Submarine Channel Association with Seamount Chain Alignment on the Ontong Java Plateau

Howard Meyers and Leslie Sautter – Department of Geology and Environmental Geosciences. College of Charleston

Abstract

The Ontong Java Plateau (OJP), north of the Solomon Islands, Indonesia, is a submerged seafloor platform, larger than Alaska and full of intricate systems of channels, atolls and seamounts. This area has remained relatively unstudied because of both the area's remote location and low number of ships carrying advanced sonar systems. The OJP is believed to have been formed by one of the largest volcanic eruptions in Earth's history. This study uses EM302 multibeam sonar data collected on the R/V *Falkor* in 2014 by the University of Tasmania's Institute for Marine and Antarctic Studies to better understand relationships between the seafloor geomorphology and tectonic processes that formed numerous unexplored seamounts. The area surveyed is situated along the OJP's central northeast margin, and includes a small chain of six seamounts that range from 300 to 700 m in vertical relief. These seamounts are situated within the axis of a major 14 km wide submarine channel that was likely formed by a sequence of turbidity currents. Using CARIS HIPS and SIPS 9.0 post-processing software, seamount and channel morphology were characterized with 2 dimensional profiles and 3 dimensional images. Backscatter intensity was used to identify relative substrate hardness of the seamounts and surrounding seafloor areas. Scour and depositional features from the turbidity flows are evident at the base of several seamounts, indicating that the submarine channel bifurcated when turbidity flows encountered the seamount chain.

Background

The Ontong Java Plateau (OJP) is a large submarine plateau, largely un-explored and whose origins are not fully understood. The OJP occupies an area of about 1,900,000 km^2, roughly the size of the Continental United States. The area around the Solomon Islands is very tectonically active, and the plateau was formed from a massive magma plume (Mann and Asahiko, 2004). The Australian-Pacific Boundary is complex but generally convergent with the Pacific Plate subducting under the Australian. The OJP is now broken up due to the complexity of the region, including translational faults and movement of small microplates independent of the two major tectonic plates (Mann et al., 2004). Multibeam sonar surveys conducted in 2014 on the R/V *Falkor* (led by Mike Coffin from the University of Tasmania's Institute for Marine and Antarctic Studies) were primarily aimed at finding a window to the OJP basement that would allow drilling to collect deep samples at the base of the overlying sediment. One area surveyed was the Kroenke Canyon and adjacent Kroenke Channel (Figure 1b). This study focuses on the seamounts on the northern end of the Kroenke Canyon, using profiles and 3D images to study their morphology and relationship with the canyon, as many are in linear succession. Little is known about the formation of these canyons, though Coffin hypothesized a process called dewatering carving of the canyons, where water that had squeezed out of sediments during lithification flowed along small paths eventually carving out a large canyon.

