A Mineralogical Approach to Understanding Oyster Shells

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Background

- Oysters (used as a food source for over 125,000 years) are farmed today in the Chesapeake Bay and valued at $30M/year.
- Instances of noticeably weaker oyster shells were observed during a year of low salinity.
- Oyster shells are formed from calcite crystals in foliated, prismatic, and other micron scale.
- We took a mineralogical approach to investigate how salinity affects oyster shells on the atomic scale and micron scale.
- Raman spectroscopy is a powerful, nondestructive method that uses inelastic scattering laser light to probe chemical bonding environments in crystals.

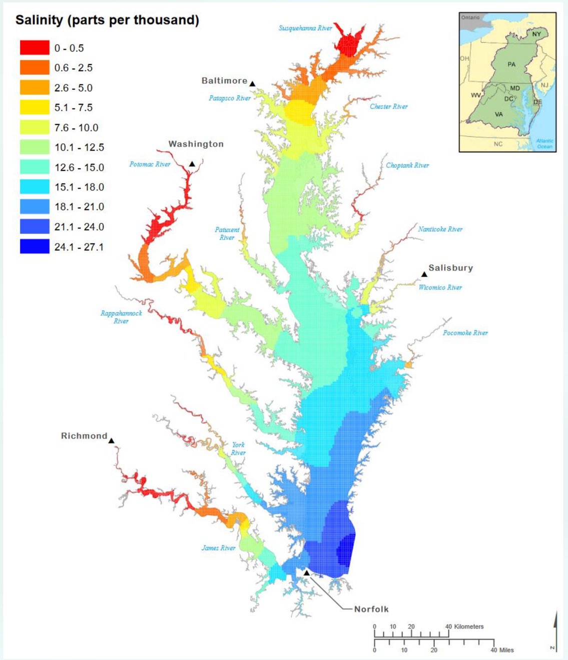

Figure 1: Map of Chesapeake Bay mean surface salinity ranges 1985–2018

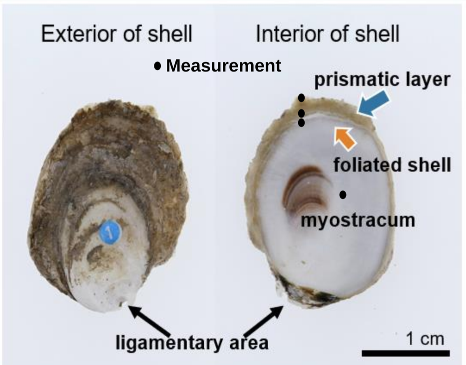

Figure 2: Hand samples

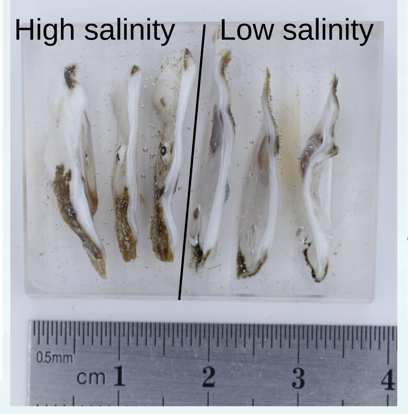

Figure 3: Polished thick section

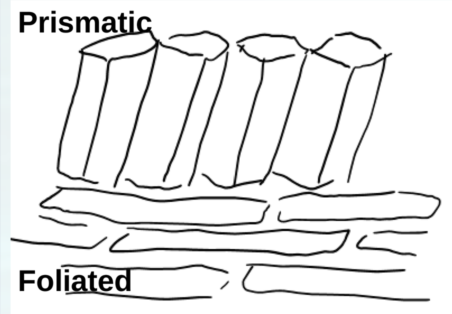

Figure 4: Sketch of microstructures

Methods

- Two groups of juvenile "spat" of *Crassostrea virginica*, the Eastern Oyster, were incubated in low (5–15 psu) and high (15–25 psu) salinity treatments at the Smithsonian Environmental Research Center.
- Raman spectroscopy was used to measure chemical bonding environments across microstructures and salinity treatments.
- We targeted the ν_1 Raman vibrational mode and its full width half maximum (FWHM) to estimate disorder in the crystal structures.
- Scanning electron microscopy (SEM) and energy dispersive x-ray spectroscopy (EDS) were used to image microstructures and measure elemental abundances in the shells.

