

Mineralogical Studies on Medium to High grade Metasedimentary rocks from Mount Mitchell State Park, NC, USA

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Abstract

Mount Mitchell was discovered in 1835 by Dr. Elisha Mitchell from the University of North Carolina. It became a state park in 1916, and after the late 1980's and 1990's, geological files regarding the mountain ceased being updated with new research findings. Although it's known that Mt. Mitchell lies in the Ashe Metamorphic suite which contains Metasedimentary rocks such as schist, gneiss and metagraywacke, updating these geological files on Mt. Mitchell could provide more in-depth information regarding the history of the mountain, especially in regards to how it was formed and what minerals formed during the mountain building events. Updating the information of Mount Mitchell began by going through all the geological files that the park had on site. A brief and general rock report was compiled for initial hand sample observations. At the lab, an assessment of each sample in terms of what minerals are present and their compositions were done by using a Polarized Light Microscope (PLM), Energy Dispersive Spectroscopy (EDS) via Scanning Electron Microscope (SEM) and spindle stage systems. A final extensive rock and mineral report was compiled and compared with existing geological data at Mt. Mitchell State Park. The park's research and displays can be updated to benefit both the park and its visitors. Through the study of these particular minerals and textures, temperature and pressure constraints can be calculated and placed into context with other regional geological events for future research.

Keywords: Mount Mitchell State Park, metamorphic petrology, microscopy

1. Introduction

Mount Mitchell was discovered in 1835 by Dr. Elisha Mitchell from the University of North Carolina. It became a state park in 1916, and after the late 1980's and 1990's, geological files regarding the mountain ceased being updated with new research findings. Although we know that Mt. Mitchell lies in the Ashe Metamorphic suite which contains Metasedimentary rocks such as schist, gneiss and metagraywacke, updating these geological files on Mt. Mitchell could provide more in-depth information regarding the history of the mountain, especially in regards to how it was formed and in light what types of minerals were able to grow due to these mountain building events. In brief, the creation of the Blue Ridge Mountains in which Mt. Mitchell lies within went through three different orogenies or more simply mountain building events. Although the first orogeny, the Grenville orogeny occurred approximately 1.2 billion years ago, these particular rocks do not provide evidence behind this first mountain building event¹. Further North and even to the West, provides the evidence needed to show the Grenville orogeny. After the rifting of Grenville, other mountain building events occurred in cyclic form of converging and rifting apart. The first to occur after the Grenville, was known as the Taconic Orogeny which happened approximately 425-450 million years ago². The Acadian Orogeny followed around 350 million years ago and lastly the Alleghenian Orogeny occurred 260-325

million years ago. The Alleghenian Orogeny is what finally created the Blue Ridge Mountains and finalized the creation of the Appalachian Mountains.

Previous studies confirmed the above mountain building events, within a time range of plus or minus a couple millions of years. However, the studies performed were in surrounding areas from Mt. Mitchell, in Spruce Pine. Spruce Pine, has shown at least two periods of regional metamorphisms that were separated by dike intrusions¹. This would make sense that dike intrusions would occur due to the multiple mountain building events, in which could cause volcanism or the intrusions of magma that is being pushed up during the orogeny. Weiner and Merschat³ considered that the Mt. Mitchell area is of later Precambrian mostly the Ocoee super group known as Grandfather Mountain Formation, in which consists of biotite gneiss, amphibolite. However, the evidence is weak due to the Paleozoic events, which deformed the Precambrian formations. Lastly, one document provided that the rocks exposed at Mt. Mitchell consists of metagraywacke, biotite gneiss, and metasedimentary rocks, and furthermore provide more evidence with the geologic history and formation of the Blue Ridge Mountains⁴. Although the previous studies support rock types, they still don't go into depth of the mineralogy of the area, thus by re-analyzing the rocks can provide more information for future studies and understanding of how certain minerals may form or why they are present.

