Crystallization sequence and tectonic significance of andalusite, kyanite, and sillimanite ‘triple point’ localities, including a new locality: Lesjaverk, Norway.

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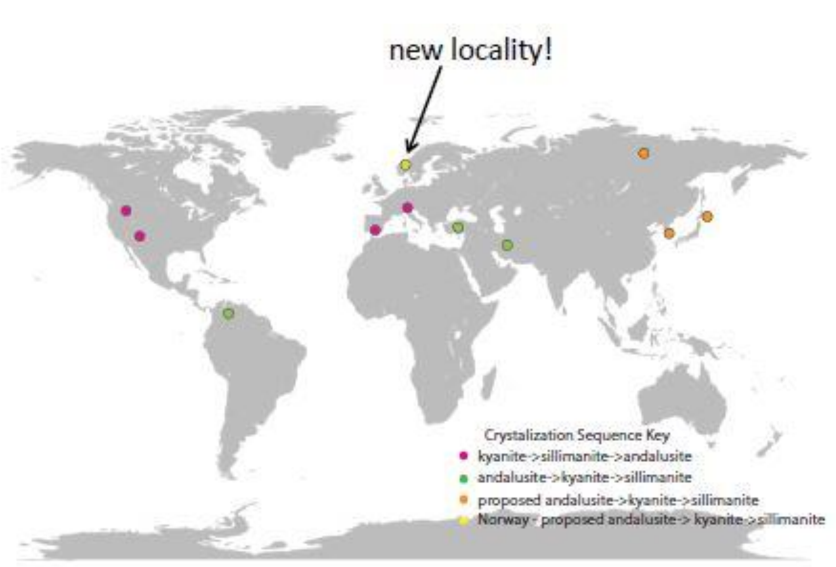
Introduction

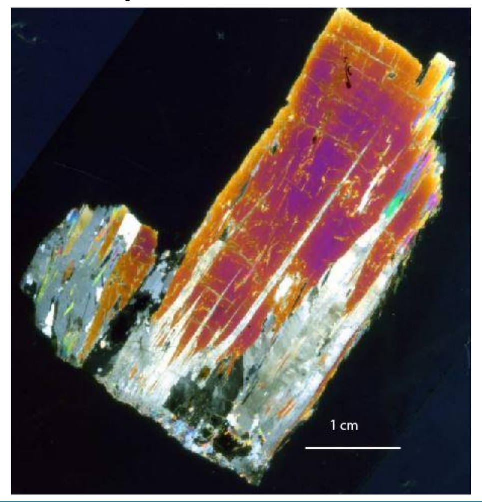
Background

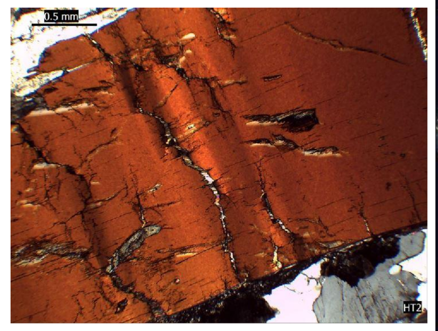
Rocks containing three Al_2SiO_5 polymorphs (andalusite, kyanite, sillimanite) are uncommon; only ten localities have previously been reported. By determining the crystallization sequence of the polymorphs, tectonic/metamorphic histories can be unlocked. Two crystallization sequences have been proposed: (1) kyanite -> sillimanite -> andalusite (Idaho, New Mexico, Spain, Italy), and (2) andalusite -> kyanite -> sillimanite (Colombia, Turkey, Iran, Russia, South Korea, and Japan). Each has a different implication for the relation of changing pressure and temperature. The newest locality is Lesjaverk, Norway; this research will determine the crystallization sequence and P-T conditions.

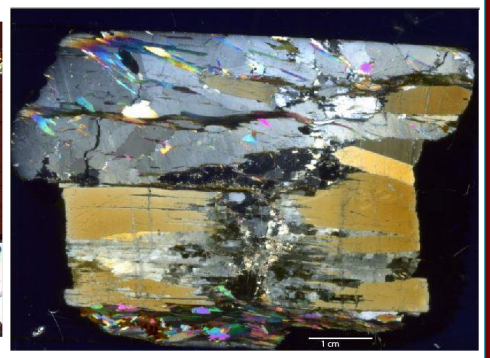


Research & Methods

- ❖ Review of previous research for other world localities.
- ❖ Petrographic analyses of deformation, accessory minerals, and indication of crystallization order.
- ❖ Microprobe analyses of rutile grains in kyanite and in the matrix.
- ❖ Temperature calculations using Zr-in-rutile thermometry.
- ❖ Evaluation of element substitution in rutile.
- ❖ Interpretation of pressure-temperature conditions and Al2SiO5 crystallization order in the context of tectonic environment.



