Combustion Metamorphism of Clay Sediments in Western North Dakota

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Figure 1: Painted Canyon overlook off Interstate 94 near Medora. (National Park Service)

Introduction

- Pyrometamorphism occurs at very high temperatures (> 1000 degrees C) and low pressures (< 1 kbar). (Cosca et al., 1989)

- Combustion metamorphism is a specific type of pyrometamorphism caused by the combustion of buried coal veins. (Clark, Peacor, 2004)

Introduction

- In Western North Dakota, buried lignite coal combusts and alters overlying clay and silt sediments, leaving behind a low grade metamorphic rock.
- This rock is often called scoria. This is a misnomer; however, because scoria is actually an igneous rock associated with basaltic lava flows.

Introduction

- Argillaceous sediments altered by combustion metamorphism can be classified into two different groups, clinker and paralava. (Grapes, 2006)
- Clinker is defined as a low grade metamorphic rock, often red in color, that have been baked or partially melted by pyrometamorphism. (Grapes, 2006)
- Paralava is a higher grade metamorphic rock formed immediately adjacent to burning coal seams. This rock is highly vesiculated and often has a ropy texture. It is often mistaken for basalt. (Grapes, 2006)

Figure 2: This photo shows the outcrop that the sample was collected from. (Photo courtesy of Dillon Dolezal)

Figure 3: when multiple seams burn, massive outcrops like this Can be created. (Photo courtesy of Dillon Dolezal)