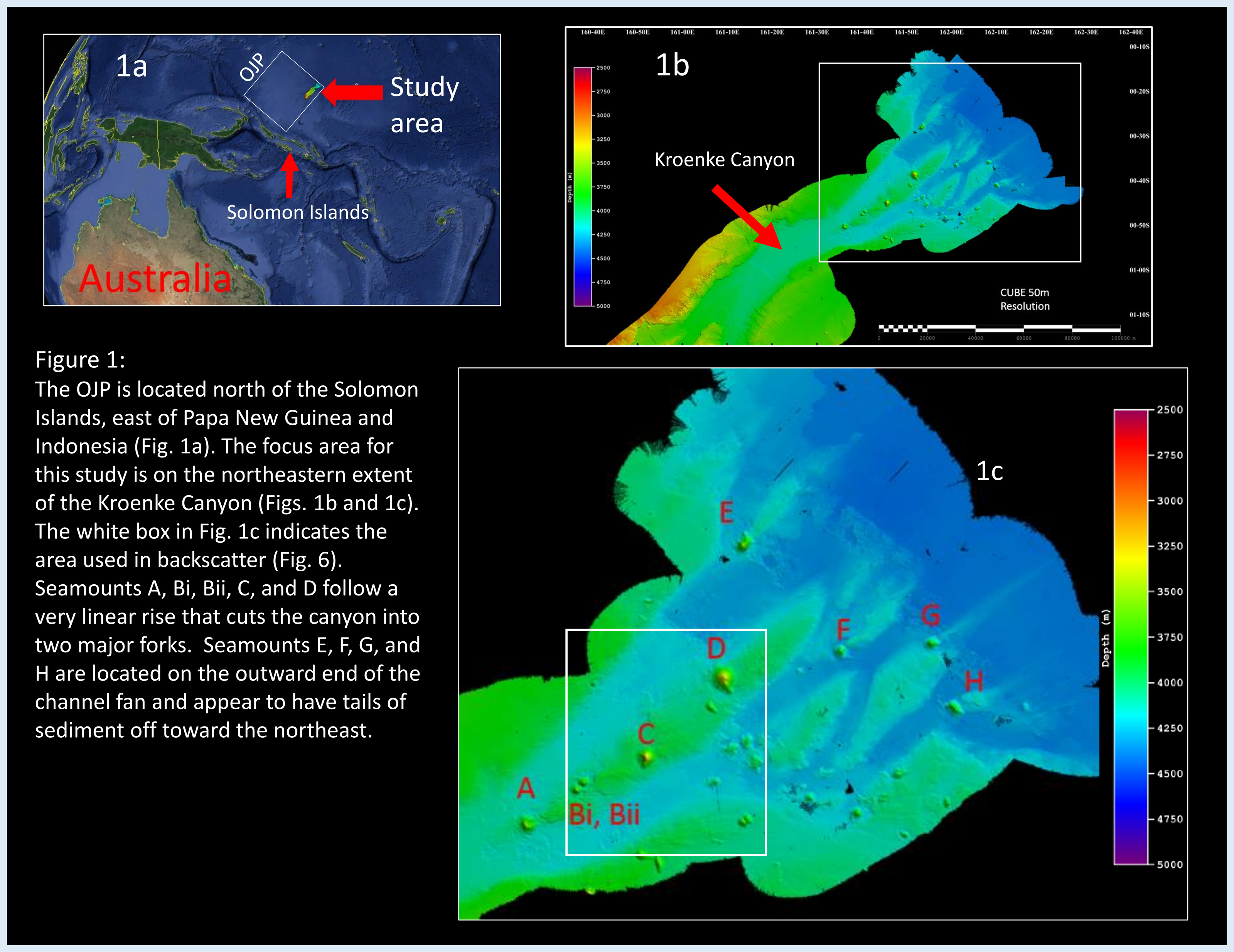


Figure 1:
The OJP is located north of the Solomon Islands, east of Papa New Guinea and Indonesia (Fig. 1a). The focus area for this study is on the northeastern extent of the Kroenke Canyon (Figs. 1b and 1c). The white box in Fig. 1c indicates the area used in backscatter (Fig. 6). Seamounts A, Bi, Bii, C, and D follow a very linear rise that cuts the canyon into two major forks. Seamounts E, F, G, and H are located on the outward end of the channel fan and appear to have tails of sediment off toward the northeast.

Methods

Using the R/V *Falkor's* Kongsberg EM302 multibeam sonar data, 3D images and 50m resolution CUBE BASE surfaces were created. Using CARIS HIPS and SIPS 9.0 for post-processing, 3-D profiles were created and provided important information regarding slopes, relief, and the sediment tail trailing down-current of the seamounts. Quantifying these data was challenging, as there is no set definition for the start or end of these features. Seamount tail length as seen in Figure 4 was measured using reference lines to define key characteristics on the seamount. The first is the depth at which the seamount base is defined. The Tail is defined as the length of relief above this depth that is down-current of the seamount and its horizontal reference line. The two vertical lines identify where these points intersect (Figure 5c). Slope was measured using the reference points from determining the sediment tail. The reference points include the point determined to be the base of the seamount and the middle of the seamount, at which there is maximum relief, to determine the height and width of the seamounts to then calculate the slope. To determine the relative hardness of the seafloor surface, a backscatter mosaic was created using SIPS post-processing. This mosaic was then altered from a grey scale color scheme, to a range of three colors to demonstrate the change in intensity (Fig. 6). This mosaic was then draped over a 3D surface of the study area to compare peaks to surrounding substrate.