Through these mountain building events, the crust kept pushing up, reforming, and morphing previous rocks into new types of rocks. Volcanism created igneous rocks and beaches were consolidated into sandstone, and then both were metamorphosed into new rocks, which make up the Ashe Metamorphic Suite. The geological results are similar to the rocks and minerals typically found in the Ashe Metamorphic Suite since Mt. Mitchell lies in the same area. Results also show rocks and minerals characteristic of medium to high heat and pressure. These materials include schist and gneiss, with minerals being a mix of quartz, feldspars, and amphiboles. Preliminary first hand examination of a few samples indicate high heat and pressure minerals such as kyanite and garnet, so one question that arises is what type of garnet was formed during these conditions. In the end, the ultimate goal of this research is to update the geological files on Mount Mitchell and to understand its history in terms of formation and what type of minerals form through these mountain building events. This information is important in determining what kind of events must have occurred to create the necessary high heat and pressures to match the rocks and minerals identified in the geological data. To further help the Mt. Mitchell State Park understand its intrinsic history, this research will be conducted in cooperation with the park staff, with all results made readily available to the park and therefore to its visitors. With the information provided the geological displays in the museum of the park can be updated and made more interactive to excite and educate the visitors to Mt. Mitchell.

2. Methods

The method of approach for updating the information on Mt. Mitchell started with going through all the geological files that the park had on site. Examining the files helped define an understanding of the history of the park in terms of geological studies and to set a foundation for the research. The next step was to collect samples, covering an area from the mountain's semi-base to the summit. Most of the samples were gathered right off of the trails within the park, starting with the Commissary trail and working up to the summit. After collecting samples, a brief and general rock report was compiled. This will help to organize the samples with images of each area of interest for the park's files. In the lab, each sample was prepared as powders, grain mounts and thin sections. Thus far, powders and grain mounts have been most valuable in analyzing the samples in terms of what minerals are present in the rock obtained from Mt. Mitchell. By placing grain mounts, which are sprinkled powders that are then submersed in a selected refractive index liquid, are analyzed by the polarized light microscope (PLM). Observing these optical properties aid in identifying minerals. A spindle stage, constructed per instructions in Dyar and Gunter⁵, which is a paper stage placed on the PLM that has a dial that allows a single grain to be spun around from 0 to 180 degrees while being rotated on the stage on the microscope. When the microscope stage is spun around at a certain spindle angle the mineral can go extinct, which means no light is able to pass through. This in turn will further confirm what type of mineral the grain is. However, this process does not specify exactly what type of mineral species.

With a general idea of what types of minerals are present through the PLM, using carbon coated sprinkle mounts, again obtained from powders, are placed in a Scanning Electron Microscope (SEM) to obtain the minerals' composition. The chemical composition of a mineral is collected by using the attached system in the SEM known as the Energy Dispersion Spectrometer (EDS). The SEM used two detectors known as the Everhart Thornley, which shows the topography of the samples, and the Back Scatter Electron (BSE) detector measures the average atomic weight of the mineral. By using these detectors, it helps to define the different mineral assemblages within the field of view. Thin sections, which are 30 microns thin rock slices from samples that are then epoxied on a glass slide, will

also be placed under the PLM and SEM for similar analysis. Analysis of thin sections include performing mineralogical studies through the PLM and chemical composition by the SEM/EDS. During the method of the SEM, the BSE detector was unable to stay mounted to the pole piece inside the SEM, thus using a manual BSE photometer to provide an image of the section of interest within the thin section. However, switching between the BSE Photometer, and the Everhart Thornley, the chemical analysis of a specific area may have been skewed due to the readjusting of the stage between detector switches. Thus, taking two images both in Everhart and BSE provided a map to where a specific mineral of interest can be analyzed for chemical analysis. Through the analysis of thin sections we are able to further our understanding of the history of the rocks by looking at micro-scale structures. Micro-scale structures include the presence of folding within the thin section, augens, which are typically deformed quartz, feldspars, and garnets in the shape of an eye, and the presence of inclusions in a single mineral. Inclusions are simply other minerals that have been encapsulated inside another larger mineral that grew after the encapsulated mineral.

