Analysis of Gorda Escarpment Geomorphology, Mendocino Fracture Zone

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R/V *Atlantis*


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ABSTRACT

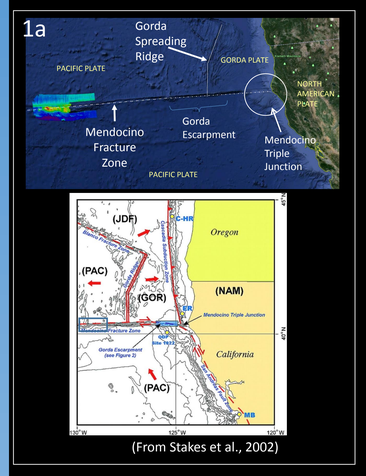
Multibeam survey data from the R/V *Atlantis* 2014 cruise-AT26-21 were used to examine the east-west trending Mendocino Fracture Zone along the Gorda Escarpment, west of the Gorda Spreading Ridge. This area lies on the Pacific Plate and includes several seamounts and geologic structures. Using CARIS HIPS and SIPS 9.0 software and GeoMapApp, features along the fracture zone were characterized to evaluate offsets from plate movement along with analysis of associated seamount geomorphology. The extent of movement along the fault line was determined by relating seafloor bedrock age and spreading rate to the presence of curved seafloor fabric. The northern abyssal hills have warped, with a curvature along the fracture zone towards the east, indicating that this portion of the Pacific Plate north of the fracture is migrating westward at a faster rate than the area south of the fracture. The result is a sequence of curved seafloor fabric along the fracture. The seamount chain to the south of and parallel to the fracture zone is approximately 124 km long with the largest seamount to the west. Lava lobes and terraces are significantly more abundant on the seamount's south flanks suggesting asymmetry in eruptive sequences. Information gathered from the study area is beneficial to understanding fracture zones of the Mendocino Triple Junction and may contribute to studies of tectonic and seismic activity for the nearby Northern California coast.

Mendocino Fracture Zone- Gorda Escarpment

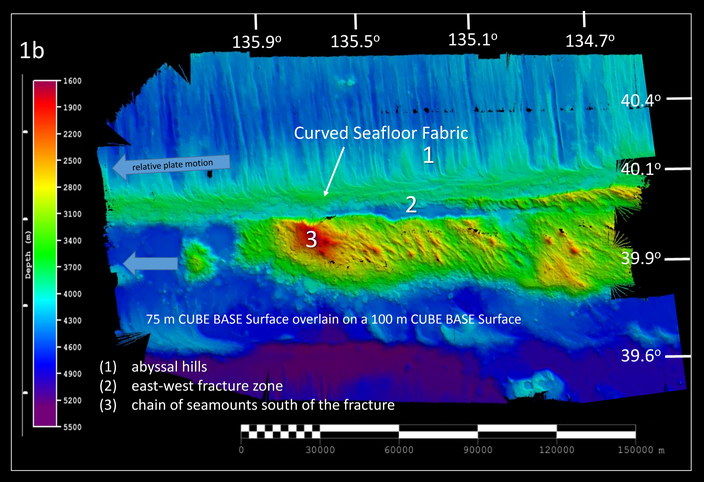
FIGURE 1:

a) The Mendocino Fracture Zone is located off of Northern California. It is a transform boundary within the Pacific Plate, west of the Gorda Spreading Ridge. At the study site (blue box), both the northern and southern sides of the fracture zone are part of the Pacific Plate, and both are generally moving westward.

b) Bathymetry of study area. Curved seafloor fabric is evident in the abyssal hills (1). The fracture zone (2) and seamount chain (3) are prominent features.



