Geomorphic Analysis of the Galapagos Spreading Center

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Abstract

Multibeam sonar data of the Galapagos Spreading Center were obtained by the Scripps Institution of Oceanography in 2010 from aboard the R/V *Melville*. Surveys were conducted using a Kongsberg EM122 and processed using the CARIS HIPS & SIPS 7.1.2 software. The Galapagos Islands sit over the Galapagos hotspot, a complicated geologic setting close to the boundary between the Cocos and Nazca Plates. The Galapagos Spreading Center is located just north of the island cluster. Bathymetry and morphology of the spreading center were observed and analyzed in an attempt to understand and characterize the region's geomorphological history. Research associated with this area will be beneficial to the understanding of hot spots and related seafloor tectonic features and deep sea volcanism, as well as being potentially useful for benthic habitat characterization.

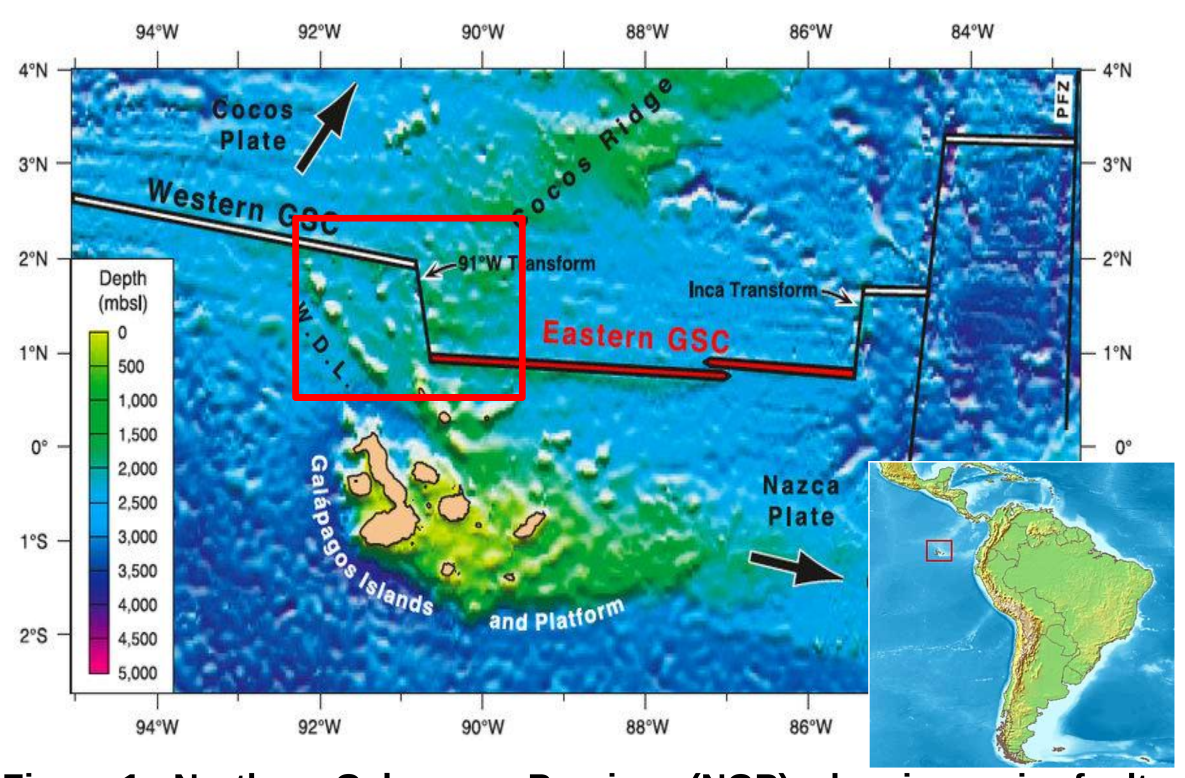


Figure 1 - Northern Galapagos Province (NGP), showing major faults and nearby ridges. Black arrows indicate plate movement direction. Red box indicates multibeam survey area for this study.

