Systematics of Fine Detail Fossil Preservation

An Elemental Analysis of the Mazon Creek Lagerstatte

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

Brendan Shimizu (394)

Advisors: Dr. Ash, Dr. Holtz

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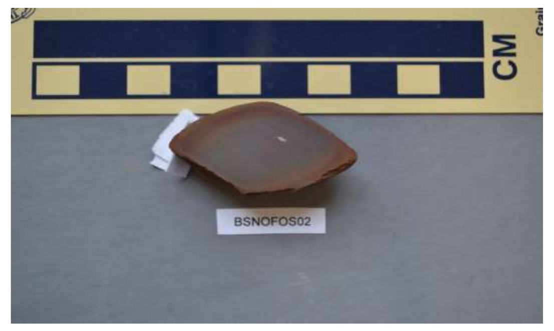
Introduction

The Mazon Creek Lagerstatte is a world famous fossil locality that has yielded exceptionally preserved fossils housed in siderite nodules. Some of the siderite nodules from the Mazon Creek Lagerstatte do not contain fossils. In order for siderite to form at surface pressures and temperatures, the environment must be reducing. The formation of the Mazon Creek nodules is hypothesized to be the result of bacterial sulfate reduction (BSR) which provided the requisite reducing agents. It has been hypothesized that the non-fossiliferous nodules precipitated from organic debris, in contrast to the fossiliferous nodules that precipitated from macroscopic organic material.

Figure 1: Fossiliferous Sample, Mazon Creek siderite nodule, Pectopteris sp., provided by the University of Maryland Geology Department.

Figure 2: Non-fossiliferous Sample, Mazon Creek siderite nodule, provided by the University of Maryland Geology Department.



Hypothesis

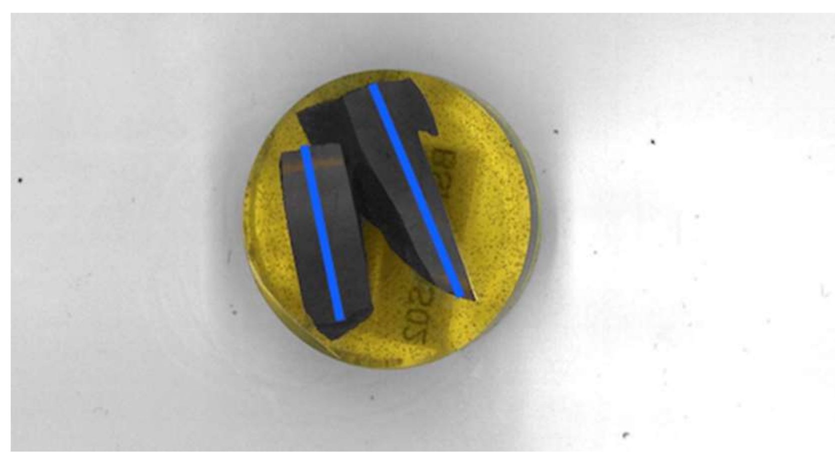
Siderite nodules with fossils will be more enriched in reduced elemental markers relative to the non-fossiliferous nodules due to higher rates of BSR.

Methods

Fossiliferous and non-fossiliferous nodules were analyzed for reduced elemental markers using LA-ICP-MS. Samples were tested for Eu*, V/Sc, V/Cr, Th/U. Individual samples were ablated 10-13 times along a line. Ablation spots were separated by 150 microns. Samples were analyzed for weight percent oxide using EPMA to determine compositional variation.

Figure 3: Example of sample in context

Figure 4: Samples after preparation, with line of sampling highlighted in blue



Results

Figure 5: Summary of two sample T-test comparing concentrations of redox sensitive ratios

