Divergent Ridge Features on the Juan de Fuca and Gorda Ridges

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NOAA Ship *Okeanos Explorer*

R/V *Marcus G. Langseth*

Abstract

Geomorphological features of the Juan de Fuca and Gorda Ridges, and the Blanco and Mendocino Fracture Zones were observed, to relate them to the seismic activity associated with the diverging plate boundaries of the Northeast Pacific Ocean. These ridges and fracture zones comprise the divergent plate boundary of the eastern edge of the Pacific Plate and the western edges of the Juan de Fuca and Gorda Plates. Both of these eastern plates are being subducted beneath the western edge of the North American Plate. Fault and ridge orientations are used to compare the direction of seafloor spreading, and indicate that both the Juan de Fuca Plate and Gorda Plate are spreading in a southeastern direction. Younger ridges from the Gorda Ridge system mapped in the study run parallel to the boundary; however older ridges do not show the same orientation, indicating a change in spreading direction.

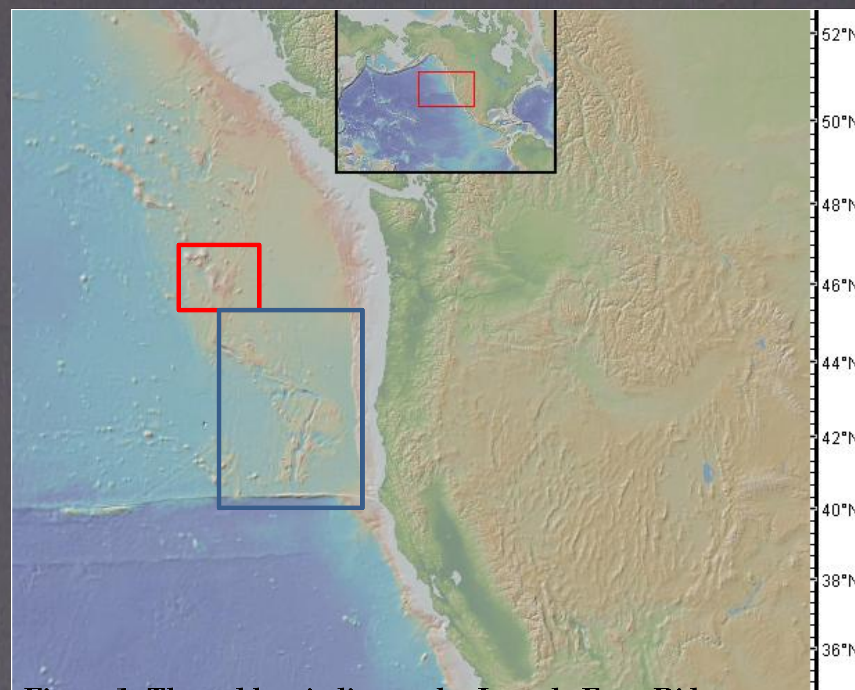

Figure 1. The red box indicates the Juan de Fuca Ridge (Figure 2) and the blue box indicates the Gorda Ridge and the Blanco and Mendocino Fracture Zones (Figure 3).

Introduction

Off the coast of the Pacific Northwest of the United States is not only where the North American, Pacific, Juan de Fuca, and Gorda Plates all meet, but it is also an area rich with a variety of geomorphologic features (Oppenheimer et al., 1993). Specific features that are the focus of this study are the Juan de Fuca and Gorda Ridges, as well as the Mendocino and Blanco Fracture Zones using data collected by NOAA's ***Okeanos Explorer*** and the *R/V Marcus G. Langseth*. These geomorphological features are attributed to the tectonic activity occurring in this region. Some of the activity is due to the Cascadian Subduction Zone, where the oceanic crust of the Juan De Fuca and Gorda Plates is sinking beneath the continental North American Plate (Monastersky, 1990). In addition there is the Mendocino triple junction, which is the meeting point of the San Andreas Fault to the Cascadian Subduction Zone, the Mendocino Fault, and the region where the Pacific, North American, and Gorda Plates interact with each other (Oppenheimer et al., 1993). These interactions result in hydrothermally and seismically active occurrences off the coast.

