

## Introduction

This research aims to study slag from the historical iron smelter in Standish, NY. Slag is a byproduct formed when pure metal is extracted from an ore. Once this processing is complete, the slag is usually dumped into a pile and left to weather over time.

### Geographical information about Standish:

- Standish is located within the North East region of the Adirondack park in New York.
- The slag pile shown on the map below has an area of approximately 12.8 acres.

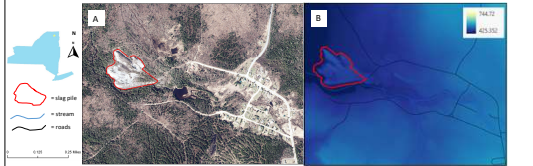


Figure 1 (A): Aerial Photo Map of Standish, NY, 2017 (NYS Office of Information Technology Services). (B): Digital Elevation Model of Standish, NY, 2016 (NYS Office of Information Technology Services).

### Historical Background of Iron in Standish, NY:

1749: Iron ore had been seen by Swedish explorers in the region.  
1812-1814: Iron mining and smelting began in the Adirondacks started with settlement.  
Mid 1800s: the Adirondacks was one of the top iron regions in the US.  
The Civil war, urbanization, and industrialization helped the iron industry remain strong.  
Continued expansion of the nation's rail network and the replacement of iron trackage with steel rails created huge new markets.  
1883: The Chateaugay Ore and Iron Company had an 8-fire bloomery at Standish (See figure 1,2,3).  
1885: The company constructed a blast furnace at Standish to produce pig iron in addition to bloom iron (See figure 1,2,3).  
Early 1900s: The industry started to die down Due to nationwide financial struggles.



Figure 2: Historical photo of railroad tracks leading to blast furnace in Standish, NY, most likely taken from the West facing East toward the pile. (Keller, 1932).



Figure 3: Historical photo of blast furnace in Standish, NY. (Keller, 1932).

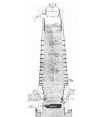
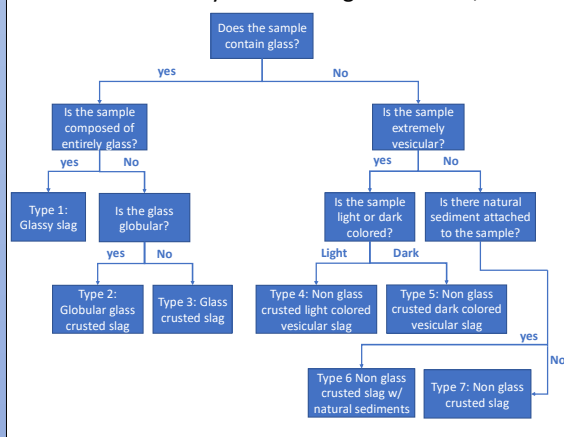


Figure 4: Diagram of blast furnace (Dawson et al., 1988).

### Research Rationale and Goals:

- Spatial analysis of size and position of the slag pile, topography, and soil data using GIS (geographic information systems). (See Figure 1 A,B).
- Creation of a new classification system for the slag at Standish, NY composing of seven different types of slag. (See flow chart below).
- An acid experiment with four different slag types to see how they react comparatively.

## Classification System for Slag at Standish, NY.



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Table 1: Abbreviations used for samples involved in chemical analysis.

Code	Sample
St-G	Type 1 slag, pre acid
St-GA	Type 1 slag, post acid
St-GC	Type 3 slag, pre acid
St-GCA	Type 3 slag, post acid
St-B	Type 3 slag, no glass, pre acid
St-BA	Type 3 slag, no glass, post acid
St-V	Type 4 slag, pre acid
St-VA	Type 4 slag, post acid
St-NG	Type 6 slag, no acid
St-E	Type 3 slag, highly eroded, no acid

## Methodology of the Acid Leaching Test

- Add solid slag samples to 100 ml of room temperature 2M nitric acid.
- Cover the beakers with parafilm and let sit for six hours with no agitation.
- Remove slag samples from acid bath and wash in individual beakers of deionized water for 15 seconds. Repeat wash in a second beaker of deionized water.
- Remove each slag sample from the second water bath and let dry overnight.

