



Chemical Diffusion In Watermelon Tourmaline: Parallel Versus Perpendicular to C-axis

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Abstract

The chemical composition of tourmaline can provide unique insights into the thermal evolution of their growth environment, including that of pegmatites (in igneous systems) and hydrothermal veins (in metamorphic systems). With its wide open channels that run parallel to the crystallographic c-axis, the tourmaline lattice structure can accommodate a wide range of contaminant species. It is well known that multiple absorption bands in the infrared spectrum can be characterized to document the uptake of dozens of individual hydroxyl-bearing contaminant species within single tourmaline crystals. In a companion abstract (this volume), we show that concentration gradients in several of these contaminant species can be used to document diffusion during post-crystallization thermal evolution. The diffusion of these species may be the cause of the color variation in these samples. Here, we examine a single crystal of watermelon tourmaline with prominent color variations both perpendicular and parallel to the c-axis. We compare the gradients in chemical contaminants as measured using high-resolution micro-infrared spectroscopy both parallel and perpendicular to the c-axis to determine if the color variation is related to observed abundances in hydroxyl species.

How do Watermelon Tourmalines Grow?



- From a Hot Fluid
- Nucleated on Host Rock



Two Potential Mechanisms for Color Causation in Watermelon Tourmaline



- **Growth Model**- variation occurs during growth
Changing concentrations of hydrous impurities (coloring agents) entrained in crystal during growth.
- **Diffusion Model**- variation occurs after growth
Diffusion of entrained hydrous impurities (coloring agents) after crystal growth create gradients in concentration throughout the crystal.