Formation

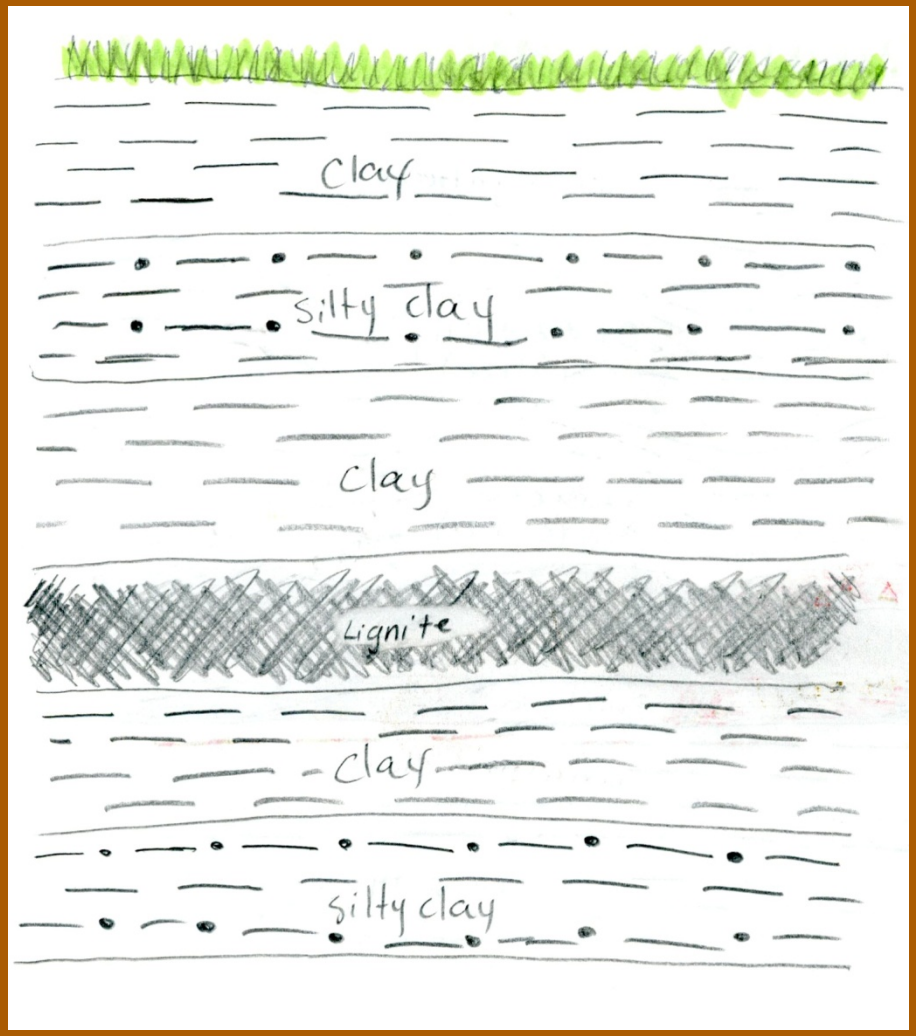

Figure 4: Example of a column before combustion

Formation

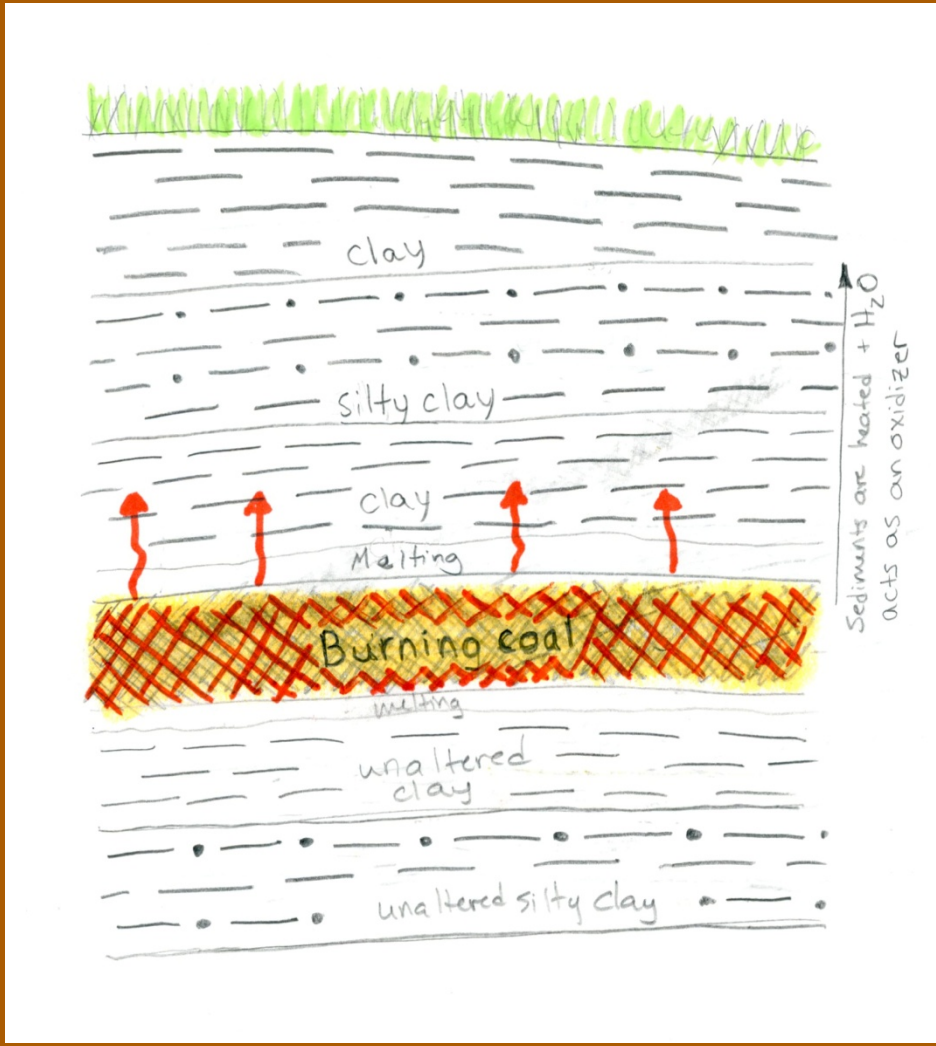

Figure 5: Coal combusts and metamorphism Begins.

Formation

Figure 6: After coal ceases to burn, a layer of ash is left behind along with metamorphosed rock.

Question

- What is the composition of our metamorphic rock?
- How did it form?
- How is it different from its parent material?
- What pyrometamorphic feature would this be classified as?

Methods

- We used XRD, XRF, and microscopy in order to analyze our rock and determine it's composition.

- This data was then cross referenced with prior work done on similar rocks in the powder river basin to determine how our rock would be classified.

