University of North Carolina Asheville
Journal of Undergraduate Research
Asheville, North Carolina
November 2020

Analysis of the Aspect Ratios of Tremolite and Anthophyllite/Talc Grains in Mine Tailings and Products

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Abstract

This project is part of a series of studies to further understand the relationship between morphology and composition of talc and amphibole minerals in the Gouverneur Mining District in New York. The interest in the morphology and composition of these minerals is a result of the concern that asbestiform tremolite and anthophyllite amphiboles may occur in these deposits. Samples include rock tailings from the Arnold Pit and Talcville talc mines and commercial talc products produced from these mines. Each sample was measured so that the length is approximately the longest distance across a particular grain with the width segmented perpendicularly along that length. At each of these segments, an aspect ratio between the corresponding width and the overall length was used to find an average aspect ratio for each grain. The average aspect ratios are used to determine potential correlations for the tremolite and anthophyllite/talc grains based on their source, their form, and as a whole. Additionally, the average aspect ratios are graphed against the corresponding SiO_2/MgO ratios to determine possible correlations between composition and morphology. The only correlation that was supported was between the length and average aspect ratio of the raw tremolite grains, though it is possible that some of the results were impacted by an insufficient number of grains being examined.

1. Introduction

The data for this study originated from research that examined the chemical composition and morphology of samples of tremolite and anthophyllite/talc grains sourced from the Talcville and Arnold Pit mines. Part of the interest in these minerals is based in previous controversies of whether the tremolite and anthophyllite amphiboles occur with asbestiform morphology, which resulted in concerns that some products, such as fillers in paint and paper products, may have exposed people to asbestos[1]. McNamee and Gunter's research aimed to "provide precise compositional data and morphological relationships" for the minerals sourced from the Gouverneur Mining District[1].

From these two mines, samples include those that are in their natural, or raw, state and those that have been processed into commercial products. Tremolite grains from the rock samples were noted to appear to have been altered only slightly while having low SiO_2/MgO weight percent oxide ratios in comparison to an ideal tremolite[1]. When examining the products, the tremolite grains were also found to have low SiO_2/MgO weight percent oxide ratios[2]. Additionally, McNamee and Gunter found that several of the anthophyllite grains (naturally occurs in a needle-like habit) were altering to talc (typically occurs in platy habit and occasionally in fibers) along the grain margins and internal fractures[1,2]. Overall, the compositions and textures of the products were concluded to be similar from both mines[2].

This study aims to identify correlations between the composition and morphology of a sample of tremolite and anthophyllite/talc grains. McNamee and Gunter's research collected and examined data about the composition and morphology of amphibole and anthophyllite/talc grain samples[1,2]. The samples selected from this research are grouped based either on source or if the grains were processed or natural. The presence of correlations may help describe these relationships for the tremolite and anthophyllite/talc grains, which are likely to be affected by factors such as the source or if the grains were processed. Additionally, the absence of correlations may suggest that these relationships are too complex to be described in this manner or possibly non-existent between the selected variables.

2. Methodology

The images used for this study are from a two-part study done by McNamee and Gunter[1,2] and were generated with a backscatter electron (BSE) detector equipped in an electron microscope. The BSE detector and software generates an image where each pixel represents a relative average atomic number. The brighter the shade of grey, the higher the average atomic number within the pixel. McNamee and Gunter prepared the rock samples as polished thin sections and the products were prepared as polished epoxy grain mounts for image and chemical analysis using an electron microprobe[1,2]. Due to the altered nature of the anthophyllite, the grains will be divided into two groups: tremolite and anthophyllite/talc.

As the mineral grains of interest are irregular shapes, each of the grains are divided into ten sections so that widths can be found at nine separate locations along the length. The length of each grain is approximately the longest distance between two edges of the grain while the width measurements are orthogonal at each division. An aspect ratio (length/width) is calculated between the width at each division and the overall length and then averaged. The average aspect ratio is used to identify potential correlations between the length of a grain and its aspect ratio or if there is a correlation between the aspect ratio and the SiO_2/MgO ratio.

In order to help contextualize the results above, boxplots will be created for each sample that has at least five separate grains to determine if there is any skewing present in the data as well as if there were any identifiable outliers or extremes[4]. Additionally, the presence of skew in the average aspect ratios for a particular dataset may correspond to a similar skew in the respective SiO_2/MgO data.

2.1. Measurements

Figures 1-3 depict how each of the grains being analyzed were measured. The green lines represent each approximated total length, the red lines divide each grain into ten equal length segments, and the blue lines are positioned between each segment to approximate the width at that location. The measurements of each of these segments can be seen in the tables below along with the calculated aspect ratios. Some of the grains that are being examined did not have the composition of MgO or SiO_2 measured, so they are excluded for the comparisons of average aspect ratio to SiO_2/MgO in the graphs in the following section.