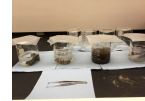


Figure 6: picture of the set up of the Acid leaching test.

## Results: Acid Leaching Test

- The starting pH of the acid was approximately 2.
- After the leaching experiment the pH in each beaker had increased.
- The St-BA increased the most and the St-GA increased the least.
- The powdered samples of slag after the acid experiment were darker in comparison to the samples powdered before the experiment. (Figure 7)

Table 2: Changes in mass due to leaching experiment.

Sample	Initial Mass (g)	Post-acid Mass (g)	% Mass lost
St-GA	21.4	19.5	8.9
St-GCA	21.6	18.5	14.4
St-VA	21.4	14.7	31.3
St-BA	25.8	22.2	14.0



Figure 7: powdered samples of St-G and St-GA (pre acid and post acid leaching).

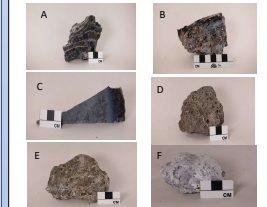


Figure 5: (A) St-G, (B) St-GC, (C) St-B, (D) St-V, (E) St-NG, (F) St-E. All samples were broken up into smaller samples for testing.

## Results: Chemical Data

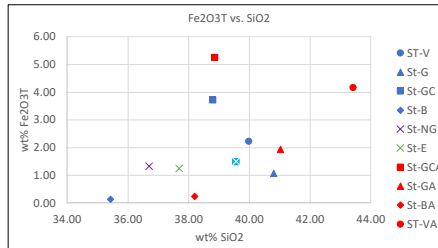


Figure 8 : a scatter plot graph showing the wt% of Fe2O3t vs. the wt% of SiO2.

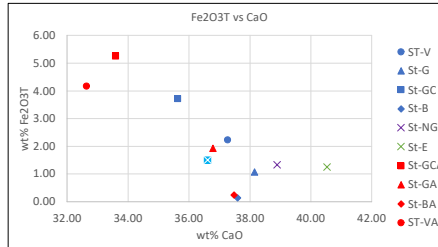


Figure 10: a scatter plot graph showing the wt% of Fe2O3t vs. the wt% of CaO.

### Major Oxide Observations:

- The biggest changes in Major oxide content after the Acid leaching testing were in SiO<sub>2</sub>, CaO, and Fe<sub>2</sub>O<sub>3</sub>.
- St-GCR doesn't follow the trend of St-GC to St-GCA in major oxide changes.

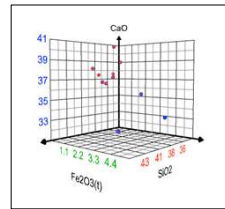


Figure 9: a 3D scatter plot graph showing the wt% of CaO vs. Fe2O3t vs. SiO2.

### Trace Elements Observations:

Table 3: Trace element data for pre and post acid leaching tests. (entries with a < indicate below detection level)

	St-V	St-VA	St-G	St-GC	St-GCA	St-B	St-BA	St-E
Rb	39.5	31.4	24.7	24.1	37.3	38.7	40.9	41.5
Zr	418	366	440	443	421	402	605	756
Y	49.3	56.3	46.5	47.3	45.3	44	50.8	52.9
Zr	363	451	288	297	269	279	245	208
V	32	19	7	<3	56	85	<3	3
Ni	9	14	4	5	3	5	3	5
Cr	48	59	64	100	57	70	57	29
Nb	6.2	6.6	6.3	5.7	6.1	6.7	6.8	10.1
Co	24	23	10	10	8	8	7	21
Zn	198	114	12	11	11	11	10	13
Ba	340	327	246	243	198	206	449	1595
La	48	52	37	41	35	32	41	40
Ce	83	106	81	82	85	84	84	82
U	3.5	4.1	2.1	2.6	3.3	4	6.3	4.9
Th	20.9	25.3	9.8	11.5	18.2	18.3	17.5	15.7
Sc	46	45	40	38	41	38	42	41
Cl	554	599	<40	59	60	63	53	56
Pb	99	59	<1	<1	<1	<1	<1	<1

Figure 11: a line graph showing the levels of trace elements of samples in comparison to St-B because it is the bulk slag type

## Discussion

### Physical results of Leaching Test:

Most of the mass loss was physical shown by the particulates left in the beakers. This aligns with a past study done by Kelk and Leonard in 2019. The color change shown in figure 7 is due to the loss of the calcite.