Methods

- Gorda Ridge data collected by NOAA Ship *Okeanos Explorer* with Kongsberg EM302, cruises EX0903 and EX0904 in 2009.
- Juan de Fuca Ridge data collected with Kongsberg EM122 on the *R/V Marcus G. Langseth* Cruise MGL0910 in 2009.
- Data downloaded from NOAA's NGDC site.
- CARIS HIPS 8.1 post processing software

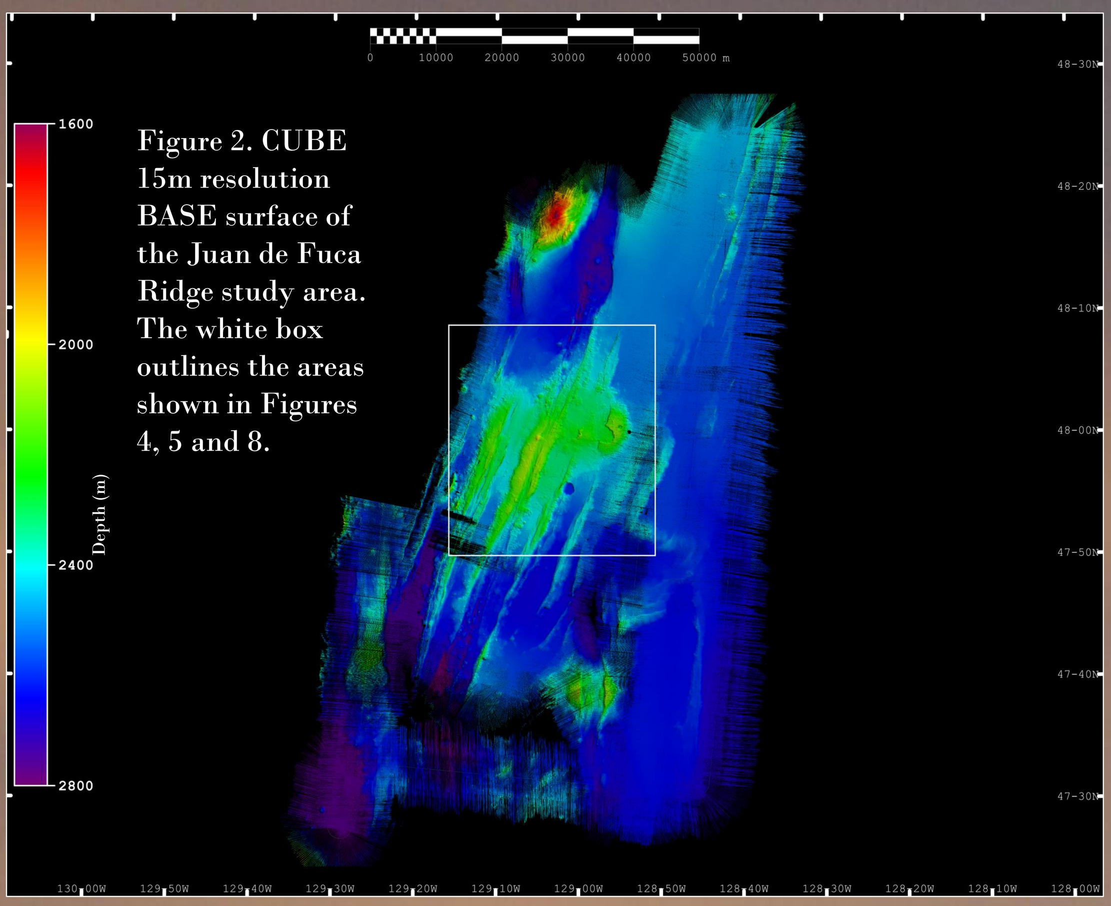

Figure 2. CUBE 15m resolution BASE surface of the Juan de Fuca Ridge study area. The white box outlines the areas shown in Figures 4, 5 and 8.