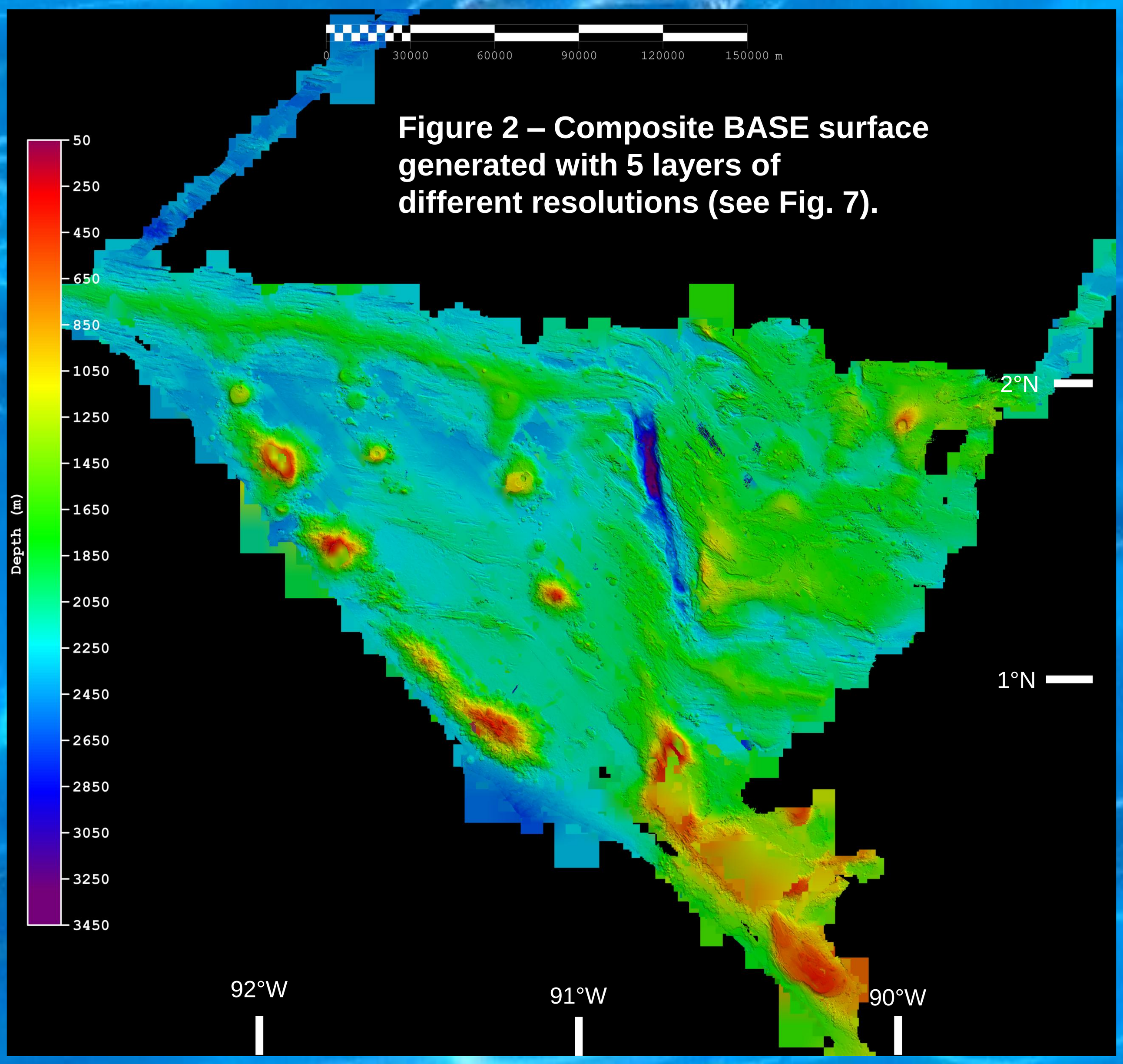
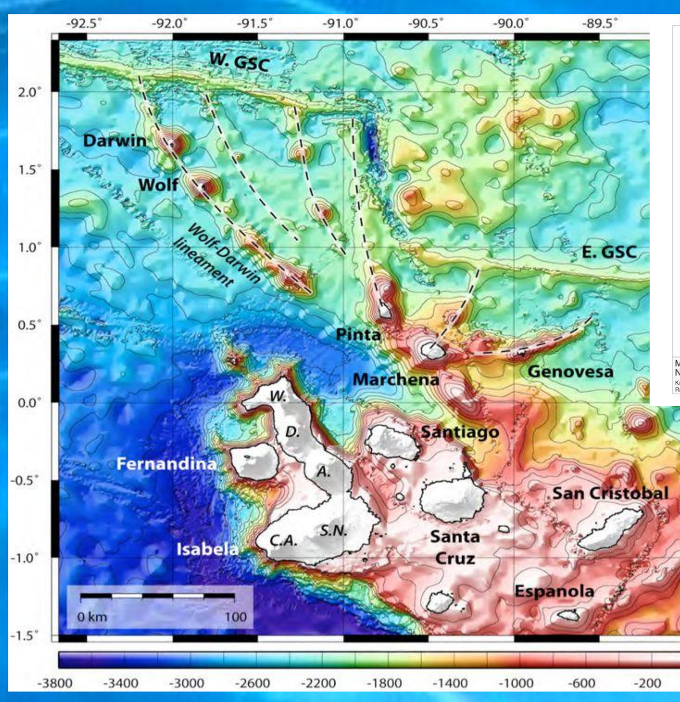