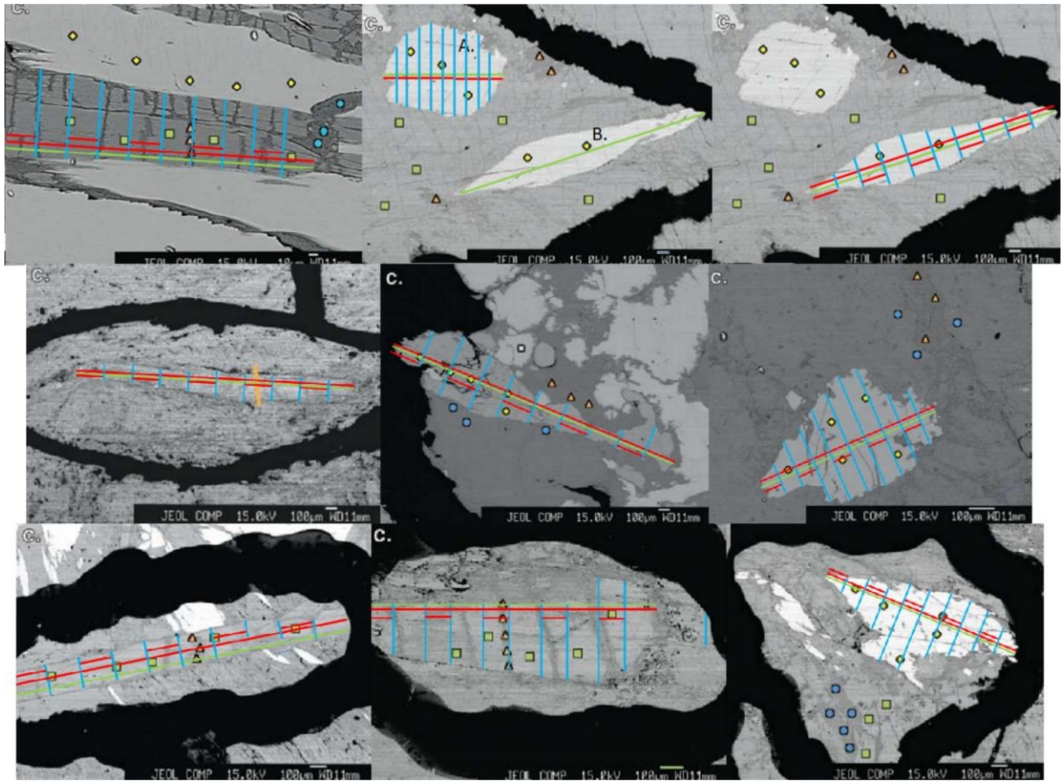

Figure 1. Thin sections from rock tailings

Figure 1 shows backscatter electron (BSE) images of thin sections from rock samples with colored line annotations to illustrate measurements used to measure the length and width of select raw mineral grains (reproduced from McNamee and Gunter[1]). The labels for each grain are taken from McNamee's unpublished data when available and otherwise corresponds to the figure(s) they appear in; from left to right, the grains are the following: (top) R1_3, R1-T6a, R1-T6b; (middle) Figure 5, R4_1, R4_2; (bottom) R6-T1, R7-T3, R7-T4[1,3].

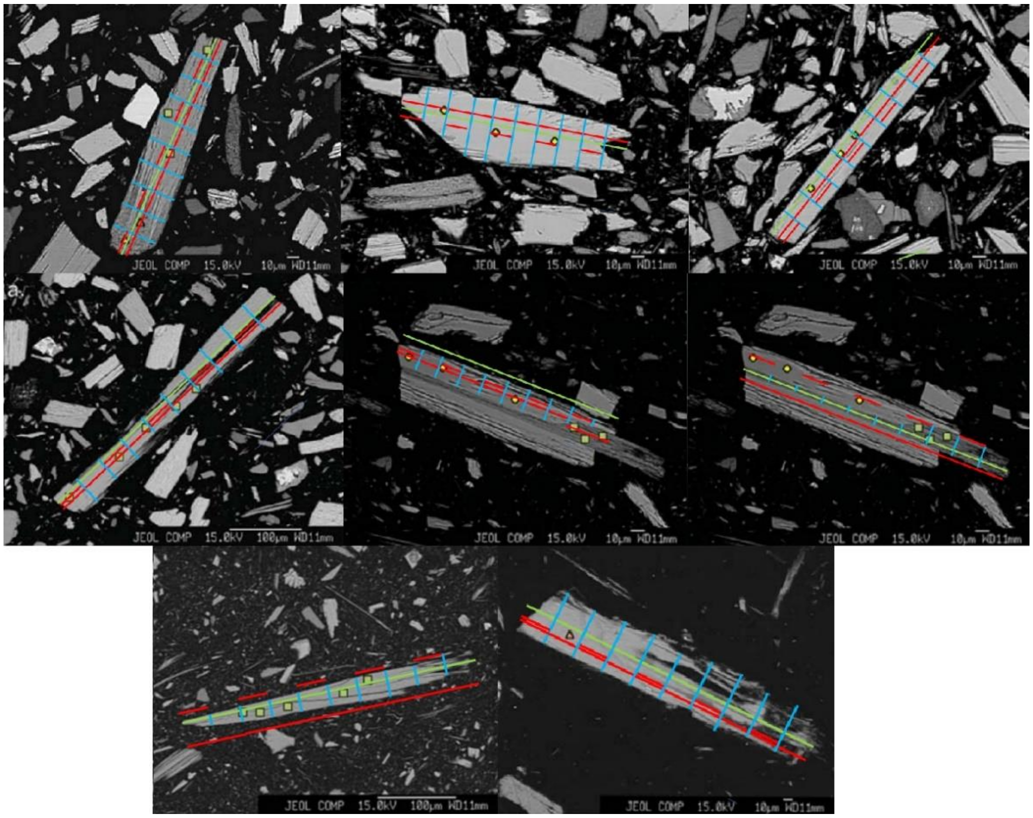

Figure 2. Thin sections from rock products

Figure 2 shows BSE images of thin sections from rock samples with colored line annotations to illustrate measurements used to measure the length and width of select mineral grains (reproduced from McNamee and Gunter[2]); from left to right, the labels used correspond to the figures in the source and are the following: (top) Figure 15, Figure 16, Figure 17; (middle) Figure 18, Figure 24-A, Figure 24-B; (bottom) Figure 25, Figure 26.

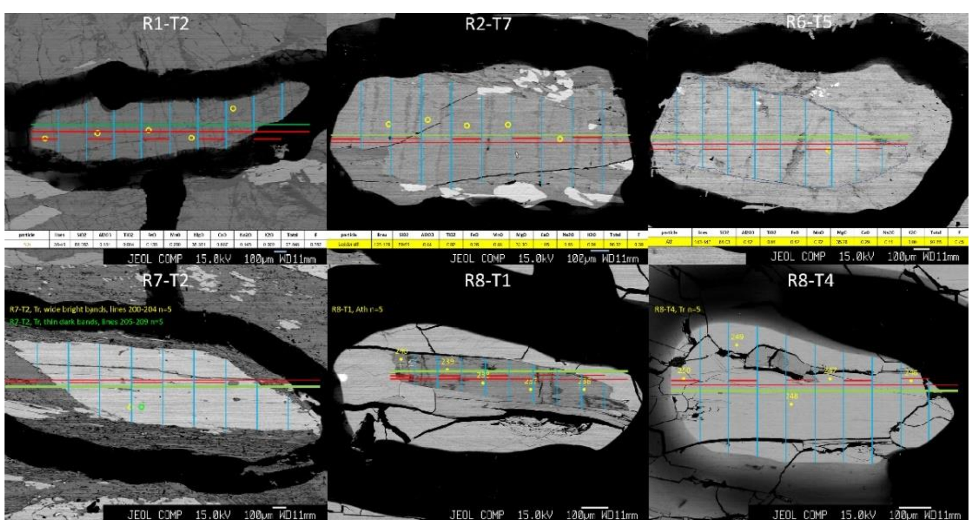

Figure 3. Additional thin sections from rock tailings

Figure 3 shows the grains that were sourced from unprocessed, or raw, rock samples that were not originally published[3]. Each image has a label present on it that is used for future reference.

