Temporal variations in the formation of oceanic lithosphere at the Central Indian Ridge recorded along the Marie Celeste fracture zone

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Mid-ocean ridges are where the oceanic lithosphere is formed, and both the spatial and temporal variations of mid-ocean ridge process is essential for a better understanding of plate tectonics. Although spatial variations of formation of oceanic lithosphere have been well investigated, how the process varies through time is less known. Bonatti et al. (2003) and Cipriani et al. (2009) revealed a 3–4 Myr periodical variation in the degree of mantle melting and crustal thickness from geophysical data and rock samples acquired along the Vema fracture zone. However, no other example of Myr-scale variation has been reported. Furthermore, the cause of this temporal variation is yet to be solved. This study aims to reveal temporal variations in the formation of lithosphere along the Marie Celeste fracture zone of Central Indian Ridge and explore the relationship between the variations and the magma composition.

The Central Indian Ridge (CIR) is a slow- to intermediate- spreading ridge system (half-spreading rate of 20 mm/yr at 18°S) bounding the Somali, Indian, and Capricorn plate (DeMets et al., 2010). The Marie Celeste transform fault (TF) is one of the longest TFs of CIR, which offsets the segments CIR-S16 and S17 by 220 km, recording 11-Myr history of mid-ocean ridge process.

We analyzed multibeam bathymetry, gravity anomaly, and rock chemistry using the data and samples collected along the Marie Celeste transform fault. Multibeam bathymetry data were obtained during cruises KH-06-4, KH-15-5, YK16-E01, and YK16-E01. The data were merged into 100 m x 100 m grid data. Topographic features were depicted based on the newly obtained bathymetric map. Global marine gravity data (Sandwell et al., 2014) was used as Free-air Anomaly data. According to the method of Parker (1972), the Mantle Bouguer Anomaly (MBA) was calculated assuming constant thickness crust of 6 km. The residual MBA (RMBA) was calculated using the method of Kuo & Forsyth (1988), subtracting the thermal effect of plate cooling. The variation of crustal thickness was also estimated from the RMBA. A total of 38 rock samples dredged at three sites along the Marie Celeste transform fault (DR01–03) were selected for this study.

The variations in seafloor morphology and estimated crustal thickness along flow lines suggest the temporal change in mantle melt productivity. The seafloor of 11–5.2 Ma is characterized by regular abyssal hills and average crustal thickness, implying sufficient melt supply at that time. Between 5.2–2.8 Ma, the distribution of oceanic core complexes (OCCs) and detachment fault type morphology and estimated thinner crust indicate low magmatic productivity near the TF; on the other hand, the crust of average thickness and well-organized abyssal hills are observed further south of detachment fault type morphology, suggesting sufficient melt supply. These results imply that CIR-S16 was divided into two subsegments in this period. The seafloor of 2.9–0.8 Ma is characterized by abyssal hills and the thinner crust by up to 2 km, except for the thickest crust beneath the seamounts. This suggests reduced melt productivity in 2.9–0.8 Ma. The seamounts are not deformed by faults, but abyssal hills of this era are continuous across the seamounts. Well-ordered abyssal hills and the thicker crust by 1 km of the seafloor of 0.8 Ma to present suggest an excess of melt supply. These observations indicate that the origin of two seamounts is off-axis volcanism later than 0.8 Ma, when the ridge segment was inferred magmatically robust.

Some oxide gabbro samples from DR01 and DR03 show notably high Fe_2O_3 and TiO_2 content. Undifferentiated rocks recovered from DR02, located near the OCCs, suggest that rocks were transported along detachment fault from the depth beneath the seafloor.

The strike of the TF changes ~4° at 66°00' E, and a transverse ridge exists further east of 66°00' E. These observations suggest an adjustment of the transform fault relative to the local stress regime.

Keywords: transform fault, oceanic lithosphere, mid-ocean ridge process, Central Indian Ridge, gravity anomaly, rock geochemistry