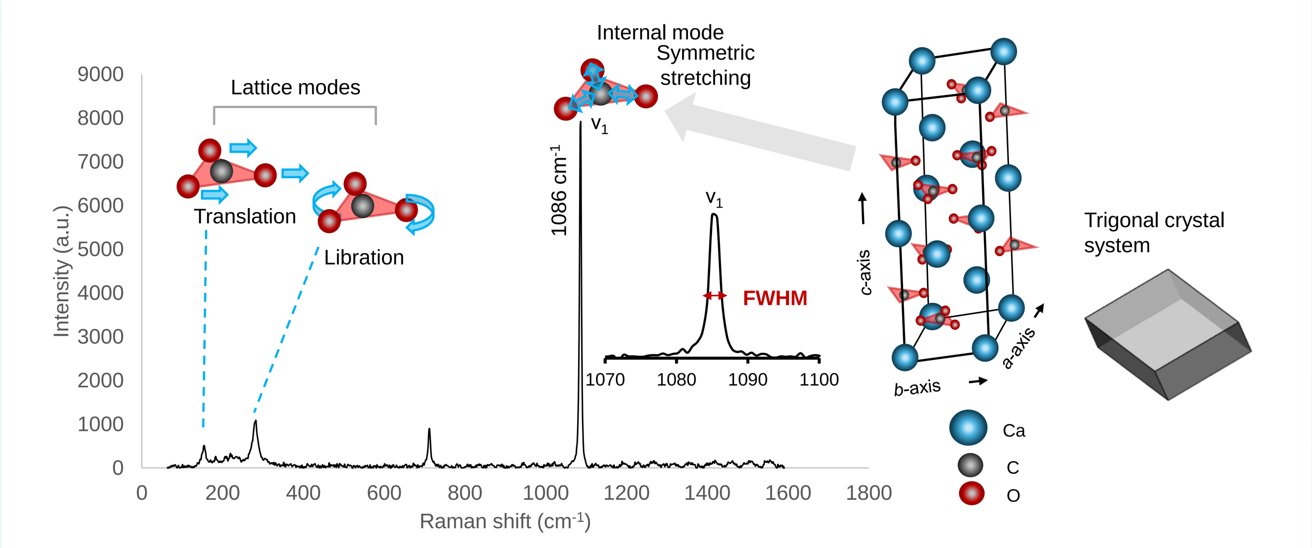

Figure 5: Raman spectra of typical calcite crystal; calcite's vibrational modes and full width half maximum (FWHM)

