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AN EXPLORATION INTO CRUSTAL SUBSIDENCE RECORDED ON THE SAN JUAN SEAMOUNT

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ABSTRACT

The San Juan Seamount lies off the coast of Southern California with its shallowest depth at 560 m. The volcanic seamount exhibits rough ridges trending northeast-southwest. The majority of California Borderland seamounts are smooth and sediment covered, whereas the San Juan Seamount is one of the few to exhibit weathered grooves and worn rocks. Several ROV *Tiburon* dives by Monterey Bay Aquarium Research Institute researchers in 2003 and 2004 explored the seamount and collected 102 rock samples. Those dives revealed numerous sub-aerial features such as coastal cliffs and cobble beaches. A12 kHz multibeam sonar also surveyed the seamount and detected a slight break in the seamount's slope at a depth of 700 m, suggesting that the San Juan Seamount was an island before it subsided by between 550 and 700 m, likely since the Late Miocene. In 2011, the NOAA Ship OKEANOS EXPLORER conducted a survey of the seamount and adjacent abyssal region using a Kongsberg EM302 multibeam sonar. These data have been processed using CARIS HIPS & SIPS 7.1 to produce a CUBE BASE Surface and backscatter mosaic to reveal new insights into past crustal subsidence. Distinct discontinuities in seabed gradient and the extent of gravel have been identified.