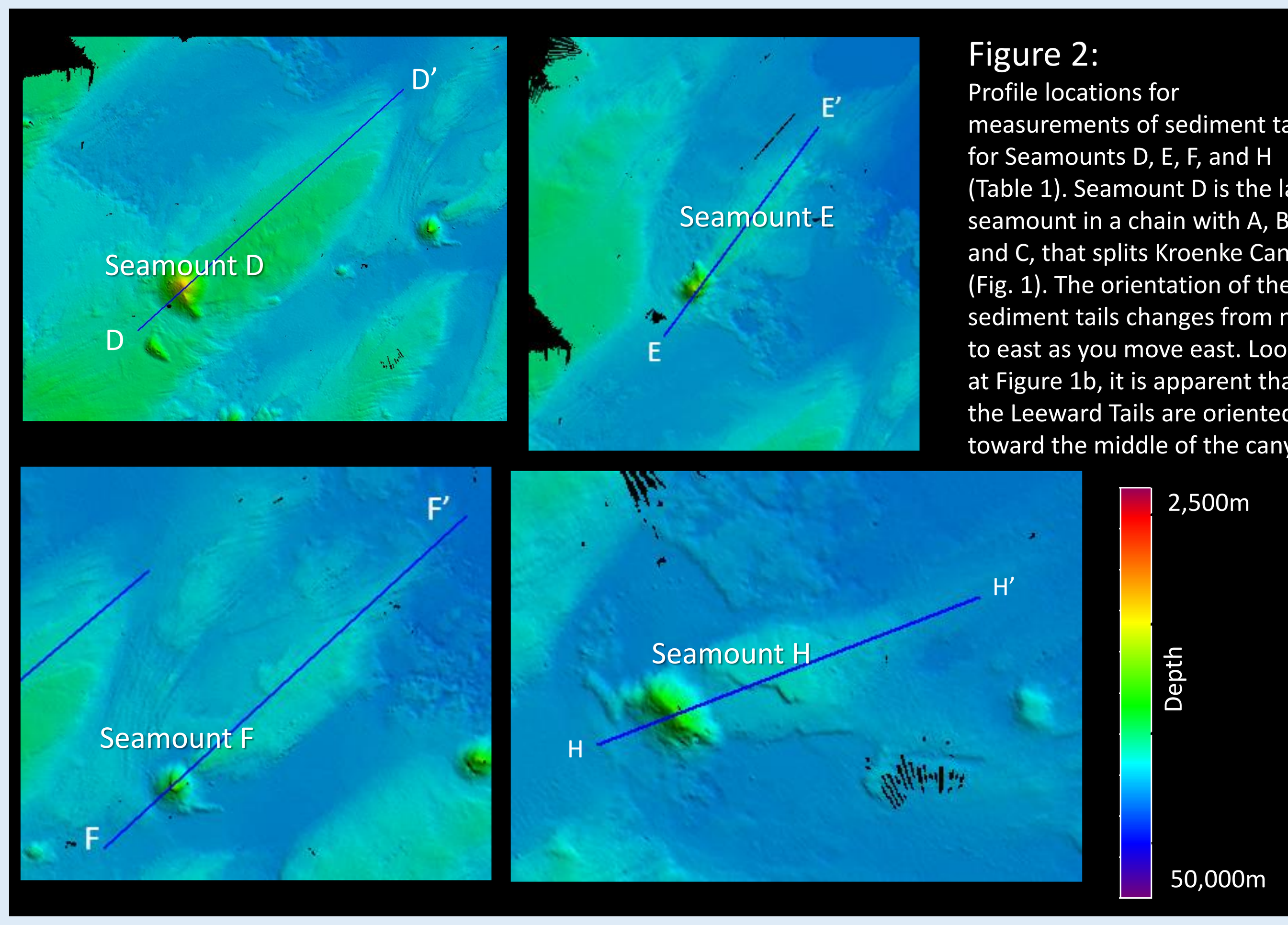
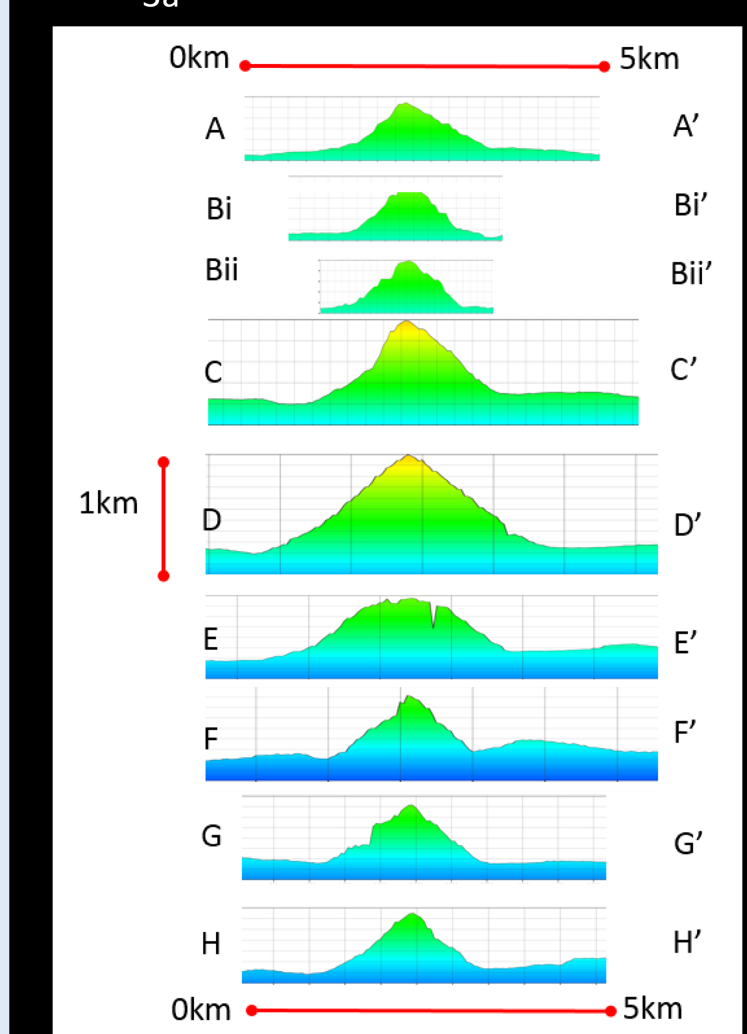