Methods

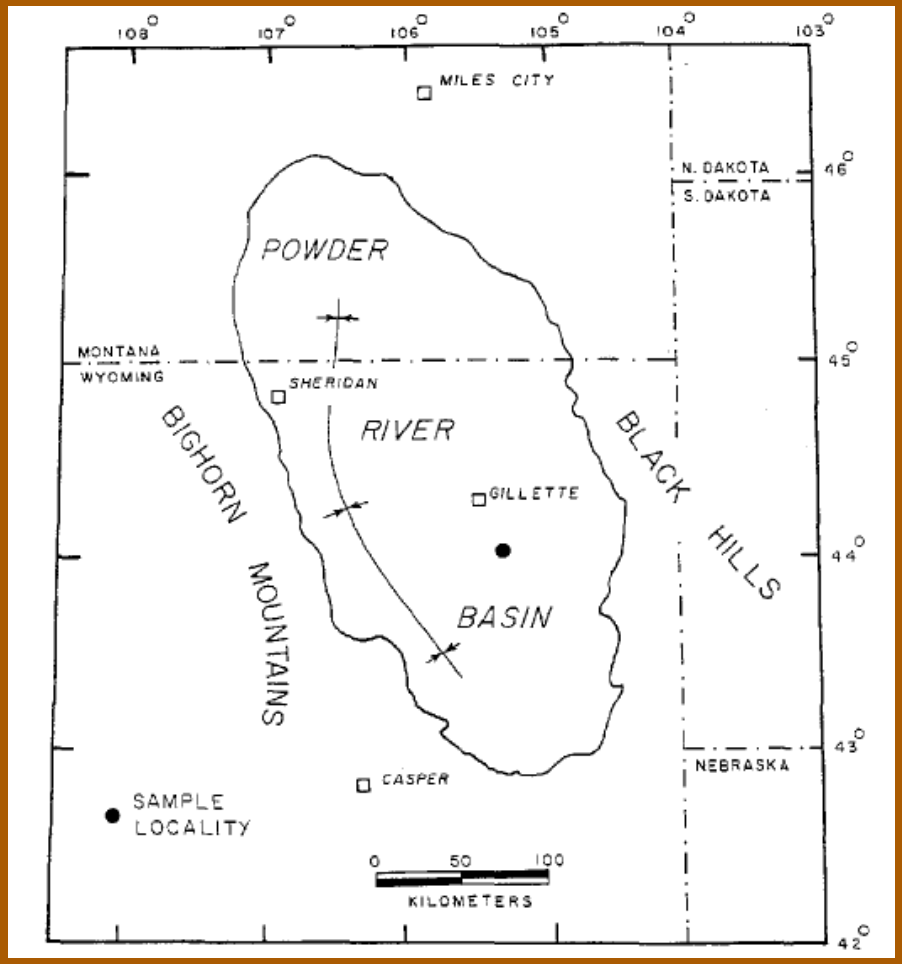

Figure 7: The location in which Clark and Peacor samples were collected. (Clark Peacor, 1992)

Microscopy

Figure 8: Scanned image of our thin section.

Microscopy

Figure 9: Approximate location of Figure M-1.

Microscopy

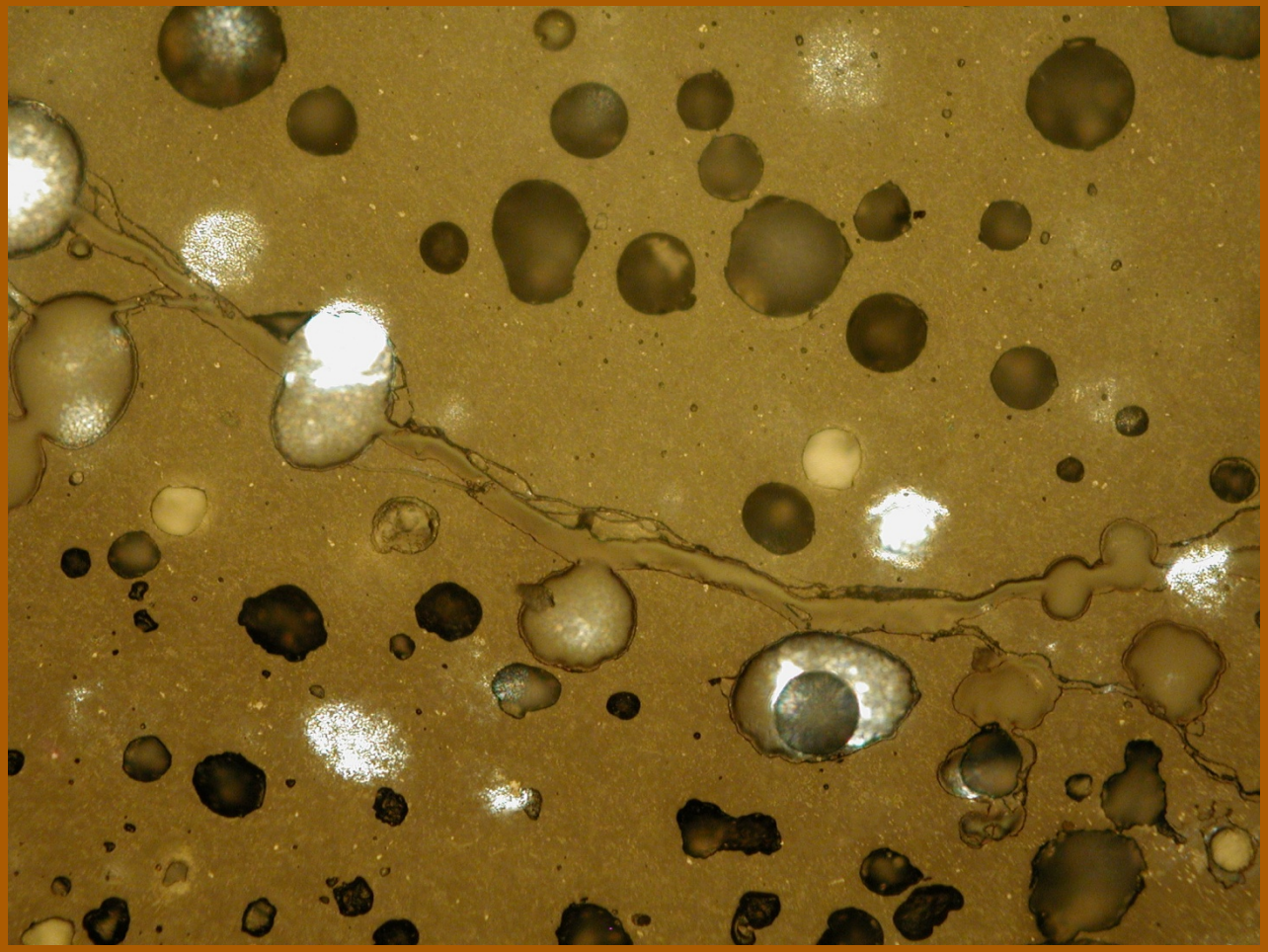

Figure M-1: Portion of red sample in PPL. (FOV= .7 mm)

Microscopy

Figure 10: Approximate location of Figure M-2.

