A Bathymetric Analysis Comparing the Geomorphology of Two U.S New England Seamounts

Caitlyn Coker Mayer and Dr. Leslie Sautter

Dept. of Geology and Environmental Geosciences

College of Charleston, Charleston, SC USA

COLLEGE of CHARLESTON DEPARTMENT OF GEOLOGY AND ENVIRONMENTAL GEOSCIENCES

NOAA Ship *Okeanos Explorer*

ABSTRACT

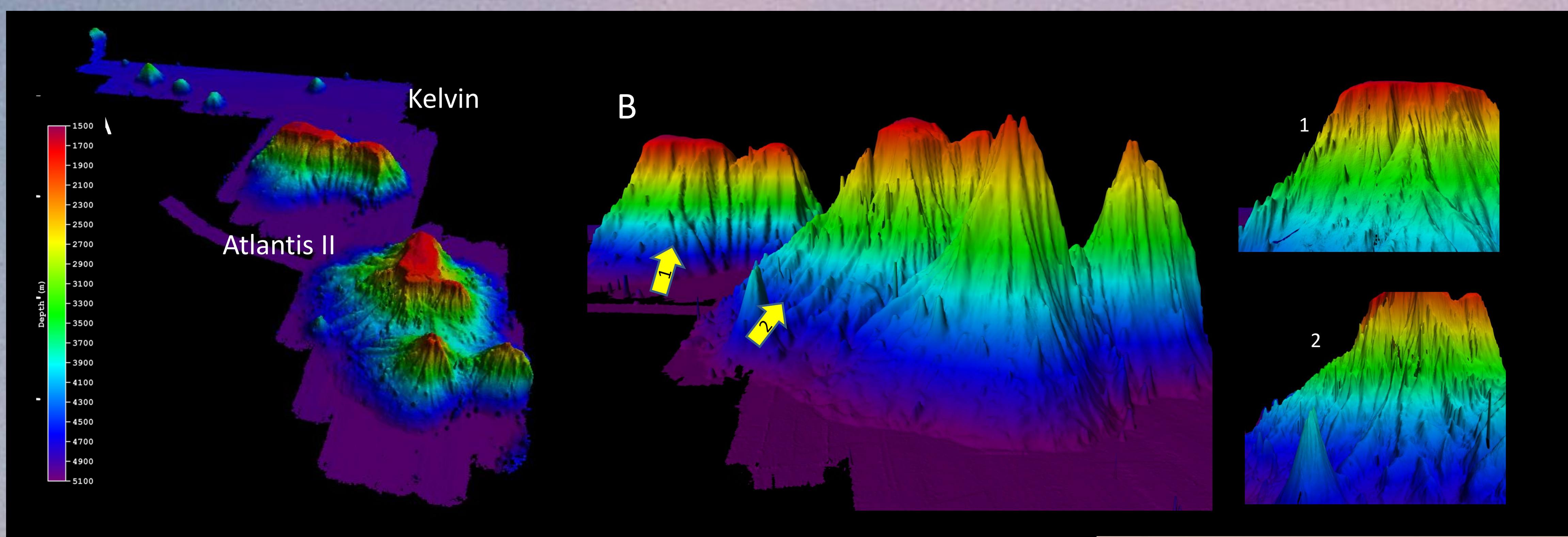
An east-west trending seamount chain occurs off the New England coast in the western Atlantic Ocean. This chain of submarine volcanoes ranges in age from 80 to 103 million years old, formed when the North American Plate began to diverge from the Mid-Atlantic Ridge, moving westward over the Great Meteor hotspot. The two largest seamounts, Kelvin and Atlantis II Seamounts, were characterized using multibeam sonar, and seamount volumes and vertical reliefs were calculated. Volumes of 3,445 and 2,503 km^3, and vertical reliefs of 3422 and 3277 m for Kelvin and Atlantis II Seamounts, respectively suggest Kelvin formed over a longer period of time or the magma plume erupted at a greater intensity while forming Kelvin. Gradient, alignment, and age similarities indicate that the seamounts formed by the same method, presumably by eruptions from a hotspot.