3. Results and Discussion

As hypothesized, the rock formations found at Mt. Mitchell State Park stayed within the regime of previous studies and of the U.S Geologic map in terms of metasedimentary rocks. The rock types primarily found at Mt. Mitchell were metagraywacke, gneiss, and schist, which are a range of medium to high-grade metamorphic rocks. In addition, the minerals that are typically found in these types of rocks were confirmed as quartz, plagioclase feldspar (Figure 1) garnets, biotite, and muscovite. These types of minerals were documented in previous studies/programs within the park and have been seen in these types of rocks before. Furthermore, kyanite has been reported to be present within the rocks and surrounding areas as well as the possibility of sillimanite. Kyanite, sillimanite, and andalusite are metamorphic minerals and are polymorphs of each other, minerals that have similar chemistries but different crystal structures. Kyanite forms in metamorphic environments of intense pressures and sillimanite forms in metamorphic environments of high temperatures. The possibility of kyanite and sillimanite co-existing in the same rocks constrains the range of the temperature and pressure of the metamorphic environment⁵. Kyanite is a bladed mineral that has a range of color between white/clear, orange, gray or light blue. There was a light blue kyanite blade located right above an outcrop termed Camp Rock, which lies towards the top of the mountain (Figure 2). A few thin sections also contained relatively small blades of kyanite, which has a chemical composition of aluminum, silicon, and oxygen. One grain mount from the Commissary Trail may contain sillimanite, however a chemical analysis of the mineral still needs to be conducted to confirm identification.

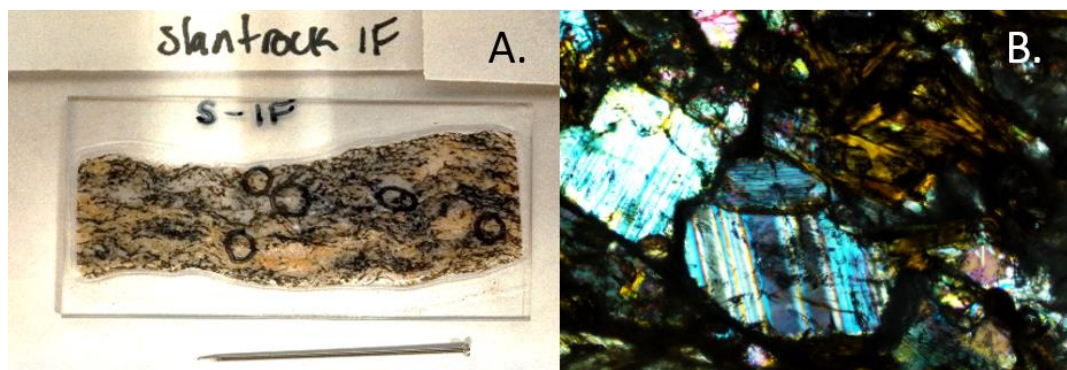


Figure 1. Photographs of the Slant Rock 1F sample.

A.) Photograph of the sample in thin section with a straight pin for scale and B.) Crossed polarized light photograph at 100x magnification, focused on two grains of plagioclase feldspar with twinning.



Figure 2: Kyanite in the Camp Rock Outcrop.

Photograph of a 2-3 inch long kyanite blade with a light blue coloration.

Titanium bearing biotite and non- titanium bearing biotite were present among all the samples, but both occurred within the Slant Rock sample (Figure 3). The substitution of titanium for Fe or Mg in biotite and in metamorphic environments is dependent upon interactions between temperature, pressure, crystal chemistry, and coexisting mineral assemblages⁶. Titanium could have substituted into the biotite during metamorphism from coexisting rutile (Figure 4), a titanium oxide, however there were no rutile crystals observed to be breaking down. The presence of both biotite with and without Ti suggests two different sediment sources for the greywacke protolith. However, note that it is not entirely certain how the Ti substitution mechanism(s) works (Henry and Guiditti, 2002).

Furthermore, we see that rutile may have been encapsulated within a garnet (Figure 5). Note that the thin sections are not quite paper thin, thus the rutile could be overlying the garnet and not actually be encapsulated. Therefore, in order to determine the growth period of both minerals, the thin sections need to be grind down to 30 microns for confirmation. On the other hand, many other minerals have been seen to be included within garnets, predominantly oxides and biotite.

