Near-Axis Seamounts as Probes of Mantle Melting at the East Pacific Rise

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Purpose

It is imperative to our understanding of how oceanic crust is formed to also understand how the melts in the upper mantle generate and focus at mid-ocean ridges. The current paradigm is that melt migrates hundreds of kilometers to the ridge axis where they are then erupted. However, it is difficult to test this hypothesis because the majority of mid-ocean ridge basalt samples have been collected from the narrow ridge axis. Near-axis seamounts provide excellent opportunities to test this hypothesis because they act as geochemical 'probes' into the melting of the upper mantle.

Area of Interest

The focus of this study is the East Pacific Rise (EPR) at the Clipperton and Siqueiros transform zones and the seamounts located between 14ºN and 5ºN. We have sorted the seamounts in this area into 8 chains and an array of outliers spanning the area.

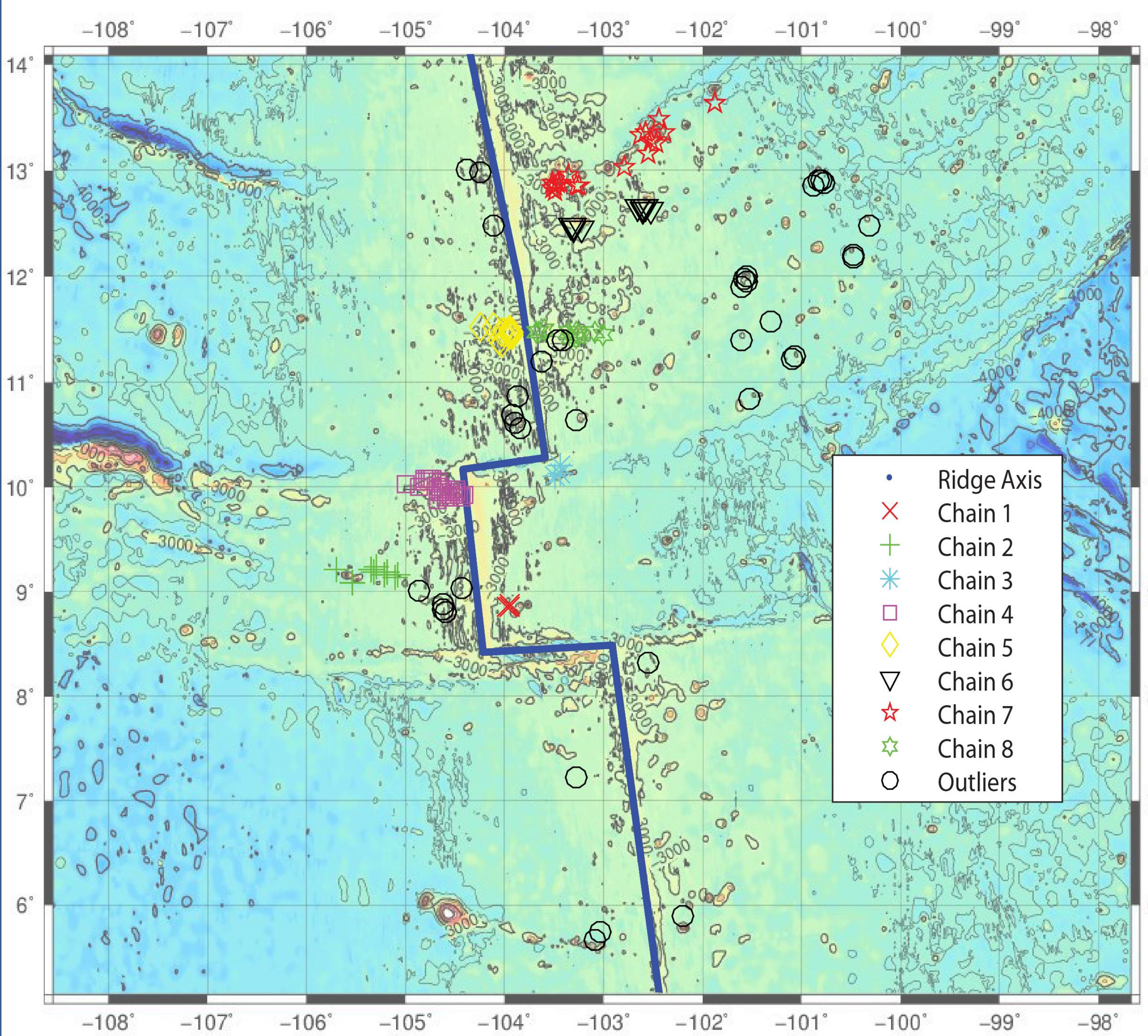
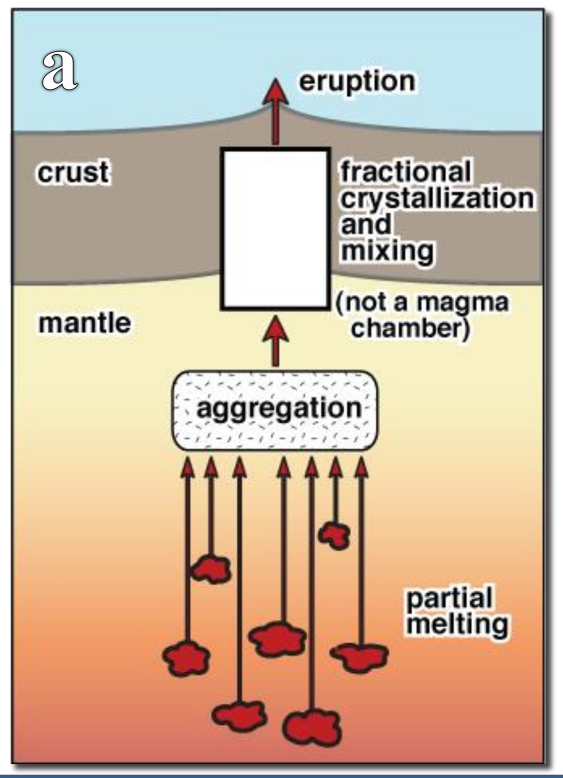