Figure 2 – Composite BASE surface generated with 5 layers of different resolutions (see Fig. 7).

Methods

- Multibeam sonar data of the Northern Galapagos Province was collected by the R/V *Melville* in May/June of 2010.
- Data were collected with a Kongsberg EM 122 multibeam echosounder, using SIS acquisition software.
- Bathymetric processing was done with CARIS HIPS & SIPS 7.1.2
- CUBE base surface generated with 50m resolution
- Final 2D composite CUBE BASE surface was generated (Figure 2) with 5 layers of varying resolution to fill in data gaps. The top layer has a 50 m resolution surface, while the bottom 4 layers have resolutions of 1500, 3000, 8000, and 16,000 meters, respectively (Figure 7). Depth color scales adjusted for a seamless overlap.
- Cross-sectional profiles for areas of interest were made from the 50 m surface.



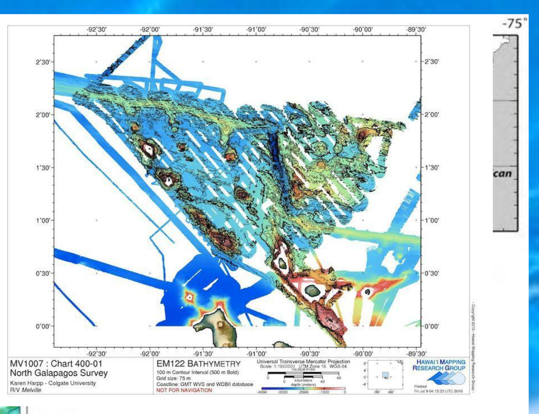
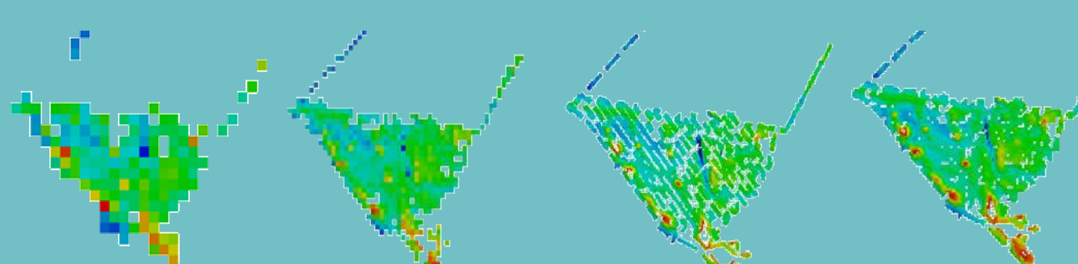