Microscopy

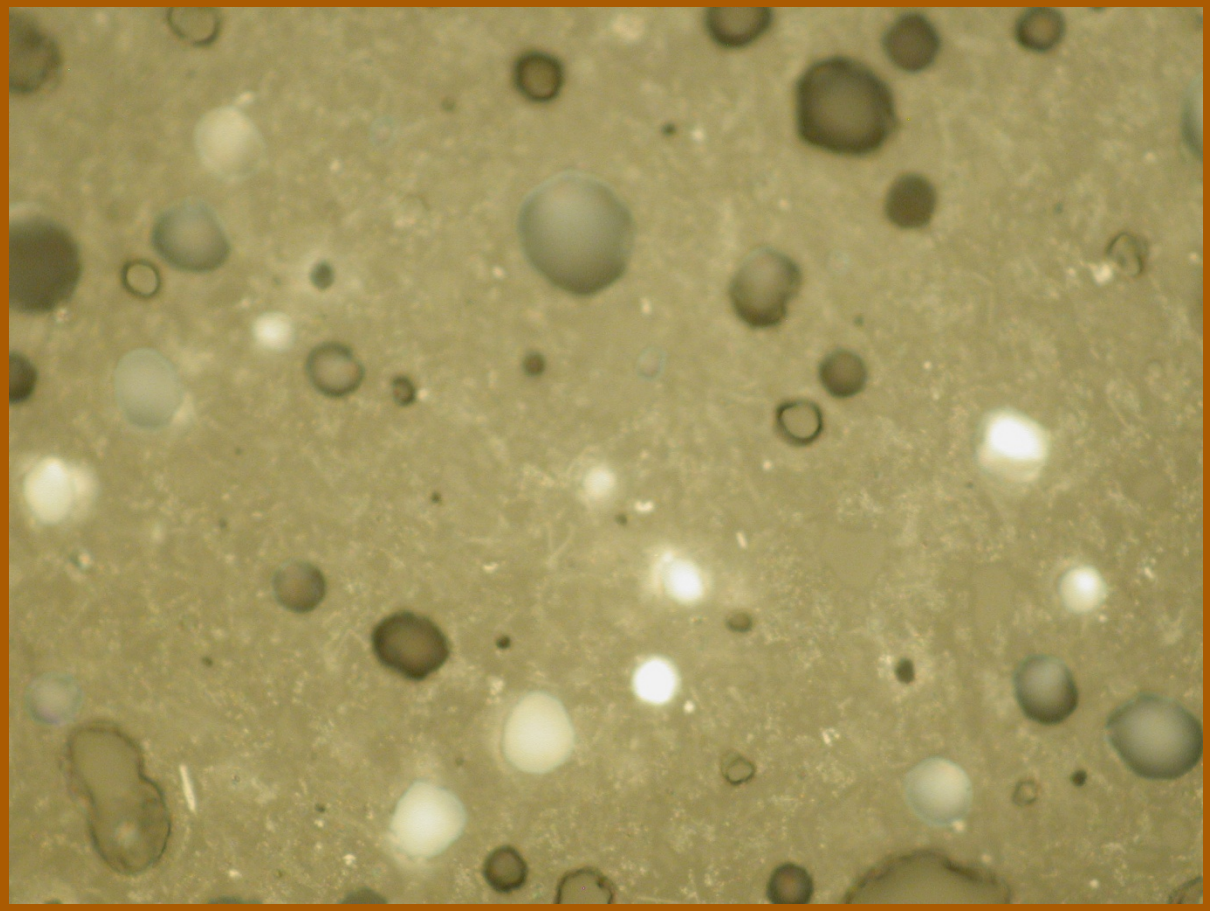

Figure M-2: Portion of black sample under incident light. (FOV= .7mm)

Microscopy

Figure 11: Approximate location of Figure M-3.

