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

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Abstract

The Ontong Java Plateau (OJP), north of the Solomon Islands, Indonesia, is a submergent 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 is surveyed 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 seamount channel bifurcated when turbidity flows encountered the seamount chain.

Background

The Ontong Java Plateau (OJP) is a large submarine plateau, largely unexplored and whose origins are not fully understood. The OJP occupies an area of about 1,900,000 km², 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 magmatic pile (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, likely due to the complexity of the region, including transcontinental 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 Kronke Canyon and adjacent Kronke Channel (Figure 1b). This study focuses on the seamounts on the northern end of the Kronke 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 pathways eventually carving out a large canyon.

Figure 2: Profile locations for measurements of sediment tail for Seamounts D, E, F, and H (Table 1). Seamounts D to the left are the first seamount in a chain with A, B, and C, that form Kronke Canyon (Fig. 1). The orientation of the seamount chain changes from north to east as you move east. Looking at Figure 1, it appears that the Lahaina Fis 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.

Figure 4: a) Three 2D images of Seamounts E and F, showing the dramatic morphology of the seamounts and respective sediment leeward tails. b) Profiles of the seamounts with significant sediment borders of tails. Scoured areas are also evident on the up-current side of each seamount. Radial distance is the length from the seamount height and depth of the seamount. c) There is a weak to moderate correlation between seamount height and tan as seen by the \( R^2 \) value of 0.412, although \( n \) is small and additional measurements are necessary for validation. However, the negative slope of the regression indicated a negative correlation.

Figure 5: a) Rays (red arrows) were drawn starting from the peak of seamount A, where the submarine channel splits into two forks, and intersect the peaks of the seamounts with sediment tails present around them. These rays are in very close alignment with the angle of the sediment tails behind the seamounts. b) Seamount tail length was measured using reference lines to determine the length of relief down current of the seamount that is above this horizontal reference line. The two vertical lines are used to identify where these points intersect.

Table 1. Morphological Features of seamounts

<table>
<thead>
<tr>
<th>Seamount</th>
<th>Length (m)</th>
<th>Width (m)</th>
<th>Slope</th>
<th>Relief</th>
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<tbody>
<tr>
<td>D</td>
<td>1200</td>
<td>600</td>
<td>0.30</td>
<td>400</td>
</tr>
<tr>
<td>E</td>
<td>1000</td>
<td>400</td>
<td>0.25</td>
<td>300</td>
</tr>
<tr>
<td>F</td>
<td>800</td>
<td>300</td>
<td>0.20</td>
<td>200</td>
</tr>
<tr>
<td>G</td>
<td>600</td>
<td>200</td>
<td>0.15</td>
<td>150</td>
</tr>
<tr>
<td>H</td>
<td>400</td>
<td>100</td>
<td>0.10</td>
<td>50</td>
</tr>
</tbody>
</table>

Figure 6: a) 2D view of calculated backscatter mosaic, showing the orientation (white arrows) of 3D images of seamounts C and D (Fig. 6b). b) Yellow indicates a higher intensity and thus a harder surface. c) Contoured backscatter mosaic of 3D BASE surfaces with \( \bar{v} = 1.3 \times 10^{-3} \pm 0.1 \times 10^{-3} \) of seamounts A, B, and C. d) Distribution of intensity frequencies for the backscatter mosaic.

Discussion

The presence of these leeward tails paired with evidence for erosional scars 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 Kronke 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, and F, and that are in line with their respective sediment tails. Seamount A is located at the divergent point of the Kronke 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, I, and the smaller area to its east. Further studies should be done on the origins of the Kronke Canyon, development of small tributaries starting at stulls 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 bank 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.

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, 3D profiles were created and provided important information regarding slopes, relief, and the sediment tail tracting 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 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.

Acknowledgments

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References
