Redox Conditions of Late Neoproterozoic and Early Cambrian *Lagerstätten*

COLLEGE OF COMPUTER, MATHMATICAL, & NATURAL SCIENCES
DEPARTMENT OF GEOLOGY

Andrew Doerrler (Geol 394)

Advisor: Dr. Alan Jay Kaufman

COLLEGE OF COMPUTER, MATHMATICAL, & NATURAL SCIENCES
DEPARTMENT OF GEOLOGY

Introduction

Lagerstätten are deposits that exhibit fossils with exceptional preservation. The Zimnie Gory and Erga formations in Russia preserve the White Sea assemblage of the Ediacara biota. The soft-bodied fossils from these formations are well-preserved in mudstone. The shale of the Chuskuna Formation in the Olenek Uplift (~530 Ma) contains organic tissues that provide the oldest fossil evidence of a Burgess Shale-type fauna. This implies that the Cambrian explosion of animals happened faster than previously believed.

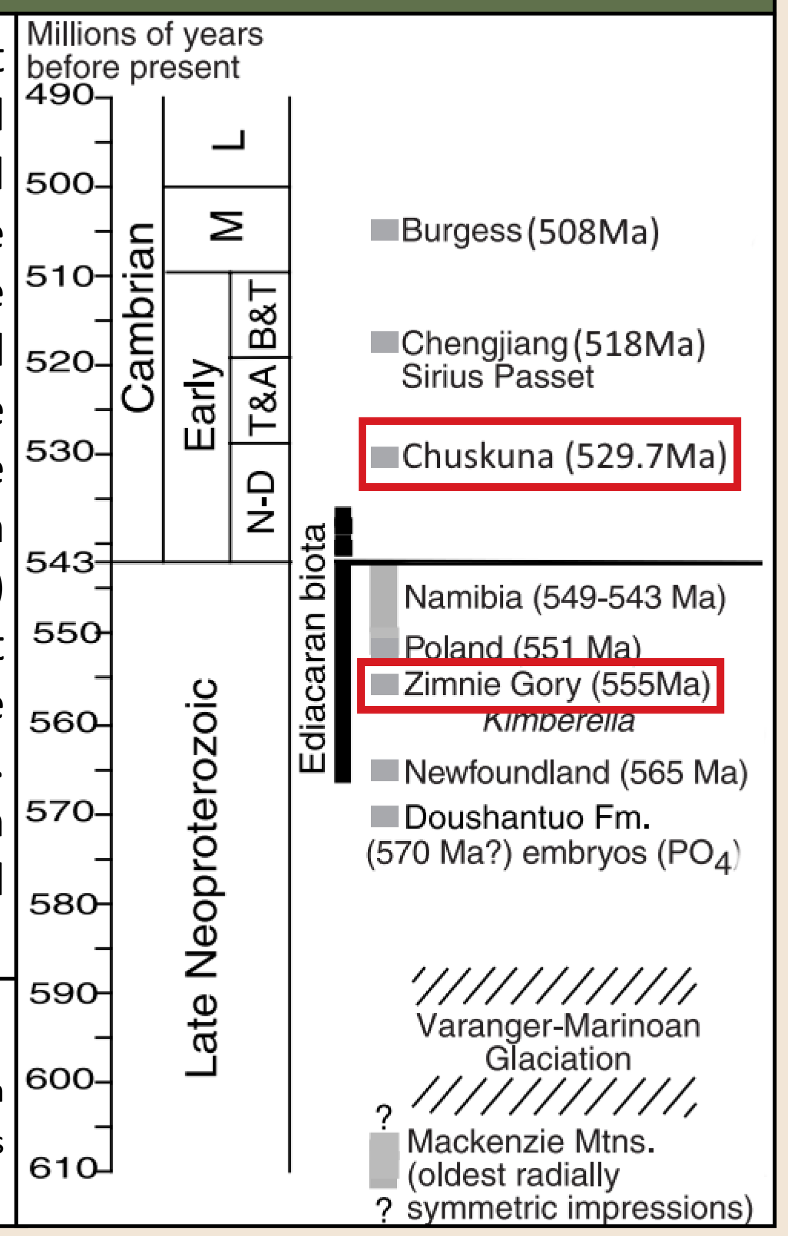


Figure 1: Geologic time scale.