INTRODUCTION

The New England Seamounts are the longest seamount chain in the North Atlantic Ocean, stretching 1000 km from the Mid-Atlantic Ridge to the U.S New England coast (Figures 1 and 2). The two seamounts compared in the study are the Kelvin Seamount and the Atlantis II Seamount, both located at 38.5⁰N. Similarities between the two seamounts in age, volume, composition and slope indicate a similar method of formation. The seamounts are extinct submarine volcanoes that are believed to have formed when the North American Plate moved over the Great Meteor Hotspot. The seamounts are "islands" of hard rock substrate, most likely basalt, on an otherwise sediment-covered abyssal plain. A combination of strong ocean currents that move over and around them and wave energy erosion from when the mounts were near sea level caused the seamounts to be flat topped. In June 2013, the NOAA Ship *Okeanos Explorer* mapped this area by collecting seafloor bathymetric data (Okeanos Explorer, 2013). The research cruise provided online datasets that were processed for this study in order to understand the geomorphology of intraplate seamounts and find supportive evidence of the "hotspot hypothesis" as their origin. This hypothesis states that seamounts form above stationary plumes in Earth's mantle. As the plates move over these magma sources seamounts develop. The seamounts are eventually carried away from the magma source and cease to be active. The net result is a linear chain of extinct submarine volcanoes that illustrate a steady age progression that matches the history of the plate's motion (Wilson, 1961). Due to their frequent alignment into linear, sub-parallel chains that seem to correlate with the direction of past plate motions, the most widely accepted origin of intraplate seamounts is the "hotspot hypothesis"(O'Neille et al., 2005).

METHODS

- The NOAA Ship *Okeanos Explorer* surveyed the western portion of the New England Seamount chain in June 2013, equipped with a Kongsberg EM302 multibeam sonar system.
- CARIS HIPS & SIPS 8.1 was used to create a 50m resolution CUBE BASE surface.
- Estimated seamount volume was calculated using the cone volume formula ($V=\pi r^2(h/3)$, where r = radius of base and h = vertical relief (Fig. 3), shown as Base Depth-Peak Depth in Table 1.
- Slopes of each flank were calculated using the slope formula(Y_1-Y_2/X_1-X_2) where the x,y values where taken at intersecting grid lines from each side of the topographical profiles.