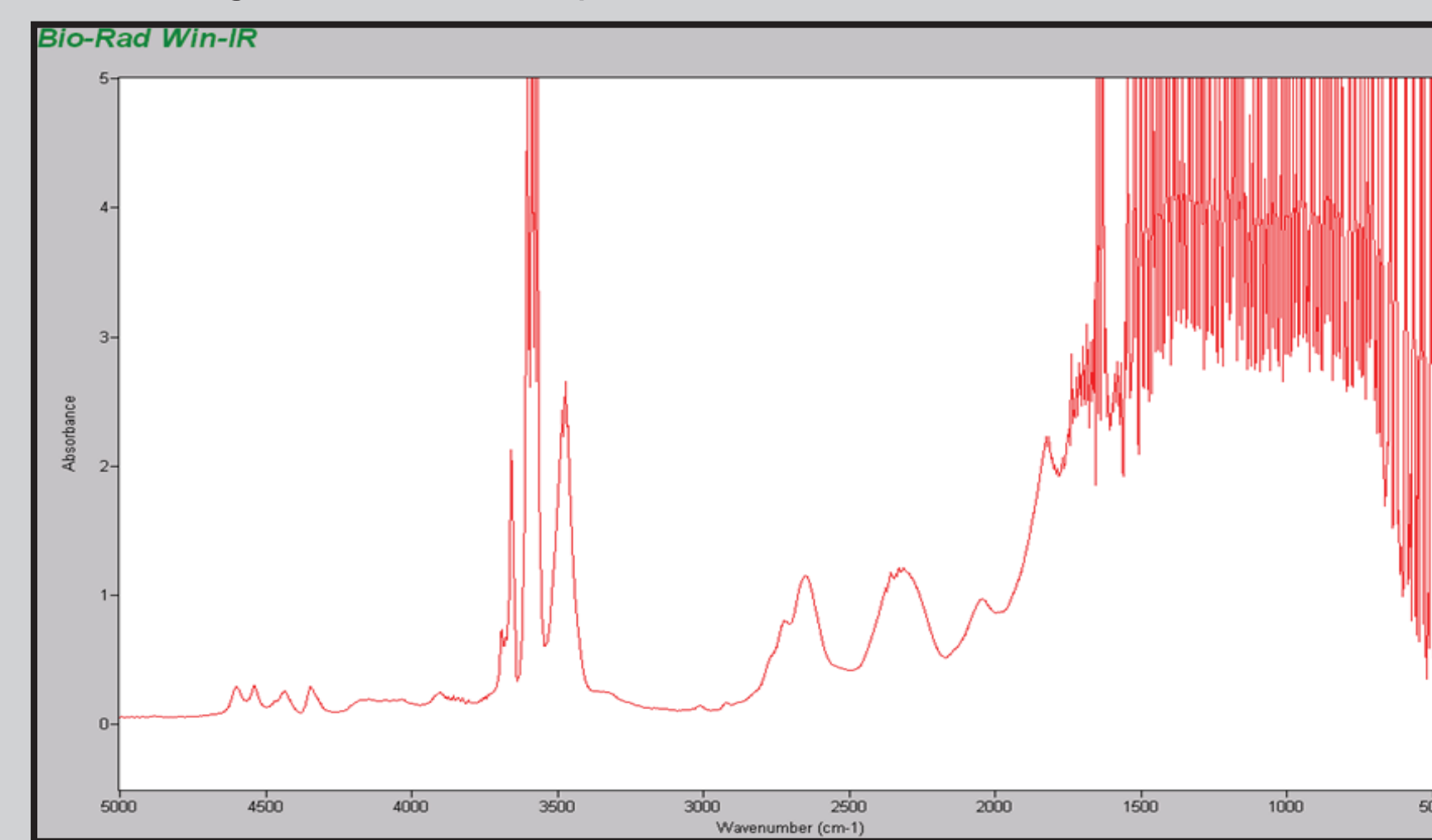
Infrared Spectroscopy



- Infrared photons can be used to detect trace hydroxyl-bearing constituents in crystals. The energy of the absorbed photon correlates with the energy of the chemical bond of the trace constituent.
- Absorbance reflects the number of photons absorbed for each hydroxyl species.
- Absorbance quantifies the hydrous impurity (coloring agent)