Figure 1. Above is a bathymetric map of the studied area along the East Pacific Rise (blue line). Symbols indicate samples collected and analyzed for major and trace element composition by previous workers.

Methods

- In order to constrain the melt region, we created a passive flow, convection model using COMSOL Multiphysics 5.2 [1][6]
- Using a petrologic model of melting based on temperature, pressure, and composition[1][2][3][4] , we modeled partial melt generation under the ridge.
- An algorithm[1] was used to migrate and aggregate the melts at the base of the lithosphere.
- Fractional crystallization was calculated to track melt composition as it cools in the crust prior to eruption.[5]
- Liquid Lines of Decent were created to model the estimated erupted lavas and were then compared to real data from GeoMapApp



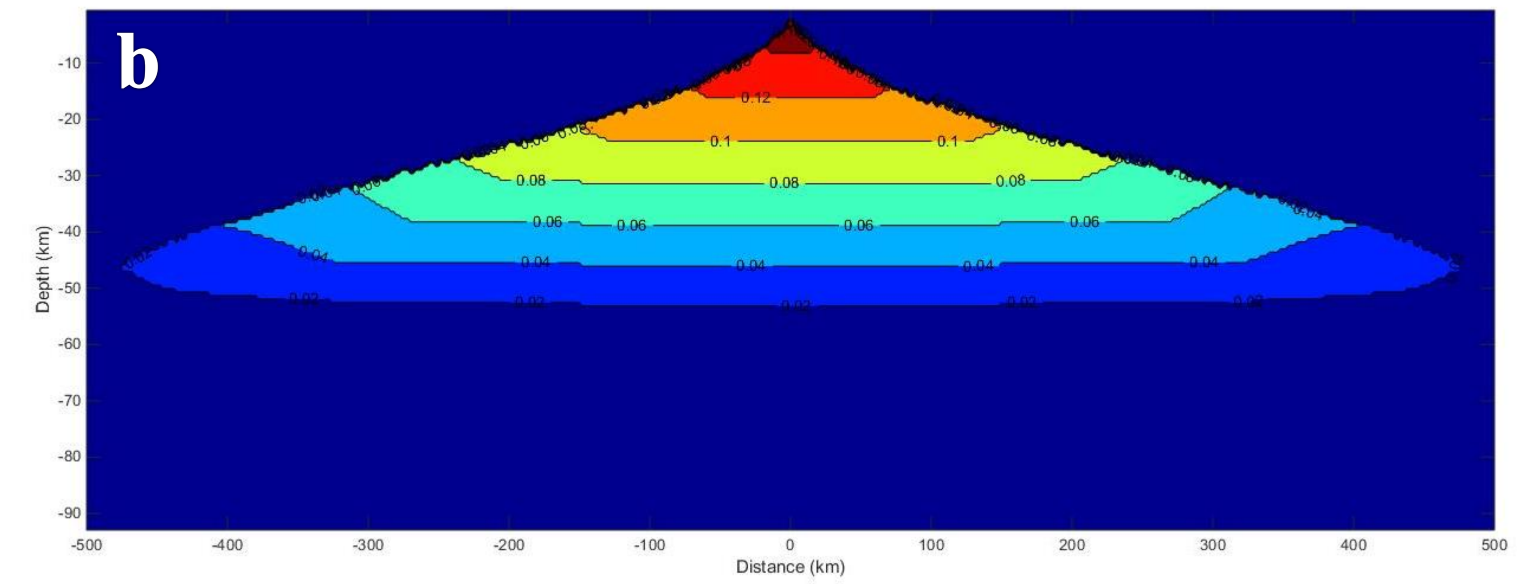


Figure 2. (a) Cartoon depicting our modeling approach[3][4] (b) The estimated melt region for a fast spreading ridge where the plates are diverging at a rate of 100 mm/yr, which is analogous to what is expected in our area of interest at the East Pacific Rise

Results & Conclusions

Below, the real data from a representive seamount chain (Chain 4, symbolized by the magenta squares on the map and figures) is shown. Major element oxides were plotted against the sample's distance from the ridge axis and versus MgO. On the chemical variation diagram, the liquid lines of decent that were modeled are overlaid the real data points.

A quick glance shows that the trends of the real data versus to the liquid lines of decent are comparable. However, the values differ . For Na_2O, the estimated value for this oxide is higher than what is actually seen. It is expected to see higher values this oxide because the erupted lavas should be coming from the flanks of the melt region. The lower oxide percentage in the real data could suggest that there is more melting than predicted by our model. It has been suggested that this chain is associated with "hot spot" activity.