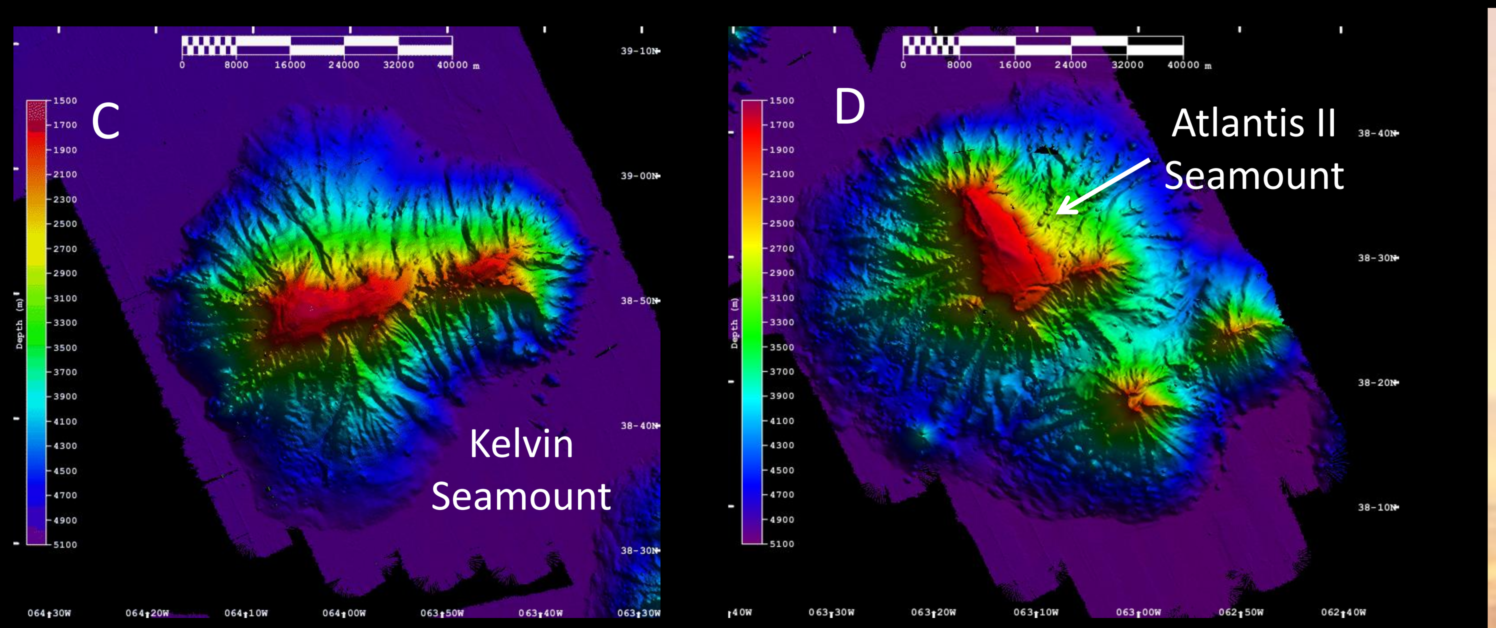


Figure 1. A) 3D image of the entire seamount chain study area, viewed looking northwest. B) 3D image of the two seamounts compared. B1 is the Kelvin Seamount, Image B2 is the Atlantis II Seamount. C) and D) 2D BASE surfaces of the Kelvin Seamount and Atlantis II Seamount, respectively. The two small seamounts southeast of Atlantis II were not used in the study.

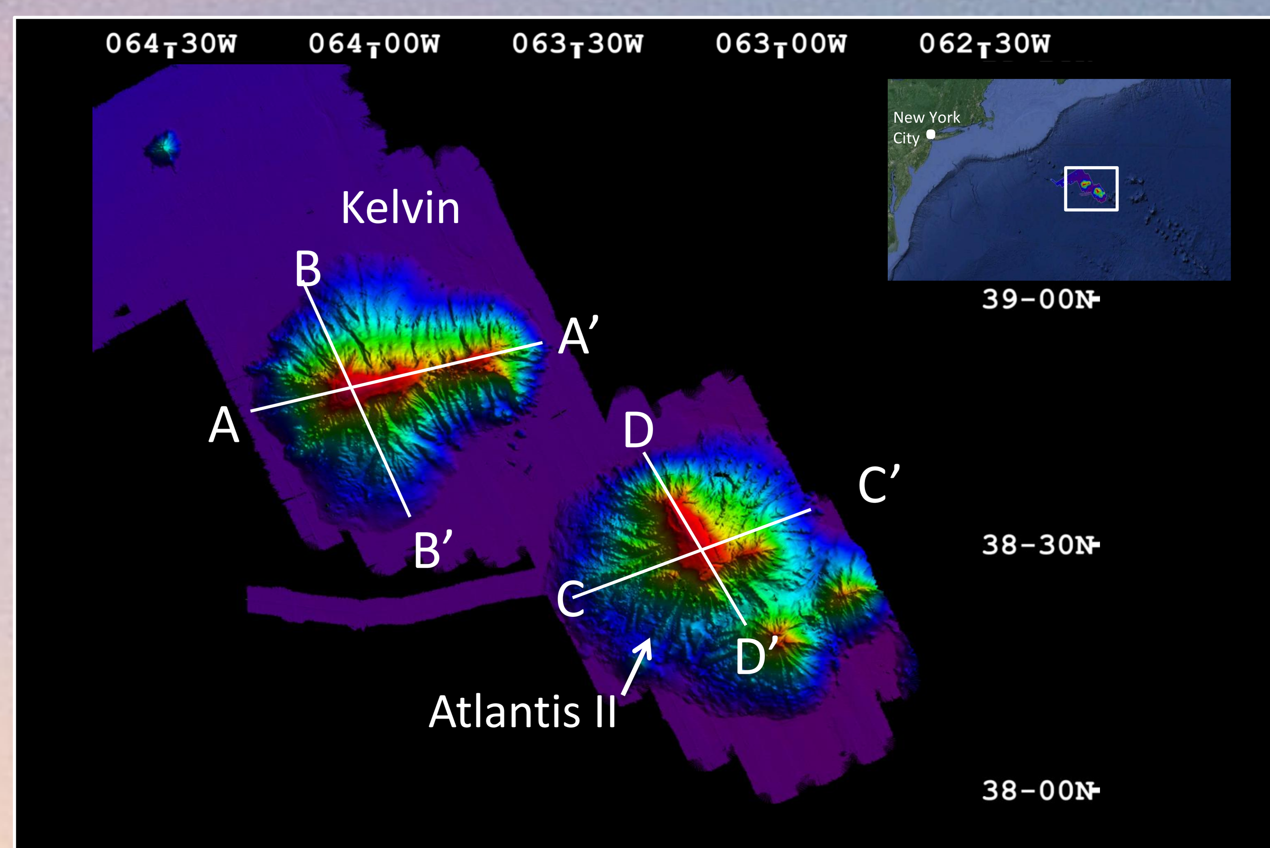


Figure 2. CUBE BASE surface (50 m resolution) of seamount location, showing the orientation of four profiles illustrated in Figure 3.

