Plateau.



Figure 1. Study Area/Sites



The Blake Spur study area is located approximately 400 km off the coast of Charleston, S.C. (above) Within the study area, three study sites were examined (left): Escarpment North, Escarpment South, and Blake Spur.

METHODS:

- Raw multibeam sonar data from the following surveys were utilized:
 - NOAA OE Blake Plateau region expedition *Windows to the Deep 2018: Exploration of the Southeast U.S. Continental Margin* (EX1805).
 - NOAA OE Blake Plateau region expedition *Windows to the Deep 2021: Southwest U.S. ROV and Mapping* (EX2107).
 - 2005 UNCLOS *Pathfinder* survey (PF0501) in the Blake Spur/Blake Plateau region.
- Two research/survey vessels were utilized as sonar platforms:
 - NOAA Ship *Okeanos Explorer* utilizing a Kongsberg EM302 (EX1805) and Kongsberg EM304 (EX2107) multibeam system.
 - USNS *Pathfinder* utilizing a Simrad EM121 (PF0501) multibeam system.
- Raw multibeam sonar data were processed with CARIS HIPS & SIPS 11.4 to generate 2D/3D bathymetry and slope surfaces with resolutions of 40 m and 100 m.
- Depth profiles were analyzed to compare slope variations, intra-slope terrace features, and escarpment features.
- 2D classified backscatter intensity mosaics with 40 m resolution were generated and draped onto the 3D bathymetric surface.
- Two dives by ROV *Deep Discoverer* were analyzed from HD footage collected during the NOAA *Windows to the Deep 2021: Southwest U.S. ROV and Mapping expedition* (EX2107-DIVE06, EX2107-DIVE07), and were used to ground-truth the sonar data collected.

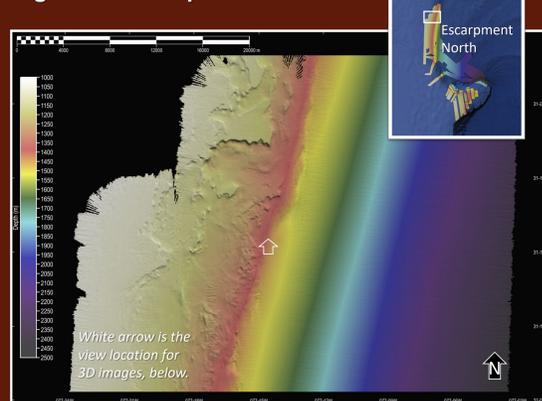
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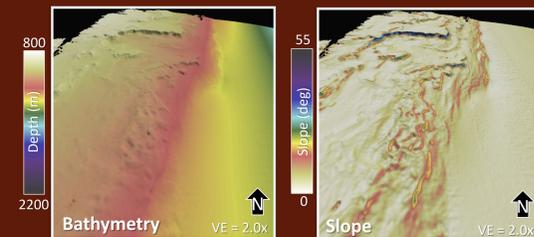
ACKNOWLEDGEMENTS

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Figure 2. Escarpment North

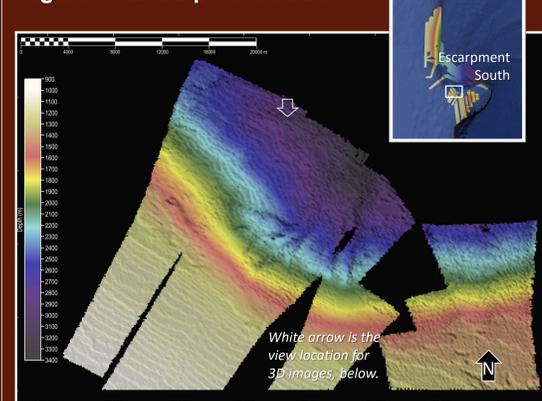


Escarpment North is distinctive in that the eastern half is nearly featureless, while the western half displays intra-slope terraces and small scarp features.