(From Stakes et al., 2002)



BACKGROUND

The Mendocino Fracture Zone is located off the northern coast of California along the Gorda Escarpment, and is part of the Mendocino Triple Junction (Figure 1). The abyssal hills to its north are warped with an offset to the west. Seafloor spreading from the Gorda Ridge 450 km east of the site has caused the lateral offset along the fracture, as the northern boundary of the fracture has moved westward (McCarthy et al., 1996). In addition to the curved seafloor fabric observed, volcanism along the southern fracture boundary formed a seamount chain as fracturing weakened lithospheric material provides a conduit for volcanism (Kruse et al., 1996). Fracture-related processes can be better understood through the characterization of the geomorphology of the Mendocino Fracture Zone. The information gathered from mapping the study area provides an in-depth look into abyssal hills and seamounts that are associated with oceanic fracture zones.

METHODS

Multibeam sonar data of the Mendocino Fracture Zone from the 2014 R/V *Atlantis* cruise-AT26-21 (Chief Scientist Andrew Armstrong) were acquired using a Kongsberg EM122 and post processed using CARIS HIPS and SIPS 9.0 software. A 75m resolution CUBE BASE surface was created to observe the study area's bathymetry and bottom features. GeoMapApp seafloor age data (Muller et al., 2008) were also utilized in studying the fracture zone. Length, slope, and curved seafloor fabric offsets were observed in order to characterize the north-south trending ridges and the east-west trending seamount chain associated with the fracture zone.

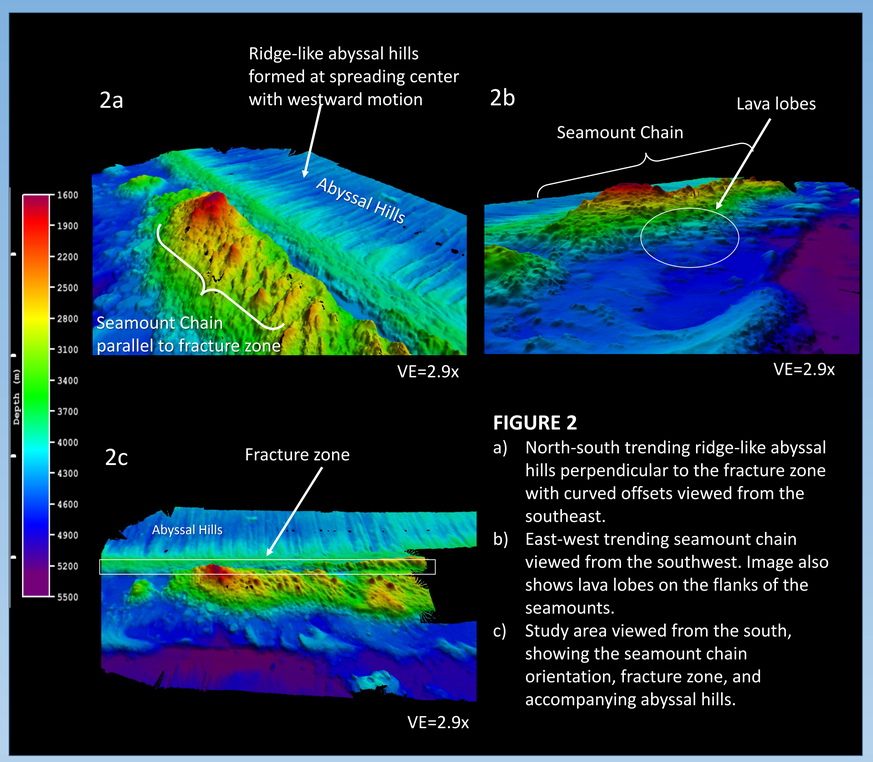


FIGURE 2

a) North-south trending ridge-like abyssal hills perpendicular to the fracture zone with curved offsets viewed from the southeast.

b) East-west trending seamount chain viewed from the southwest. Image also shows lava lobes on the flanks of the seamounts.

c) Study area viewed from the south, showing the seamount chain orientation, fracture zone, and accompanying abyssal hills.