Microscopy

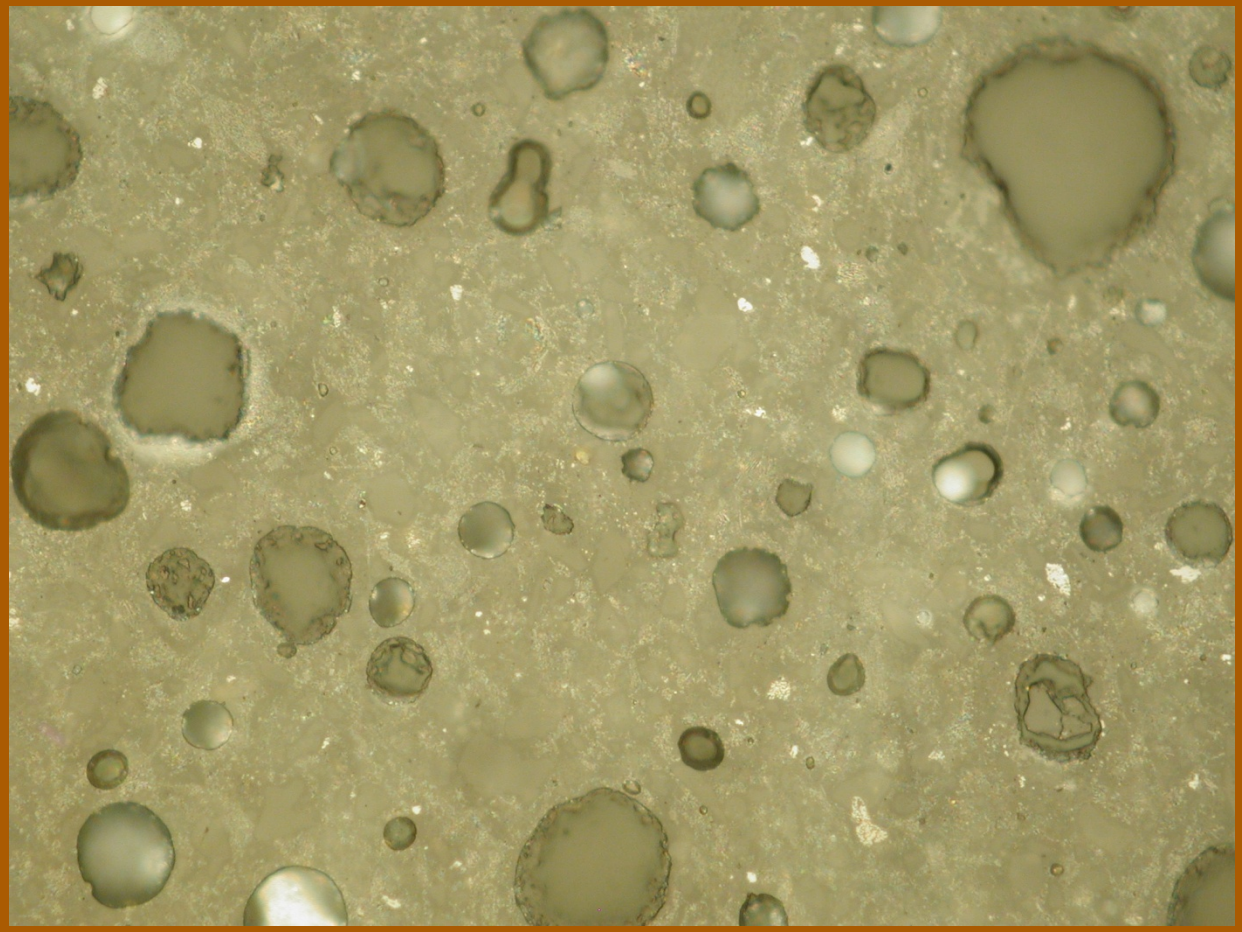

Figure M-3: Portion of black sample under incident light. (FOV= .7mm)

Microscopy Analysis

- The round air vesicles indicate that the sample was completely melted.
- Some quartz crystals could be observed in the thin section but were very small.
- Bright spots shown in incidental light indicate iron oxides.