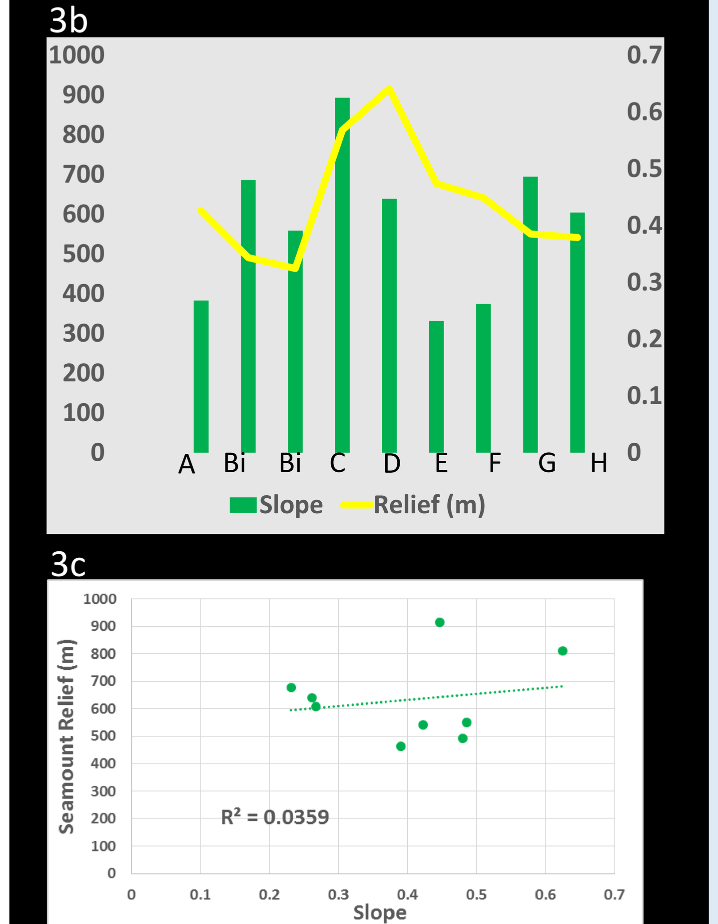
Figure 2:
Profile locations for measurements of sediment tails for Seamounts D, E, F, and H (Table 1). Seamount D is the last seamount in a chain with A, B, and C, that splits Kroenke Canyon (Fig. 1). The orientation of the sediment tails changes from north to east as you move east. Looking at Figure 1b, it is apparent that the Leeward Tails are oriented toward the middle of the canyon.