### Major Oxide Chemistry:

The biggest chemical changes between the initial samples and the acid leached samples were in SiO<sub>2</sub>, Fe<sub>2</sub>O<sub>3</sub>T, and CaO (table 1).  
Past work by Farthing and Sidlauskas (2006) suggested that the dominant mineral phases in Standish slag are gehlenite (Ca<sub>2</sub>Al<sub>2</sub>SiO<sub>7</sub>), wollastonite (CaSiO<sub>3</sub>), organic carbon, iron (both as rust and as a pure metal) and wurtzite (Zn, FeS). The white weathered material was identified by Farthing and Sidlauskas (2006) as calcite (CaCO<sub>3</sub>). This proposed mineralogy and the dominance of Si, Fe, and Ca in the chemical analyses correspond well.

The results of the leaching tests also indicate that acid attacked the calcite more so than wollastonite or gehlenite because only the CaO content decreased in post-leach samples. The variations in FeO content in pre and post test samples is likely due to the acid impacting both the wurtzite, pre-existing rust, and metallic iron.  
St-V showed the largest changes in chemistry due to acid leaching. This is due to the vesicles permeating through the entire sample. St-VA didn't float which means that the sample is both porous and permeable-allowing for a larger surface area for the nitric acid reactions compared with just the outer surface of the non-porous samples.

Overall, the change in major oxides never exceeded 5 wt%. The leaching test was formulated to show extreme acid settings, suggesting that a natural setting might actually be even less impacted. HNO<sub>3</sub> is abundant in acid rain but other acids present in nature might play a more important role in the weathering process.

### Major elements and St-GCR (Rain Sample):

St-GCR was expected to act as a midpoint between St-GC and St-GCA because there was some erosion and mass loss but not as much as under the acid conditions. However, the major oxide data doesn't show much of a correlation. This is likely due to the heterogeneous nature of slag. It is likely that St-GCR came from a part of the slag that contained more iron (and thus minimizing the dominance of the SiO<sub>2</sub>).

### Trace Element Chemistry:

The most dominant of the trace elements present in all the samples are Sr, Zr, and Ba (all over 100 ppm; table 3). Sr and Ba are likely to be associated with Ca due to their similar valence states and would be impacted by the acid-induced loss of calcite. The decrease in Zr due to the leaching tests may be associated with changes to Fe-bearing minerals or may also be due to the impact of acid on Zr-specific minerals that have not yet been identified. V, although not as dominant as the above trace elements also changes and is linked to changes in the Fe-bearing minerals.

The comparison between St-B, St-NG, and St-GC (fig. 11), suggests that because St-NG and St-GC follow a similar trend that they are related. It is likely that slag that originally classified as type 6 ("not glassy"; e.g., St-NG) was actually a type 3 slag ("glassy crusted") but that it lost its rind due to erosion. The results of this weathering process is observed in the field where the ground it profusely littered with small pieces of glassy rind that has become separated from its crystalline "host".

### Implications:

The slag pile in Standish covers a significant parcel of land and sits along a waterway. Slag at the site clearly is weathering physically and chemically and is impacting the environment. The slag does neutralize the acidity in the rain of the region, but according to our leaching results, elements are lost which may be troublesome. For example, Frank et al. (1996) found that the use of slag as a fertilizer helped crops grow, but also poisoned cattle eating grass from the fields that were enriched in V and CaO-elements that also are present at Standish.

## Further Research

- Using the Scanning electron microscope to analyze samples.
- Doing a chemical analysis of the plant life of the area near the slag pile.
- Collect water samples from Wolf pond and Standish Brook for chemical analysis.
- Create a unique topographic base-map of the area using GIS

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