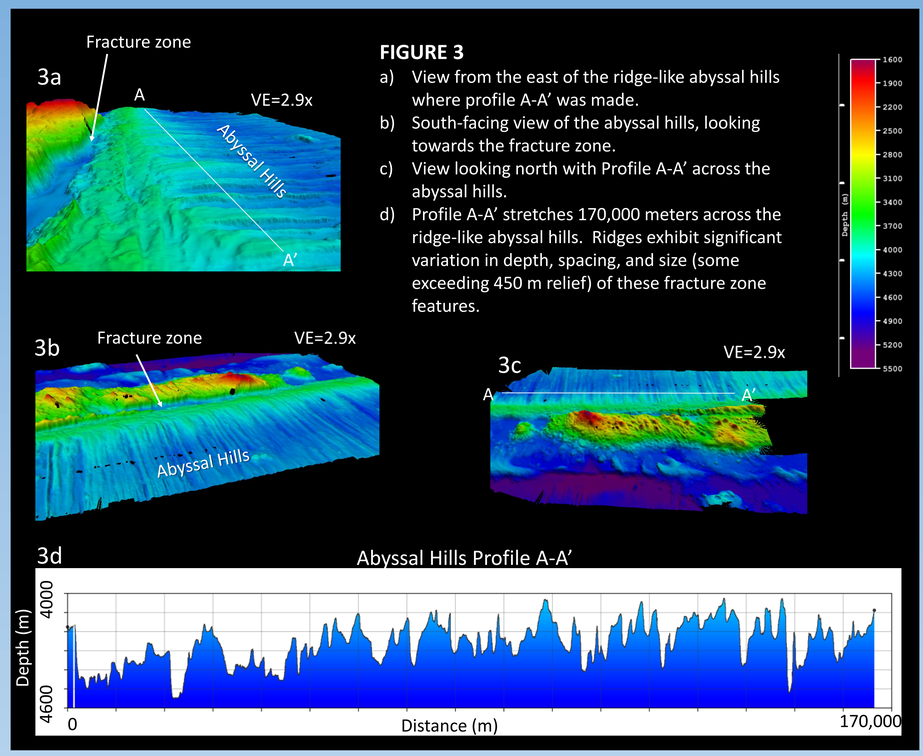


FIGURE 3

a) View from the east of the ridge-like abyssal hills where profile A-A' was made.

b) South-facing view of the abyssal hills, looking towards the fracture zone.

c) View looking north with Profile A-A' across the abyssal hills.

d) Profile A-A' stretches 170,000 meters across the ridge-like abyssal hills. Ridges exhibit significant variation in depth, spacing, and size (some exceeding 450 m relief) of these fracture zone features.

FIGURE 4

a) GeoMapApp image of entire fracture zone, with overlain seafloor age contours in millions of years (Muller, 2008). White rectangle indicates study area, shown in 4b.

b) Study area enlarged, with seafloor ages shown in millions of years.

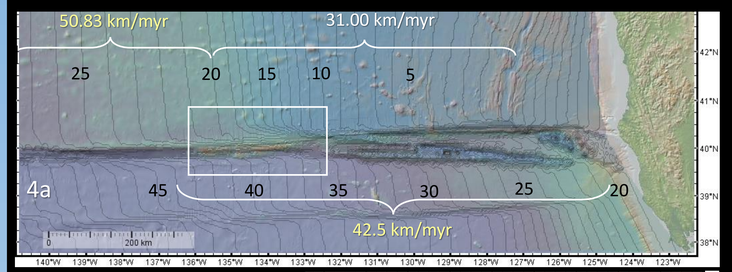
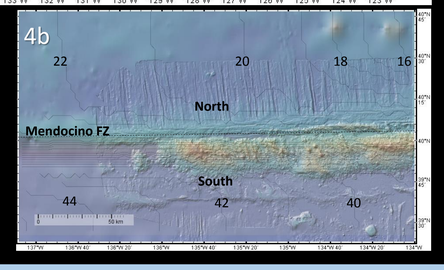


Table 1. Seafloor ages (Muller et al., 2008) and rates of motion for areas north and south of the fracture zone.