NOAA Ship *Okeanos Explorer*

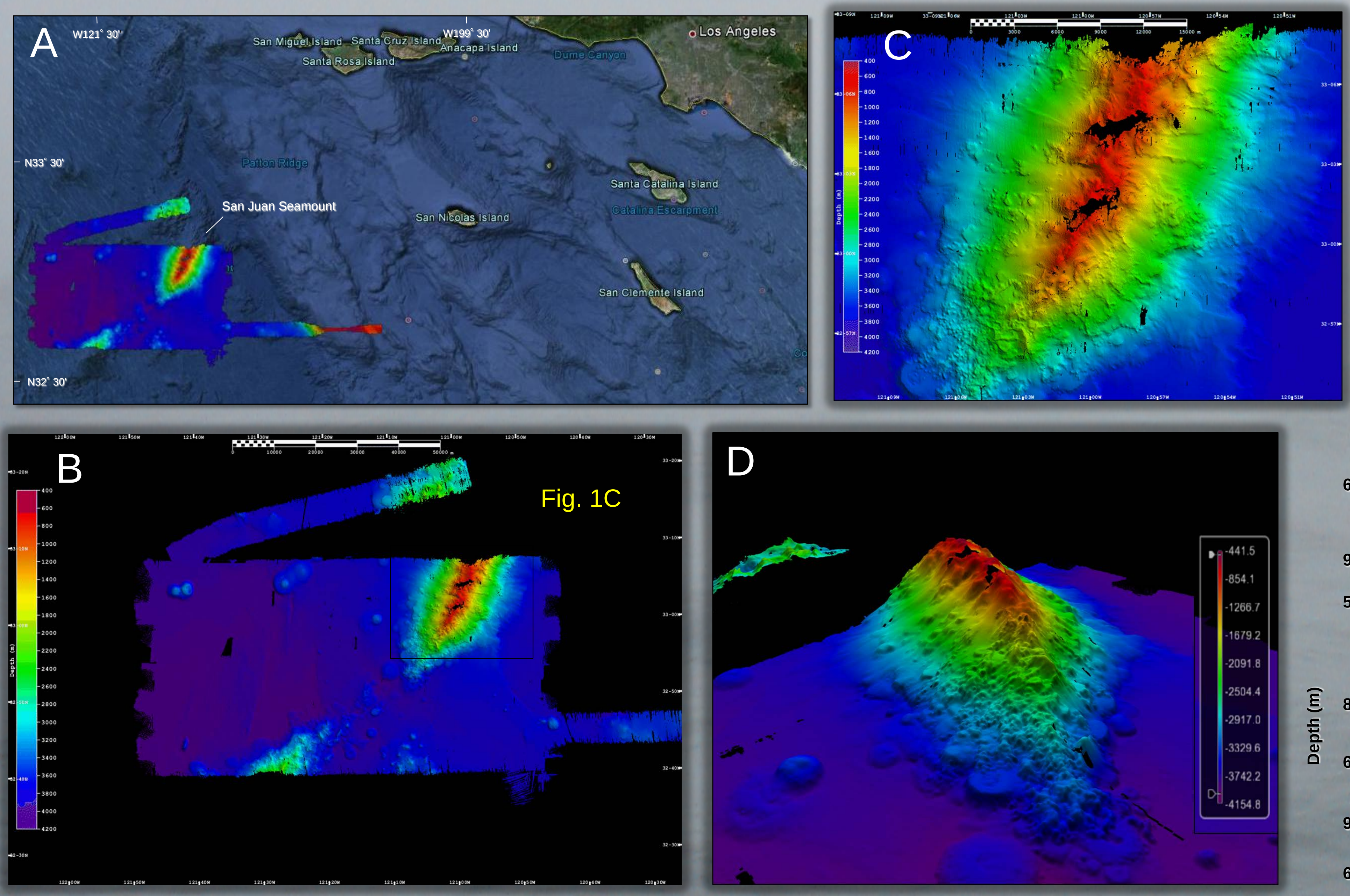
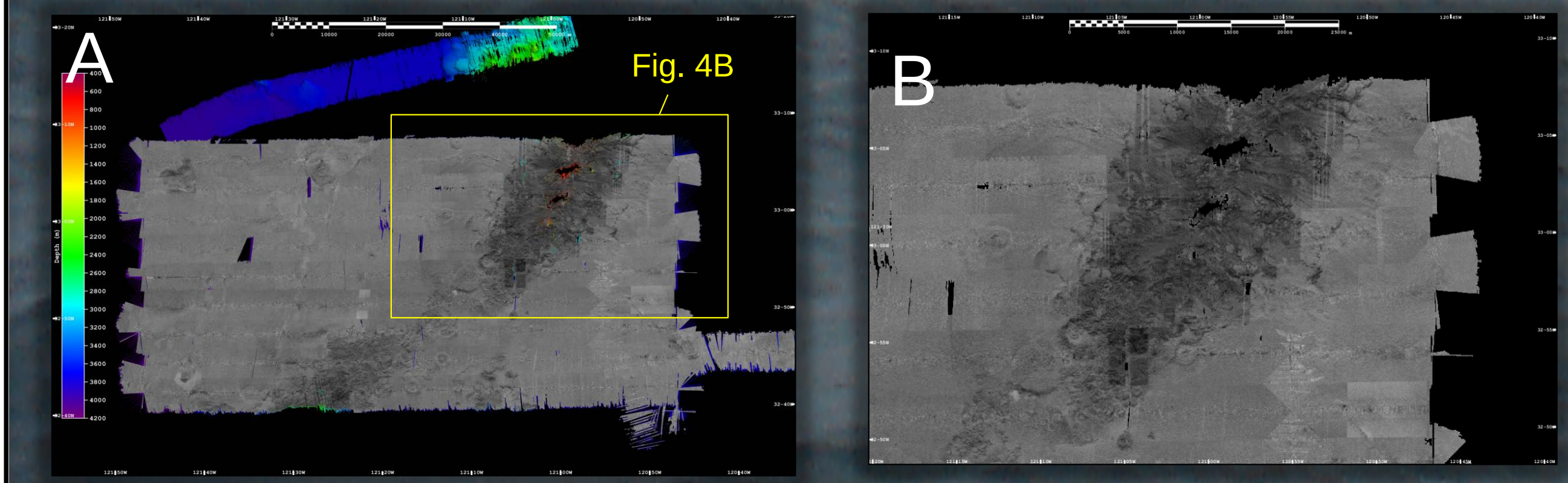