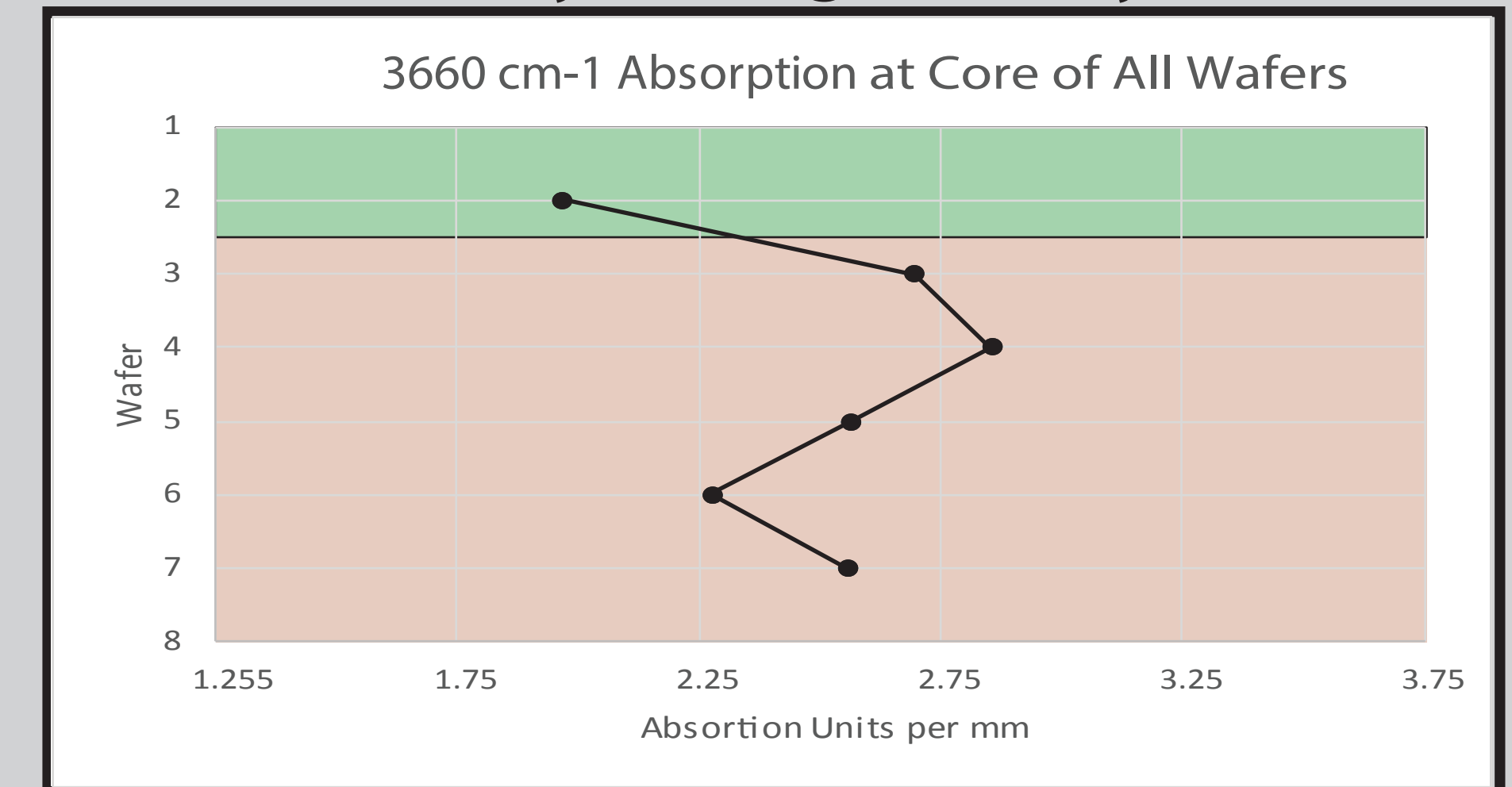
Infrared Spectrum

Showing numerous absorption bands associated