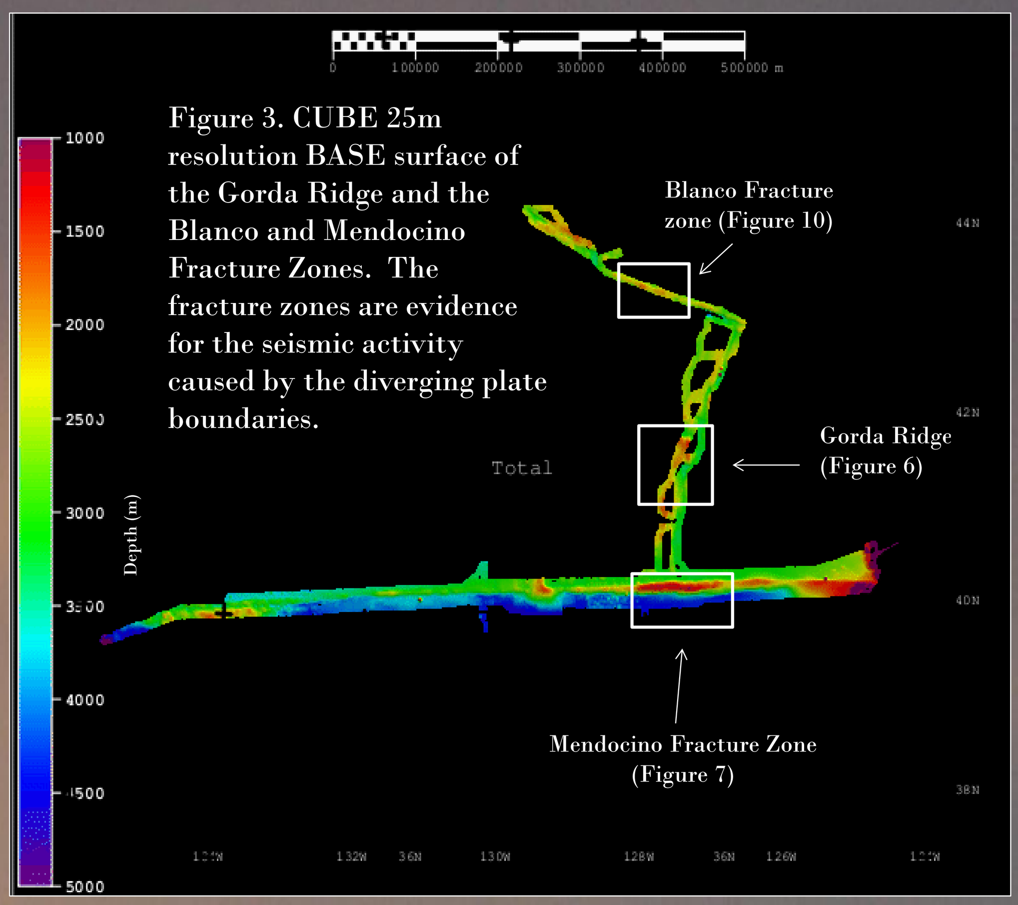

Figure 3. CUBE 25m resolution BASE surface of the Gorda Ridge and the Blanco and Mendocino Fracture Zones. The fracture zones are evidence for the seismic activity caused by the diverging plate boundaries.