Figure 1 (above). A) The San Juan Seamount lies off the coast of southern California. B) A 2011 CUBE BASE Surface of the seamount was made using CARIS HIPS 7.1, with a 35 m resolution. C) A close-up view of the San Juan Seamount highlights the topography. Black areas indicate absence of sonar data. D) A 3D view (VE = 2x) illustrates the highest peaks of the seamount. Cross-sectional profiles of the four highest peaks are shown in Figure 2.

RESULTS

- Peaks of the southern portion of the San Juan Seamount lie at a depth of approximately 550 m. The seamount's base lies approximately 3,500 m deep.
- Four cross-sectional profiles made from the 2011 BASE Surface show a clear discontinuity in slope at a depth of approximately 700 m, where the volcanic flanks below this boundary are steeper than above.
- Sediment on the all four peaks is coarse and contains gravel, and corresponds with the large, rounded, sculpted rocks found in previous ROV *Tiburon* dives.

Figure 4 (below). A) A backscatter mosaic from 2011 (10 m resolution) reveals the grain size distribution on the San Juan Seamount and surrounding area. Dark areas indicate coarse-grained sediment; light areas are fine-grained.
B) A close-up view of the seamount shows that sediment on the peaks is comprised of coarse sand and gravel (dark gray), whereas the flanks are covered with silt to fine sand (medium gray), and the surrounding seafloor is blanketed with clay (lightest gray). Sediment sizes were determined using GeoCoder.



METHODS

- The NOAA Ship OKEANOS EXPLORER surveyed the southern portion of the San Juan Seamount in March 2011.
- The ship was equipped with a Kongsberg EM302 multibeam sonar system.
- The acquisition software used was Kongsberg's Seafloor Information System (SIS).
- CARIS HIPS & SIPS 7.1 was used to create a 35m resolution CUBE BASE surface.
- Backscatter was analyzed and a mosaic was created using GeoCoder.

INTRODUCTION

Seamounts are more than submerged volcanic mountains; their bathymetry and surface features can hold important insights into crustal subsidence. The 19 million year old San Juan Seamount (Atwater and Severinghaus, 1989), which lies on the continental slope of the Southern California Borderlands approximately 255 km west southwest of Los Angeles (Fig. 1), formed above an abandoned spreading center and was once a chain of islands (Paduan et al., 2009; Davis et al., 2010), though today its summit is 560 m below sea level. Before the seamount submerged, eight of its highest peaks formed a line of small volcanic islands with a combined area of 2.8 km^2. The tallest peak reached 140 m above sea level (Paduan et al., 2009). The seamount exhibits several features that reveal its subaerial past such as a subtle break in gradient at a depth of approximately 700 m, the likely boundary between the subaerial and steeper submarine lava flows. Profiles were made of four summits from the 2011 BASE Surface (Fig. 2) and seabed gradients above and below the previous sea level boundary were calculated (Table 1) to clearly show this bathymetric feature.

Rounded rocks, features not common of deep sea environments, have also been found on the seamount (Fig. 3). These anomalous features are likely products of wave-erosion indicating the seamount once had cobble beaches and coastal cliffs, unlike other seamounts that retain their original lava flow morphology due to the lack of subaerial erosion (Paduan et al., 2009). Backscatter of the 2011 BASE Surface revealed that the seamount's peaks are covered with gravelly sediment, possibly due to ancient cobble beaches, while sand and silt blanket the lower flanks (Fig. 4). This evidence supports earlier findings that the San Juan Seamount formed above sea level and then subsided at least 500-700 m to its current position due to lithospheric cooling and contraction (Paduan et al., 2009).

