Multibeam Analysis of U.S. Atlantic Continental Margin Slump and Submarine Landslide Morphology

Nick Guzzardo, Gabrielle Byrd, and Dr. Leslie Sautter
College of Charleston Dept. of Geology and Environmental Geosciences

ABSTRACT:

Focusing on the U.S. Atlantic Continental margins of the Delmarva Peninsula, New Jersey, Rhode Island, and Georges Bank analysis of slump characteristics and features was conducted in order to hypothesize potential slope-sourced triggers of submarine landslides and tsunamis. Using Reson multibeam sonar data collected by the U.S. Geological Survey aboard the NOAA ship *Ronald H. Brown* in 2009, CARIS HIPS and SIPS 7.1 was utilized to determine specific slump features such as existing slope gradient above the scarp, and depth of slump detachments. By generating profiles of the slump depths ranging from 200 to 3000 meters, gradients and slope angles were calculated and used for determining which areas are more subject to failure. Feature types were compared to evaluate possible submarine landslide and tsunami trigger sites. This research may provide a characterization of slump features which will allow for improved accuracy to identify potential tsunami and submarine landslide sites.

BACKGROUND:

- Submarine landslides have very distinct morphologies. The main scarp is where the seafloor mass has moved downward in a rotational fashion in which underlying seafloor bedding and gravitational forces are usually the main cause (Hampton et al., 1996). In some instances a mound of displaced material occurs at the slump's foot (toe).
- It is important to study these submarine landslides due to the dangers they create by generating tsunamis. On November 18, 1929 an earthquake with a magnitude of 7.2 off the coast of Newfoundland, Canada activated a submarine landslide. The submarine landslide sent multiple tsunami waves with amplitudes of 3-12 meters high to Canada's shores killing more than 27 people (Fine et al., 2004).

Objectives of this Sudy:

- Determine submarine landslide sites on the U.S. Atlantic Continental Slope
- Generate profiles and multibeam images of slump features
- Characterize slump features
- Hypothesize potential slope-sourced triggers that generate landslides which in turn could produce dangerous tsunamis affecting our coasts

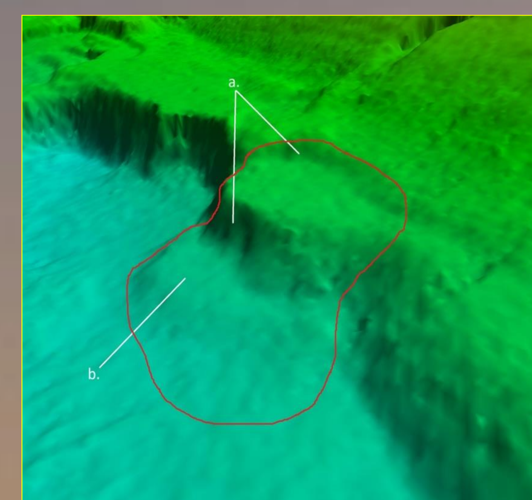

FIGURE 1: 3D bathymetric image of a submarine landslide at a vertical exaggeration of 3.1 off the coast of Rhode Island. Distinct morphological features are labeled **a** and **b**. Label **a.** points to the scarp. Label **b.** points to a raised area that is most likely the material that was displaced from the landslide.

METHODS:

- Data collected aboard the NOAA ship *Ronald H. Brown* during May 11-25, 2009. SeaBeam 2112 multibeam echo sounder used to collect data for this study and to map the continental slope/rise from Cape Hatteras, in the south, to the eastern end of Georges Bank, in the north, a total distance of 750 miles.
- CARIS HIPS and SIPS 7.1 software was used for editing data collected and used to create bathymetric images and profiles of mapped area.
- Excel was used to catalog width and gradients of each measured slope failure.

Table 1

Region	Slump Type	Number of Slumps in Region	Average Slump Value
Rhode Island	Wide-Mouth	5	17.33
	Finger-Slump	6	26.09
	Slope-Split	6	12.94
Mid-Atlantic	Wide-Mouth	2	15.04
	Finger-Slump	2	18.21
	Slope-Split	1	11.67
Georges Bank	Wide-Mouth	3	13.59
	Finger-Slump	0	NA
	Slope-Split	0	NA