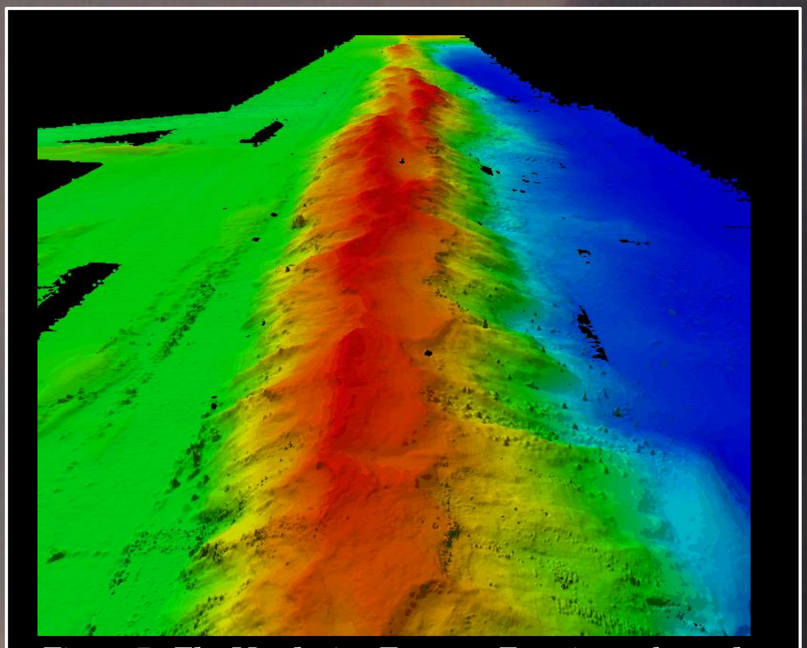

Figure 7. The Mendocino Fracture Zone is an elevated feature with 250 m of relief, the result of translational offset generated by tectonic activity from the Gorda and Pacific Plates. (VE= 1x)

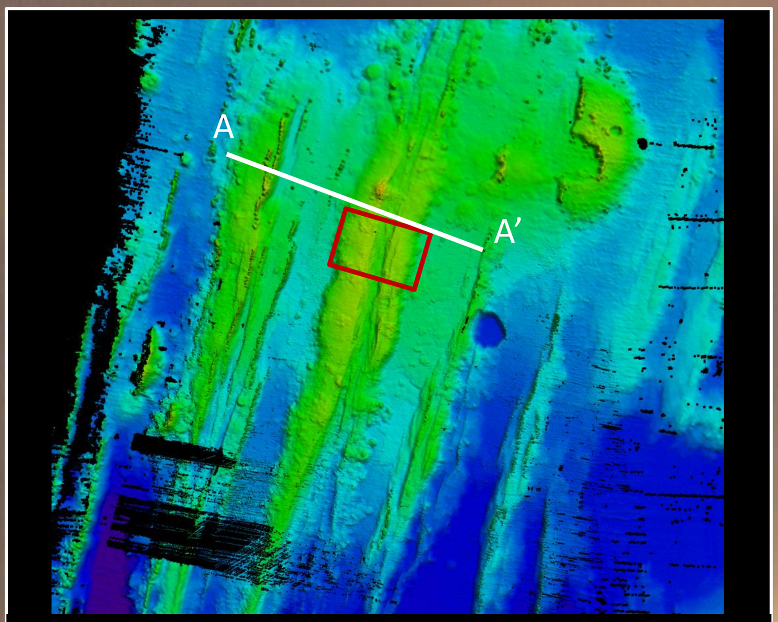

Figure 4. 2D view of the Juan de Fuca Ridge. Ridges are parallel to one another, showing that the plate has not changed direction of spreading during the time the ridges were formed. The red box indicates the area of focus in Figure 5.