with contaminants



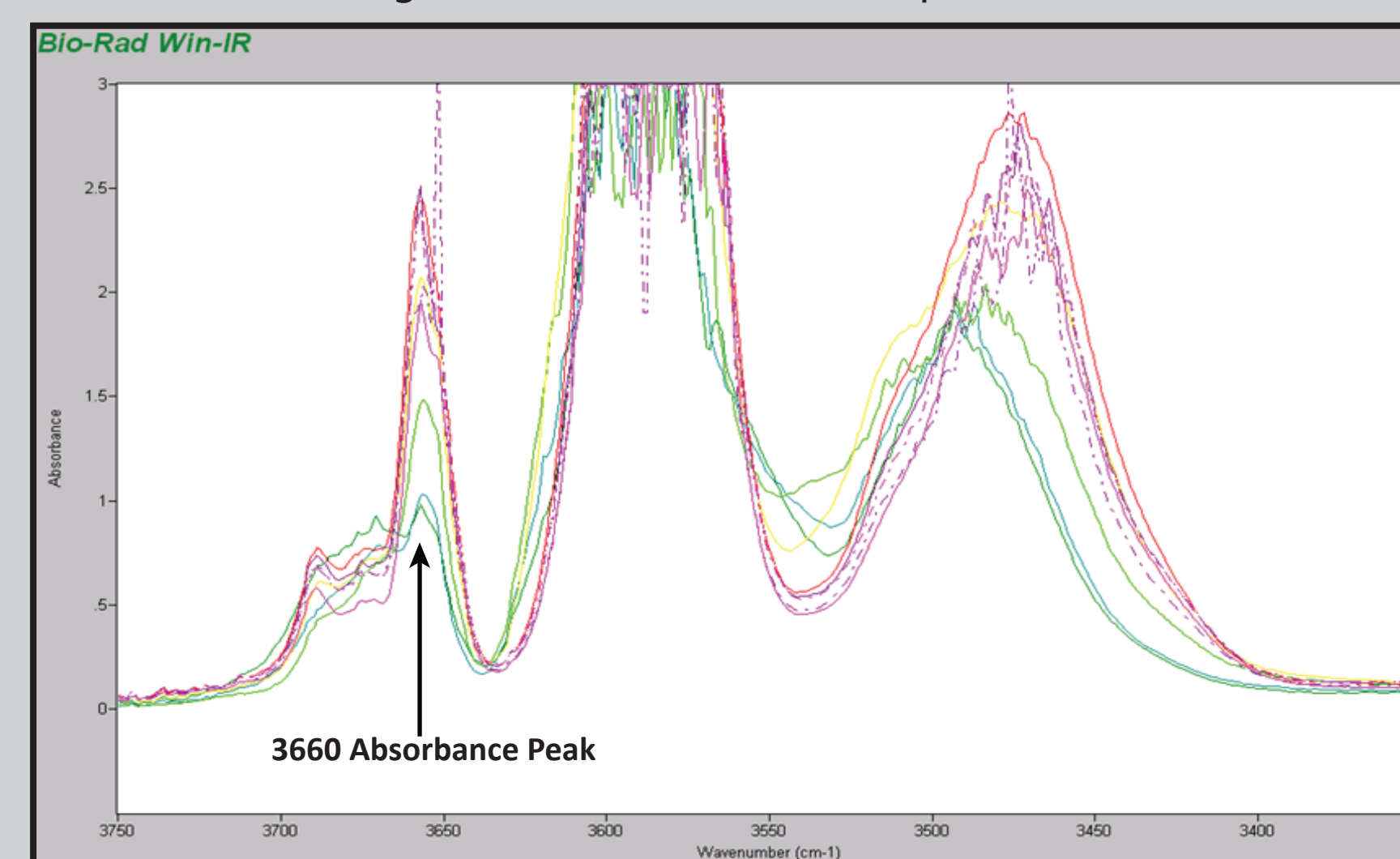
Results

Contaminant Concentrations