Results: Raman and SEM

Raman spectra show differences between prismatic and foliated layers

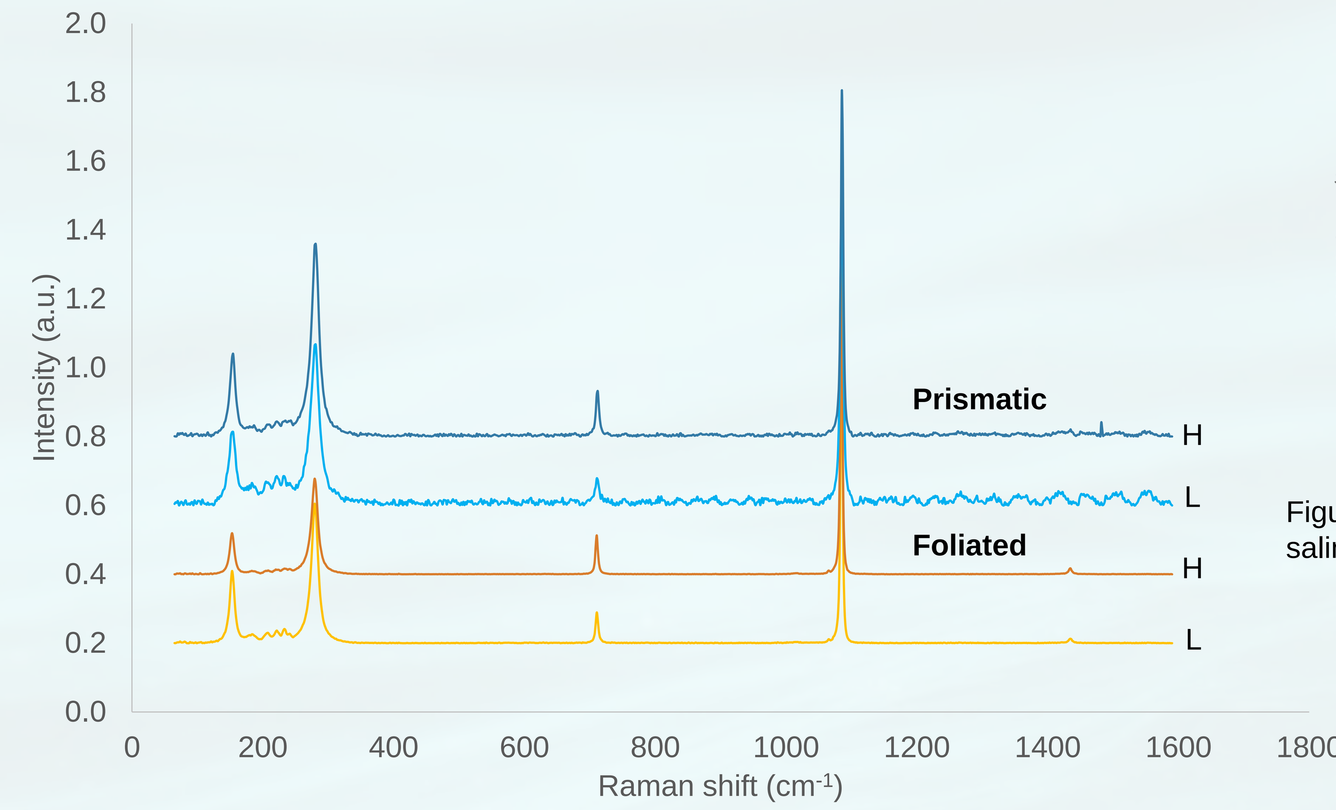

Figure 6: Representative Raman spectra of oyster calcite for each treatment and microstructure combination. H=high salinity; L=low salinity

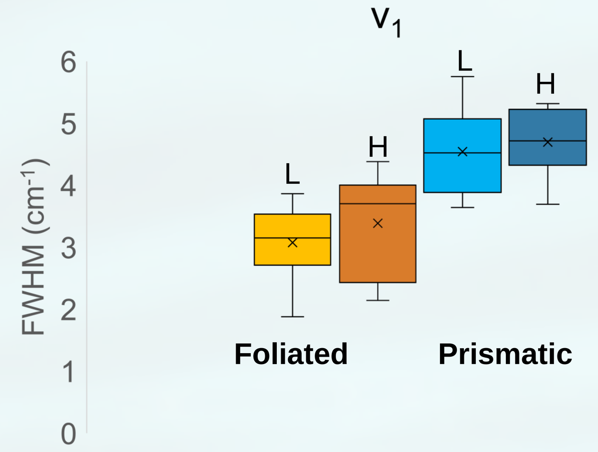

Figure 7: FWHM depends on microstructure type, not salinity. n=6 per treatment and microstructure combination

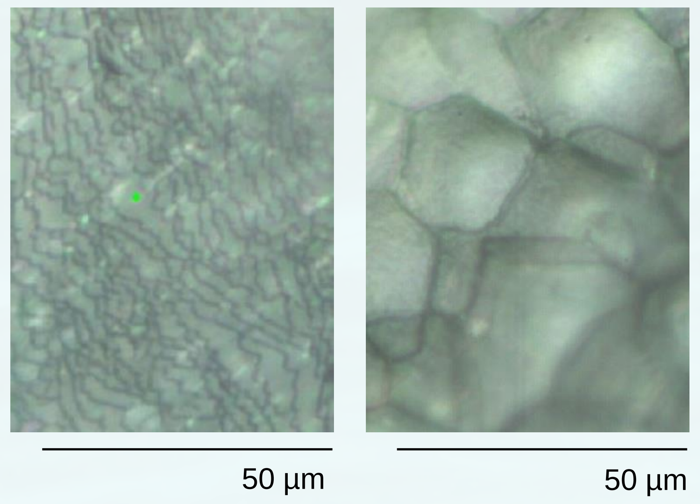

Figure 8: Foliated layer in hand sample (left); Prismatic layer in hand sample (right)