Figure 3 – Overview of study area highlighting seamount lineaments (left), and CUBE surface from initial cruise report (right) (Harpp et al., 2010)

Introduction

The Galapagos Spreading Center (GSC) is a divergent plate boundary that separates the Cocos and Nazca Plates. It is made up of three sections, the West Galapagos Spreading Center, East Galapagos Spreading Center, and the West 91 transform that separates the two rift segments by ~ 100 km. The geologically young Galapagos hotspot sits just under this boundary, beneath the Nazca Plate, and has an observable influence on the GSC (Chen and Lin, 2004). This area of interaction between the spreading center and the hotspot is known as the Northern Galapagos Province (NGP), and is a unique location, ideal for studying the interactions between ridges and mantle plumes (Harpp et al., 2010). Underwater earthquakes and volcanism along the GSC have been observed and studied since the 1970s, and the GSC hydrothermal vent communities were the first ecosystems ever known to exist free of light (Haymon et al., 2007). Mapping and studying this region's bathymetry and geology will provide a better understanding of plume-ridge interactions as well as hydrothermal vent field characteristics.

The area of focus is located between 89 30'W-92 50'W and 0 30'N – 2 30'N (Figure 1), and is centered on the West 91 transform fault. Depths in this region range from approximately 200 to 3500 m, with greatest depths along the transform fault, and shallowest at the seamounts on the study area's western edge. Preliminary observations of the region reveal very different seafloor structures existing on each plate. The Nazca Plate (west of transform fault) seems to be more volcanically influenced, with large NW-SE trending seamounts, while Cocos Plate has a shallower seafloor, but has only one seamount and a few cones, which show no lineation (Harpp et al., 2010).



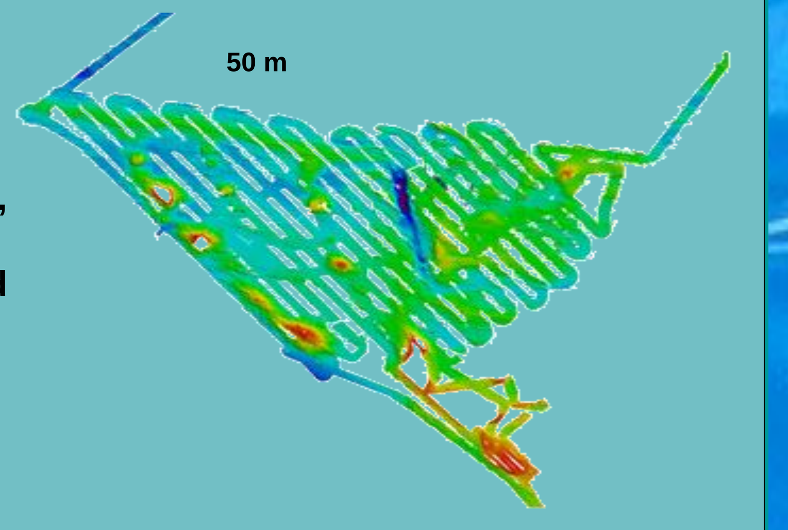


Figure 7. Five layers, each with a different resolution, ranging from 50 to 16,000 m were used to generate the composite surface (Fig. 2). The top 50 m resolution layer is enlarged (right).