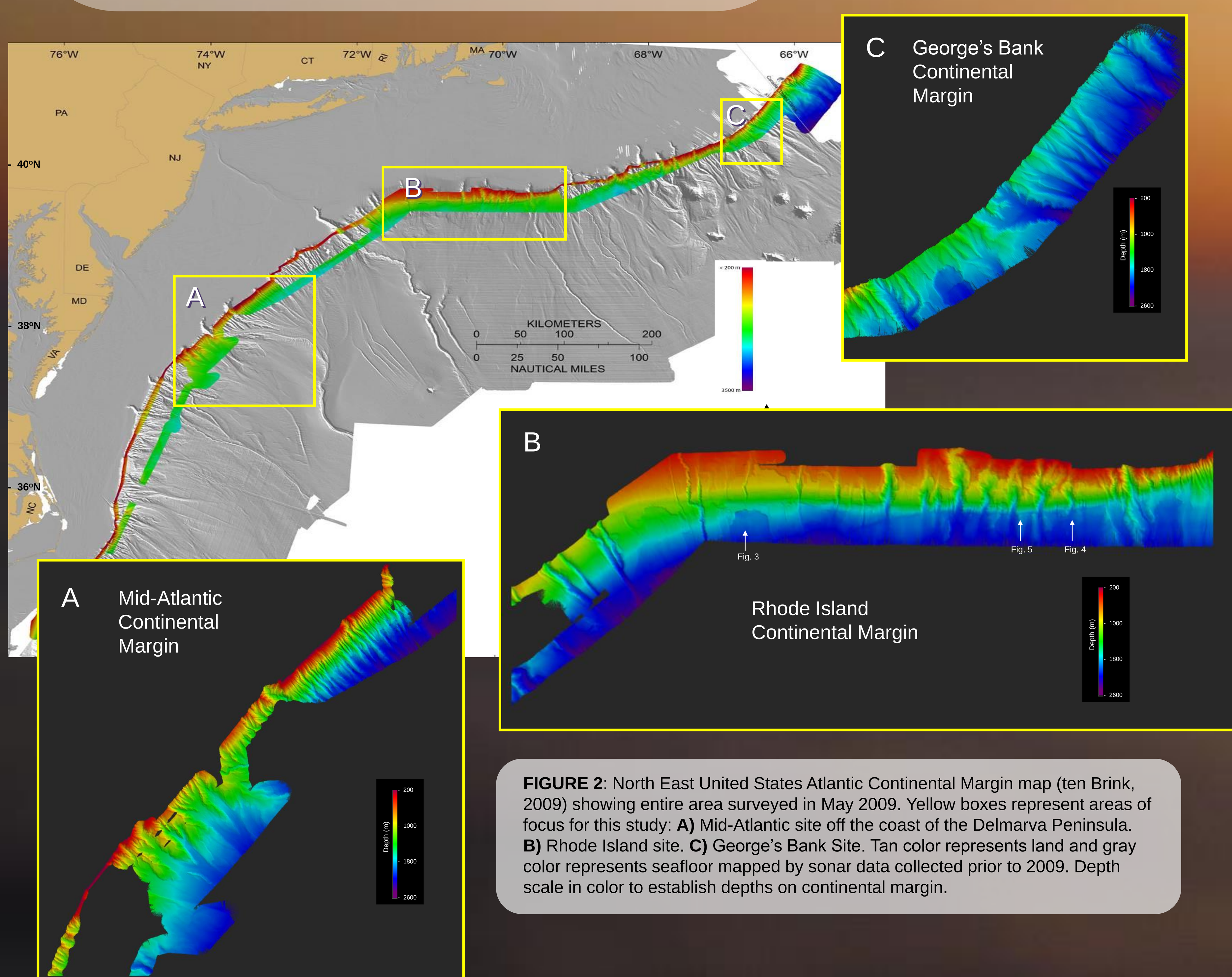

FIGURE 2: North East United States Atlantic Continental Margin map (ten Brink, 2009) showing entire area surveyed in May 2009. Yellow boxes represent areas of focus for this study: **A)** Mid-Atlantic site off the coast of the Delmarva Peninsula. **B)** Rhode Island site. **C)** George's Bank Site. Tan color represents land and gray color represents seafloor mapped by sonar data collected prior to 2009. Depth scale in color to establish depths on continental margin.

DISCUSSION/CONCLUSION:

After analysis of the Atlantic continental margin slope-sourced submarine landslides, three main characterizations of slumping, hereafter referred to as: **Wide-Mouth Slump (WM), Finger Slump (FS), and Slump-Split Slump (SS)**, were categorized by a width-to-gradient ratio. Although three different sites (Figure 2: a,b, and c) were studied, the three characterizations of slumps populate the Rhode Island area (Fig. 2b) more than the other two areas (Mid-Atlantic and George's Bank). The Rhode Island area features a great amount of the continental slope and rise and therefore more suitable for study.