3. Data

Table 1: Measurements of length and aspect ratio for all grains from Figure 1.

	R1-T3		R1-T6a		R1-T6b		Figure 5		R4-1	
	Length	Aspect Ratio (Length/Width)	Length	Aspect Ratio (Length/Width)	Length	Aspect Ratio (Length/Width)	Length	Aspect Ratio (Length/Width)	Length	Aspect Ratio (Length/Width)
Total Length (µm)	405.00		1006.67		2140.00		2140.00		2530.00	
(1/9) (µm)	45.00	3.46	111.85	2.16	237.78	17.83	237.78	17.12	281.11	8.03
(2/9) (µm)	90.00	3.62	223.70	1.64	475.56	8.68	475.56	15.29	562.22	4.73
(3/9) (µm)	135.00	3.93	335.56	1.47	713.33	5.94	713.33	16.46	843.33	5.22
(4/9) (µm)	180.00	4.18	447.41	1.37	951.11	5.84	951.11	13.38	1124.44	6.75
(5/9) (µm)	225.00	4.40	559.26	1.39	1188.89	6.29	1188.89	9.95	1405.56	8.72
(6/9) (µm)	270.00	4.45	671.11	1.37	1426.67	7.83	1426.67	9.73	1686.67	10.54
(7/9) (µm)	315.00	4.50	782.96	1.47	1664.44	11.89	1664.44	10.70	1967.78	33.73
(8/9) (µm)	360.00	4.55	894.81	1.62	1902.22	11.46	1902.22	11.57	2248.89	15.33
(9/9) (µm)	405.00	4.45	1006.67	2.52	2140.00	13.38	2140.00	12.59	2530.00	8.43
Average Aspect Ratio		4.17		1.67		9.90		12.98		11.28
	R4_2		R6-T1		R7-T3		R7-T4			
	Length	Aspect Ratio (Length/Width)	Length	Aspect Ratio (Length/Width)	Length	Aspect Ratio (Length/Width)	Length	Aspect Ratio (Length/Width)		
Total Length (µm)	697.78		1954.17		1250.00		1276.00			
(1/9) (µm)	77.53	5.71	217.13	10.91	138.89	5.63	141.78	12.27		
(2/9) (µm)	155.06	3.83	434.26	10.91	277.78	5.00	283.56	6.13		
(3/9) (µm)	232.59	2.38	651.39	11.72	416.67	4.74	425.33	4.49		
(4/9) (µm)	310.12	1.90	868.52	10.42	555.56	4.41	567.11	2.45		
(5/9) (µm)	387.65	1.76	1085.65	10.42	694.44	4.33	708.89	2.38		
(6/9) (µm)	465.19	1.58	1302.78	10.66	833.33	3.95	850.67	3.04		
(7/9) (µm)	542.72	1.63	1519.91	20.39	972.22	3.85	992.44	3.39		
(8/9) (µm)	620.25	2.62	1737.04	18.76	1111.11	2.68	1134.22	4.76		
(9/9) (µm)	697.78	3.27	1954.17	18.04	1250.00	3.21	1276.00	7.98		
Average Aspect Ratio		2.74		13.58		4.20		5.21		

Table 2: Measurements of length and aspect ratio for all grains from Figure 2.

	Figure 15		Figure 16		Figure 17		Figure 18		Figure 24-A	
	Length	**Aspect Ratio (Length/Width)**	**Length**	**Aspect Ratio (Length/Width)**	**Length**	**Aspect Ratio (Length/Width)**	**Length**	**Aspect Ratio (Length/Width)**	**Length**	**Aspect Ratio (Length/Width)**
Total Length (µm)	184.50		175.50		202.00		417.00		166.50	
(1/9) (µm)	20.50	5.05	19.50	6.38	22.44	8.98	46.33	9.48	18.50	10.41
(2/9) (µm)	41.00	4.92	39.00	4.74	44.89	8.78	92.67	11.27	37.00	10.41
(3/9) (µm)	61.50	5.05	58.50	3.86	67.33	8.78	139.00	11.27	55.50	10.09
(4/9) (µm)	82.00	4.92	78.00	3.55	89.78	8.60	185.33	14.89	74.00	10.09
(5/9) (µm)	102.50	5.27	97.50	3.62	112.22	8.60	231.67	10.97	92.50	9.79
(6/9) (µm)	123.00	5.59	117.00	3.90	134.67	8.78	278.00	10.43	111.00	9.79
(7/9) (µm)	143.50	6.15	136.50	4.33	157.11	8.60	324.33	9.07	129.50	9.79
(8/9) (µm)	164.00	7.24	156.00	4.39	179.56	9.18	370.67	9.07	148.00	13.32
(9/9) (µm)	184.50	7.85	175.50	5.01	202.00	11.88	417.00	9.07	166.50	27.75
Average Aspect Ratio		5.78		4.42		9.13		10.61		12.38
	Figure 24-B		**Figure 25**		**Figure 26**					
	Length	**Aspect Ratio (Length/Width)**	**Length**	**Aspect Ratio (Length/Width)**	**Length**	**Aspect Ratio (Length/Width)**				
Total Length (µm)	203.50		183.50		170.50					
(1/9) (µm)	22.61	5.02	20.39	28.23	18.94	5.68				
(2/9) (µm)	45.22	5.29	40.78	18.35	37.89	6.20				
(3/9) (µm)	67.83	5.15	61.17	16.68	56.83	5.78				
(4/9) (µm)	90.44	5.09	81.56	15.29	75.78	5.68				
(5/9) (µm)	113.06	5.22	101.94	14.12	94.72	6.31				
(6/9) (µm)	135.67	5.22	122.33	12.23	113.67	6.09				
(7/9) (µm)	158.28	5.58	142.72	11.12	132.61	5.09				
(8/9) (µm)	180.89	13.13	163.11	14.68	151.56	6.56				
(9/9) (µm)	203.50	12.72	183.50	13.59	170.50	6.20				
Average Aspect Ratio		6.93		16.03		5.96				

Table 3. Measurements of length and aspect ratio for all grains from Figure 3.