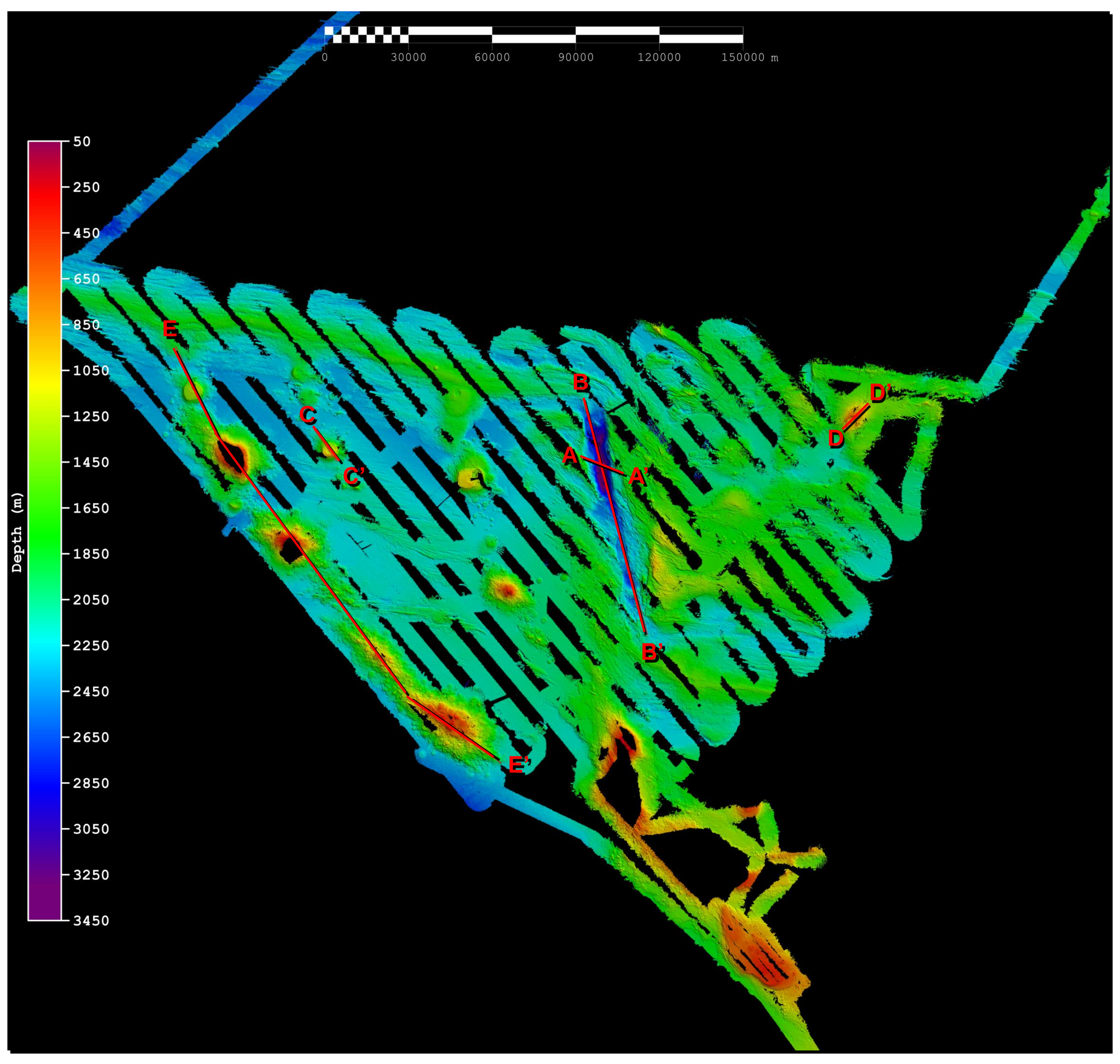