Maps of Raman ν_1 peak heights show heterogeneity

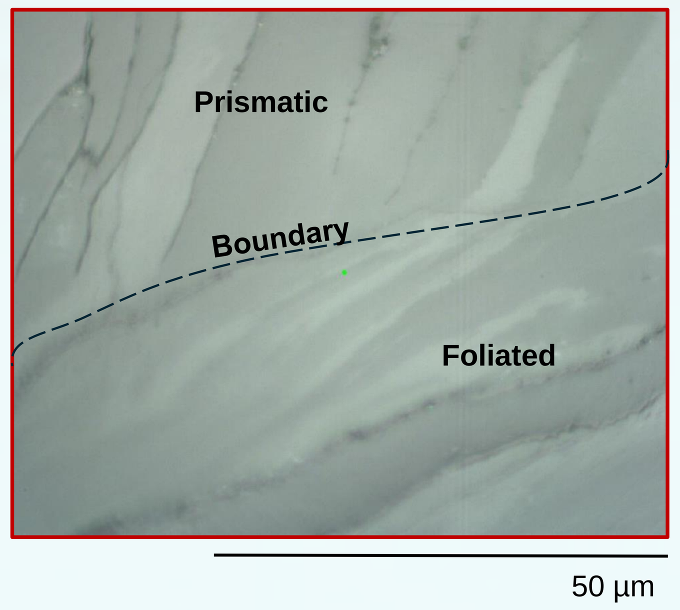

Figure 9: Examining the boundary between the foliated and prismatic layers in thick section