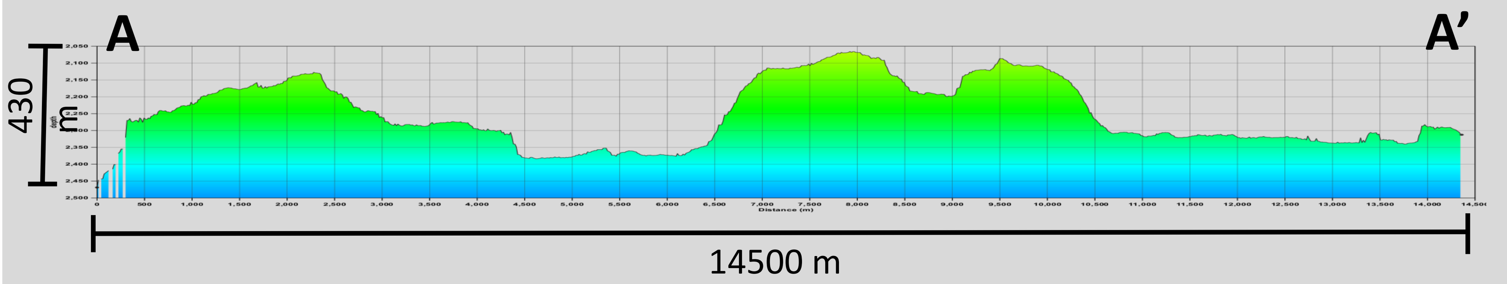

Figure 8. Profile view of the Juan de Fuca Ridge System showing the morphology of the ridge system. The profile shows that the Juan de Fuca Ridge has less elevated and fewer ridges than The Gorda Ridge system indicating faster spreading rates. The line from which the profile was made is shown on Figure 4.

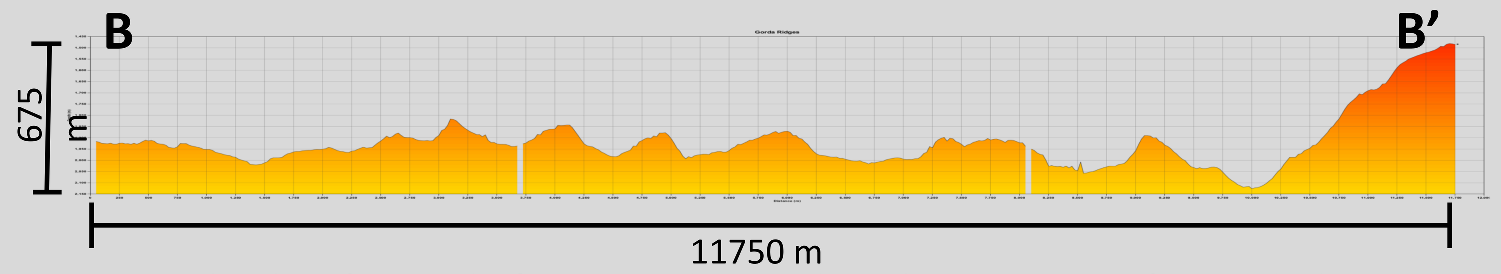

Figure 9. Profile of the Gorda Ridge System morphology. The profile shows that the Gorda Ridge has a greater number of elevated ridges than the Juan de Fuca Ridge indicating slower rate of spreading. The line from which the profile was made is shown on Figure 6.

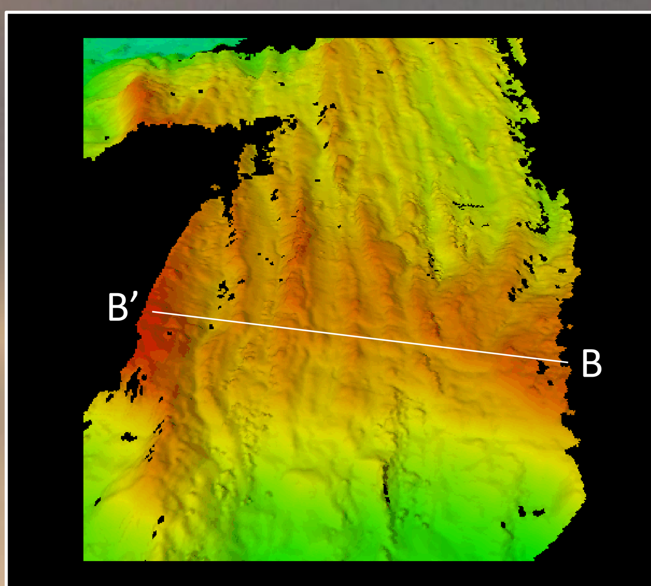

Figure 6. The Gorda Ridge showing that younger ridges are formed at a different orientation that older ones indicating that the plate has changed direction of movement as it has spread. (VE= 1x)