In order to select the slumps used for characterization multiple profiles, down-dip and across-strike, were created to further confirm any distinct morphologies of a submarine landslide. The following equation was created to characterize the types of slumping:

$$SlumpVal = W / (gradient \times 1000)$$

Width *(W)* was measured in meters between the horizontal distance of each slump feature as seen in B to B' (Fig. 3). The gradient of each slope was calculated from the top of the scarp to the base of the scarp where intensity decreases. The data reveal that a *SlumpVal* value $\leq$ 13 suggests a *SS*, values 13 through 18 suggest a *WM* slump, and values $\geq$ 18 are categorized as *FS* (Table 1).

Since the equation is comprised of a measurement in width and gradient of slump, this gives a foundation for an estimate of how much material was displaced during slope failure. Tsunamis catalyzed from submarine landslides are typically elevated by volume displaced by slope failure and acceleration of the mass that is being wasted (Harbitz et al., 2006).

As the *SlumpVal* decreases, there is a reduced risk for submarine landslides and therefore a reduced risk of tsunami generation. Furthermore, it appears as though the risk for a slope-sourced landslide is highest at the values of 16-18 and therefore a higher risk of slope failure, which in turn could generate tsunami. Areas on the U.S. Atlantic Continental slope/upper rise that express *WM* slumps and *FS* slump morphologies are consequently areas that in the future may produce more submarine landslides and in turn produce elevated tsunamis.

In further study it would be beneficial to add more parameters to the *SlumpVal* formula (such as slope angle) to better predict slumping patterns and therefore predicting where submarine landslide induced tsunamis might be produced. In addition, core data would be beneficial in determining composite materials of slump detachments to gain assessment of sediment type causing slope failure.

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RESULTS:

- Slope-sourced submarine landslides can be divided into three distinct types along the Atlantic margin, with further quantitative analysis yielding a width-to-gradient ratio used to characterize slumps.
- Figure 3 (3D image: VE = 3.3x) depicts a **Wide-Mouth Slump *(WM)*** located off the coast of Rhode Island (71.03º W, 39.43º N). This type of slump is characterized by a main scarp gradient of 0.4238 and maximum width at 12,065 meters.
- Figure 4 (3D image: VE = 2.7x) depicts a **Finger Slump *(FS)*** located off the coast of Rhode Island (69.46º W, 39.48º N). Finger Slumps are characterized by a main scarp gradient of 0.21667 and maximum width between hedge scarps at 615 meters.
- Figure 5 (3D image: VE = 2.4x) depicts a **Slope-Split Slump *(SS)*** located off the coast of Rhode Island (69.57º W, 39.45º N). This type of slump is characterized by a main slope gradient of 0.1552 and a maximum width of slump detachment at 850 meters.

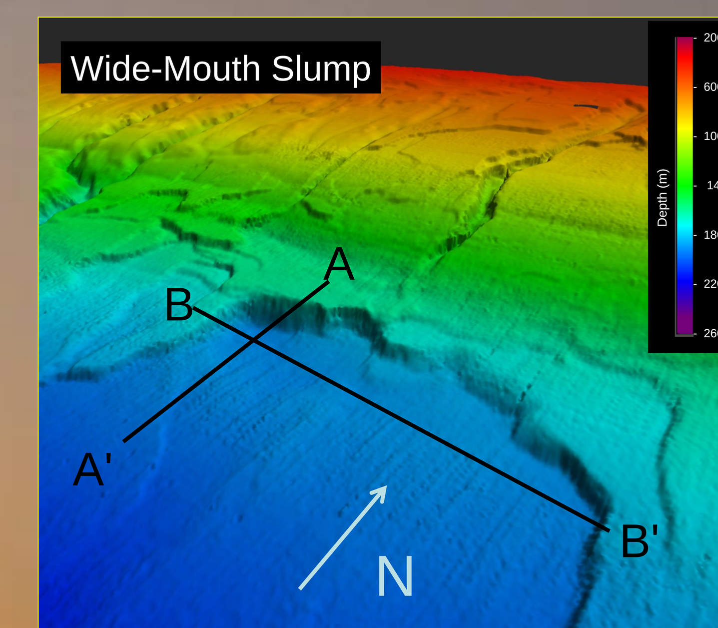
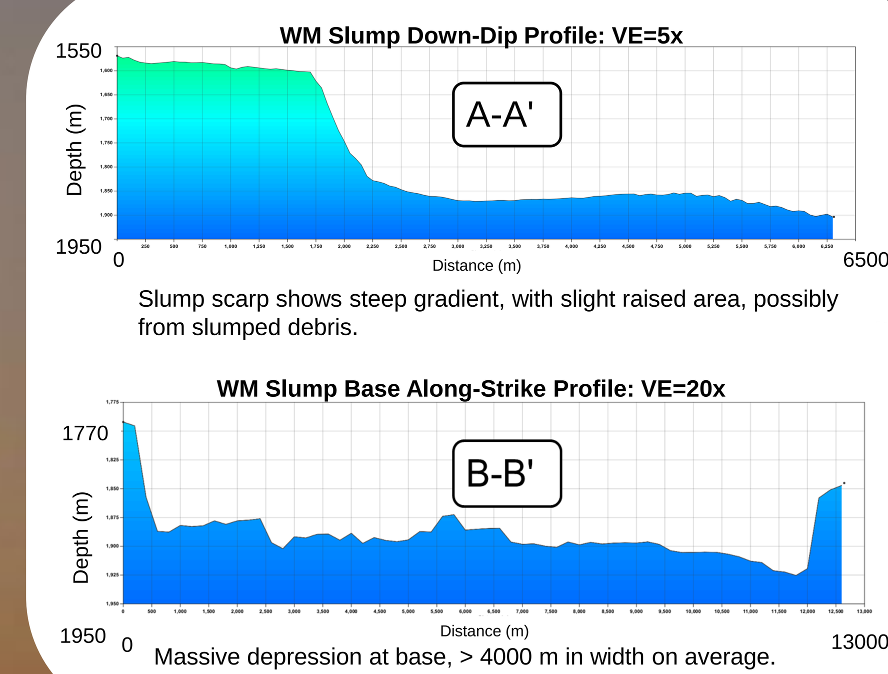