Highlights the temporal relationship between the Zimnie Gory and Chuskuna formations (Modified from Martin et al., 2000).

Hypothesis

Anoxia in the sediments/water column led to the exceptional preservation of the fossils in both the Ediacaran and Fortunian examples from the Russian Federation.

Methods

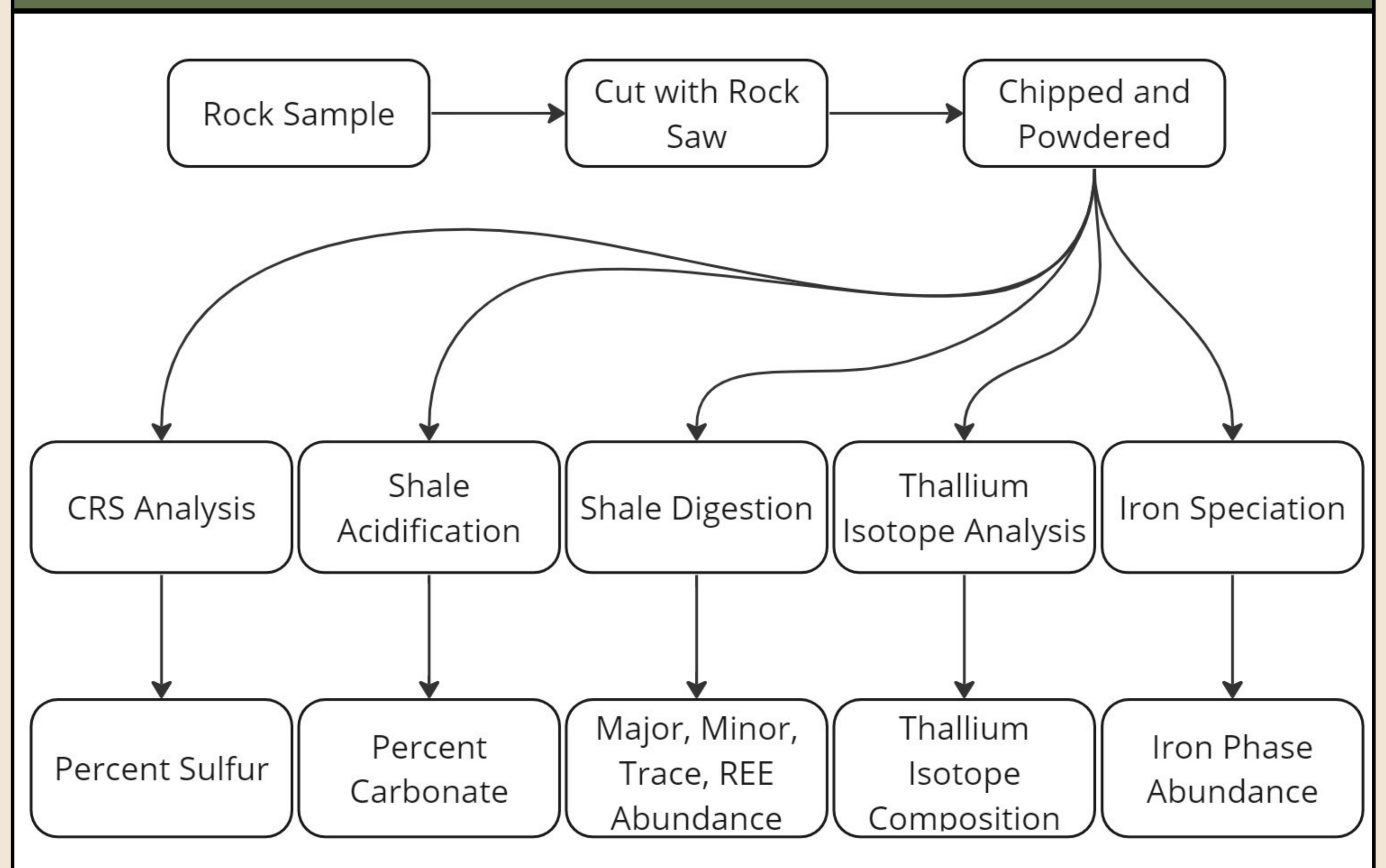


Figure 2: Flow diagram of procedures completed and types of results.