	R1-T2		R2-T7		R6-T5	
	Length	Aspect Ratio (Length/Width)	Length	Aspect Ratio (Length/Width)	Length	Aspect Ratio (Length/Width)
Total Length (µm)	2333.33		1554.55		1610.87	
(1/9) (µm)	259.26	6.49	172.73	4.45	178.99	3.56
(2/9) (µm)	518.52	4.85	345.45	3.05	357.97	2.85
(3/9) (µm)	777.78	5.73	518.18	2.74	536.96	2.93
(4/9) (µm)	1037.04	5.04	690.91	2.77	715.94	2.84
(5/9) (µm)	1296.30	5.34	863.64	3.35	894.93	2.91
(6/9) (µm)	1555.56	5.48	1036.36	3.49	1073.91	2.98
(7/9) (µm)	1814.81	5.83	1209.09	3.35	1252.90	3.34
(8/9) (µm)	2074.07	7.41	1381.82	3.21	1431.88	4.55
(9/9) (µm)	2333.33	7.59	1554.55	3.00	1610.87	7.80
Average Aspect Ratio		5.97		3.27		3.75
	R7-T2		R8-T1		R8-T4	
	Length	Aspect Ratio (Length/Width)	Length	Aspect Ratio (Length/Width)	Length	Aspect Ratio (Length/Width)
Total Length (µm)	2307.69		871.79		881.72	
(1/9) (µm)	256.41	12.86	96.87	7.73	97.97	2.52
(2/9) (µm)	512.82	6.34	193.73	7.16	195.94	2.20
(3/9) (µm)	769.23	4.35	290.60	6.80	293.91	2.20
(4/9) (µm)	1025.64	4.19	387.46	6.18	391.88	2.25
(5/9) (µm)	1282.05	4.13	484.33	5.91	489.84	2.41
(6/9) (µm)	1538.46	4.15	581.20	6.18	587.81	2.60
(7/9) (µm)	1794.87	4.29	678.06	6.48	685.78	2.69
(8/9) (µm)	2051.28	6.52	774.93	7.16	783.75	3.28
(9/9) (µm)	2307.69	9.47	871.79	9.32	881.72	4.82
Average Aspect Ratio		6.25		6.99		2.77

Table 4. Measurements of the SiO_2/MgO ratios for all grains from Figure 1.

	R1_3	R1-T6a	R1-T6b	Figure 5	R4_1
SiO2/MgO Ratio	1.72	2.30	2.30	1.89	2.26
	R4_2	R6-T1	R7-T3	R7-T4	
SiO2/MgO Ratio	2.26	1.70	1.72	2.29	

Table 5. Measurements of the SiO_2/MgO ratios for all grains from Figure 2.

	Figure 15	Figure 16	Figure 17	Figure 18	Figure 24-A
SiO2/MgO Ratio	1.66	2.20	2.19	1.77	2.24
	Figure 24-B	**Figure 25**	**Figure 26**		
SiO2/MgO Ratio	1.77	1.69	1.89		

Table 6. Measurements of the SiO_2/MgO ratios for all grains from Figure 3.

	R1-T2	R2-T7	R6-T5
SiO2/MgO Ratio	1.73	1.79	1.73
	R7-T2	**R8-T1**	**R8-T4**
SiO2/MgO Ratio	N/A	N/A	N/A

Tables 4-6 above show the measurements for the SiO_2/MgO ratios for the mineral grains either provided or calculated using McNamee and Gunter's research. Table 4 above makes use of numbers provided in Table 1 from the first part of McNamee and Gunter's research while Table 2 is sourced from Table 4 in the second part of this research[1,2]. The grains represented in Table 3 above had the separate weight percent oxide values provided along with the grains, which were then used to calculate the SiO_2/MgO ratios corresponding to these grains[3].

4. Results

4.1. Length vs. Average Aspect Ratio of Samples

4.1.1. all grain samples

Graphing length against average aspect ratio, a linear relation would be describable if not for the three smallest grains going against the trend. Additionally, the graph plotting length versus width for all the tremolite grains shows shapes that have some resemblance to parabolas in that the ends of the grains are typically where they are narrowest while somewhere around the center is where they are the widest. The graphs corresponding to the anthophyllite/talc grains do not show or suggest a trend of the grains adopting a similar form.

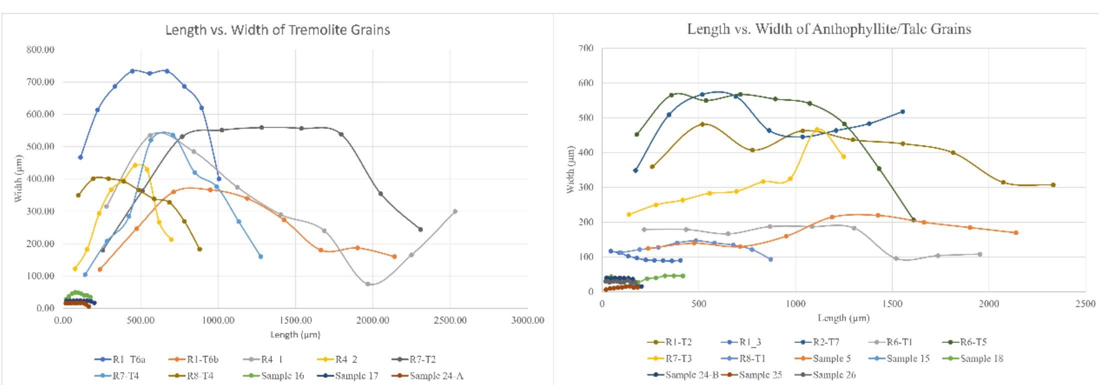

Figure 4. Length versus width graphs for all grains

Figure 4 illustrates how the width of each grain changes along the length of the grain. Compared to one another, tremolite grains would appear to have a different relationship between length and width to anthophyllite/talc grains.