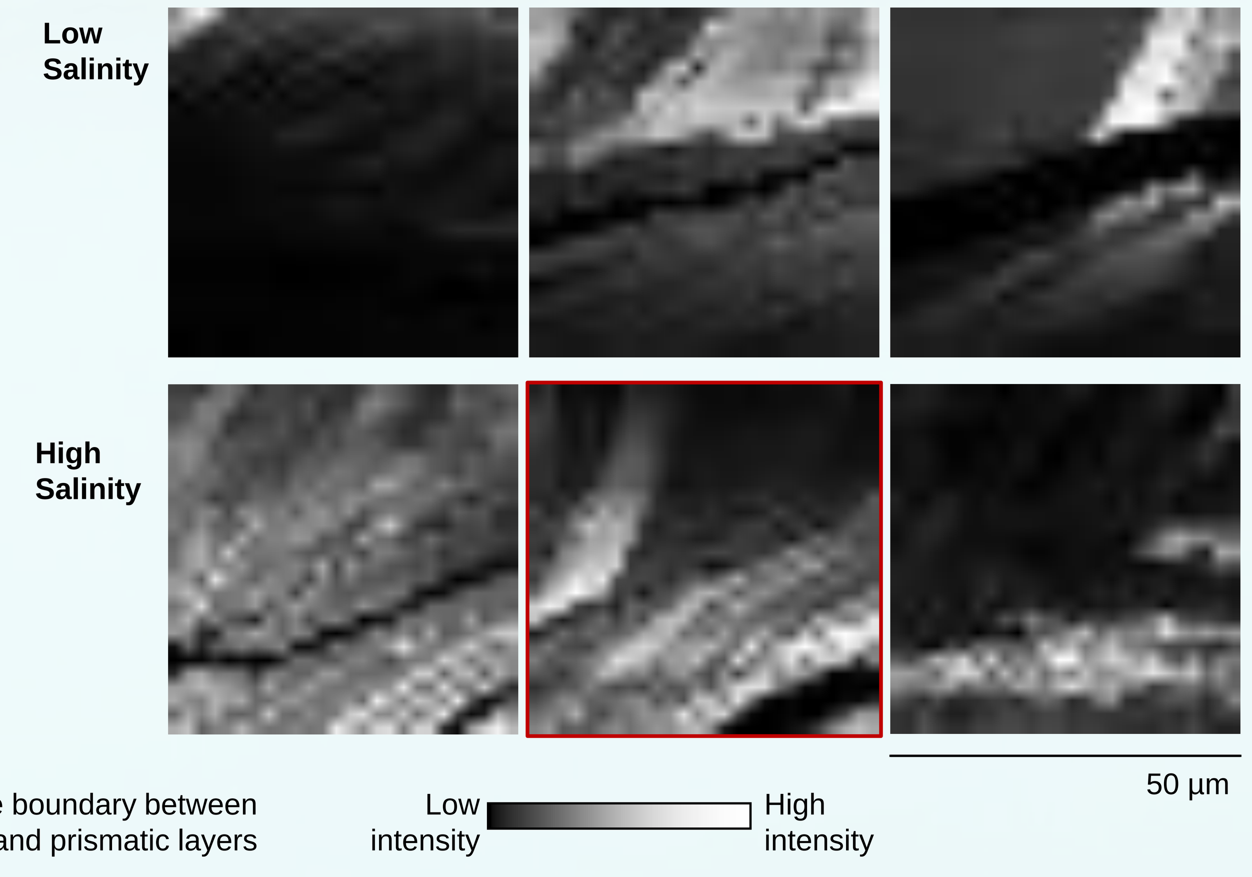

Figure 10: Raman maps of the boundary between the foliated and prismatic layers

SEM shows various microstructure morphologies

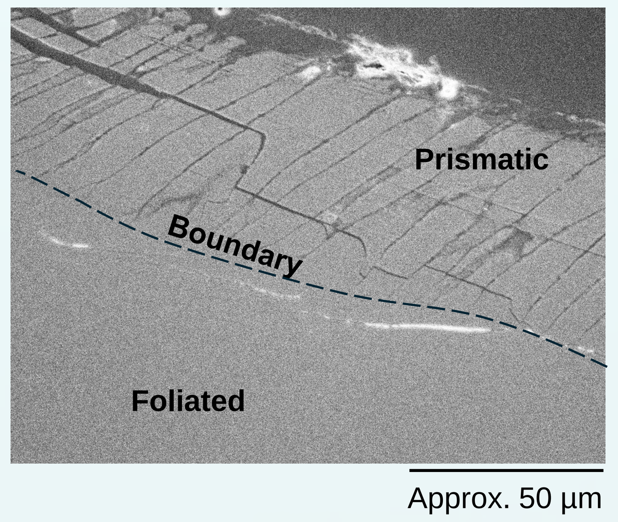

Figure 11: Secondary electron image of the boundary between the foliated and prismatic layers of a low salinity sample; measurements indicated by numbered dots

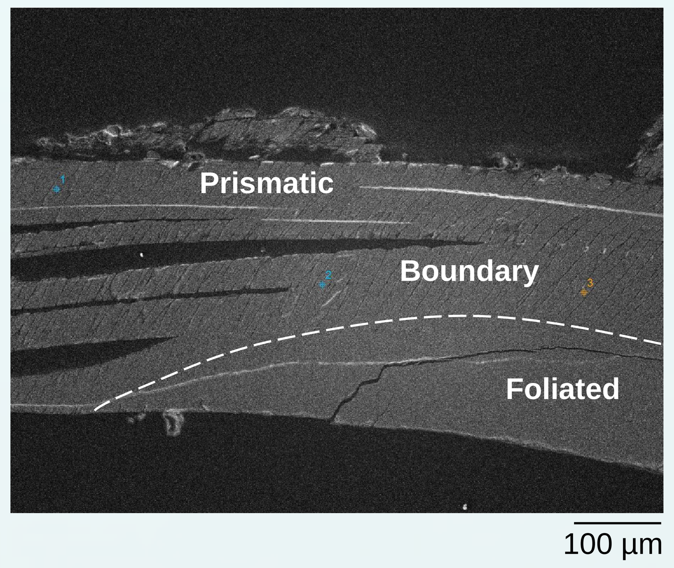

Figure 12: Examining the boundary between the foliated and prismatic layers in thick section

Results: EDS

EDS shows different elemental abundances between prismatic and foliated layers

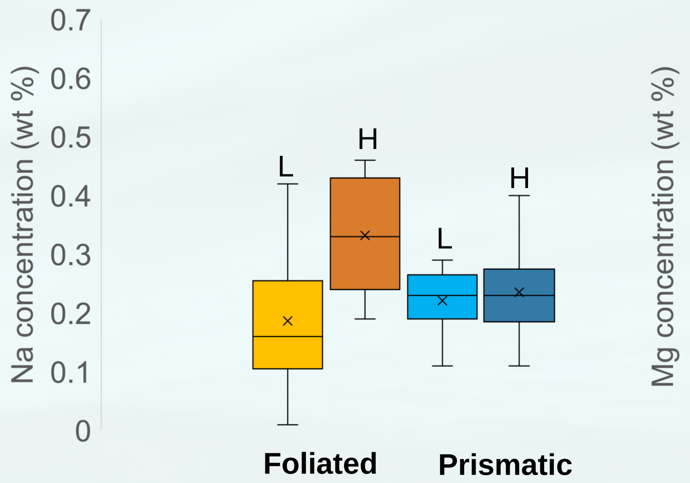

Figure 13: Sodium abundance is higher in the foliated shell at high salinity. n=6 per treatment and microstructure combination