Figure 3:
a) Slopes and relief of all the seamounts studied.
b) Relationship between slope and relief of seamounts.
c) R^2 value indicates no correlation between Slope and Relief of seamounts.

Table 1. Morphological Features of seamounts

Seamount	Seamount Peak (m)	Relief (m)	½ Width (m)	Slope
A	3550	490	1830	0.268
B:i	3560	470	980	0.480
B:ii	3600	450	1150	0.391
C	3200	750	1200	0.625
D	3200	850	1900	0.447
E	3640	580	2500	0.232
F	3900	340	1300	0.262
G	3690	510	1050	0.486
H	3750	550	1300	0.423





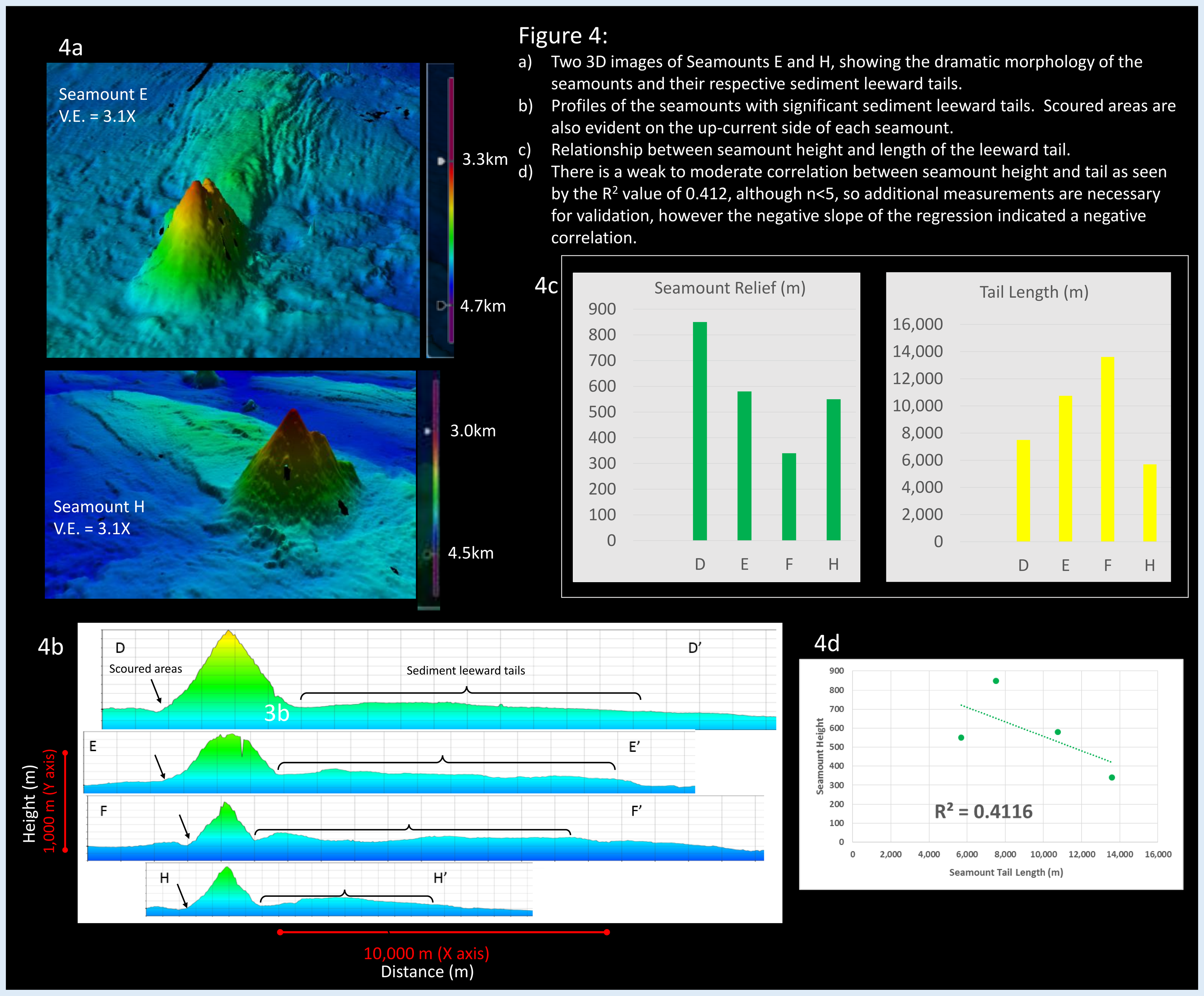


Figure 4:
a) Two 3D images of Seamounts E and H, showing the dramatic morphology of the seamounts and their respective sediment leeward tails.
