Temperatures of Ancient Eclogites Estimated Using Zirconium-in-Rutile Geothermometry

Audrey Graham (GEOL394)

Advisor: Dr. Sarah Penniston-Dorland

Introduction

- The Belomorian Province represents an ancient subduction zone (up to 2.87 Gyr old). Subduction zone conditions in the Precambrian have been measured to be hotter[1].
- Zr-in-rutile geothermometry can be used to determine temperatures recorded by the rock.
- Determining the temperatures these rocks experienced during their subduction can provide insight into Precambrian subduction zone conditions.

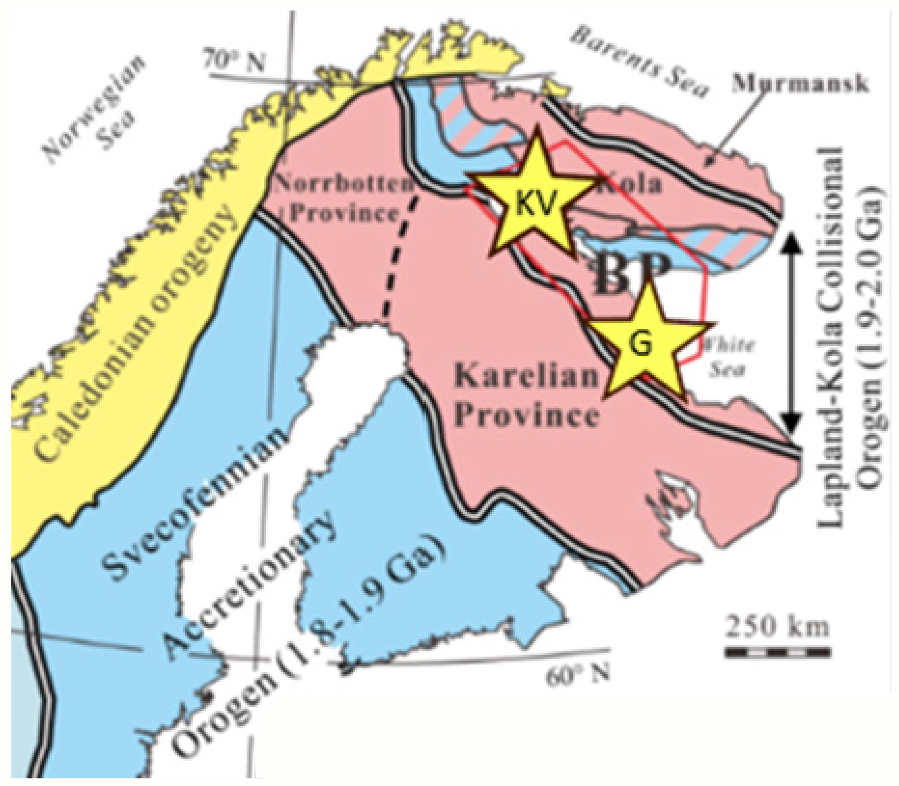

Fig 1. Belomorian Province (BP) outlined in red, with Kuru-Vaara (KV) and Gridino (G) sampling locations indicated by a star[2].

Methods

Zr-in-rutile geothermometry

$$T(\mathrm{C}^\circ) = \frac{71360 + 0.378 \cdot P(\mathrm{bars}) - 0.130 \cdot C(\mathrm{ppm})}{130.66 - R \cdot \ln\left[C(\mathrm{ppm})\right]} - 273.1$$

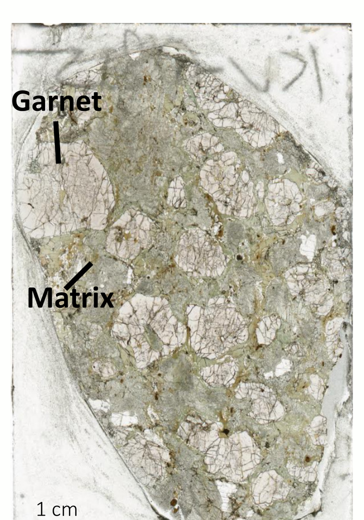

Fig 2. Representative thin section scan of eclogite.

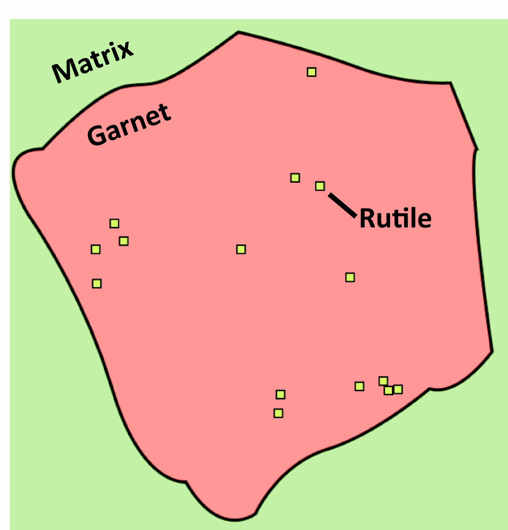

Fig 3. Illustration of a single garnet with rutile crystals mapped.