RESULTS

The Kelvin Seamount has a base diameter maximum of 63,111 m and the Atlantis II Seamount has a base diameter of 60,091 m. The Kelvin Seamount is slightly larger, with an estimated volume of 3445 km^3 while the Atlantis II Seamount has a volume of 2503 km^3. The vertical reliefs and peak depths are also similar (Table 1). Both Seamounts have similarities in their slopes, however these slopes do not follow the same orientation. (Figures 1-B1, 1-B2, and 3; Table 2). The steep gradients change from Atlantis II's East-West orientation to Kelvin's North-South orientation.

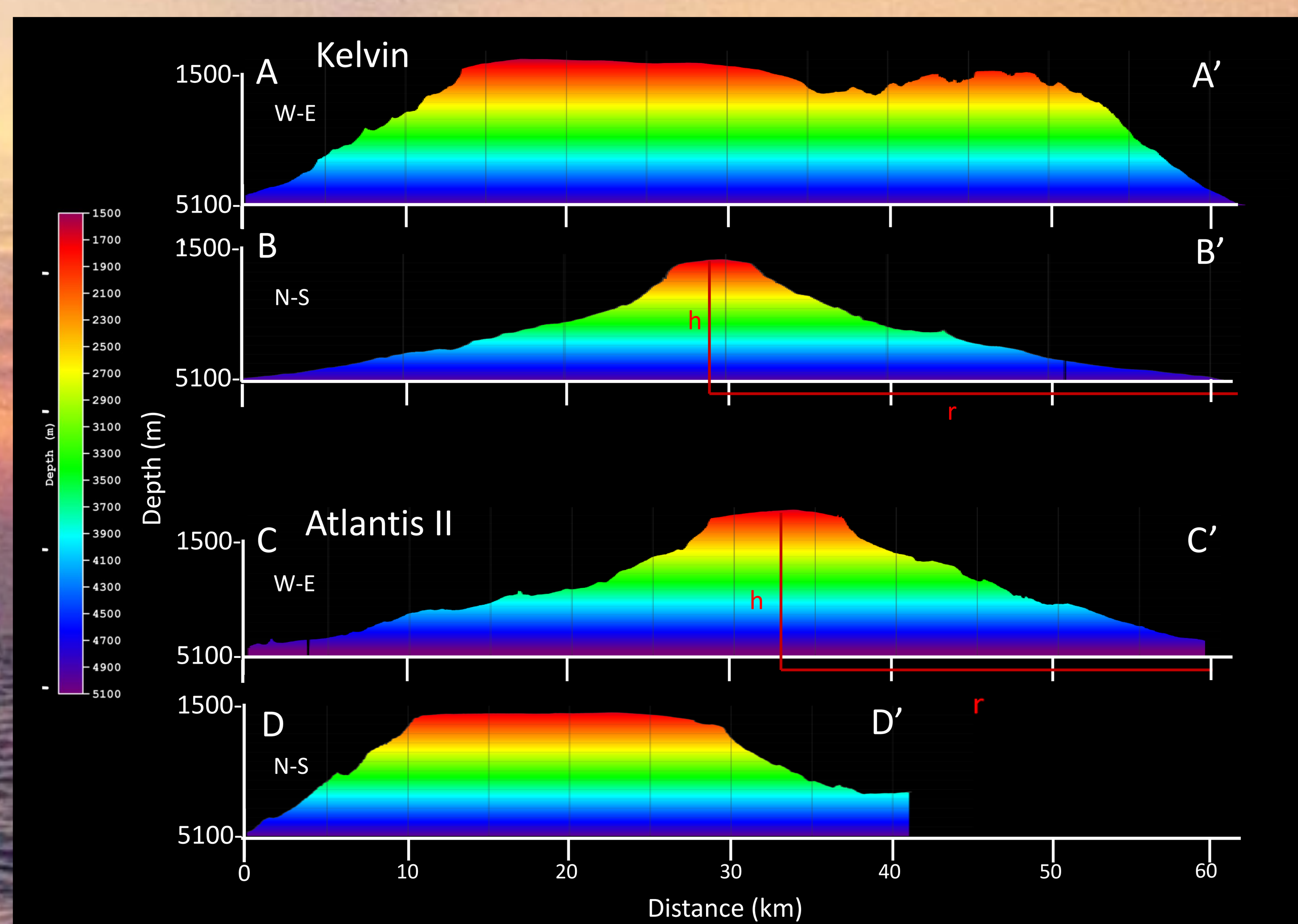


Figure 3. Cross-sectional profiles of Kelvin and Atlantis II Seamounts: West-East orientation of Kelvin(A-A') and Atlantis II(C-C'); North-South orientation of Kelvin(B-B') and Atlantis II(D-D'). Measurements used for volume analysis: vertical relief is represented by h and radius is represented by r on profiles B-B' and C-C'.