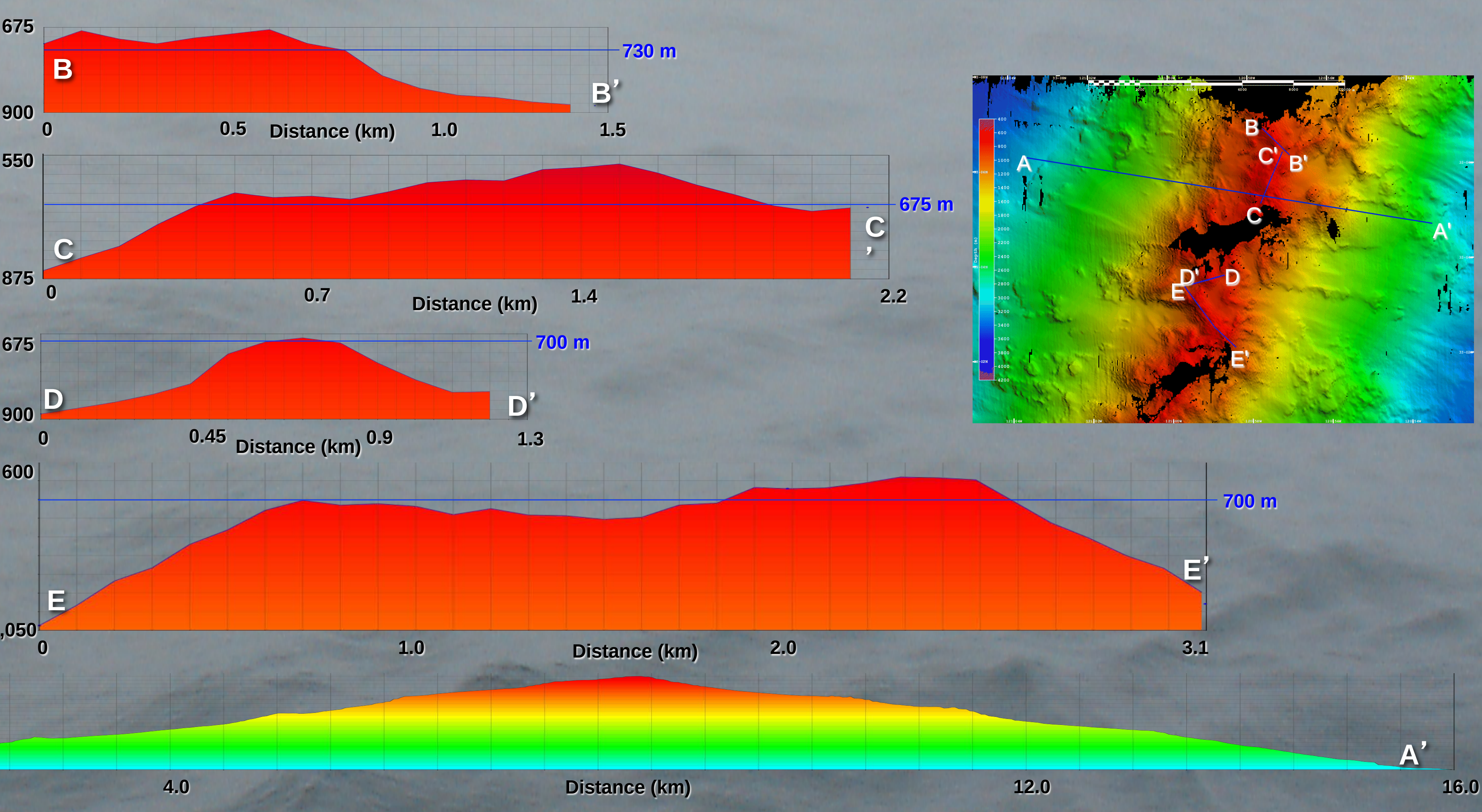


Figure 2 (above). Profile A illustrates the topography across the entire seamount. Profiles B, C, D, and E are of the four highest peaks. Profile locations are shown in the figure to the right of the profiles. Blue lines going through the profiles designate the approximate location of the break in gradient, indicating the depth where the previous sea level boundary lies.