With the powdered sample, chrome reducible sulfur (CRS) extractions were performed to obtain sulfur content, which is later used in iron speciation calculation. The powdered sample was also acidified and dissolved in order to obtain % carbonate and whole rock major, minor, trace, and rare earth element (REE) abundance data, respectively. Iron speciation was performed to quantify the redox conditions. Thallium isotopes were measured as another redox proxy.

Results

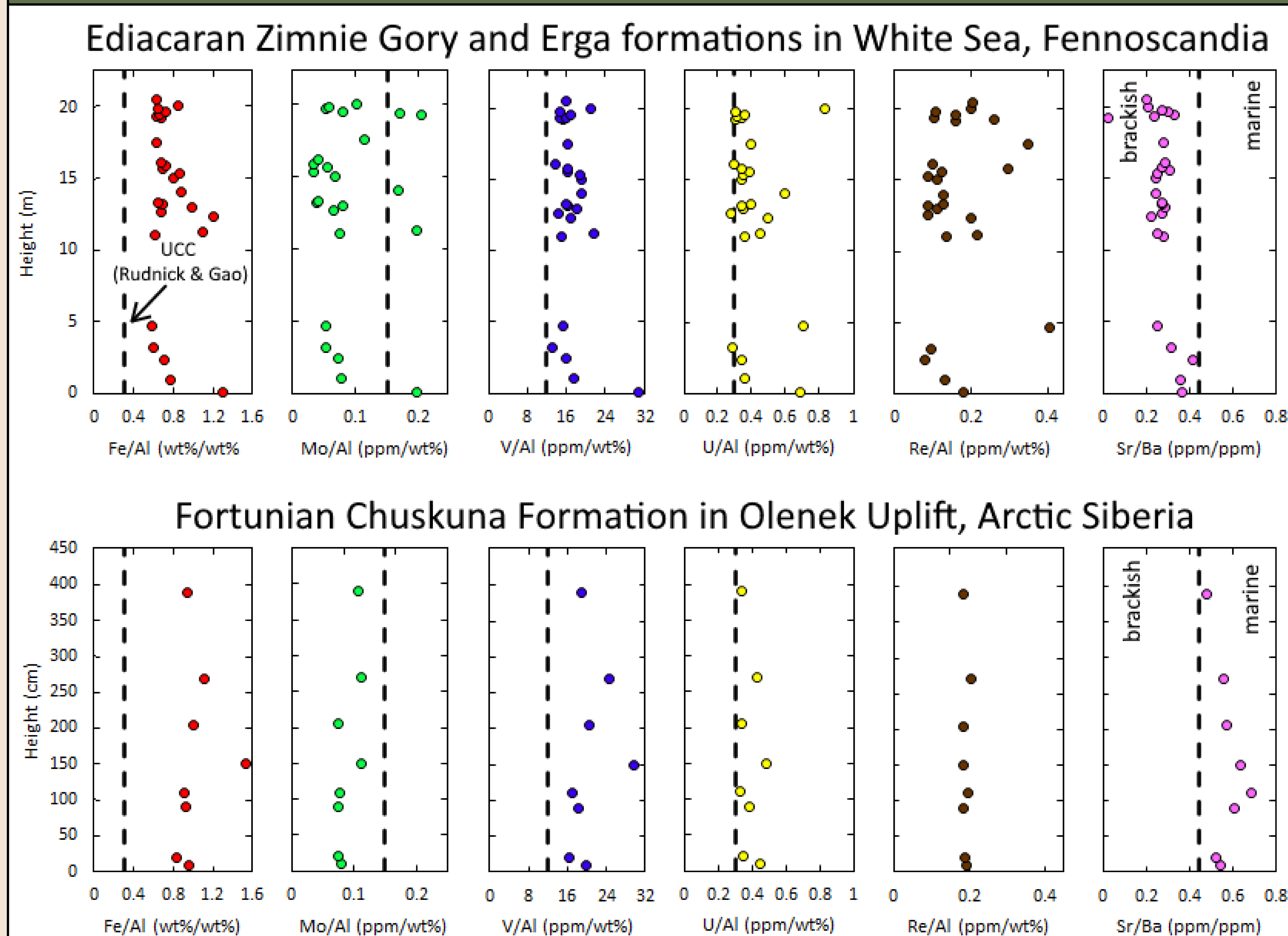