b) Profiles of the seamounts with significant sediment leeward tails. Scoured areas are also evident on the up-current side of each seamount.
c) Relationship between seamount height and length of the leeward tail.
d) There is a weak to moderate correlation between seamount height and tail as seen by the R^2 value of 0.412, although n<5, so additional measurements are necessary for validation, however the negative slope of the regression indicated a negative correlation.

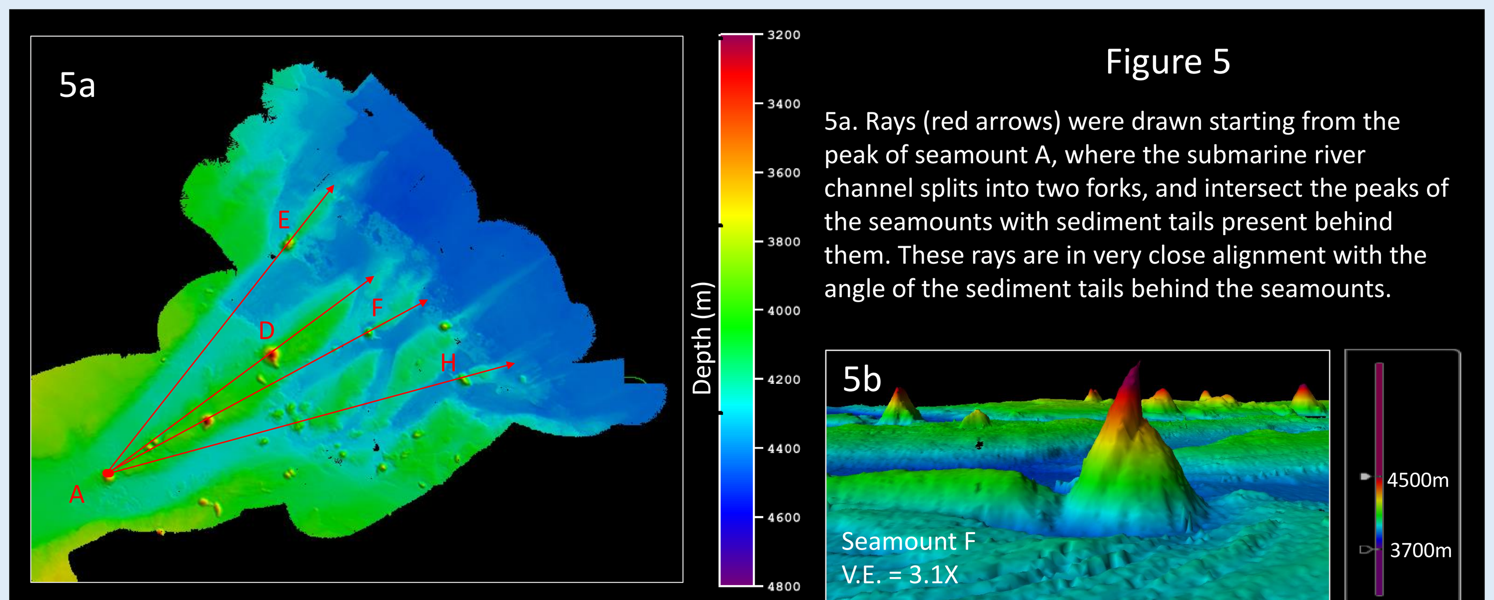
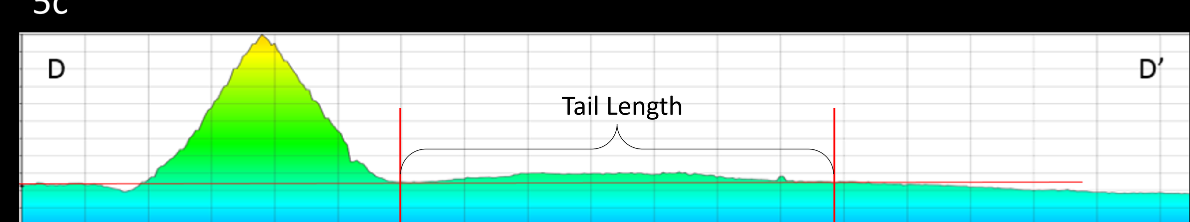