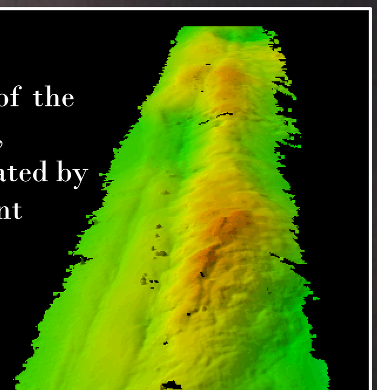

Figure 10. A portion of the Blanco Fracture Zone, another feature generated by translational movement of tectonic plates. Vertical relief of this feature is 40m. (VE=1x)

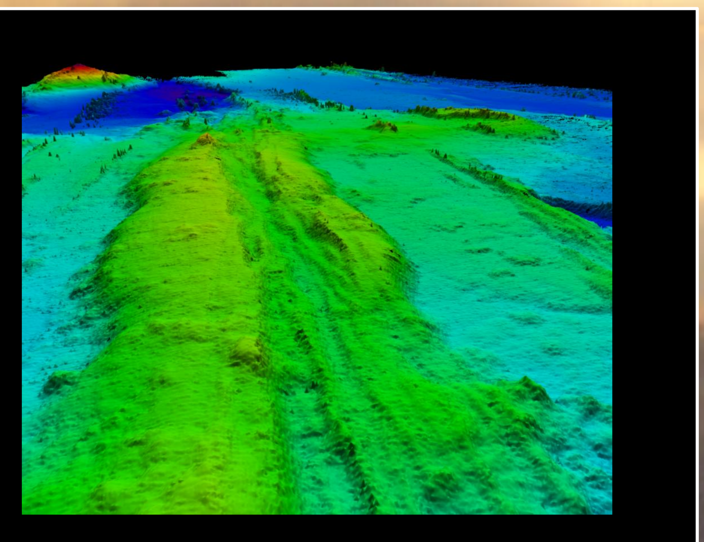

Figure 5. 3D view of the Juan de Fuca Ridge, looking NNE. The V-shaped morphology of the ridge is typical of spreading ocean ridges, and is evident in Profile A-A' (Fig. 8). (VE=2x)

Results

- Peaks of Gorda Ridges are closer together and have a greater height than those of the Juan de Fuca Ridges.
- Juan de Fuca Ridges maintain parallel orientation to spreading ridges while the Gorda Ridges become nonparallel as the distance from spreading ridge increase.
- Higher magnitude and more frequent earthquakes occur on the fracture zones compared to the ridge systems (Table 1).
- Blanco Fracture Zone had the greatest concentration of earthquakes associated with it from 1973 to 2013.
- Mendocino Fracture Zone had earthquake epicenters directly above it while the Blanco Fracture Zone earthquakes were offset to the north.
- The Mendocino Fracture Zone has a greater vertical relief than the Blanco Fracture Zone (Figures 7 and 10).

Geomorphological Feature	Number of Earthquakes	Orientation to Feature
Juan De Fuca Ridge	4	East
Blanco Fracture Zone	29	North
Gorda Ridge	6	East
Mendocino Fracture Zone	11	Directly above, north, south

Table 1. Association between earthquakes and study site locations. Blanco and Mendocino Fracture Zones have more high-magnitude earthquakes associated with their features when compared to the Juan De Fuca and Gorda Ridge systems.