- Zr concentrations in rutile are used as a proxy for temperature[3]. The goal is to find the rock's peak temperature along its prograde path.
- Exhumation temperatures in Belamorian Province rocks are expected to exceed subduction temperatures.
- Garnet crystals prevent the Zr concentrations of rutile crystals from changing in response to temperature.
- Zr concentrations of rutile crystals inside garnet and in the matrix can be compared to investigate the rock's P-T path.

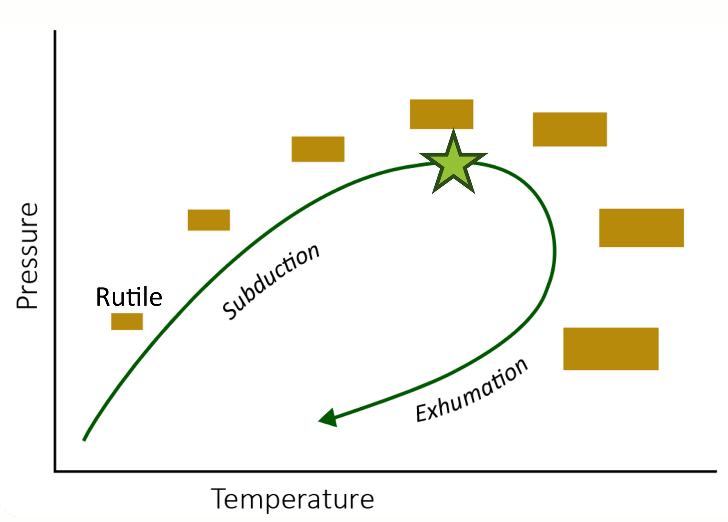

Fig 4. A simplified P-T path of a subduction zone rock.

Hypotheses

Null: Zr concentrations of rutile crystals included within garnet will not be different than rutile in the matrix.

Alternative: Zr concentrations of these two separate populations will be different from one another.