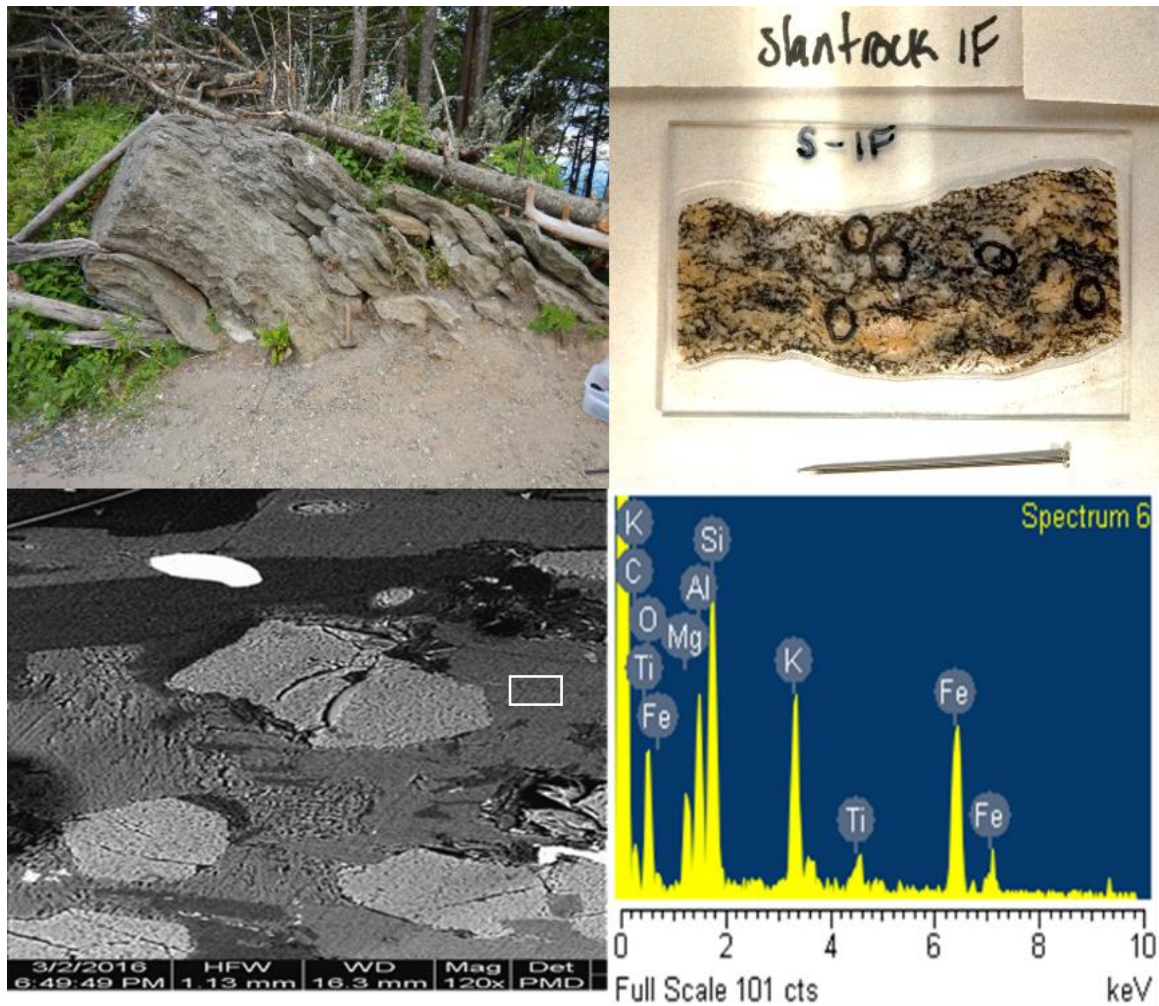


Figure 3. Titanium-rich biotite within Slant Rock 1F sample

A.) Photograph of the outcrop, located towards the summit of Mt. Mitchell, B.) photograph of the sample thin section, C.) BSE image of thin section, with the white box highlighting EDS analysis point on a biotite crystal and D.) EDS spectrum confirming the presence of titanium within the biotite.

The sigma types (or rotation tails) of the garnet were also observed. By finding sigma types, this provides more evidence behind compressional forces, moreover that there were multiple compressional forces to cause the rock to be rotated or compressed and therefore causing the garnets and other minerals to be compressed (Figure 5). These deformed tails and their directions can be used as shear-sense indicators in which can further explain more detail on the direction of the mountain building events previously mentioned^{7,8}. However, further study is needed to inquire the shear-sense indicator in terms of the direction of forces. The inclusions are following the line of rotation of the garnets indicating that the inclusions were present during the growth of the garnet and then the whole garnet with inclusions were then rotated (Figure 5). Thus, garnets are important in the fact that they can preserve a record of their history in the sense of inclusions of other minerals⁷. Another indication of compressional forces is the bending of muscovite sheets with the growth of multiple quartz grains (Figure 4).