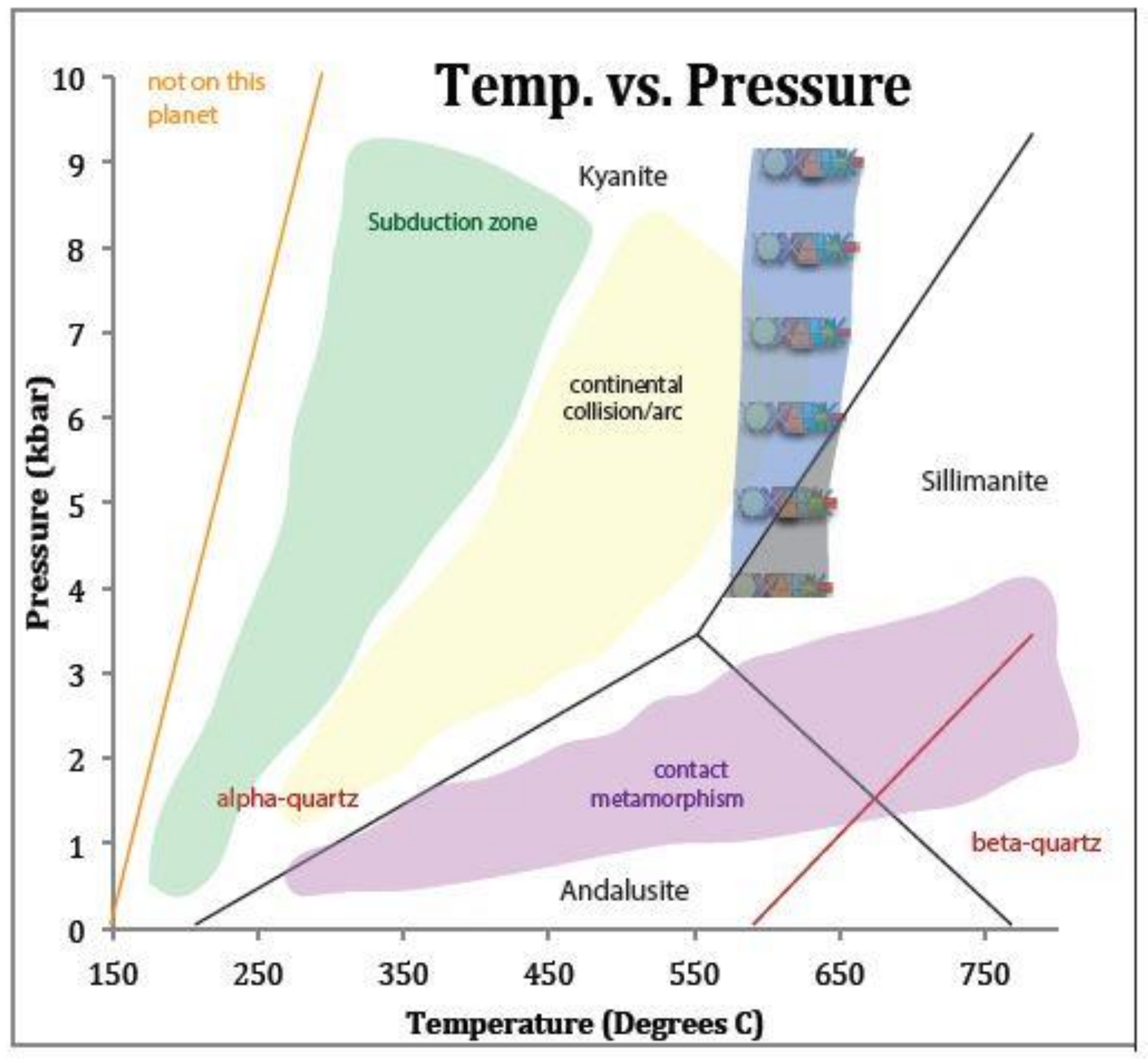


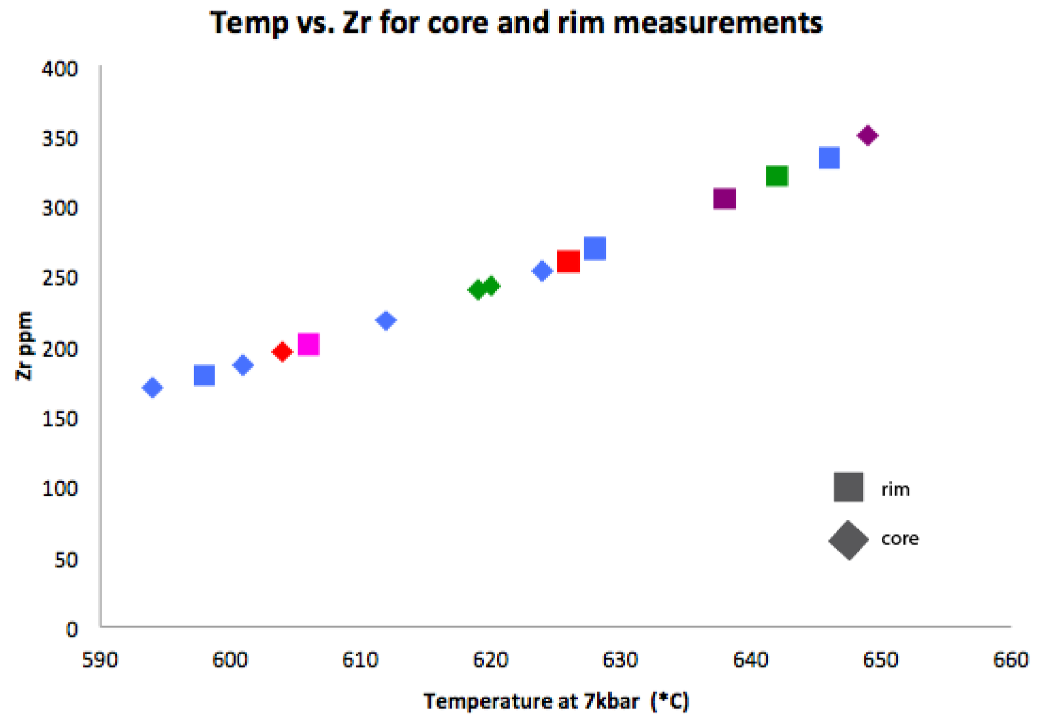


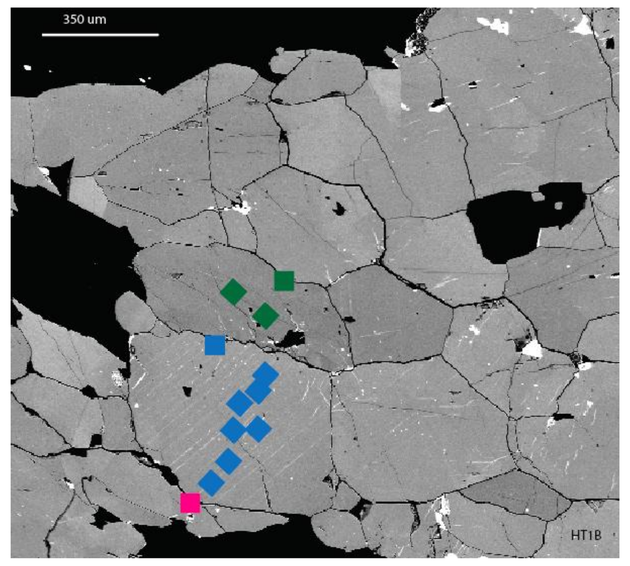
Rutile Data

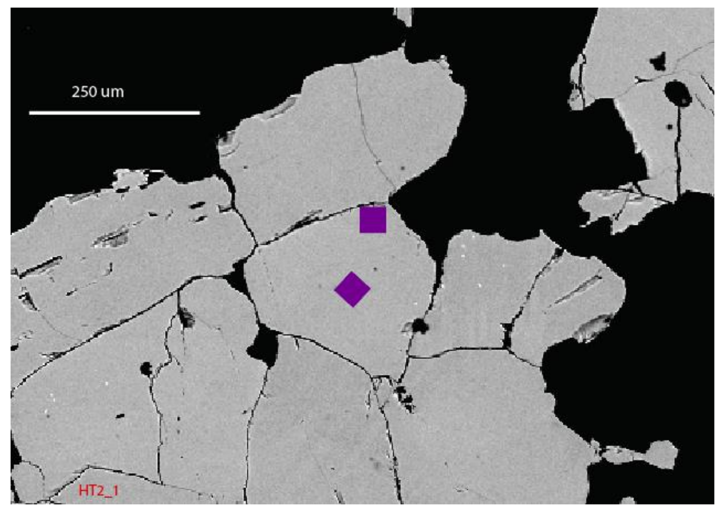
Pressure-Temperature

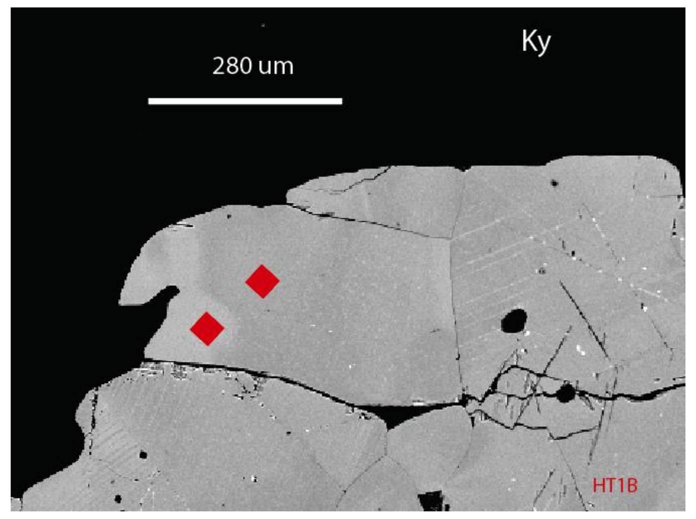
Using 16 electron microprobe analysis points within 5 rutile grains from 2 samples, temperatures were calculated using the Zr in rutile thermometer (equations from Tomkins et al., (2007). Pressure is unknown, so T was calculated over a range of P: 4-9 kbar, for both the alpha and beta-quartz fields. For this P range at a constant Zr value, T only varies by ~21°C. Results indicate temperatures of ~580-660°C.











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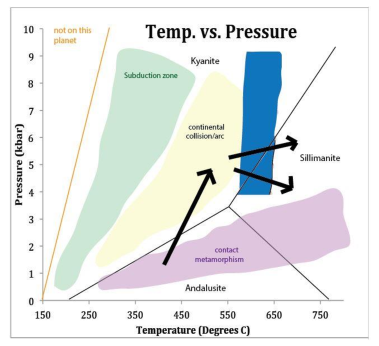
Discussion

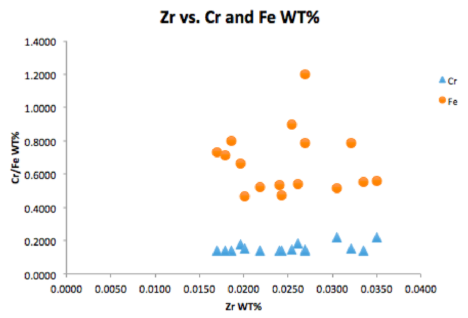
Interpretation