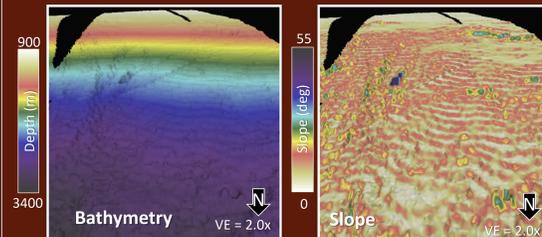


The depth range for this site is 800 to 2,200 m over a 40 km distance. Escarpment North's eastern half is extremely flat with slope <math>< 5^\circ</math>. The western section's numerous intra-slope terrace features have an eastward-facing steep side with slope ranging 25-55°. (3D view has VE=2x)

Figure 3. Escarpment South

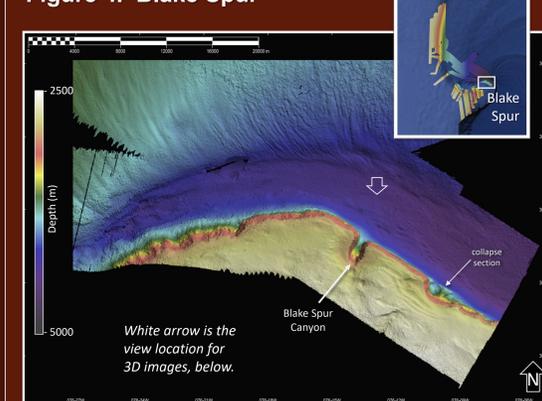


At this site, the key features are the prominent stair-step morphology of intra-slope terraces, seen along the entire Escarpment South site.

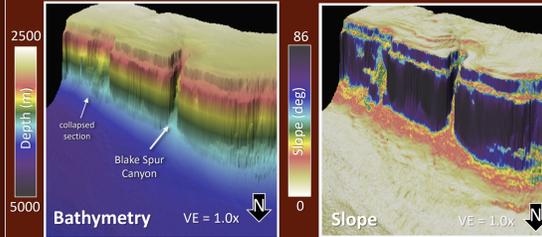


Escarpment South has a smooth transition in vertical relief (900-3400 m). The distinctive stair-step features are the many intra-slope terraces. Their terrace wall slopes range 25-55° but are flat (<math>< 5^\circ</math>) on the terraces. (3D view has VE=2x)

Figure 4. Blake Spur



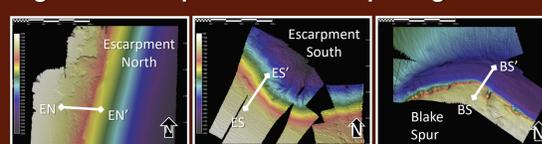
Blake Spur's geomorphology is significantly different from the other sites, dropping steeply from 2500 to 5000 m in a cliff-like scarp. A large, single terrace occurs in the top 250 m of the scarp wall.



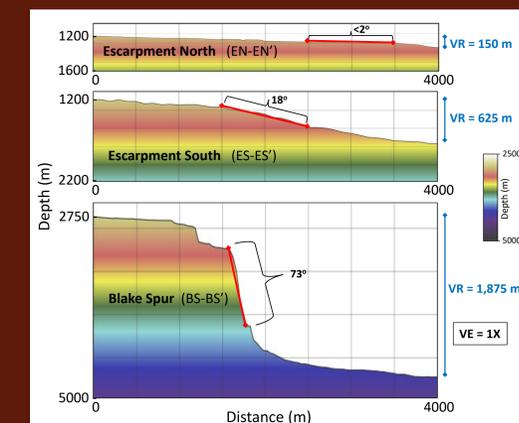
(Note the change in vertical exaggeration to VE=1x)

The near-vertical (86°) scarp wall has a vertical relief of 1,125 m. Both slope and vertical relief are significantly greater than either of the two Escarpment study sites. The Blake Spur Canyon and collapsed section of the wall are significant features. (3D view has VE=1x)