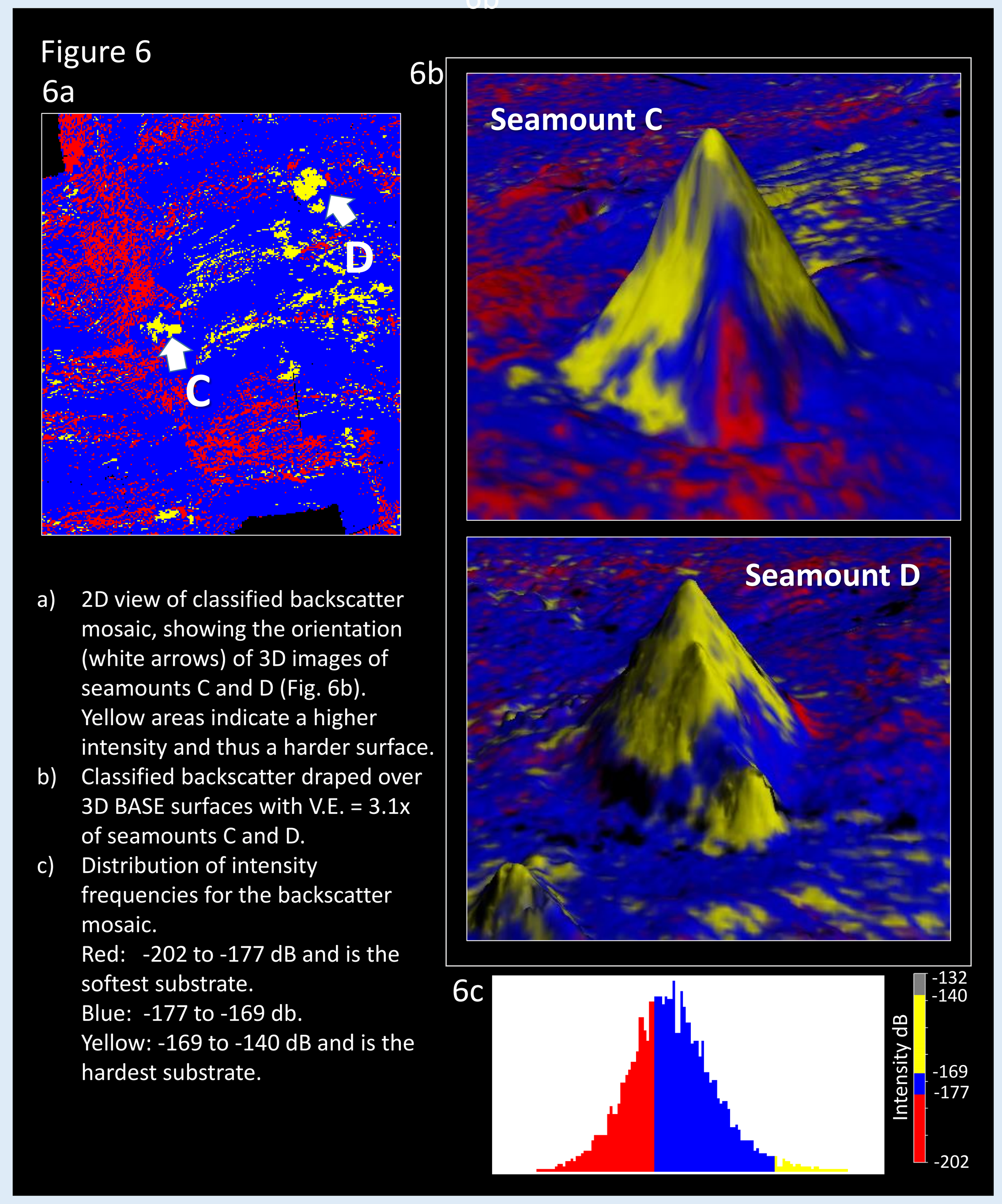
Figure 5

5a. Rays (red arrows) were drawn starting from the peak of seamount A, where the submarine river channel splits into two forks, and intersect the peaks of the seamounts with sediment tails present behind them. These rays are in very close alignment with the angle of the sediment tails behind the seamounts.

5b. Seamount F has dramatic erosional features around its base, as well as a large sediment tail as seen in this 3D image.

5c. Seamount tail length was measured using reference lines to define key characteristics on the seamount. The first is the depth at which the seamount base is defined. The Tail is defined as the length of relief down current of the seamount that is above this depth and its horizontal reference line. The two vertical lines identify where these points intersect.





a) 2D view of classified backscatter mosaic, showing the orientation (white arrows) of 3D images of seamounts C and D (Fig. 6b). Yellow areas indicate a higher intensity and thus a harder surface.
b) Classified backscatter draped over 3D BASE surfaces with V.E. = 3.1x of seamounts C and D.
c) Distribution of intensity frequencies for the backscatter mosaic.
Red: -202 to -177 dB and is the softest substrate.
Blue: -177 to -169 db.
Yellow: -169 to -140 dB and is the hardest substrate.

Results

- Seamount height does not have a strong correlation with its leeward tail as one might expect (R^2 value of 0.4116), as seen in Figure 3d.
- There is no correlation between seamount relief and its slope (R^2=0.0359, Figure 4d).
- The backscatter return shows that the seamounts are harder (Figure 6). The rest of the surface along the plateau is relatively similar in hardness, and is likely sediment covered flood basalt while the seamount peaks are exposed basalt.

Discussion