Figure 3 (above): Elemental data from whole rock analysis vs. Al.

* Elemental ratios plotted against height of samples within the formations.
* Elements were normalized to Al in order to understand the enrichments that occur in the water column over the presumed average continental flux to the oceans.
* Dashed line represents the composition of the upper continental crust (Rudnick and Gao, 2003).

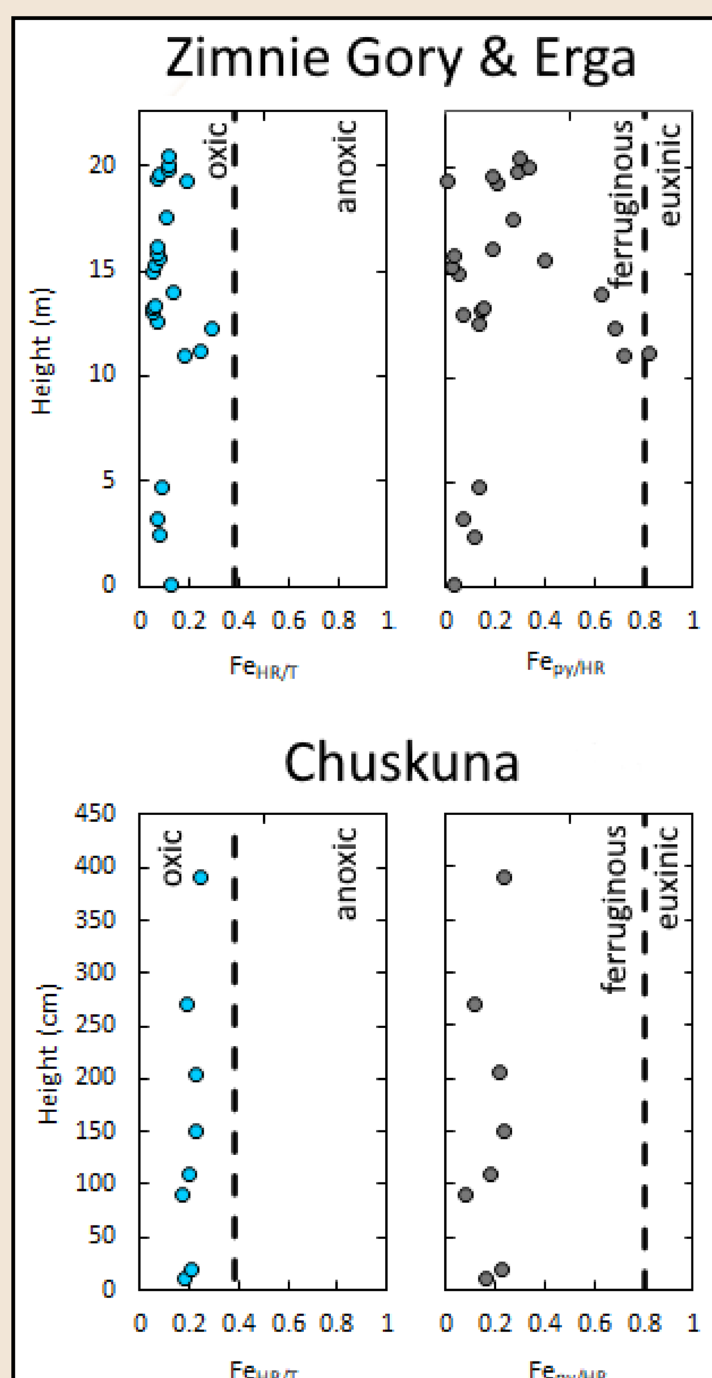


Figure 4 (left): Iron speciation and elemental data.