FIGURE 3: (VE= 3.3x) 3D bathymetric image of a Wide-Mouth Slump (WM) in the area depicted in figure 2b.



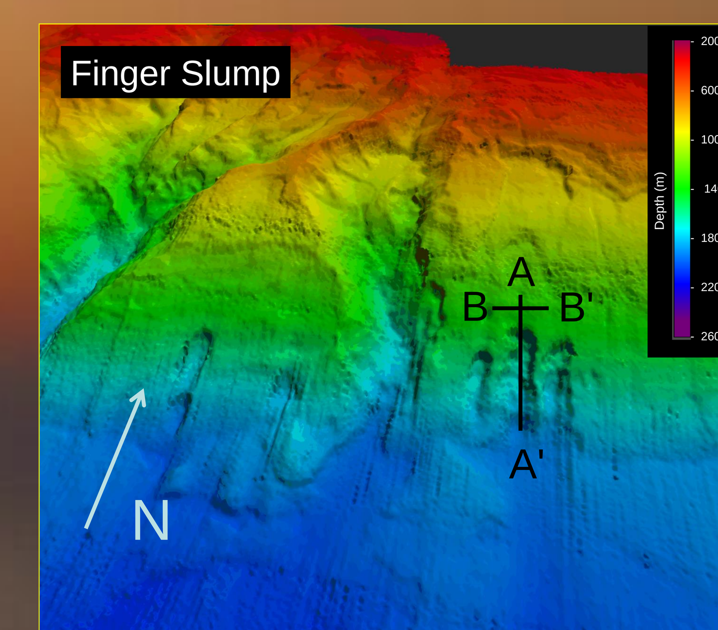
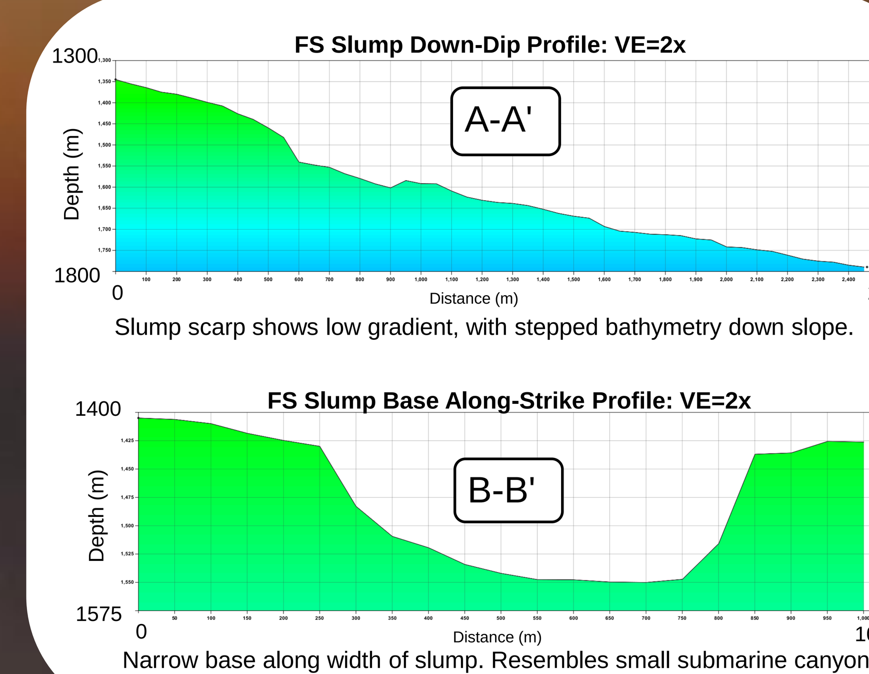