The presence of these leeward tails paired with evidence for erosional scours along the southwest side of the seamounts provides strong evidence that the flow of water in the canyon is to the northeast. While the data collected on seamount tails shows only a moderate correlation to the height of the seamount (R^2 = 0.4116), this study has provided evidence that while size probably does play an important role in the length of the tail, it is not as strong a contributor as the location of the seamount in relation to the main flow of water away from the main Kroenke Canyon. Figure 5 shows the relative orientation of the sediment tails. Starting from the peak of seamount A, rays can be drawn that intersect the peaks of seamounts D, E,F, and H, and that are in line with their respective sediment tails. Seamount A is located at the divergent point of the Kroenke channel, and the sediment tails radiate from this point. Seamount F's sediment tail is skewed to the left of the ray drawn, likely due to water bending around the raised area on which seamounts A, B, D lie, and the smaller area to its east. Further studies should be done on the origins of the Kroenke Canyon, development of small tributaries starting at atolls up current could be evidence for Coffin's hypothesis of dewatering carving. We also found no correlation between the size of the seamount and its flank slope. Backscatter data show that two seamounts, C and D showed much harder surfaces at the peaks as compared to other surfaces in the study area. In fact the Ontong Java Plateau in general had a very monotone backscatter return. Indicating similar composition and relative substrate hardness of the features observed.

Acknowledgments
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Howie Meyers
meyershg@g.cofc.edu

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