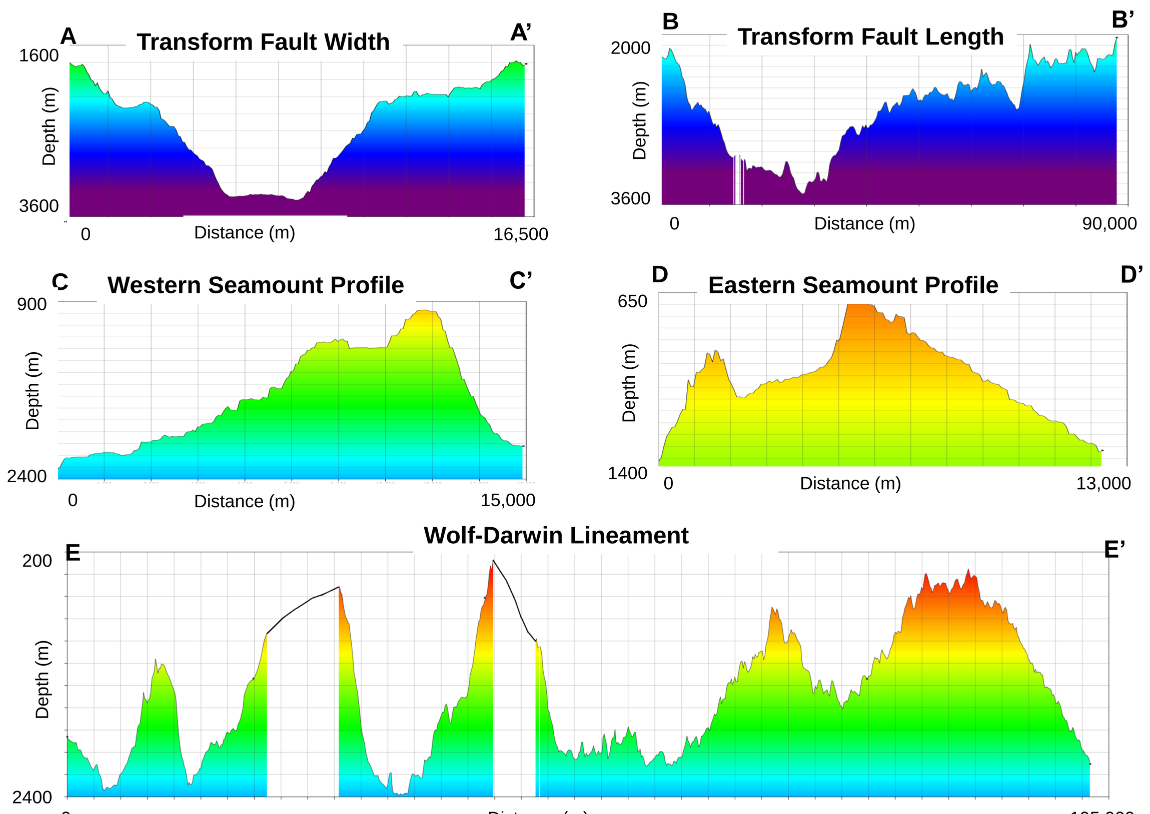