Figure 3 (left). Several rounded volcanic cobbles (left) have been found on the seamount's upper flanks (from Paduan et al., 2009).

		Average Slope Above Boundary (%)		Average Slope Below Boundary (%)		Average Change in Slope (%)	
Profile	Depth of Boundary	West Flank	East Flank	West Flank	East Flank	West Flank	East Flank
B	730 m	-	25	-	42	-	17
C	675 m	9	-	43	-	34	-
D	700 m	13	13	43	52	30	39
E	700 m	3	1	49	50	46	49

Table 1 (left). Differences in slopes above and below the sea level boundary have been calculated for profiles B, C, D, and E, to demonstrate significant steepening of flank gradients.

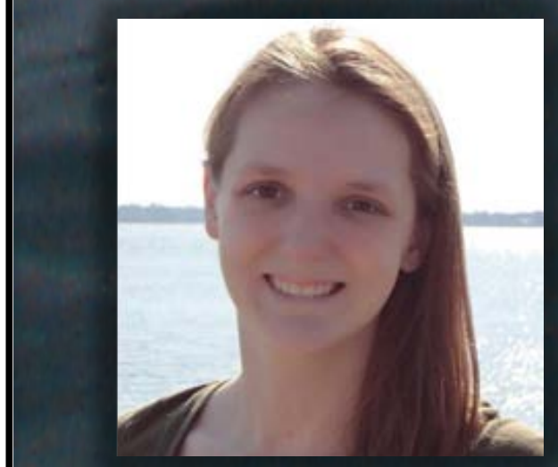
DISCUSSION

The San Juan Seamount's subaerial past is revealed by its bathymetry and backscatter acquired in the 2011 multibeam survey. A discontinuity in the seamount's flank gradient is probably a result of cool ocean water reacting with hot lava flows. Subaerial lava would have had a relatively low viscosity due to its high temperature and could have flowed easily on low gradient slopes. Upon reaching the seawater, the lava would have cooled quickly and become more viscous. Higher viscosity lava would have resisted flowing on low gradient slopes, thus creating steeper flanks and the discontinuity in the flanks' slopes. Additionally, gravelly sediment on crests of the seamount, revealed in the backscatter data, coincides with rounded cobbles found in previous dives. High energy wave erosion would have acted on the subaerial cobble beaches and cliffs producing the coarse sediment now lying over 500 m below the ocean's surface.

Since the break in slope, which now lies 700 m deep, indicates the previous boundary between subaerial and submerged portions of the seamount, it can be concluded that the seamount may have submerged 700 m since its formation. A total subsidence of between 550 and 700 m in the past 7 to 11 million years was previously suggested by considering other seamounts in the southern Californian borderlands which are also believed to be ancient islands, such as Rodriguez Seamount and Northeast Bank (Paduan et al., 2009). While cooling and subsequent contraction of underlying lithosphere is consistent with the minimum estimated subsidence (Paduan et al., 2009), the seamount may have subsided more than 700 m because Miocene sea level has been estimated to have reached up to 100 m above current levels (Müller et al., 2008). However, lower sea level variation estimates are more common (Kominz et al., 2008; Miller et al., 2005).

The 2011 multibeam sonar survey data complement earlier studies that described a subtle, indistinct break in slope around 700 m and retrieved rounded cobbles from the seamount's flanks (Paduan et al., 2009). New bathymetric and backscatter maps produced display the previous sea level gradient discontinuity and identify locations of gravel sized sediment over the entire mapped area. With these improvements, the current state and past subsidence of the seamount have become clearer. Future bathymetric maps with higher spatial resolutions will significantly aid in the pursuit to use the seamount's bathymetry to understand the past.

ACKNOWLEDGEMENTS



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