Figure 3. Model-data comparison

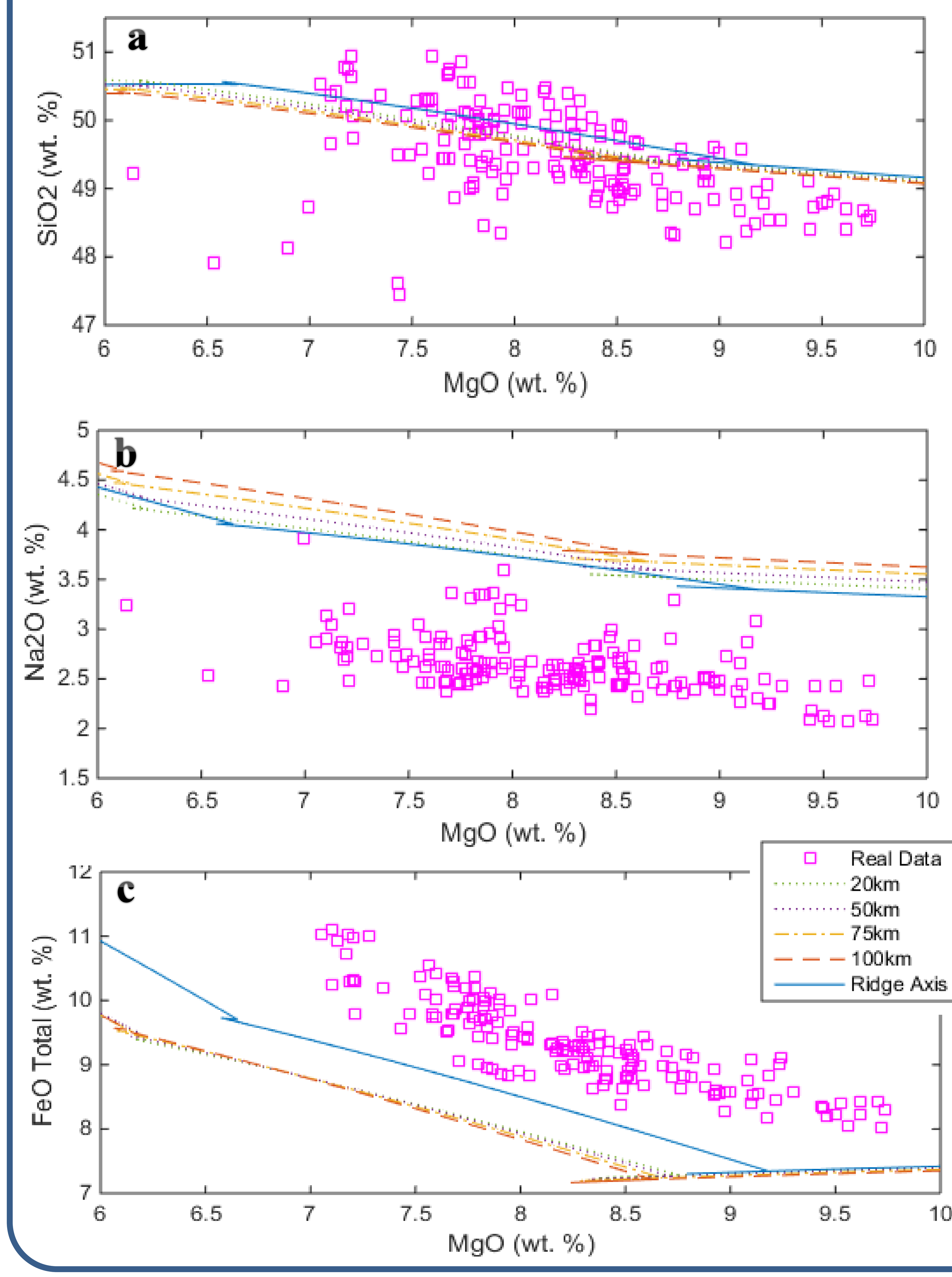


Figure 4. Variation Diagrams

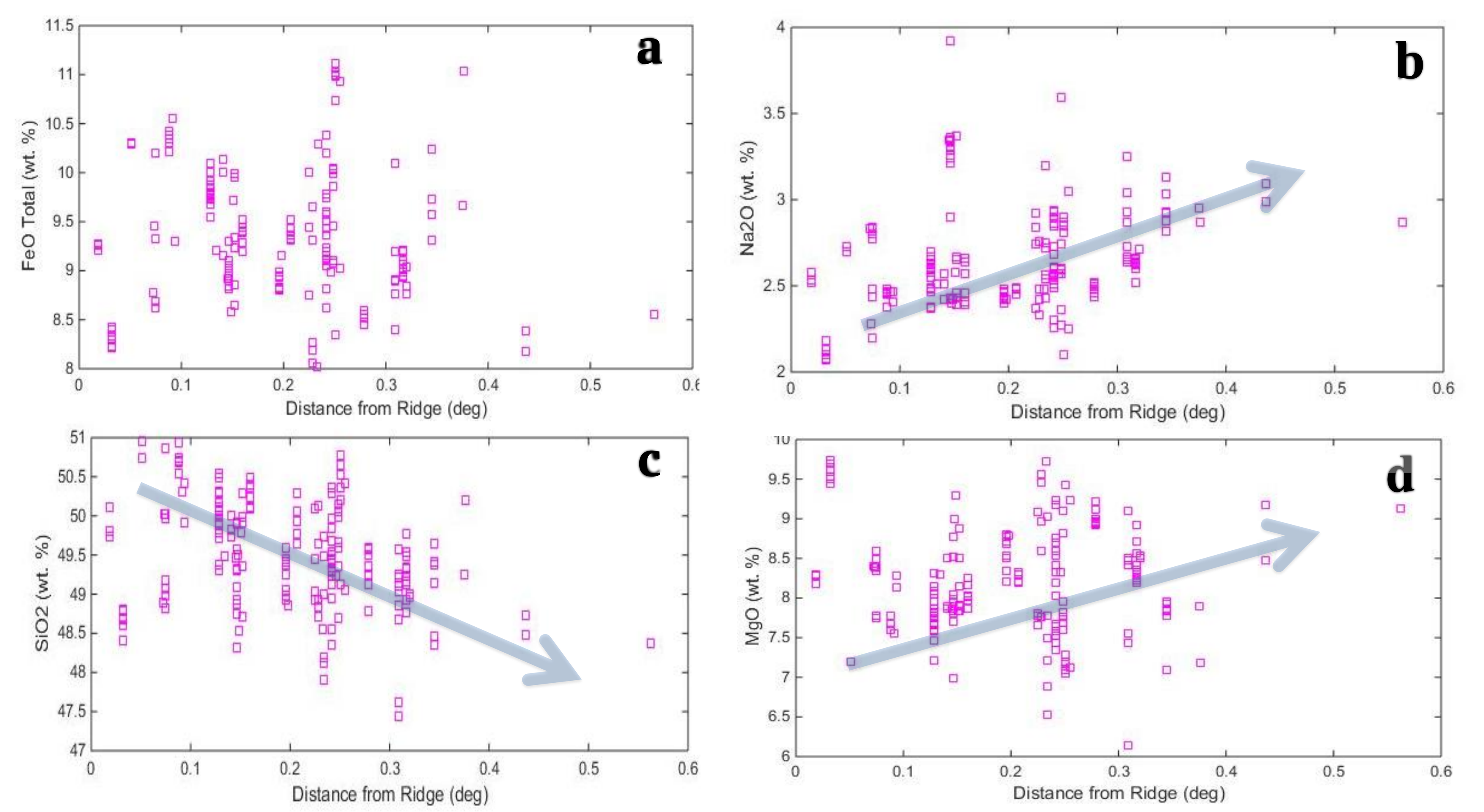


Figure 3. To the left, chemical variation diagrams for major element oxides are plotted for the seamounts found in Chain 4. The Liquid Lines of Decent that were modeled are overlaid. The different lines symbolize the estimated lava composition from the flanks of the melt regime that correspond with the chain's location from the ridge axis.

Figure 4. Above are the major element oxide percentages for each seamount in Chain 4 at 10°N plotted against the sample's distance from the ridge axis. Trends can be seen for (b)-(d), but there does not appear to be a clear trend in FeO.

Conclusions

- Near-axis seamount chains provide an opportunity to test models of melt generation and migration at mid-ocean ridges.
- Geochemical trends observed in major element data indicates a trend in SiO_2, MgO, and Na_2O with distance of seamount from the ridge axis. FeO appears to be less sensitive.
- The model appears to do a good job of tracking SiO_2 values which are a proxy for fractionation.
- The model underestimates FeO, a proxy for pressure, indicating melts were generated at higher-pressure than predicted.
- The model overestimates Na_2O, a proxy for extent of melting, indicating that there were likely higher degrees of melting than predicted by the model.

References

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