Vary Vertically Through the Crystal

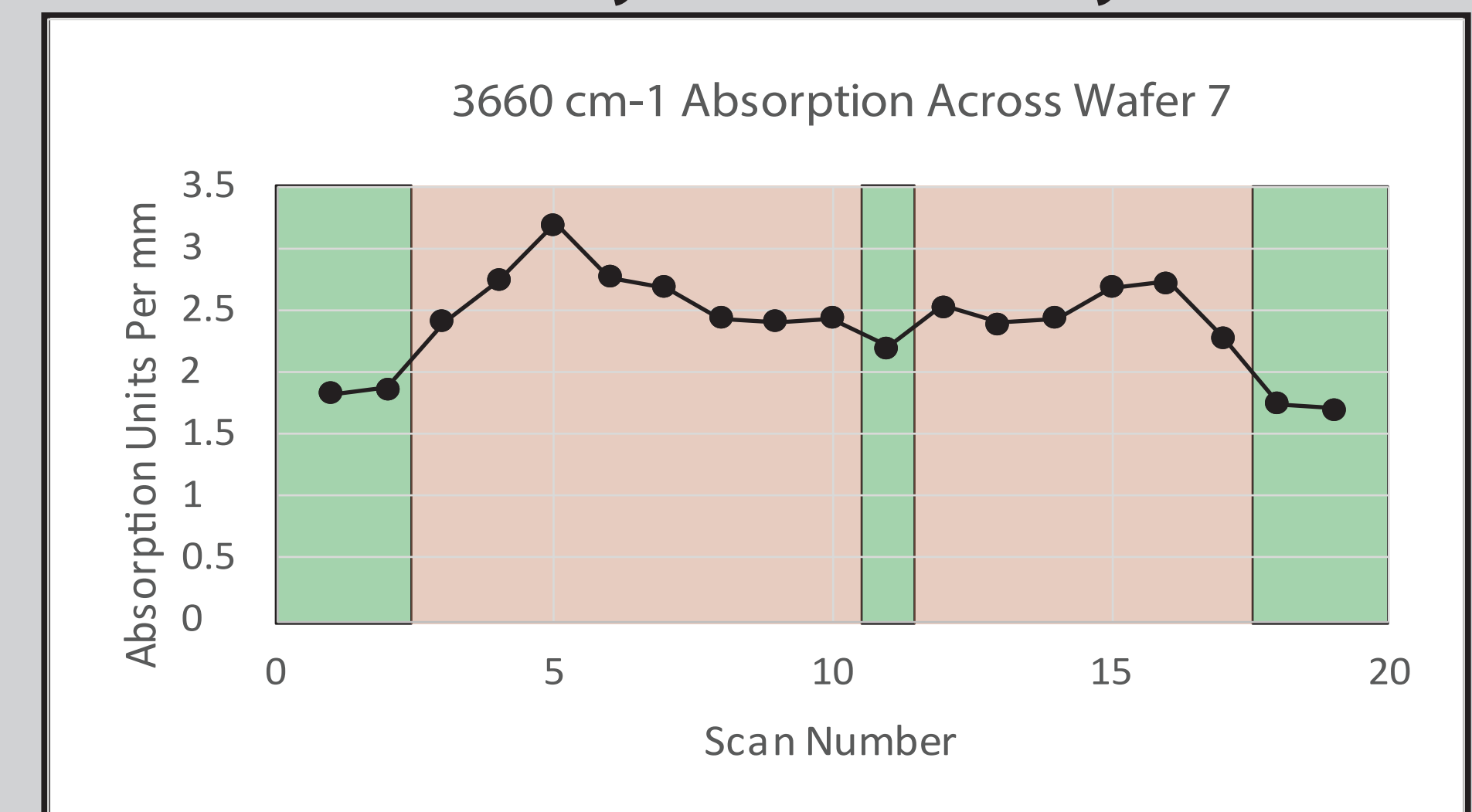


Overlaid Infrared Spectra