* The $Fe_{HR/T}$ plot is the ratio between highly reactive iron (Fe_{HR}) and total iron (Fe_T). Oxic/anoxic 0.38 (Bennett and Canfield, 2020).
* The $Fe_{py/HR}$ plot is the ratio between iron in pyrite (Fepy) and Fe_{HR}. Ferruginous/euxinic is 0.80 (Bennett and Canfield, 2020).
* Highly reactive iron was determined by the sum of the iron in the carbonates, oxides, and magnetite, (and glauconite for the Chuskuna Formation).
* Total iron was determined from shale dissolution.
* Iron in pyrite was calculated stoichiometrically using the total iron and the % sulfur from the CRS analysis.

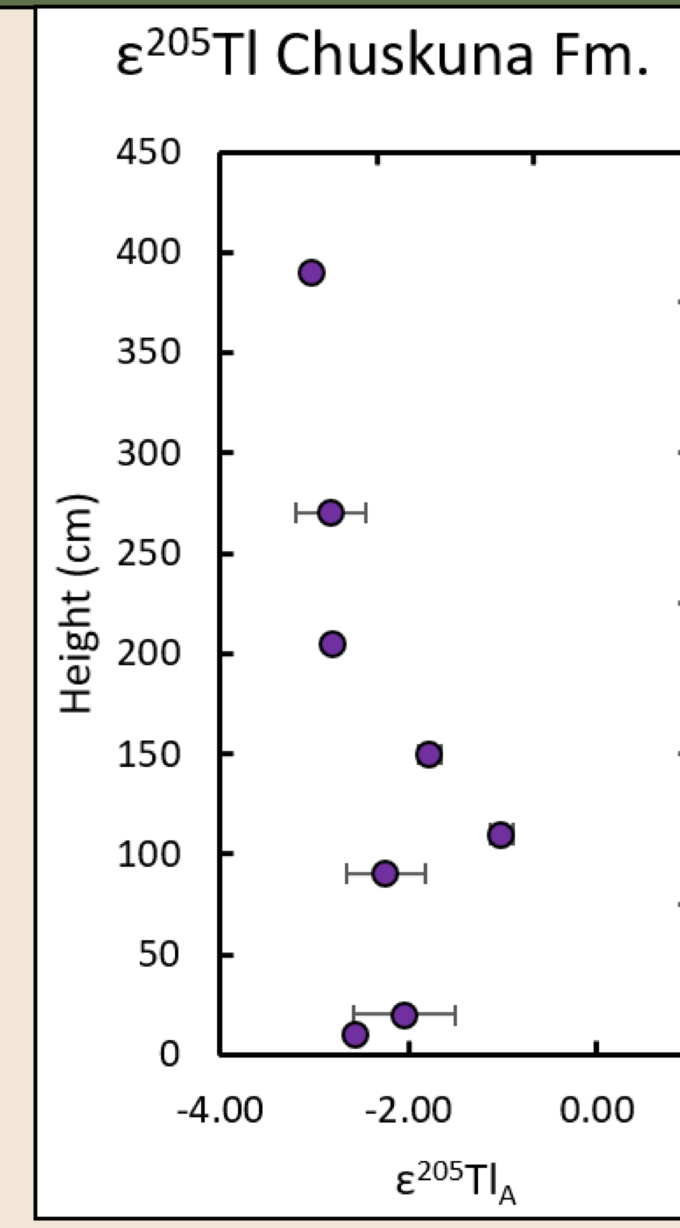
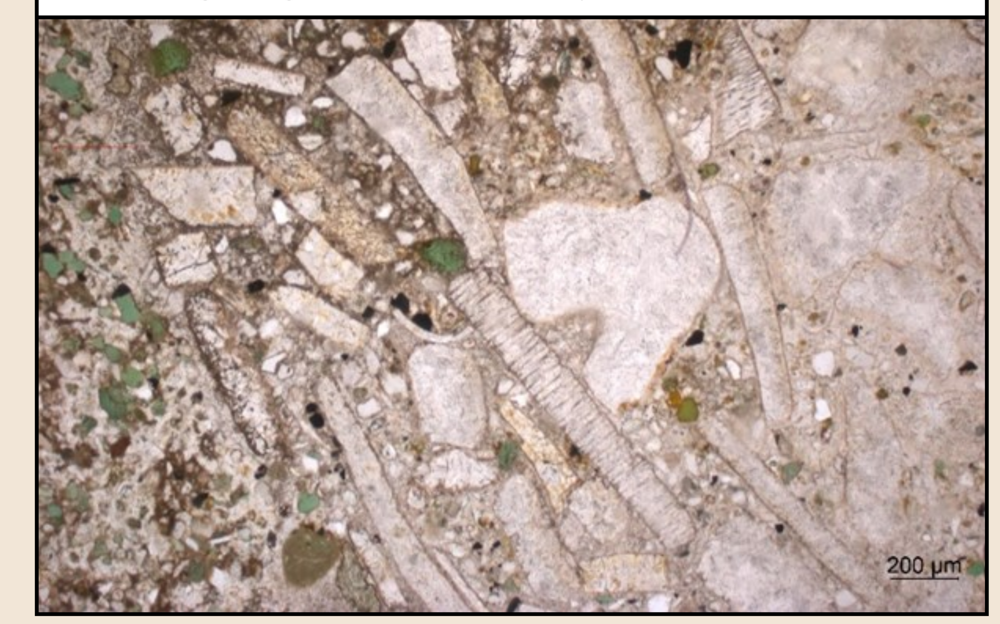