Results

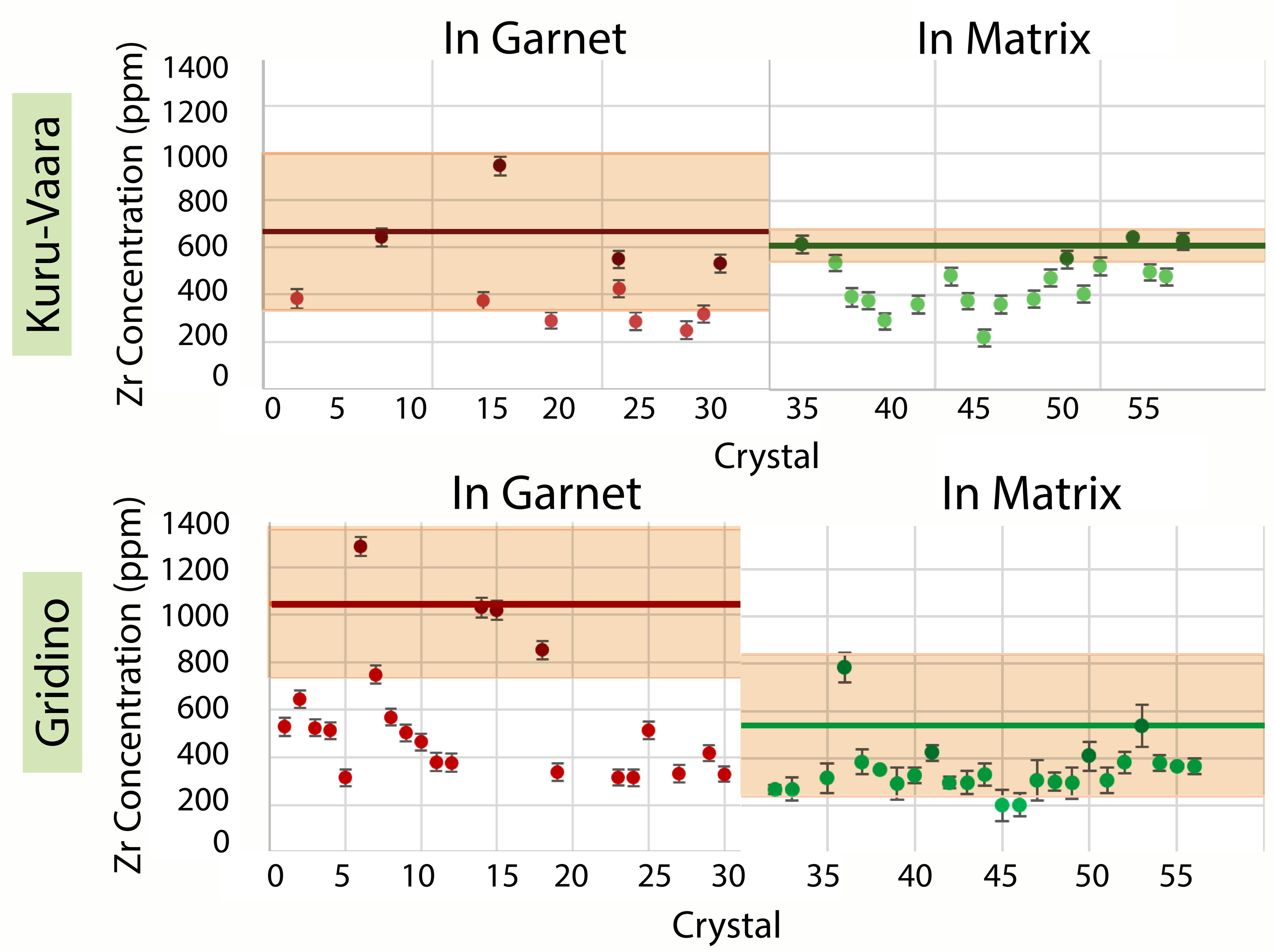

Fig 5. Graphs depicting the zirconium concentrations measured for each rutile crystal. Plotted using the mean-max method[4]: (a) Mean-max method for Kuru-Vaara sample, yields mean-max value of 753 ± 230 ppm for within garnet and 607 ± 68 ppm (all uncertainties are calculated to 2σ) within matrix; (b) Mean-max method for Gridino sample, yields mean-max value of 1046 ± 311 ppm within garnet and 539 ± 301 ppm within matrix

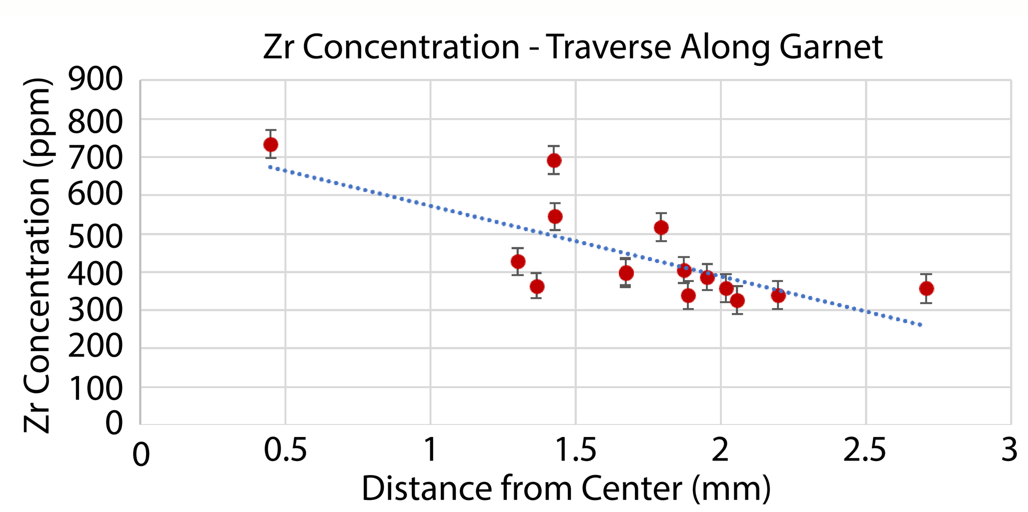

Fig 6. Zirconium concentration measurements from rutile crystal inclusions within a garnet crystal from KV(2). The data points are ordered by the measurement's distance from the core of the garnet crystal. R^2=0.5381

- As is seen in Figure 5, there is an overlap in Zr concentration within uncertainty for both the Kuru-Vaara and Gridino eclogite.
- As is seen in Figure 6, The garnet traverse exhibits a decrease in Zirconium concentration with increasing distance from the center of the garnet.