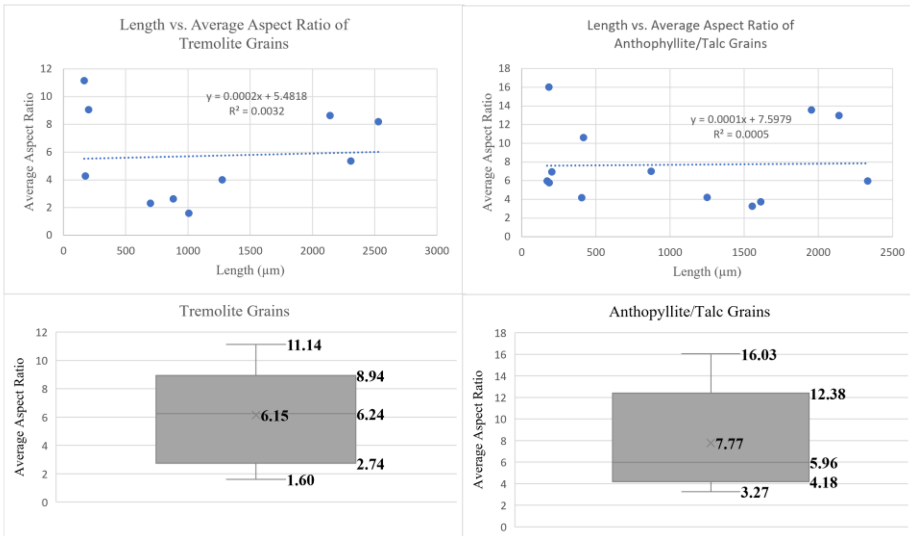

Figure 5. Length versus aspect ratio graphs for all grains

Figure 5 relates the length to the average aspect ratio of all the grains along with boxplots to show the distribution of the average aspect ratios.

4.1.2. raw grain samples

After removing the grains that were processed, there appears to be a possible linear correlation between the length and average aspect ratio of the tremolite grains in their natural form given that the R^2 is now very close to one as opposed to being nearly zero for all the tremolite grains. This could suggest that the morphology of the grains has been significantly altered such that the processed grains do not fit this regression line. There are still no outliers or extremes identified and the data becomes positively skewed in contrast to the slight negative skew present when the processed gains are also included.

Like the tremolite grains, the natural anthophyllite and talc grains also showed a significant increase to the R^2 value of the regression line, but it is not enough to be able to claim that there is a correlation between the length and the average aspect ratios of these grains. The data for the average aspect ratio shows that the data for the average aspect ratios is noticeably positively skewed.

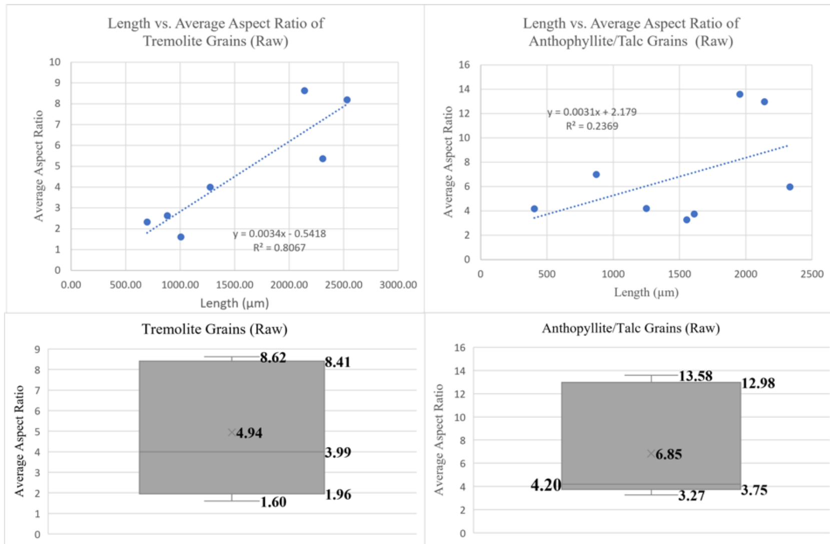

Figure 6. Length versus aspect ratio graphs for the raw grains

Figure 6 relates the length to the average aspect ratio of all the raw grains along with boxplots to show the distribution of the average aspect ratios.

4.1.3. processed grain samples

Both the tremolite and anthophyllite/talc grains that were processed into products did not show any evidence of correlation between the length and the average aspect ratio. As there was only a sample of three processed tremolite grains, a box plot was only made for the anthophyllite/talc grains. As with the plots in Figure 6, the average aspect ratios for the processed anthophyllite/tac grains has a noticeable positive skewing.

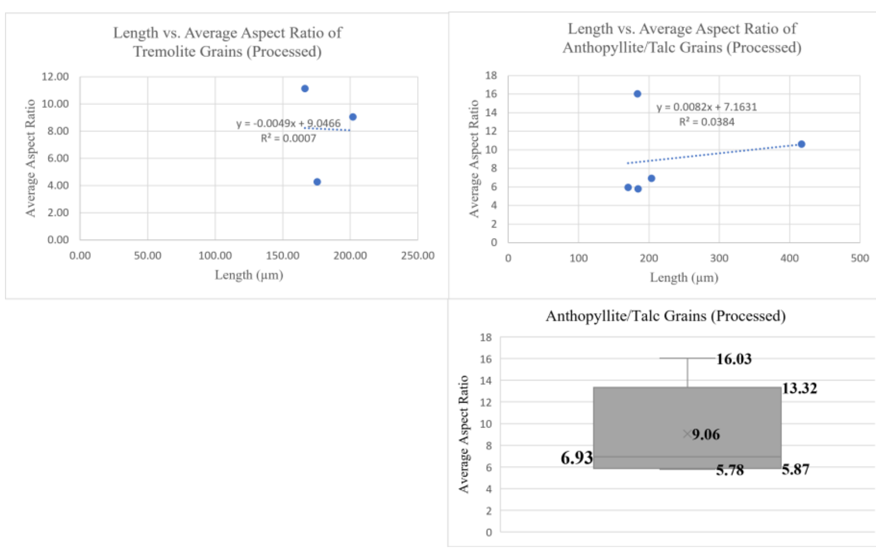

Figure 7. Length versus aspect ratio graphs for the processed grains

Figure 7 relates the length to the average aspect ratio along with a box plot for the anthophyllite/talc grains to show the distribution of the average aspect ratios.

4.1.4. arnold pit grain samples

The data does not support there being a correlation of the length and aspect ratio when only examining grains based on location. There is a higher R^2 value for the Arnold Pit sample than when all the tremolite grains are examined but it is lower than with all the raw tremolite grains. The results in the previous subsections suggest that there may be a correlation in raw tremolite grains but not in the processed grains, which suggests that processing the grains into products may have a greater effect on the morphology than where they were sourced. This is potentially supported by the processed grains only consisting of two of the six elements in this sample

While this data may indicate the effects of processing the tremolite grains, a similar result cannot be determined for the anthophyllite/talc grains. There was not a strong case for suggesting that there was any correlation between length and average aspect ratio for either the raw or processed grains, so the R^2 value being close to zero in this sample does not indicate the possibility that the presence or absence of one of these treatments affects the correlation of length and width.