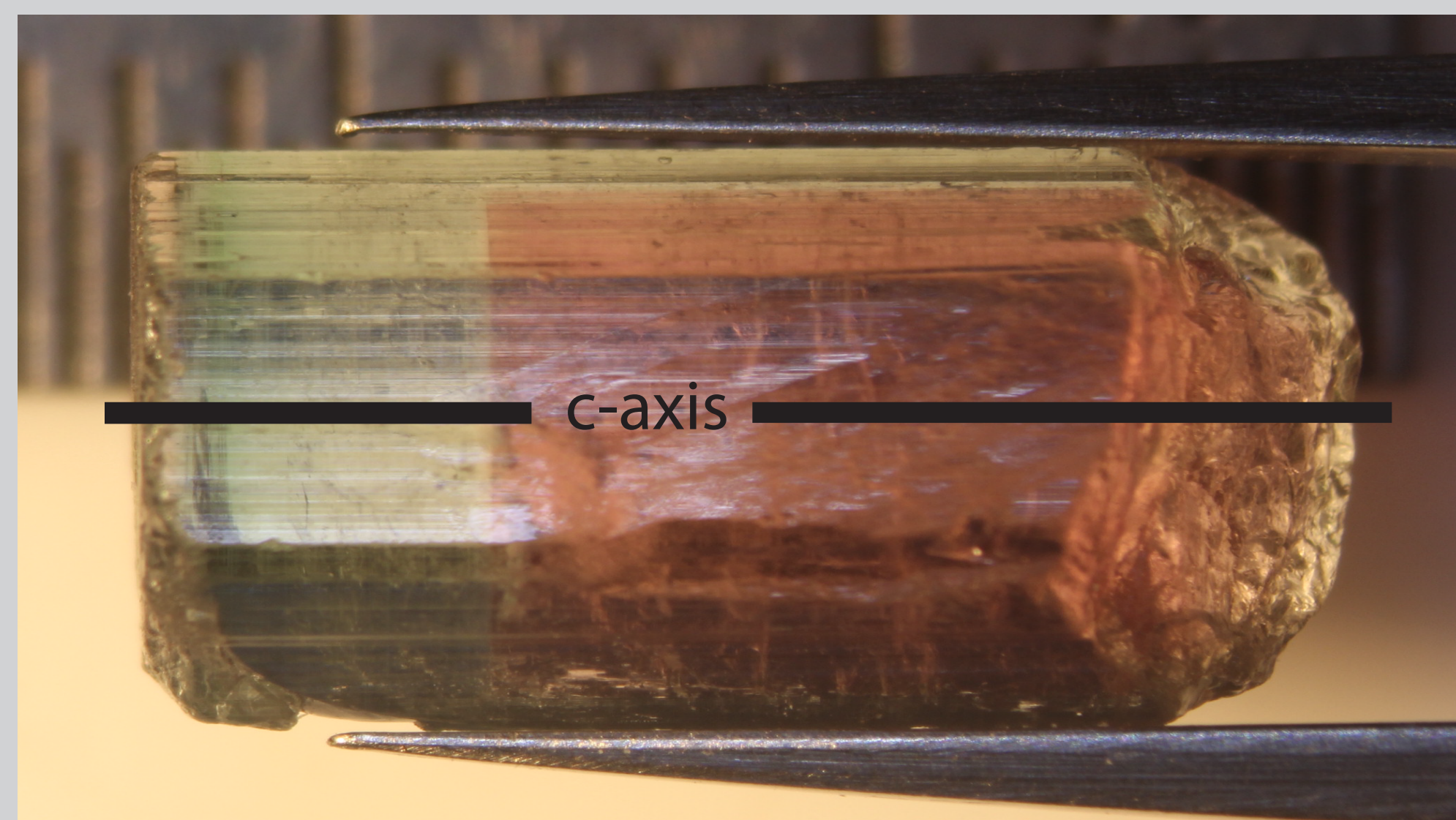
Showing variation in contaminant species at 3660 cm⁻¹