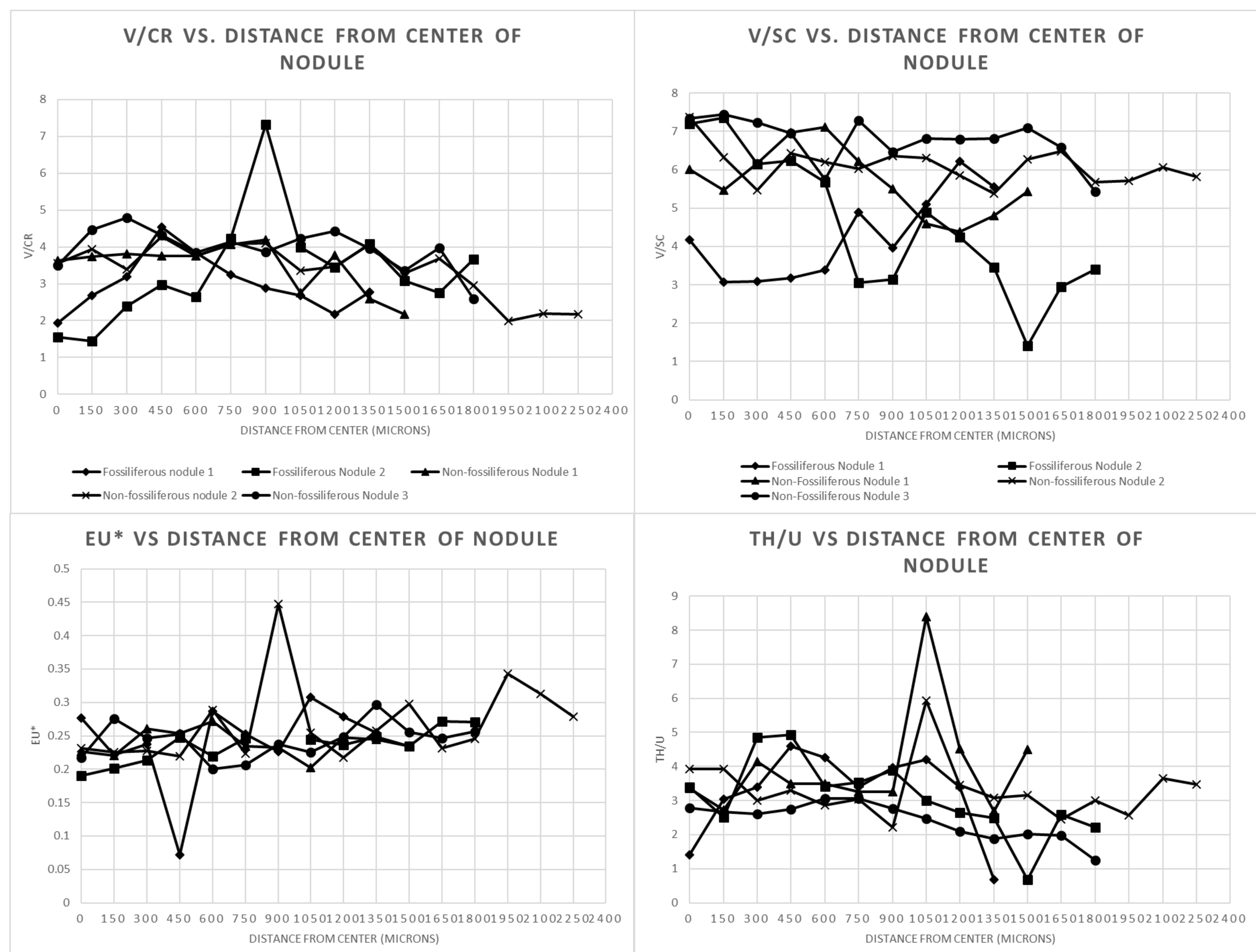
	Eu*		V/Cr		Th/U		V/Sc	
	Fossil	No Fossil	Fossil	No Fossil	Fossil	No Fossil	Fossil	No Fossil
Mean	0.27	0.25	3.06	3.60	3.23	3.20	4.44	6.21
Variance	0.02	0.00	0.67	0.49	1.27	1.43	2.51	0.61
df	23.00		36.00		46.00		27.00	
t Stat	0.39		-2.54		0.09		-4.93	
P(T<=t) one-tail	0.35		0.01		0.47		0.00	
t Critical one-tail	1.71		1.69		1.68		1.70	
P(T<=t) two-tail	0.70		0.02		0.93		0.00	
t Critical two-tail	2.07		2.03		2.01		2.05	
Significant Difference?	No		Yes		No		Yes	