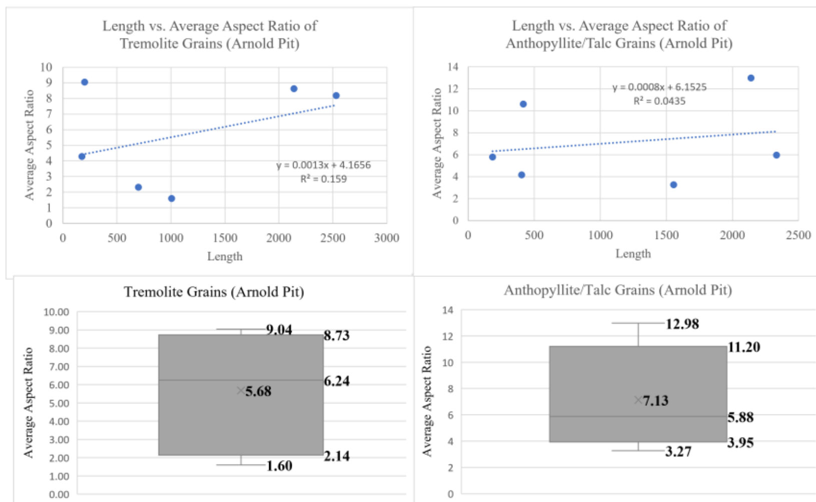

Figure 8. Length versus aspect ratio graphs for grains from Arnold Pit

Figure 8 relates the length to the average aspect ratio for all the grains sourced from Arnold Pit along with box plots to show the distribution of the average aspect ratios.

4.1.5. talcville grain samples

As was the case with the tremolite grains from Arnold Pit, the raw tremolite grains do not show as strong of a correlation between the length and the average aspect ratio. From the small size of the sample, this can be attributed to the one processed grain present, which has a large average aspect ratio with a small length. Likewise, this graph appears to indicate that the correlation for the raw tremolite grains may also hold for grains sourced from Talcville. This would suggest that this relation for raw tremolite grains is independent of these two sources, though the small sample size may not be indicative of what would be observed with more grains.

As was the data set from Arnold Pit, no hypothesis can be made regarding the effect of source on the anthophyllite/talc grains. The R^2 value remains close to zero when observing the grains sourced from this location regardless of being in a raw or processed form. The average aspect ratios for these grains continue to show a more significant amount of positive skewing than the tremolite grains for this treatment.

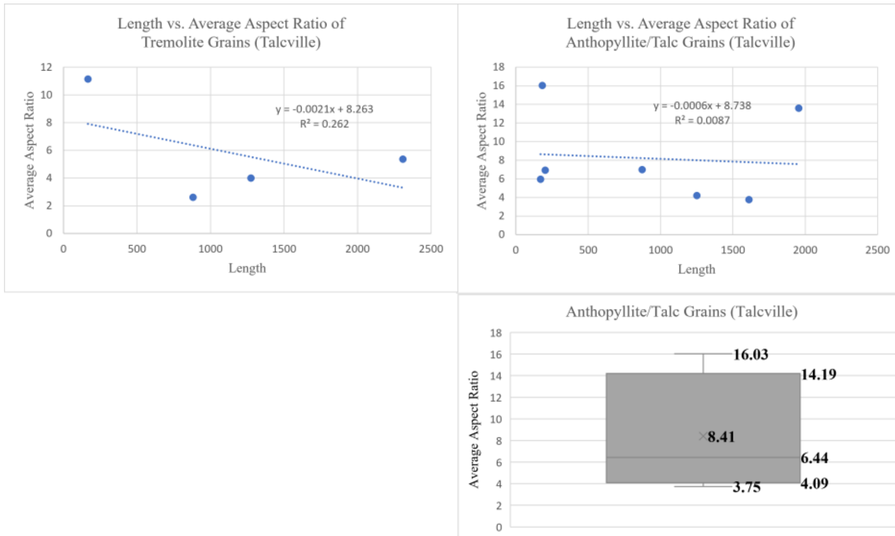

Figure 9. Length versus aspect ratio graphs for grains from Talcville

Figure 9 relates the length to the average aspect ratio of grains for each type sourced from Talcville along with a box plot for the anthophyllite/talc grains to show the distribution of the average aspect ratios.

4.2. Average Aspect Ratio vs. SiO2/MgO Ratio of Samples

4.2.1. all grain samples

Overall, the data does not show a significant amount of correlation for either of the groups of grains between their aspect rations and composition. The tremolite grains show a slightly higher R^2 than for the anthophyllite/talc grains, but not high enough to indicate that the data fits to the regression line well enough to indicate this relation between the average aspect ratio and SiO_2/MgO ratio. When comparing the distributions shown in the boxplots for SiO_2/MgO ratios to those for the average aspect ratio, the data appears to skew in a similar manner for the respective types of grains

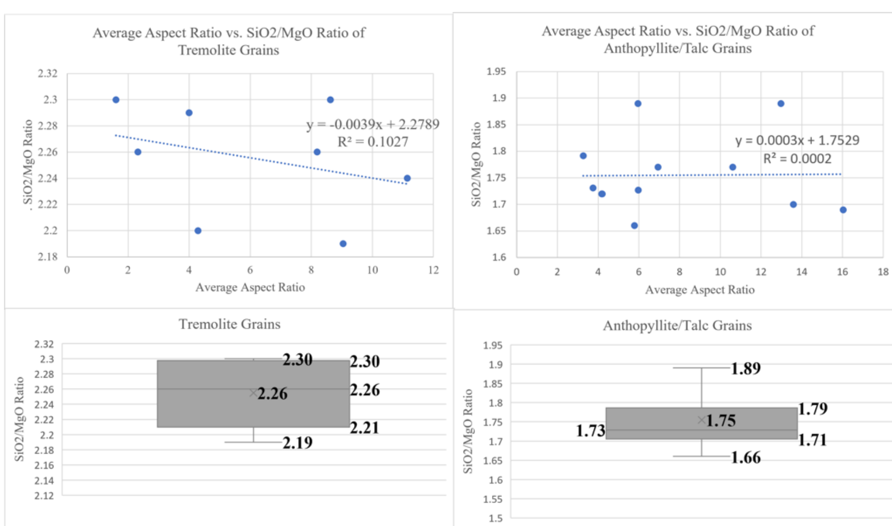

Figure 10. Average aspect ratio versus SiO2/MgO ratio graphs for all grains

Figure 10 relates the average aspect ratio and SiO_2/MgO ratio for each grain along with box plots to show the distribution of the SiO_2/MgO ratios.