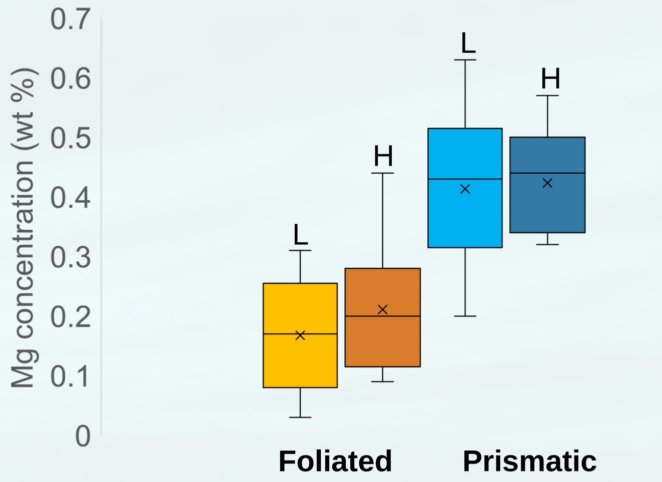

Figure 14: Magnesium abundance depends on microstructure type, not salinity. n=6 per treatment and microstructure combination

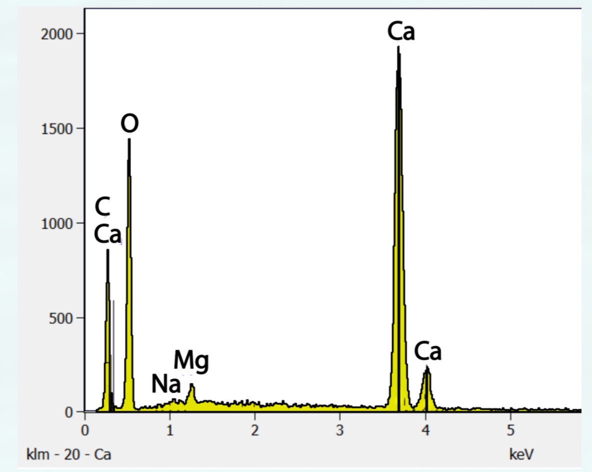

Figure 15: EDS spectrum of the low salinity prismatic layer

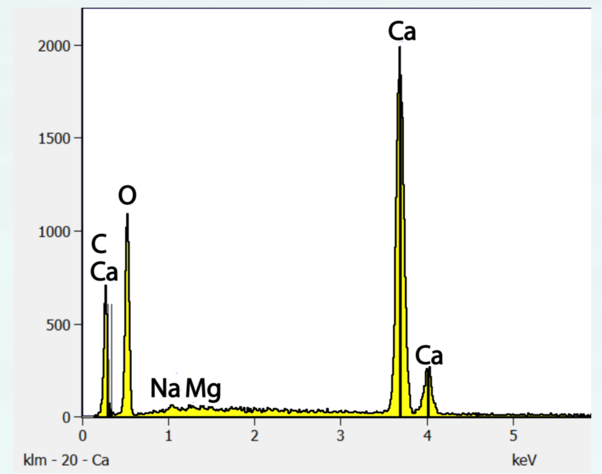

Figure 16: EDS spectrum of the high salinity foliated layer

Conclusion

- Multispectral analysis of the ν_1 mode showed no difference between low and high salinity groups, but instead a difference between foliated and prismatic microstructures.
- Optical microscopy and SEM showed how the microstructures differed in physical appearance, due to the calcite being in different orientations.
- EDS showed a difference in the foliated layer between low and high salinity groups for sodium concentration, but magnesium concentration was related to the type of microstructure.
- Results from this study show that the ions within the calcite vibrate in relation to each other differently depending on the layer where they exist.
- Possible future works include Raman maps to analyze heterogeneity in crystal orientation using Raman T:L mode ratios for low and high salinity groups.

Acknowledgements and References

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