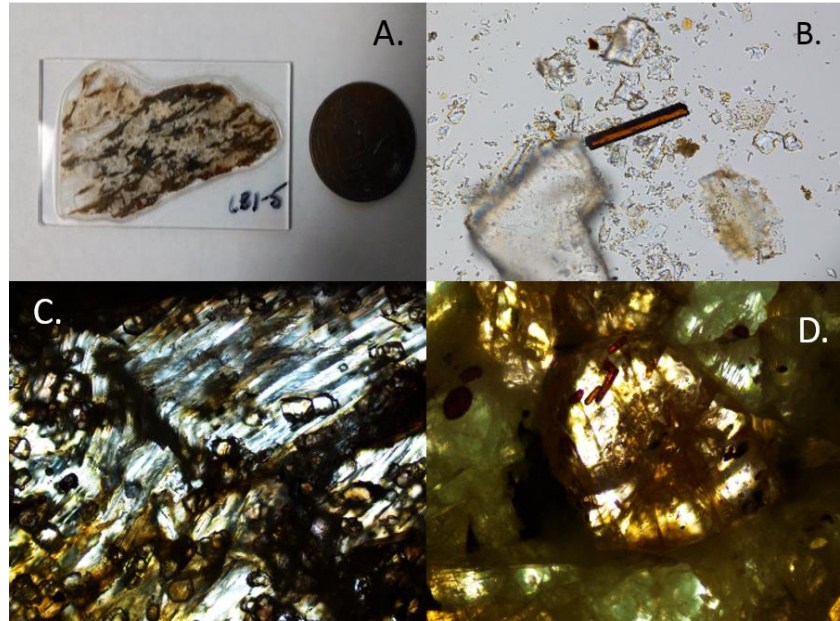


Figure 4. Photographs of LB1-5 sample

A.) Thin section of sample taken from Commissary Trail from within park boundary. B.) Plane- polarized light photograph of sample grain mount, focused on a rutile grain with 100x magnification. C.) Crossed polarized light photograph of the thin section with garnet encapsulating a few rutile grains. D.) Microstructures of folding or compressional forces on muscovite sheets with small quartz grains growing within.

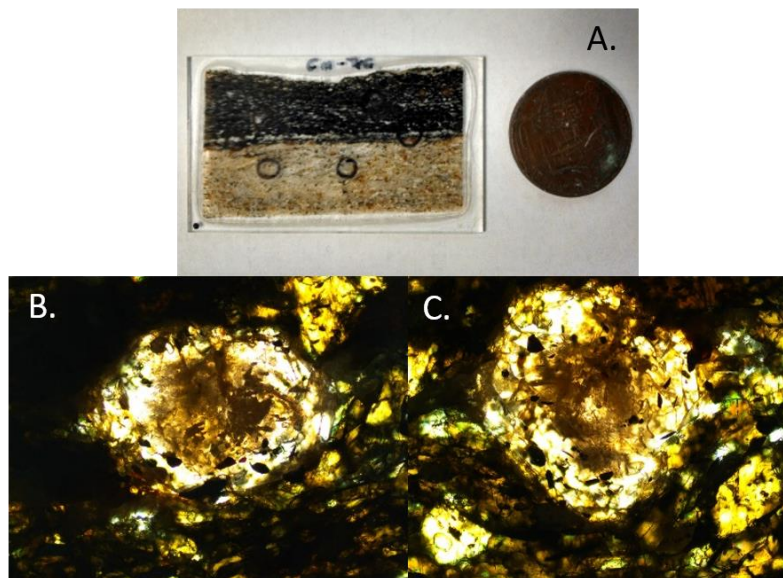


Figure 5. Garnets within Commissary 7C sample.

A.) Photograph of sample thin section collected off of Commissary Trail, B and C.) Plane polarized light photographs showing garnets with biotite or oxide inclusions have been rotated towards the left.

A few other minerals that were seen during the studies, but not found in previous literature, were zircons and monazite. Zircon is a prismatic mineral composed of zirconium, silicon and oxygen. Only through the SEM/EDS the zircons observed (Figure 6). Furthermore, it seemed that at least 5 out of 12 samples had at least one zircon present within the thin section. Similarly, monazite and zircon appear as the same brightness in BSE images due to their average atomic weight. However, monazite is composed of Lanthanum, Neodymium, Thorium, Cerium and Phosphate. Monazite is a rare earth mineral, however it can typically be found in pegmatites, granites or sands. Overall, approximately 4 out of 12 samples contained at least one monazite through the EDS (Figure 7).