Figure 5. Comparative Geomorphologies

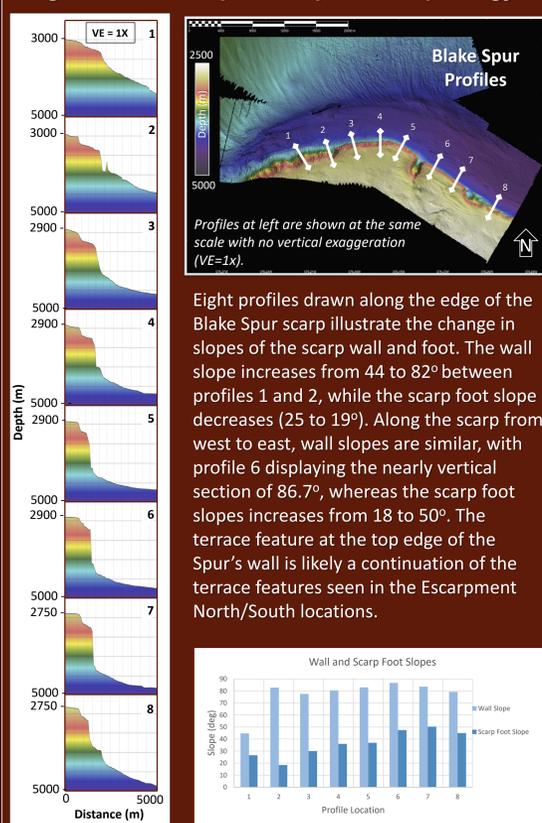


Profile location maps are shown at the same scale (above). Depth profiles (below) are shown at the same scale and have no vertical exaggeration (VE=1x).



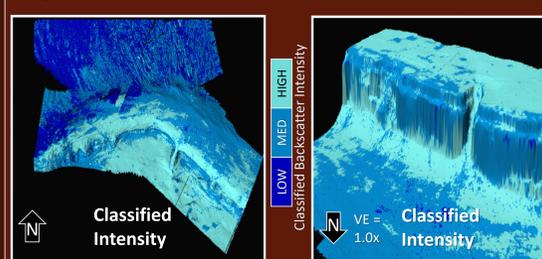
All three sites have distinct features that make them areas of interest. Vertical relief (blue lines, above) increases significantly from 150 to 625 to 1,875 m (EN, ES, and BS, respectively). **Escarpment North** and **Escarpment South** have a slope (red line, above) of 1.5 and 18.0°, respectively, however the **Blake Spur** has the greatest slope of 73°. All three sites have flat tops with slopes ranging 1.5-18.0°.

Figure 6. Blake Spur Scarp Geomorphology



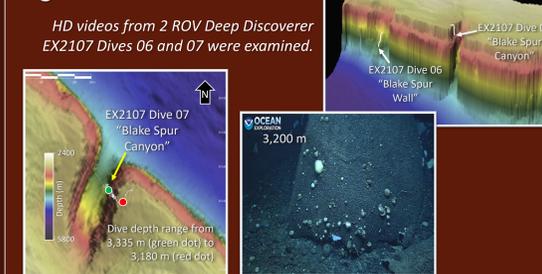
Eight profiles drawn along the edge of the Blake Spur scarp illustrate the change in slopes of the scarp wall and foot. The wall slope increases from 44 to 82° between profiles 1 and 2, while the scarp foot slope decreases (25 to 19°). Along the scarp from west to east, wall slopes are similar, with profile 6 displaying the nearly vertical section of 86.7°, whereas the scarp foot slopes increases from 18 to 50°. The terrace feature at the top edge of the Spur's wall is likely a continuation of the terrace features seen in the Escarpment North/South locations.

Figure 7. Classified Backscatter Intensity



Highest intensities are found along Blake Spur's top and on the scarp foot, indicating hard substrate. Along the Spur's terraced edge and scarp wall a medium return of backscatter occurs, suggesting rough/rocky substrate, or scattered sound due to the extreme angle. Blake Spur Canyon has high intensity as well.

Figure 8. ROV Dive Sites



The Blake Spur Canyon dive (above) revealed jumbled rocks, eroded carbonate crusts, and minimal silt along the scarp's upper terrace. The Blake Spur Wall dive (below) was deeper, on the 3,654 to 3,595 m collapsed section of the scarp wall (Fig. 4). Substrate observed was comprised of layered jumbled rocks, silt, and sand.

SUMMARY

The study sites were selected to compare the Blake Spur to nearby sections of the Blake Escarpment to show the drastic change in both depth and slope within the region. Both Escarpment North and South are characterized as intra-slope terrace features with overall slopes ranging from 2 to 18° and terrace edges ranging 25 to 55°. Escarpment South has numerous stair-step terrace features of exposed edges of flat-lying strata (Fig. 3). The Blake Spur had the greatest variability in geomorphologic features with its distinctive scarp wall with an average slope of 80° and a vertical relief of 1,875 m. A terrace feature with similar vertical slope (80°) and vertical relief of 200 m lies along the top edge of the Spur's wall. The substrate along the scarp wall is comprised of mostly layered ferro-manganese coated carbonate rocks on the scarp wall and some sands/silts on smaller carbonate rocks on the scarp foot. The foot of the scarp appears to be the accumulated debris from scarp wall erosion, and increases in height eastward along the wall, resulting in steeper gradients.