FIGURE 4: (VE= 2.7x) 3D bathymetric image of a Finger Slump in the area depicted in figure 2b.



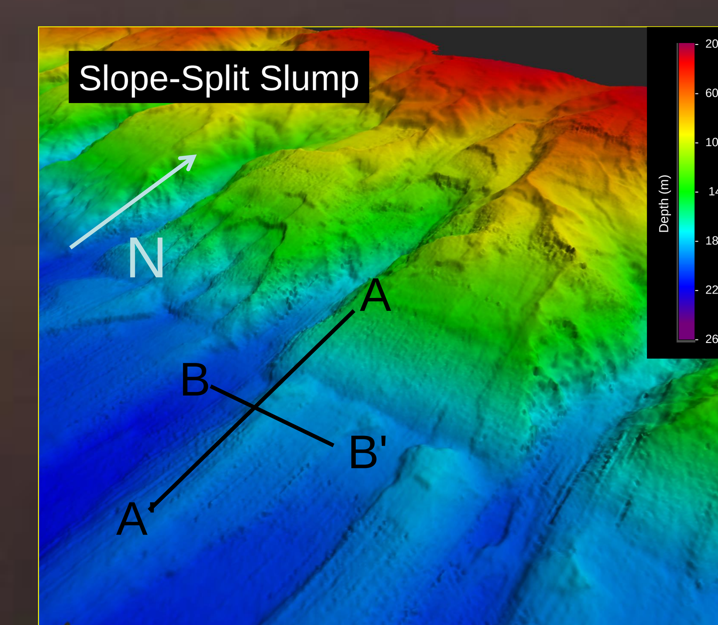
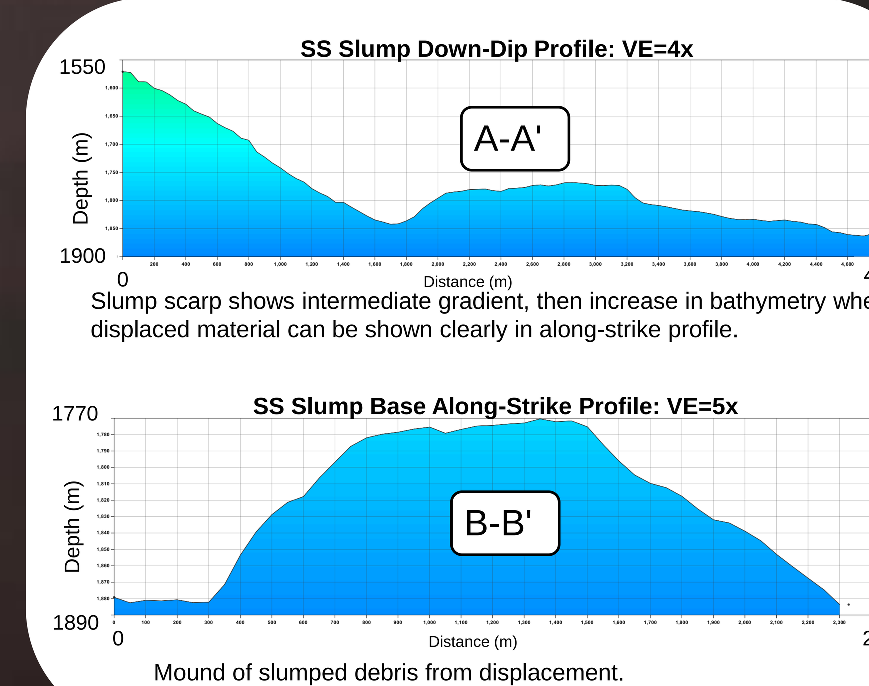


FIGURE 5: (VE= 2.4x) 3D bathymetric image of a Slope-Split Slump in area depicted in figure 2b.



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