Figure 5 (left): Thallium isotope data from the Chuskuna Fm.

Two standard deviations (2SD) calculated from multiple measurements of a standard. Suggest water column anoxia, contrary to Fe-Speciation results.

Figure 6 (below): Thin section image from the Chuskuna Fm.

Glauconite is the green mineral, seen predominantly on the left side. Authigenic glauconite forms only under anoxic conditions.



Conclusions

* Strontium/barium ratios indicate brackish and marine environments in the fossiliferous White Sea mudstone interval the and Chuskuna Formation shale respectively, which are consentient with the geological interpretations of these strata.
* The oxic signals revealed by the Fe-speciation data are inconsistent with the presence of authigenic glauconite in the Chuskuna Formation shales, suggesting a significant proportion of detrital iron silicate in the samples due to high sedimentation rates (supported by high zirconium and titanium concentrations), which could potentially mask an anoxic signal. High sedimentation rates would also explain elevated Fe/Al in our samples.
* The lack of trace metal enrichment relative to the UCC in both successions is inconsistent with the anoxic hypothesis, however prolonged euxinia in the late Ediacaran and early Fortunian interpreted from U isotope studies provides a possible mechanism for long-term seawater depletion of metals. This view is consistent with the thallium isotope data, which overlaps with UCC values pointing to a broadly anoxic or euxinic global ocean.

Acknowledgements and References

I would like to thank Alan Jay Kaufman, Geoffrey Gilleaudeau, Dmitriy Grazhdankin, Chadlin Ostrander, Olga Dantes, and Tim Mock for all their help and contributions to this project.

Bennett, W. W., & Canfield, D. E. (2020). Redox-sensitive trace metals as paleoredox proxies: A review and analysis of data from modern sediments. *Earth-Science Reviews*, *204*, 103175. https://doi.org/10.1016/j.earscirev.2020.103175

Martin, M. W., Grazhdankin, D. V., Bowring, S. A., Evans, D. A. D., Fedonkin, M. A., & Kirschvink, J. L. (2000). Age of neoproterozoic bilatarian body and trace fossils, white sea, russia: Implications for metazoan evolution. *Science*, *288*(5467), 841–845. https://doi.org/10.1126/science.288.5467.841

Rudnick, R. L., & Gao, S. (2003). Composition of the continental crust. In Treatise on Geochemistry (pp. 1–64). Elsevier. https://doi.org/10.1016/B0-08-043751-6/03016-4