Age Range (Ma)	North (km/myr)	South (km/myr)
44 to 20	50.8	42.5
20 to 0	31.0	----



RESULTS

- The study area is characterized by a series of north-south trending abyssal hills on the northern side of the east-west fracture zone. These ridge-like features are formed by the westward plate movement from the Gorda Ridge segment, 450 km to the east.
- The curved seafloor fabric associated with the abyssal hills is associated with a higher relative rate of plate motion (Fig. 1).
- The westward rate of spreading during formation of the ridge-like abyssal hills north of the MFZ has varied with age, from 50.8 km/myr between 44 and 20 Ma, to 31.0 km/myr since20 Ma (Fig. 4).
- The southern side of the fracture had a rate of only 42.5 km/myr between 44 and 20 Ma, and is no longer spreading.
- An east-west seamount chain parallel and adjacent to the southern side of the MFZ indicates significant volcanism along the fracture (Fig. 2).
- Seamounts are only present along the southern boundary of the fracture at this location.
- Seamount height decreases eastward along the chain (Figure 5).
- A moderate, positive correlation exists between seamount height and slope, indicated by R^2=0.588.

FIGURE 5. Seamount chain analysis

a) Location of seamounts A-F

b) Linear regression of slope vs. height with R^2=0.588

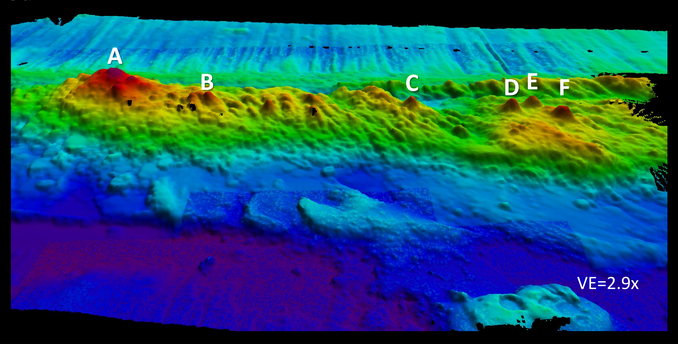
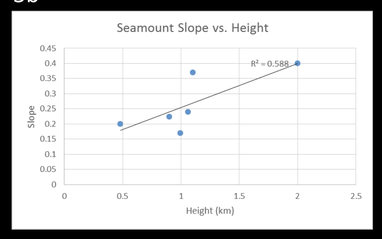


Table 2. Seamount height and slope.

Seamount	Height (km)	Slope
A	2.00	0.400
B	0.48	0.200
C	1.10	0.370
D	0.90	0.225
E	0.99	0.170
F	1.06	0.240



DISCUSSION

Transform plate boundaries and oceanic fracture zones that are under severe tension are typically characterized by parallel ridge-and-trough systems close in proximity and perpendicular to the fracture zone (McCarthy et al., 1996), also referred to as abyssal hills. Along this segment of the Mendocino Fracture Zone, the presence of curved seafloor fabric with a series of ridge-like abyssal hills provides an indication of plate movement along the fracture zone. While both plates are moving westward (Fig. 1), between 44 and 20 Ma the northern side of the transform system moved at a greater rate (50.83 km/myr) than the southern side (42.5 km/myr). This difference in spreading rates accounts for the curved seafloor fabric of the abyssal hills.

Weaker fracture zones formed by higher slipping transform rates are characterized by volcanism along the fracture (Lowrie et al., 2015). Therefore, the presence of high slipping rates and volcanism characterizes this portion of the Mendocino Fracture Zone as a weakened fracture. The relief of the parallel ridges, and the distance between each ridge (Fig. 3d) indicates tensional features likely formed from the weakened transform slip. Since 20 Ma, the northern side of the fracture has decreased in spreading rate to an average of 31.00 km/myr, however the southern side has stopped spreading, due to the subduction of the ridge segment that generated its seafloor approximately 20 Ma. Thus, the norther portion of the Pacific Plate continues to outpace the portion south of the fracture zone.

The seamount chain to the south of the fracture shows a moderate positive correlation (R^2=0.588) between seamount height and slope. Therefore, the greater the volcanism and height of the seamount the greater the slope of the seamount.

The analysis of the Mendocino Fracture Zone leads to further questions about the strength of the fracture zone as a whole. Is it locked and strong or slipping and weak? Can localized weakness occur along otherwise strong fractures resulting in volcanism?

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