Table 1 . Comparative morphology of the two seamounts with radius of base and vertical relief measurements collected from profiles B-B' and C-C'(Figure 3).

Seamount	Peak Depth (m)	Maximum Base Diameter (m)	Radius of Steep Slope Base, r (m)	Vertical Relief, h (m)	Total Estimated Volume (km^3)
Kelvin	1,578	63,111	31,000	3,422	3,445
Atlantis II	1,723	60,091	27,000	3,277	2,503

Table 2. Differences in slopes of Kelvin and Atlantis II Seamounts from North, East, South and West orientations.

	Average Slope (Degrees) of Seamount Flanks			
Profile	North Flank	East Flank	South Flank	West Flank
A	-	13.5⁰	-	11⁰
B	4.9⁰	-	4.6⁰	-
C	-	6.3⁰	-	3.4⁰
D	16.7⁰	-	14⁰	-

DISCUSSION AND CONCLUSION

The New England Seamounts' geomorphological history is revealed by the bathymetric data acquired and processed in the 2013 multibeam survey. A comparison of the Kelvin Seamount with the Atlantis II Seamount provides substantial evidence that supports the "hotspot hypothesis," first proposed by Wilson (1963). The Great Meteor Hotspot, located in the North Western Atlantic Ocean at approximately 33⁰N, 28°W, formed both the Kelvin and Atlantis II Seamounts nearly 100 million years ago. Similarities in size, shape, alignment and slope are indicative of forming along a hotspot track for the same length of time (Fig. 1). Kelvin is the largest of the seamounts in the study area (Fig. 2), with a diameter of 63,111 m and an estimated volume of 3,445 km^3. The Atlantis II Seamount follows close behind, with a diameter of 60,091 m and an estimated volume of 2,503 km^3, while the remaining eight seamounts in the study area are relatively small in comparison. The Kelvin Seamount's larger volume could be explained by a longer period over which it formed, allowing the volcano to grow more before it moved away from the hotspot. Another explanation is that Kelvin's eruption intensity and rate at which the magma flowed was greater during a similar length of time. The remaining eight seamounts in the study area are relatively small in comparison, which would suggest that they formed for shorter periods of time and possibly with lesser rates of magma flow.

The alignment of seamounts into chains provides a means to decipher the motion of the tectonic plates in relation to age and seamount location (Kroenke, 1996). When Kelvin formed, plate moved east to west, indicated by the seamount's elongated axis. Based on the north-south orientation of the younger Atlantis II's long axis, the plate later rotated and moved northward (Fig. 1). The slopes of each seamount flank would most likely have had similar angles if the plate's motion had not shifted orientation. However, the north and south flanks of Kelvin are morphologically similar to the east and west flanks of Atlantis II, and the east and west flanks of Kelvin are similar to the north and south flanks of Atlantis II (Table 2, Fig. 3).

Each of these seamounts exhibits a flat topped peak which can be attributed to several physical mechanisms such as wave energy eroding the top (prior to subsidence, when the seamount was hot and expanded and near to sea level), gravitational pressures and density changes weakening the peak, and upwelling from deep water. Statistical studies reveal that small seamounts form predominately on young and thin oceanic crust, while the larger seamounts form on old and thick lithosphere(e.g., Wessel, 2001). Similar slope angles (Table 2) of each seamount's flanks indicate similar subsidence rates and would further support that they formed sequentially, in the same way, and had undergone similar deformational mechanisms.

The mulitbeam data acquired in the 2013 *Okeanos Explorer* cruise supports previous seamount geomorphological studies. A comparison of uniform characteristics from the two largest seamounts, Kelvin and Atlantis II, provides evidence that supports the "hotspot hypothesis." Volume calculations utilized for this study are only estimates based on a conical shape and are only preliminary. Future studies might have more success using CARIS BASE Editor to calculate a more exact volume, or utilize a mixture of formulas to produce seamount volume. Bathymetric data of the entire chain also needs to be acquired and compared with other mapped intraplate seamounts to further support the "hotspot hypothesis"

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