4.2.2. raw grain samples

Neither sample seems to indicate that there is a correlation between the average aspect ratio and the SiO_2/MgO ratio. Neither type of grain shows a correlation between the aspect ratio and the SiO_2/MgO ratio.

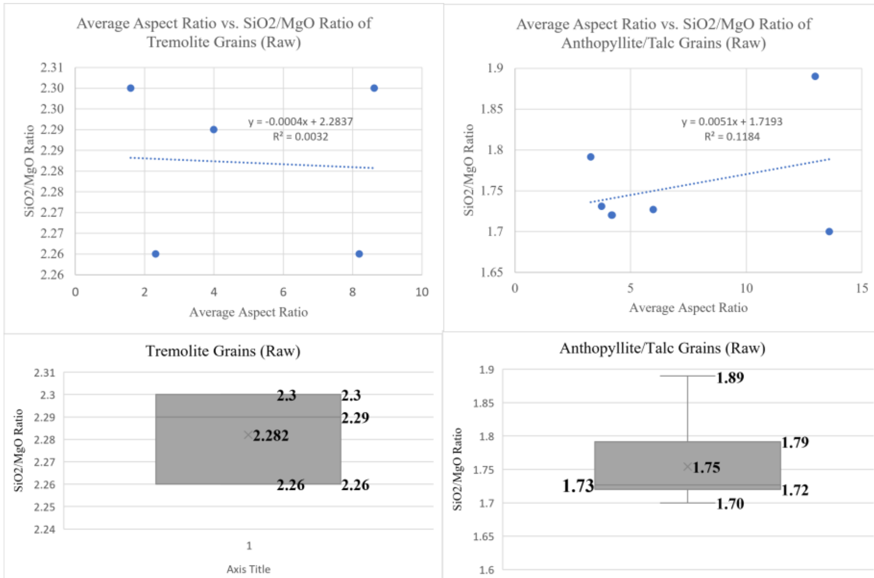

Figure 11. Average aspect ratio versus SiO_2/MgO ratio graphs for the raw grains

Figure 11 relates the average aspect ratio to SiO_2/MgO ratio for each sample consisting only of the raw grains along with a box plots to show the distribution of the average aspect ratios.

4.2.3. processed grain samples

This sample of tremolite grains has the highest R^2 value of the regression lines graphed for average aspect ratio and the SiO_2/MgO, though it is of limited value due to the small sample size. The anthophyllite/talc grains do not have as small of a sample size, but no correlation can be observed in this sample.

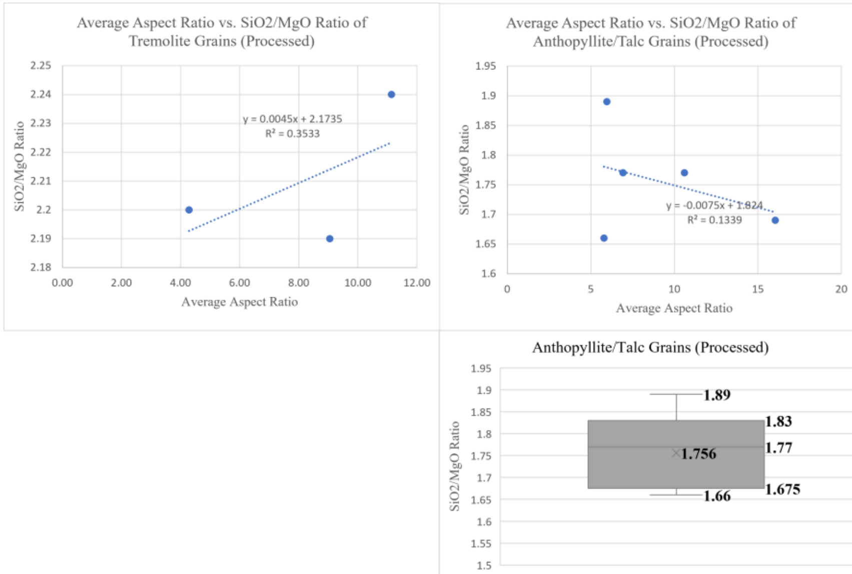

Figure 12. Average aspect ratio versus the SiO2/MgO ratio graphs for the processed grains

Figure 12 the average aspect ratio to SiO_2/MgO ratio for each sample consisting only of the processed grains along with a box plots to show the distribution of the average aspect ratios.

4.2.4. arnold pit grain samples

There was no correlation found for the tremolite grains sourced from Arnold Pit. Most notable for the Arnold Pit samples, the graph for the anthophyllite/talc grain has a significantly higher R^2 value than the other conditions being examined. This value is not high enough to indicate a correlation between the average aspect ratio and the SiO_2/MgO of the anthophyllite/talc grains from Arnold Pit, but it is possible that a higher correlation may be identifiable for raw or processed grains sourced from this location, which would indicate that one of or both treatments could potentially be dependent on their source.

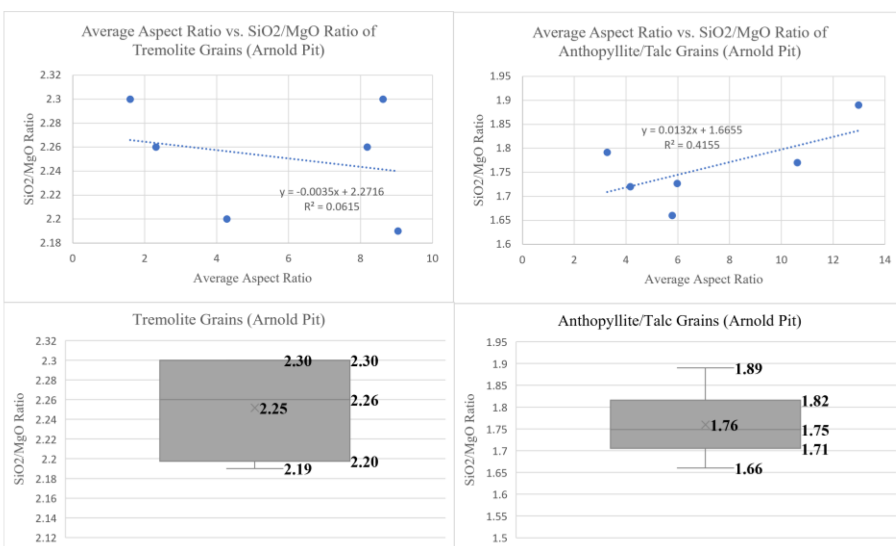

Figure 13. Average aspect ratio versus the SiO2/MgO ratio graphs for grains from Arnold Pit

Figure 13 relates the average aspect ratio to SiO_2/MgO ratio for each sample consisting only of the grains sourced from Arnold Pit along with a box plots to show the distribution of the average aspect ratios.