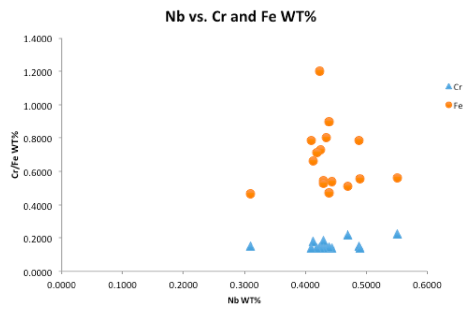
Results indicate temperatures of 580 - 660°C. This temperature range and petrographic observation suggests that rutile most likely equilibrated within the kyanite P-T stability fields and the alpha-quartz field. Analyses in 5 rutile grains were taken from rims and cores. Of the 16 analysis points, 4 were within a rutile inclusion in kyanite , and the remaining 10 were in the matrix. In matrix rutile, Zr abundance is greater at the rim (262 ppm) than in the cores (218 ppm), similar to one of the analyzed rutile inclusions in kyanite (rim: 261 ppm; core: 197 ppm). The other analyzed rutile inclusion in kyanite has higher Zr ppm in the core (350 ppm) compared to the rim (305 ppm).

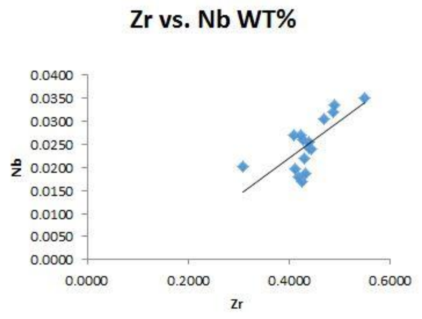
Abundances of different minor elements in rutile were plotted against each other to evaluate trends, and some elements appear to be correlated with each other. As Zr increases, Nb and Cr increase and Fe very slightly decreases. Zr and Nb appear to behave similarly, indicating elemental substitution.



Elemental trends indicate elemental substitution







Conclusion

- ❖ In matrix rutile, Zr is lower in the core and higher at the rim, indicating an increase in temperature during rutile growth.
- ❖ Rutile formed in the kyanite stability field, indicating moderately high temperatures and moderate pressures.
- ❖ Zr and Nb, Fe, and Cr participate in elemental substitution in rutile.
- ❖ Crystallization order was andalusite->kyanite->sillimanite.
- ❖ These P-T conditions are consistent with metamorphism during early contact/arc metamorphism followed by continental collision.

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