Figure 6: Summary of interpretation of redox indicator values

	Th/U		V/Cr		Eu*		V/Sc
	Oxic	Anoxic	Oxic	Anoxic	Oxic	Anoxic	Relative, X>Y
	>2	<2	<2	>2	<1	>1	
Fossil	Oxic		Anoxic		Oxic		
No Fossil	Oxic		Anoxc		Oxic		
More Reduced?	No Difference		No Fossil		No Difference		No Fossil

- No consistent interpretation of redox conditions
- No difference in redox conditions or non-fossiliferous nodules more reduced
- Ranges for Eu* and Th/U must be incorrect, or paleo-redox indicator not applicable (Eu*, Th/U)

Figure 7: Paleo-redox indicator as a function of distance to center of nodule



- Values are relatively consistent for both non-fossiliferous and fossiliferous nodules regardless of distance to center of nodule
- Excursions likely the result of inclusions of quartz or kaolinite

Figure 8: Line of best fit summary for redox sensitive ratios

		No Fossil 1	No Fossil 2	No Fossil 3	Fossil 1	Fossil 2
Th/ U	R^2	0.0051	0.0277	0.6569	0.3538	0.0016
	Slope	0	-0.0002	-0.0007	-0.0012	-0.0001
Eu*	R^2	0.0045	0.0971	0.0883	0.0761	0.6363
	Slope	0	0	0	0	0
V/Cr	R^2	0.3878	0.5312	0.2568	0.0012	0.398
	Slope	-0.0008	-0.0007	-0.0005	0	0.0011
V/Sc	R^2	0.3322	0.2031	0.7181	0.2834	0.6195
	Slope	-0.0001	-0.0003	-0.0027	-0.0005	0.002

- Slope near or equal to 0 for all indicators
- No significant correlation between distance and redox indicator values. When correlation is moderate (>0.5), slope is still close to 0

Figure 9: Bulk composition of major elements compared to end members

	Fe0 (wt%oxide)	CaO (wt%oxide)	MnO (wt%oxide)	SiO (wt%oxide)
Average of Samples (all samples)	42.3 ± 7.6 (1σ)	2.3 ± 0.3(1σ)	0.5 ± 0.1(1σ)	13.2 ± 11 (1σ)
Average for Massive Crust, Mn-Rich	43.5	1.6	12.8	1.95
Average for Massive Crust, colomorphous siderite	51	3.85	4.5	2.4
Average for Massive Crust, crystalline	56.7	0.87	1	2.4

Conclusion

- No significant difference between fossiliferous nodules and non-fossiliferous nodules except for redox indicators V/Cr and V/Sc.
- Eu* and Th/U paleo-redox proxies are either not applicable to siderite, or Eu* and Th/U not sensitive enough to detect difference in paleo-redox conditions
- V/Cr and V/Sc indicate non-fossiliferous nodule more reduced
- Could be an indication that decomposition in non-fossiliferous nodules went to completion

  --Difference can be attributed to redox conditions because t-stat of -2.54 and -4.93 (t_{crit}=2.03, 2.05) difficult to reconcile
- Redox indicators consistent regardless of sampling location. Indication that nodules formed pervasively (radially) at once, rather than concentrically over time.
- Bulk composition shows prevalence of inclusions, consistent inter-sample redox indicator values indicate limited effect on overall trends
- Future research can further hone in strength and direction of redox signal, more paleo-redox systems can be tested (Ni/Co, Ni/V, (Cu+Mo)/Zn, and Mo/U)

Acknowledgments and References

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Doveton, J. H. (1991). Lithofacies and geochemical facies profiles from nuclear wire-line logs: New subsurface templates for sedimentary modeling. Kansas Geological Survey Bulletin, 233, 101-110.

Jones, B. and Manning, D.A.C. (1994) Comparison of Geochemical Indices Used for the Interpretation of Palaeoredox Conditions in Ancient Mudstones. Chemical Geology, 111, 111-129.

Lemos, V. P., Costa, M. L. D., Lemos, R. L., & Faria, M. S. G. D. (2007). Vivianite and siderite in lateritic iron crust: an example of bioreduction. Química Nova, 30(1). https://doi.org/10.1590/s0100-40422007000100008

Sverjensky, D. A. (1984). Europium redox equilibria in aqueous solution. Earth and Planetary Science Letters, 67(1), 70–78. https://doi.org/10.1016/0012-821x(84)90039-6