Discussion

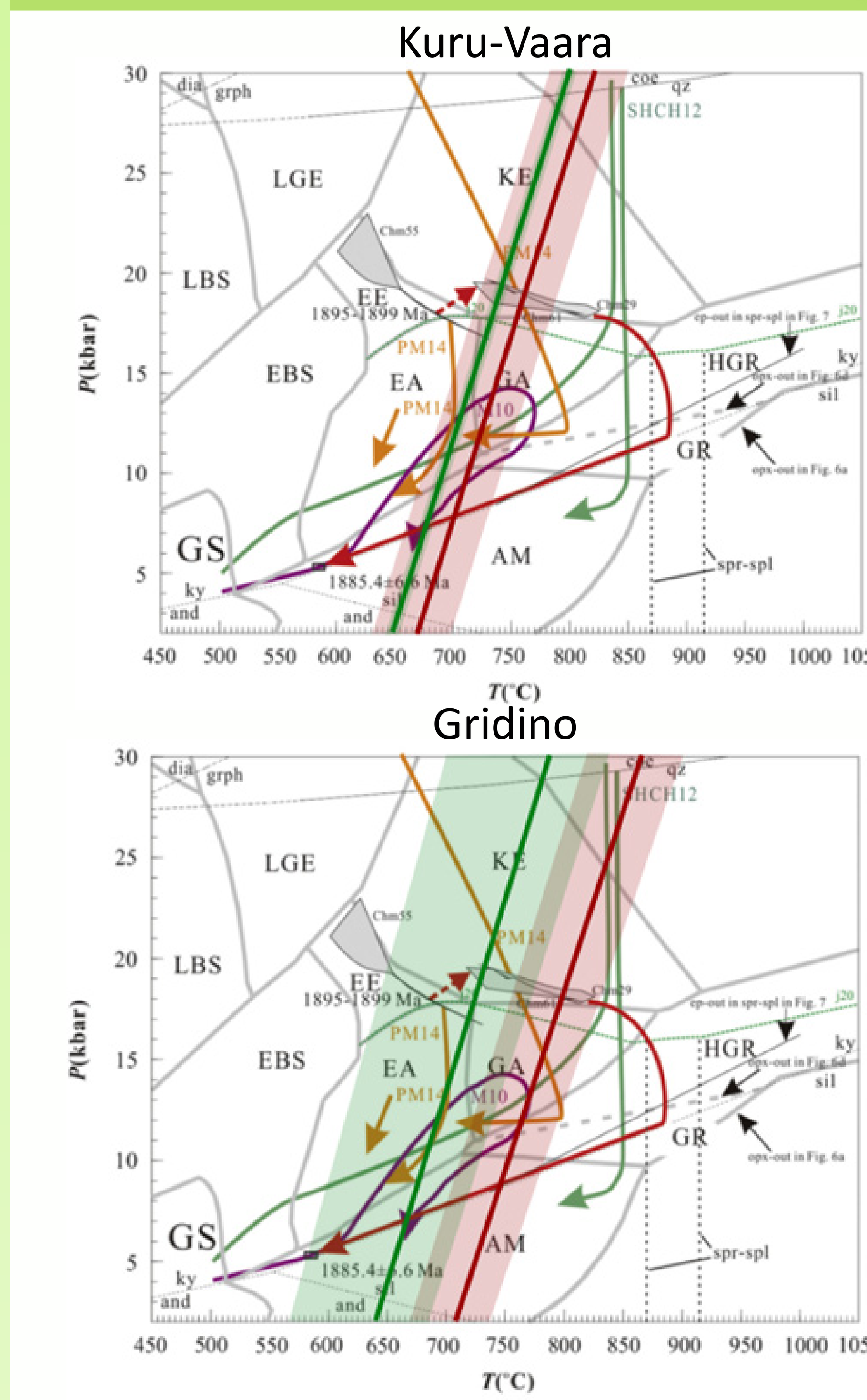

Fig 7. Zirconium-in-rutile geothermometry results superimposed onto previously calulated P-T diagram of BP rocks[5].

Temperature isopleths created using Kuru-Vaara and Gridino mean-max values have been superimposed onto pre-existing P-T paths for Belomorian Province rocks[5].

- Kuru-Vaara: Temperature isopleths overlap with Kuru-Vaara P-T arrow (red) on both the prograde and retrograde path. Peak exhumation temperatures are not recorded.
- Gridino: Temperature isopleths overlap with Gridino P-T arrows (orange) on just its retrograde path.

Conclusions

- The null hypothesis is supported. Neither the Kuru-Vaara nor the Gridino sample exhibit differences in Zr concentration outside of uncertainty.
- Temperature isopleths in Figure 7 overlap in multiple areas with both prograde and retrograde P-T conditions from previous estimates. Possible future work may include a geobarometer in order to constrain pressure.
- Peak exhumation temperatures are not recorded by these rocks.
- The garnet traverse in Figure 6 exhibits a pattern of decreasing Zr concentration, and therefore temperature, during its growth. This suggests that the garnet crystallized during the rock's exhumation.

References and Acknowledgements

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