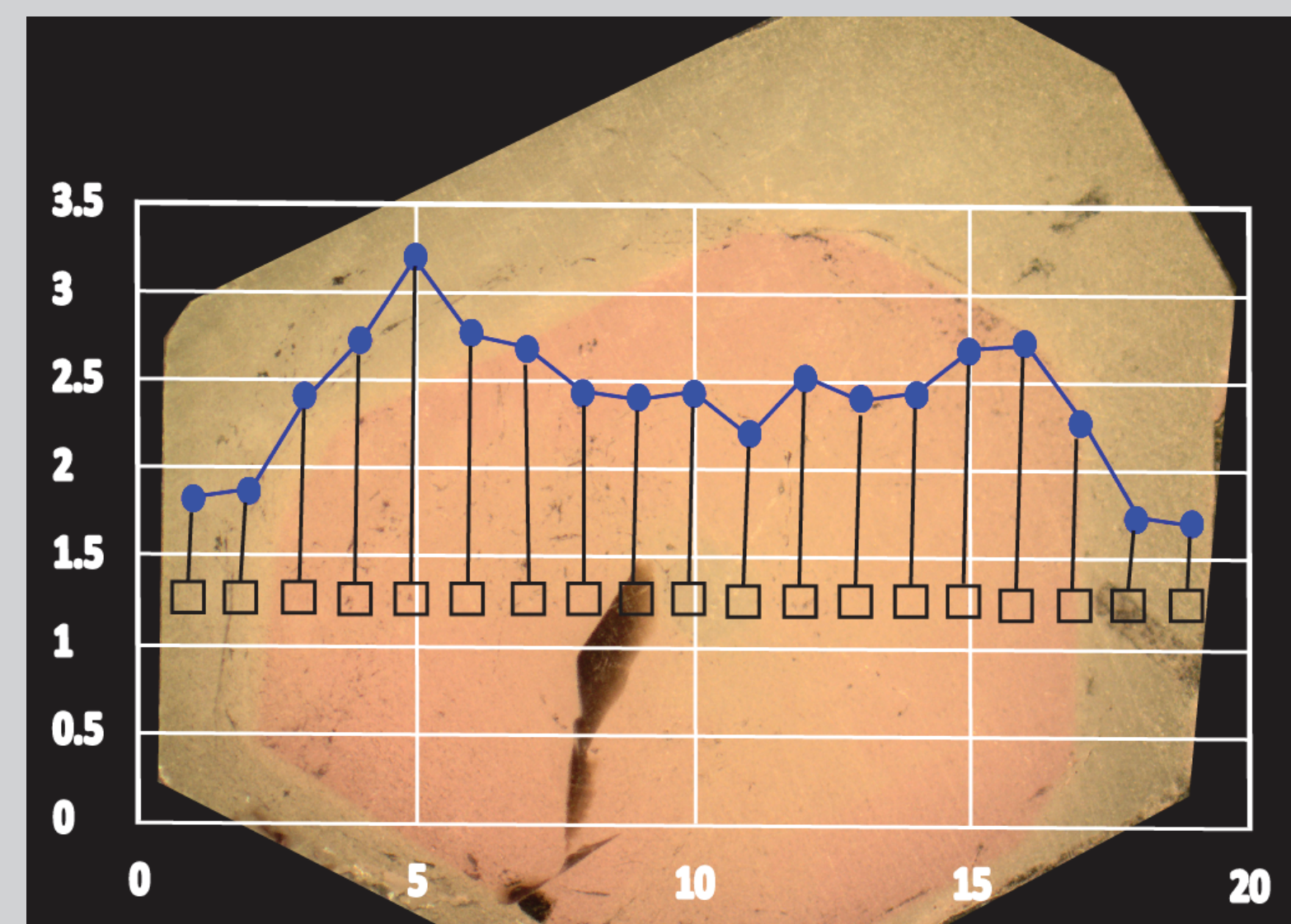
Contaminant Concentrations Vary Horizontally Across the Crystal



Watermelon Tourmaline



Wafer 7 (perpendicular to c-axis)



Observations & Conclusions

- Contaminant abundances decline with height in tourmaline, consistent with rapid diffusion up the c-axis. Our data are consistent with the model that color variations result from preferential loss of coloring agents during post-crystallization thermal soaking.
- Contaminant abundances decline radially outward in tourmaline, consistent with observable diffusion through the prism faces, perpendicular to the c-axis.
- Absorbances (per mm) greater than 2.1 correlate to pink coloration and absorbances less than 2.1 correlate to green coloration.

Future Research

- Distinguish crystal growth mechanism
- Test different compositions of tourmaline for diffusion

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References

Ertl, A., Hughes, J.M., Prowatke, S., Rossman, G.R., London, D., and Fritz, E.A., 2003, Mn-rich tourmaline from Austria: structure, chemistry, optical spectra, and relations to synthetic solid solutions: *American Mineralogist*, v. 88, p. 1369–1376.
 Ihinger, P.D., and Zink, S.J., 2000, Determination of relative growth rates of natural quartz crystals: *Nature*, v. 404, p. 865–869.
 Mattson, S.M., and Rossman, G.R., 1987, Fe²⁺-Fe³⁺ interactions in tourmaline: *Phys Chem Minerals Physics and Chemistry of Minerals*, v. 14, p. 163–171.
 Luiz Carlos B. De Miranda Pinto, Righi, A., Lameiras, F.S., Araujo, F.G.D.S., and Krambrock, K., 2011, Origin of the color in cobalt-doped quartz: *Phys Chem Minerals Physics and Chemistry of Minerals*, v. 38, p. 623–629.
 Reddy, B.J., Frost, R.L., Martens, W.N., Wain, D.L., and Kloprogge, J.T., 2007, Spectroscopic characterization of Mn-rich tourmalines: *Vibrational Spectroscopy*, v. 44, p. 42–49