XRD Data

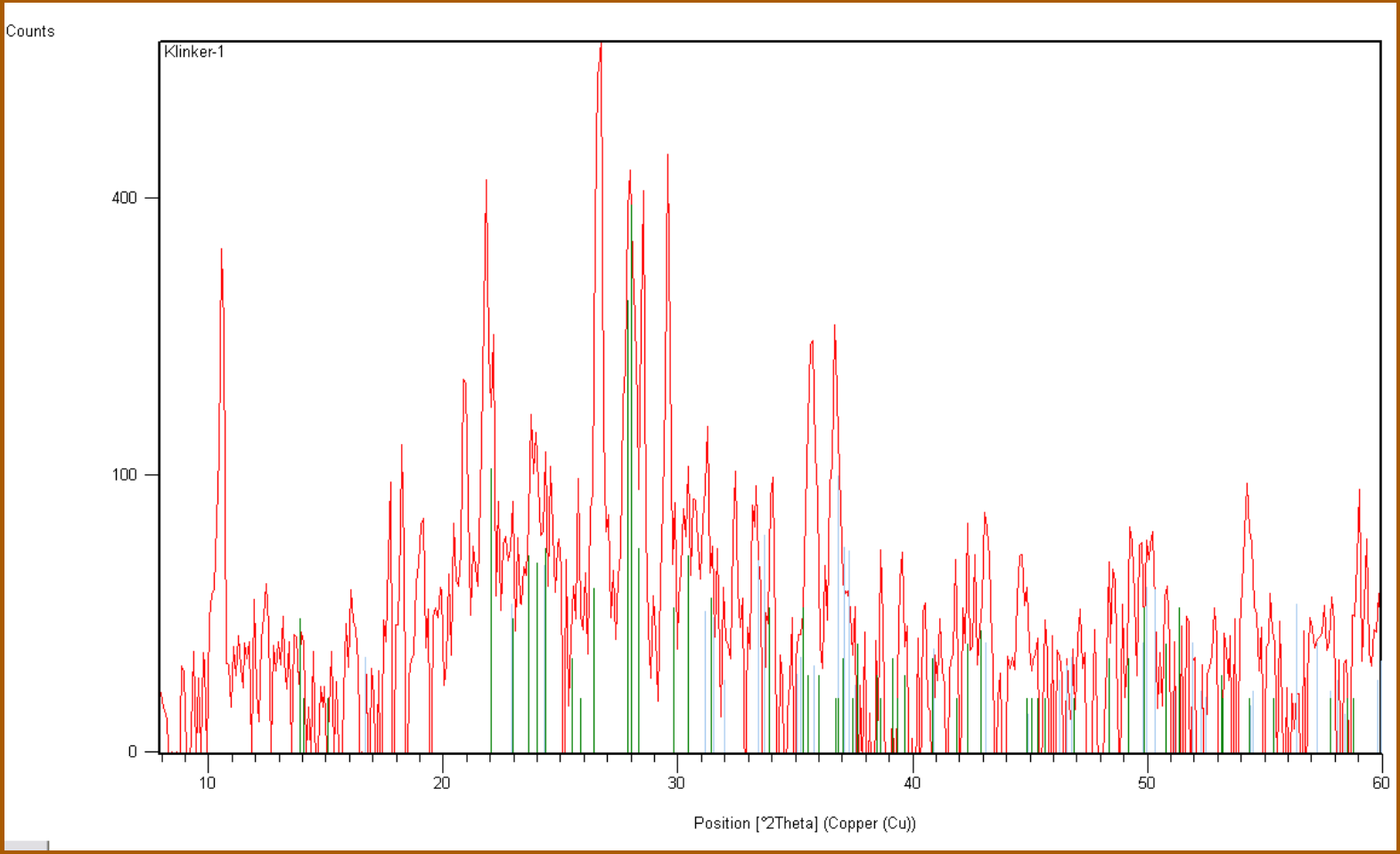

Figure 12: XRD data from powdered sample shown with corresponding Albite [NaAlSi3O8] peaks shown in green.

XRD Data

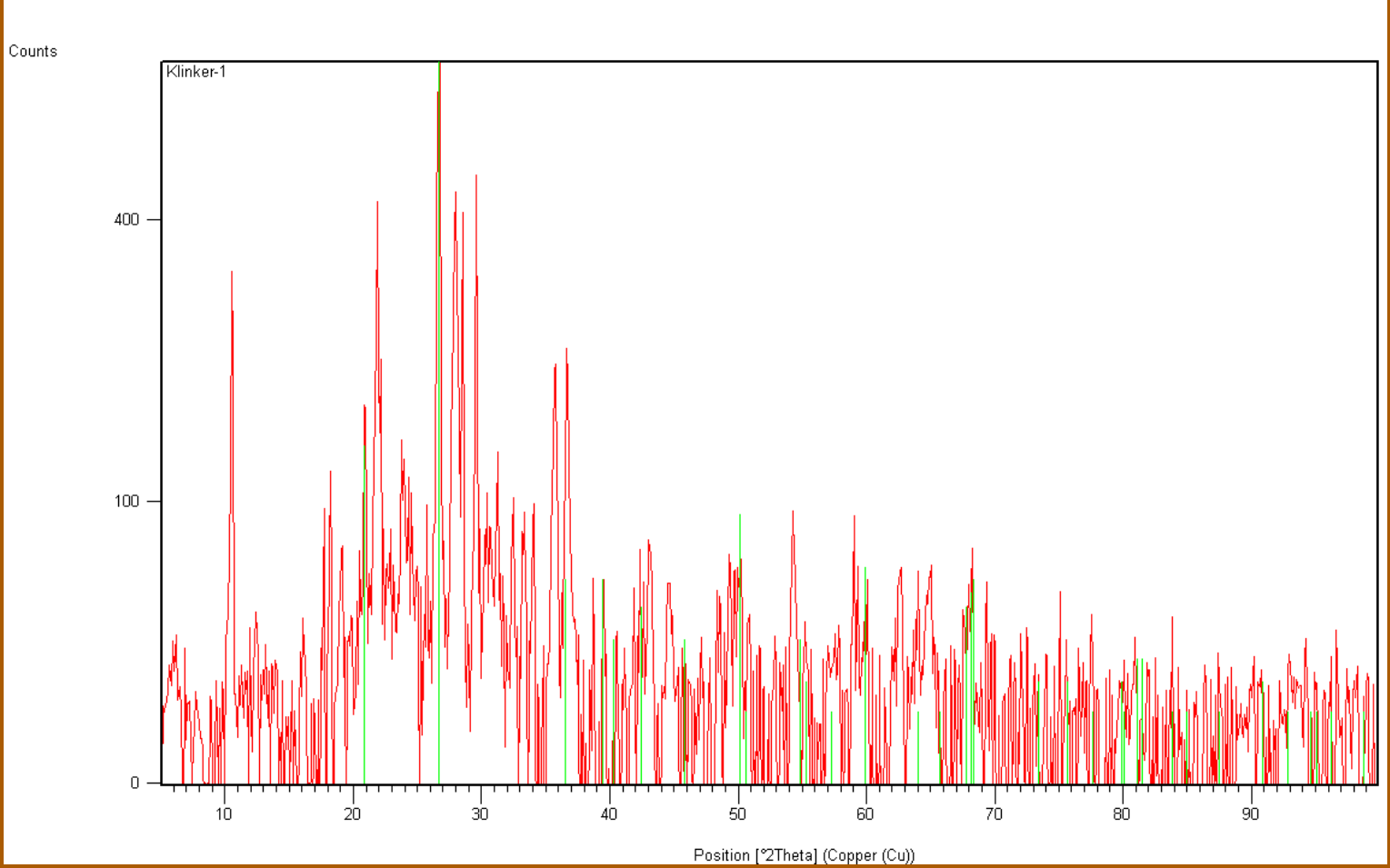

Figure 13: XRD data from powdered sample shown with corresponding quartz (SiO_2) peaks in green.