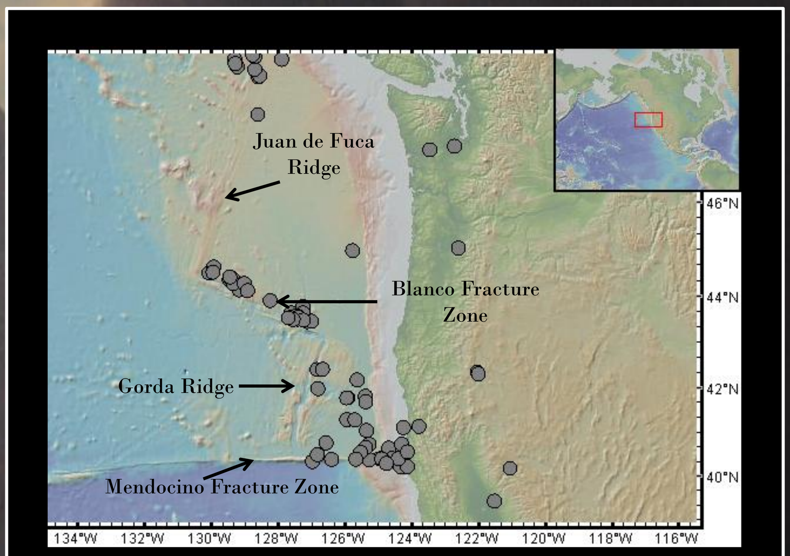

Figure 11. The study area, showing earthquakes of magnitude >5.5 (gray dots) from 1973-present (Table 1). Earthquakes occur primarily along the Blanco and Mendocino Fracture Zones rather than at the ridges. (Image from GeoMapApp)

Discussion and Conclusion

The morphology of the Juan de Fuca Ridge differs from that of the Gorda Ridge in terms of ridge orientation and spreading rates. The Gorda Ridge system is longer and ridge crests are closer together and are more elevated when compared to those of Juan de Fuca Ridge (Figs. 8 and 9), revealing that ridge systems do not spread at uniform rates, even when adjacent to each other. In fact, the Juan de Fuca Ridge is spreading at a fast rate of 6.6 cm/year, which is why there are fewer ridges and they have a less elevated morphology (UW School of Oceanography 2007)). Mid-ocean ridge basalts (MORBs) form pancake-like layers at fast spreading ridges because the ridges are spreading too fast for the basalt to build up higher while molten (Bach et al., 2010). Conversely, the Gorda Ridge is spreading at a rate of only 2.3 cm/year explaining why its ridge system is characterized by a more elevated morphology with a greater number of individual ridges (Koski, 2014).

Similarly, the direction of spreading is different for each ridge system. The ridges at the Juan de Fuca system are parallel to each other as they spread outward, showing that the plate has been spreading in roughly the same direction over time (Figure 4). However the ridge morphology at the Gorda Ridge system is curved rather than parallel indicating that the Gorda Plate is spreading in a different direction now than when older ridges in the study area were formed (Figure 6).

The ridge systems sustain seismic activity as well as hydrothermal activity, both of which are characteristic of spreading ocean ridges (Delaney et al., 1992). Earthquake shocks can be the result of intra- and inter-plate movement that is necessary to release compressional stress (Oppenheimer et al., 1993). Figure 11 is a map of the study area showing the location of >5.5 magnitude earthquakes from 1973 to 2013 and where they are in relation to the geomorphological features in this study. Table 1 organizes the information to show that more earthquakes are associated with the fracture zones than with the ridge systems. This seismic activity not only generates the shocks associated with earthquakes, but can also generate tsunamis from rapid displacement of water, alter hydrothermal circulation beneath the oceanic crust, and impacting biological communities of the seafloor (Dziak and Johnson, 2002). While these earthquakes may be occurring offshore, they can affect those living on the western coast of the United States. The Cascadian Subduction zone could generate future high magnitude earthquakes which would devastate cities such as Seattle, Portland, and Vancouver (Monastersky, 1990). Through continued studies of these offshore geomorphological features such as the Juan de Fuca and Gorda Ridges as well as the Blanco and Mendocino Fracture Zones, a greater understanding of the local plate tectonics may be attained as well as preparation for any future seismic activity that may shake the west coast.

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