4.2.5. talcville grain samples

There were only two tremolite grains from Talcville that had the measurements for their composition, so no hypothesis can be made from this plot. While not to the extent to the grains from Arnold Pit, the Talcville anthophyllite/talc grains show a higher R^2 when compared to the samples consisting entirely of raw or processed grains. Likewise, this value is not high enough to suggest that there is a correlation in this sample.

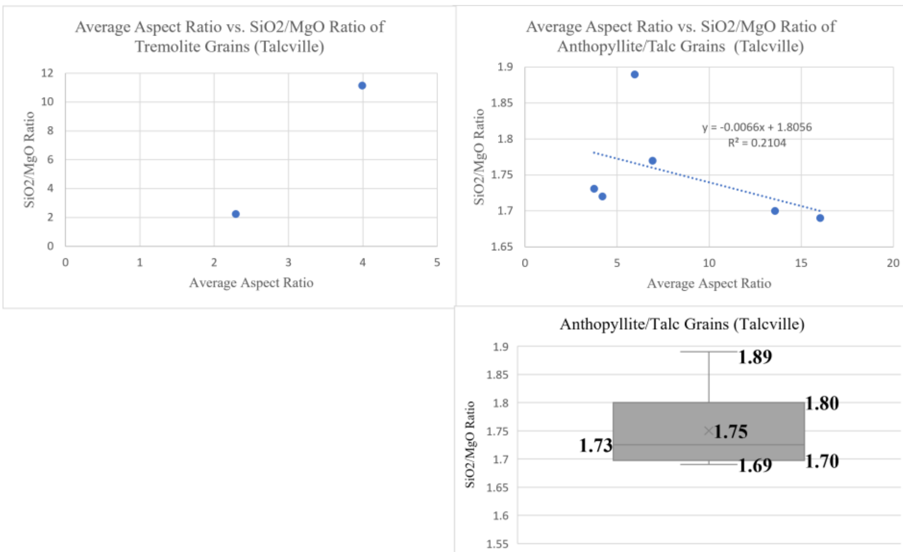

Figure 14. Average aspect ratio versus the SiO_2/MgO ratio graphs for grains from Talcville

Figure 14 relates the average aspect ratio to SiO_2/MgO ratio for each sample consisting only of the grains sourced from Talcville along with a box plots to show the distribution of the average aspect ratios.

5. Conclusions

From observing all the plots, only one showed the possibility for correlation between length and average aspect ratio of the tremolite grains, which was in the raw grains. When plotting the length against the aspect ratios along the lengths of each tremolite grain as well as length against the average aspect ratio, there is a linear correlation in between these two characteristics of the morphology of raw tremolite grains. The R^2 values for most of the graphs, both comparing length to average aspect ratio and average aspect ratio to SiO_2/MgO ratio, were typically very close to zero. Since this is the case for the processed grains, there is a possibility that processing the grains into products removed the possibility of a correlation of these characteristics in the morphology of the tremolite when only considering source. Because there were not any strong enough conclusions, tremolite grains and anthophyllite/talc grains cannot be confirmed to be able to be differentiated based on morphology.

The anthophyllite/talc grains did not show any correlation between the length and the average aspect ratio or between the average aspect ratio and the SiO_2/MgO ratio. There was a significant improvement in the R^2 value for the sample involving the raw grains, but it was not strong enough to indicate that there was a correlation with the data examined. The second highest R^2 value observed, after the raw tremolite grains, was for all the anthophyllite/talc grains sourced from the Arnold Pit mine. This value was not high enough to indicate a correlation, though it appears to be more likely that the grains from Arnold Pit show a correlation between their averaged aspect ratio and their composition than for them to have one showing suggesting a correlating the length of a grain to its average aspect ratio.

If revisited, it is possible that the current results would change if more grains were measured and added to their respective datasets. Some of the samples did not have as many grains being plotted as others, which means that the results of which could significantly change with the addition of even a small number of grains. Most notably, grains sourced from Talcville or that were processed made up a minority of the tremolite data used. The examination of the tremolite grains seems to suggest that the correlation of length and average aspect ratio may be independent of source, so a larger sample size for the raw grains for each mine may be useful for confirming that this is the case. The results for the examination of the selected anthophyllite/talc grains may also benefit from making use of a larger sample for the grains sourced from Arnold Pit so that the sample can further be broken into raw and processed grains from this location. Additionally, since the anthophyllite grains becomes replaced by talc in areas with exposed surface area, it may be useful to identify the effect this has on the morphology of these grains.

6. Acknowledgements

The author would like to thank Dr. Brittani McNamee for acting as the research advisor and for aiding with interpreting the findings and how it affects the topic at hand.

7. References

1. Brittani D. McNamee. and Mickey E. Gunter, "Compositional Analysis and Morphological Relationships of Amphiboles, Talc and Other Minerals Found in the Talc Deposits from the Gouverneur Mining District, New York* (Part 1 of 2)." The Microscope Vol. 61:4 (2013): 147-161.
2. Brittani D. McNamee. and Mickey E. Gunter, "Compositional Analysis and Morphological Relationships of Amphiboles, Talc and Other Minerals Found in the Talc Deposits from the Gouverneur Mining District, New York* (Part 2 of 2)." The Microscope Vol. 62:1 (2014): 3-13.
3. Brittani D. McNamee, "R.T. Vanderbilt talc project complete microprobe data for thin section samples" [Unpublished data]. Department of Environmental Studies, University of North Carolina.
4. Jay L. Devore, *Probability and Statistics for Engineering and the Sciences Sixth Edition* (Thompson Brooks/Cole), 41-42.