Figure 4. Above: 50 m resolution CUBE surface showing locations of profiles depicting areas of interest.
Below: Profiles A-E include the transform fault, seamounts on each plate, and the Wolf-Darwin lineament. Drawn lines on profile E show approximate depth where data was missing.



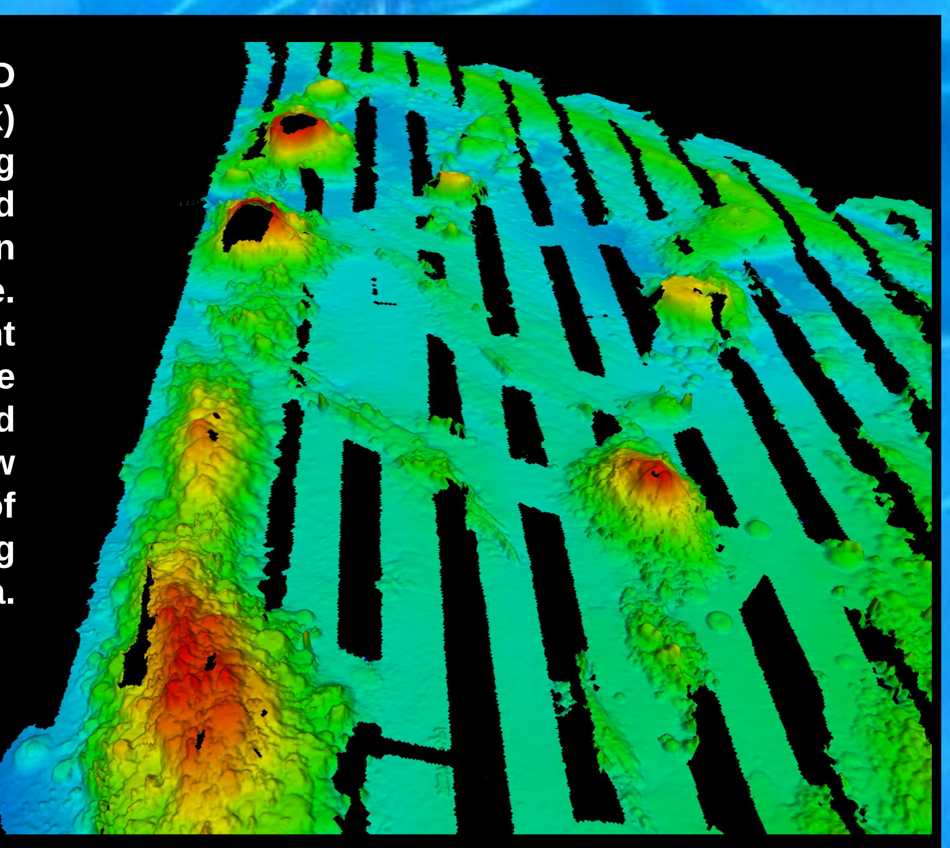


Figure 5 – 3D image (VE=3.5x) showing lineated seamounts on the Nazca Plate. Notice the slight curvature of the lineaments and relatively low topography of the surrounding area.