XRD Data

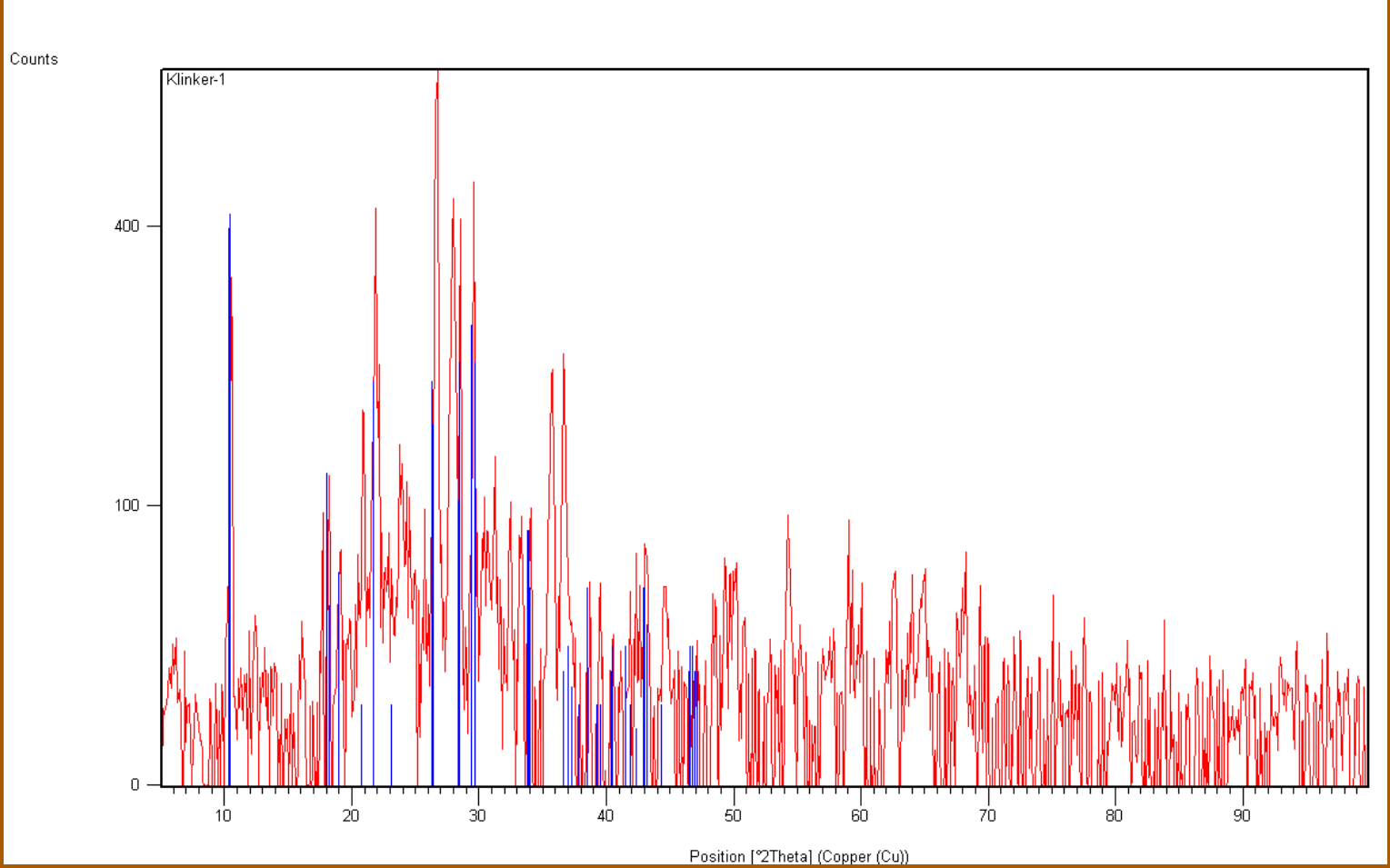

Figure 14: XRD data from powdered sample shown with corresponding Cordierite [(Mg, Fe)2Al4Si5O18]

XRD Analysis

- Albite is a feldspar commonly found in low temperature and low pressure metamorphic environments. (Mindat.org)
- Quartz in the sample may be due to contamination of the clay by siltstone or sandstone during either deposition or metamorphism.
- Cordierite is commonly found in contact metamorphosed argillaceous sedimentary rocks. (Mindat.org)

XRF Comparison

Sample	Experimental
SiO2 (%)	55.51
Al2O3 (%)	14.203
Fe2O3 (%)	7.685
CaO (%)	1.933
MgO (%)	3.043
MnO (%)	0.12
Na2O (%)	1.822
K2O (%)	3.304
P2O5 (%)	0.114
TiO2 (%)	0.815

