U-Th-Ra disequilibria along the EPR: Evidence for off-axis melting?

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Lavas erupted along Mid-Ocean Ridges provide important information on melt formation and movement beneath the oceanic lithosphere. Despite the fact that the majority of lavas are erupted along the spreading axis itself, there is increasing evidence that lavas along certain ridge sections are erupted off-axis at distances >5km.

The East Pacific Rise has a fast (5.5 cm/yr) half spreading rate and hence the age of lavas sample off-axis are well-constrained if erupted on-axis. We present U-Th-Ra disequilibria from three traverses long the East Pacific Rise (9°30, 10°30, 11°20) extending to a maximum distance of ~45 km East and ~30 km West of the ridge axis.

Our analyses show greater U-Th disequilibria than predicted solely by decay of the ridge axis signal. Relative to a calculated decay curve assuming an initial ($^{230}Th/^{238}U$) of 1.23, lavas from 9°30N have Th excess of 2-4%, lavas from 10°30 have Th excesses of 0.5-3.6% and the most extreme U and Th excesses are observed at 11°20N (<40% and <50% , respectively). ($^{226}Ra/^{230}Th$) excesses up to ~2 have been observed at 10°30 and 11°20, whereas all three traverses also display ^{226}Ra deficits with ($^{226}Ra/^{230}Th$) down to 0.63. We observe a systematic variation with increasing distance from the ridge axis. Lavas closer to the ridge axis (12-20 km) exhibit Th excess followed by U excess (20-28km) and mostly $^{230}Th/^{238}U$ equilibrium at >30km.

If formed at the ridge axis the observed Th excesses require anomalously high initial ($^{230}Th/^{238}U$) ratios of ≥ 2. However, reasonable dynamic melting parameters (e.g. upwelling rate = 0.5cm/a; 10-20% melting degree) produce initial $^{230}Th/^{238}U$ ratios of ≤ 1.4 that are too low to explain the off-axis disequilibria. ($^{226}Ra/^{230}Th$) ratios of ≥ 1 require melting within the last 8,000 years, whereas Ra deficits require $D_{Ra}>D_{Th}$, which could reflect the presence of hydrous phases such as amphibole or phlogopite in the melting regime.

The combined occurrence of both, Th and Ra excesses some 5-45 km distant from the ridge axis may be consistent with off-axis melting <8,000 years ago, largely independent from ridge axis melting. The systematic shift from Th to U excess implies a continuous re-melting of previously depleted peridotite over timescales <<75,000 years.