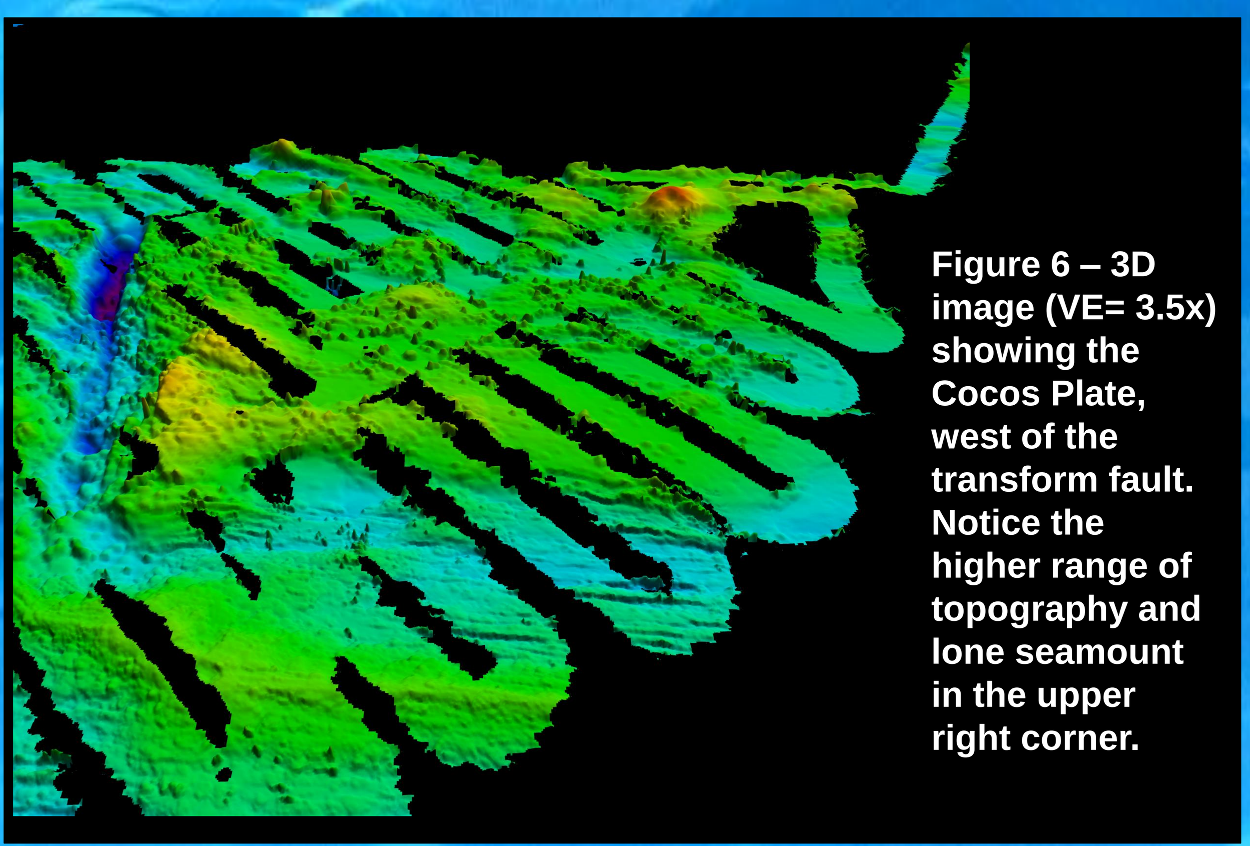


Figure 6 – 3D image (VE= 3.5x) showing the Cocos Plate, west of the transform fault. Notice the higher range of topography and lone seamount in the upper right corner.

Discussion

Bathymetric maps and 3D images generated with the data show a variety of geomorphological features around the Galapagos Spreading Center (GSC). Although the data acquisition encountered many problems due to inadequate documentation prior to the cruise (Harpp et al., 2010), the data collected still proved to be both useful and reliable. Significant gaps between track line data (seen in Figures 3, 4a, 5, 6, and 7) had little effect on the overall quality of the cruise's goals and findings.

Significant differences in structures of the two tectonic plates are evident; the Nazca Plate (south of the GSC) has constructional volcanism and shows 4 chains of linear seamounts (Figure 3), while the Cocos Plate has only one seamount, and an overall shallower depth with many faulted textures (Harpp et al., 2010). Profiles A and B (Figure 4b) show the dimensions of the transform fault that exists between the two plates and separates the east and west sections of the GSC. Profiles C and D (Figure 4b) compare seamounts on either side of the transform fault. Despite being very similar in shape, the Nazca Plate's seamount (profile C) is almost twice as large, and is significantly deeper than the Cocos Plate seamount. Additionally, the seamount on the Cocos Plate is solitary, whereas the seamounts on the Nazca Plate are numerous and show lineations.

The different structures on each plate are caused by differences in spreading rate and hot spot interaction. The Cocos Plate is moving in an east-northeast direction, while the Nazca Plate is moving eastward. Faulting to the east of the transform fault (on the Cocos Plate) is likely driven by the relative motion of the plate. The Nazca Plate has experienced widespread, relatively recent volcanism, as indicated by the presence of volcanic cones outside of the main lineaments (Harpp et al., 2010). Seamount abundance is strongly tied to spreading rate. The GSC spreads at an intermediate rate, varying between 4.6 and 5.6 cm/year (Behn et al., 2004). Because this spreading rate stays relatively constant, we can attribute the recent volcanism on the Nazca Plate to its proximity to the hotspot, which provides magma and an increased effusion rate (Behn et al., 2004).

References

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Acknowledgments

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