Sample	KM 1	KM 2	KM 3	KM 4	KM 5	Paralava
SiO2 (%)	74.88	75.03	74.89	72.99	73.97	35.71
Al2O3 (%)	18.64	18.89	18.55	19.64	18.16	9.58
Fe2O3 (%)	1.93	1.75	2.16	3.17	2.9	45.7
CaO (%)	0.48	0.48	0.45	0.24	0.5	2.58
MgO (%)	0.85	0.86	0.81	0.93	0.77	1.77
MnO (%)	0.04	0.04	0.03	0.04	0.03	1.04
Na2O (%)	0	0.07	0	0	0.02	0
K2O (%)	2.12	2.13	2.16	1.9	2.08	0.64
P2O5 (%)	0.12	0.08	0.07	0.1	0.1	0.24
TiO2 (%)	0.86	0.88	0.87	0.87	0.85	0.46

Figure 15: XRF comparisons between our tested results (left) and 5 samples of clinker from the powder river basin and a paralava from the powder river basin (Clark Peacor, 1992)

XRF Analysis

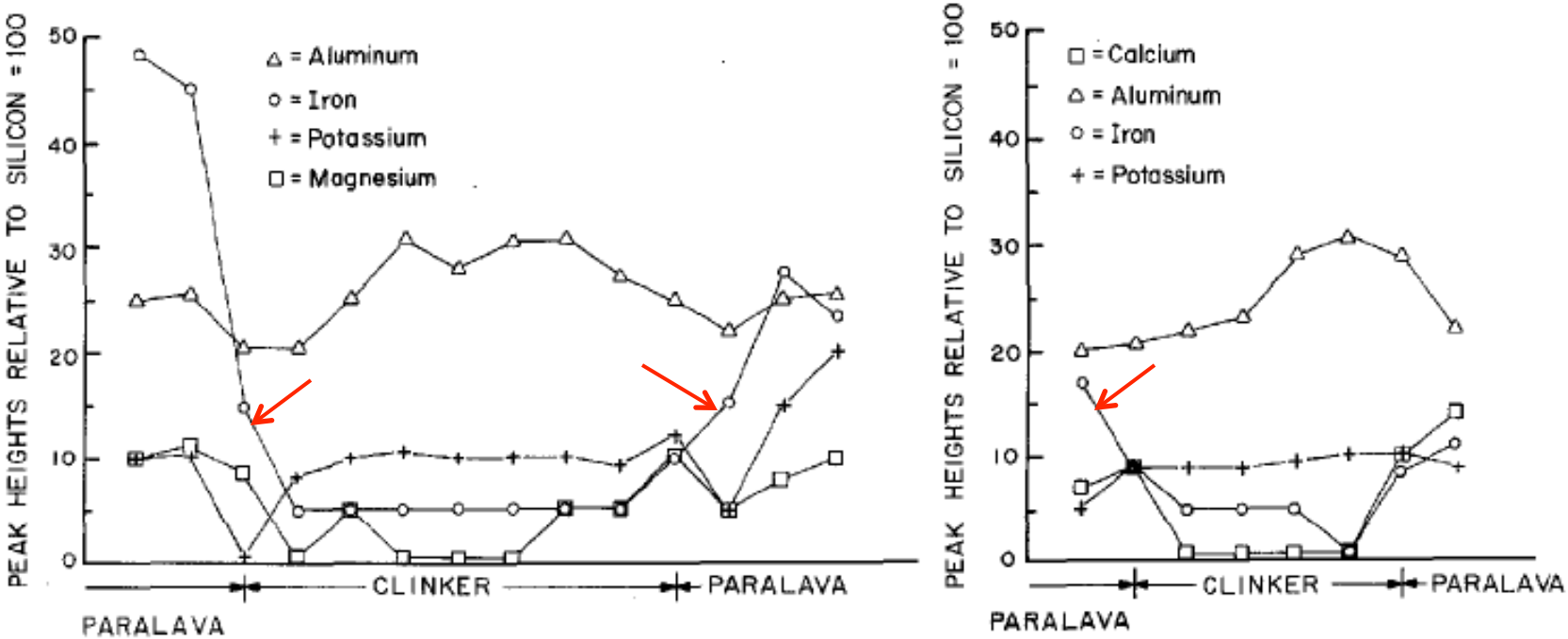

Figure 16: XRF derived iron percentages graphed along side Powder River Basin data. Points displayed as red arrows. (Clark Peacor, 1992)

Conclusion

- We have concluded, based on prior data from similar rocks, that our sample would be considered a transition rock between clinker and paralava. We base this off of iron oxide ratios in our rock compared to those in rocks analyzed in the powder river basin.
- The lower amount of alteration of our rock compared to that from the powder river basin could possibly be attributed to lower burning temperature of lignite than bituminous

References

- Cosca, Michael A., Essene, Eric J., Geissman, John W., Simmons, William B., and Coates, Donald A., 1989, Pyrometamorphic rocks associated with naturally burned coal beds, Powder River Basin, Wyoming: American Mineralogist, v74, p. 85-100

- Clark, Bryan H., and Peacor, Donald R., 1992, Pyrometamorphism and partial melting of shales during combustion metamorphism: mineralogical, textural, and chemical effects: Contributions to Mineralogy and Petrology. v. 112, p. 558-568.

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- Grapes, Rodney H., Pyrometamorphism: Springer-Verlag Berlin Heidelberg, 2006\

- www.Mindat.org