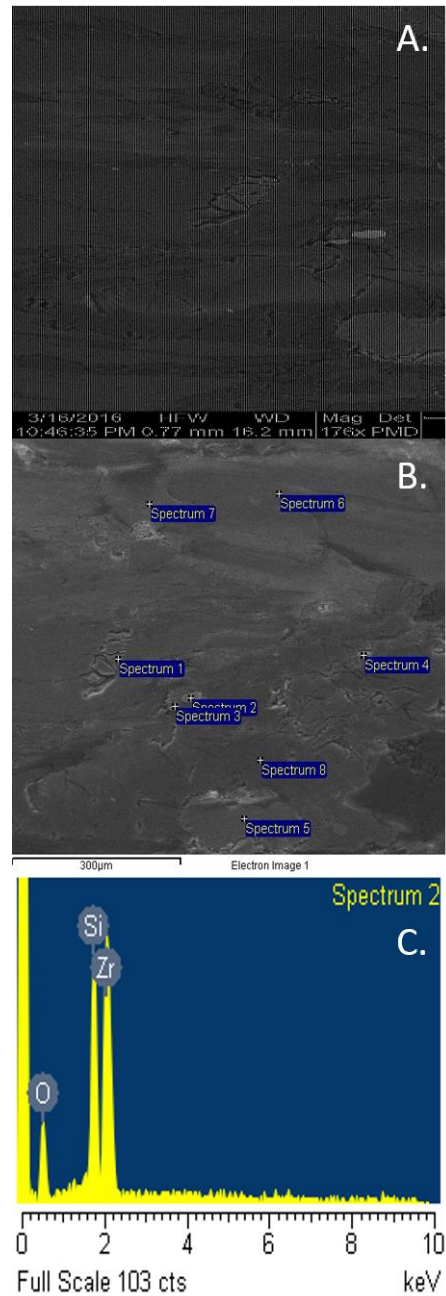


Figure 6. Zircon within Camp Rock sample.

A.) BSE image of a thin section from Camp Rock, B.) SE image of same sample with analysis points marked, and C.) EDS spectrum of analysis point 2 indicating the presence of a zircon.

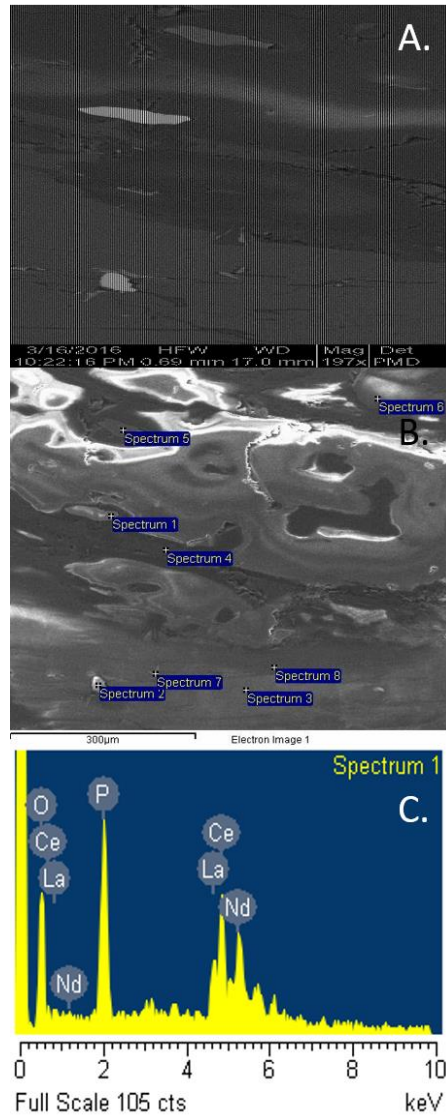


Figure 7. Monazite within Camp Rock sample.

A.) BSE image of a thin section of sample Camp Rock 2-2, B.) SE image of the same field of view, with analysis points marked, and C.) EDS spectrum indicating the presence of monazite.

One last interesting occurrence, was through the BSE image in relation to the EDS analysis of two mineral assemblages having relatively high atomic weights. At first, it seemed that they were two different types of garnet species, however why would the atomic weight count be so much higher/brighter? By calculating the average atomic number for potential minerals, the less bright spot that appears to be a garnet is a pyralspite garnet, while the brighter spot is a mixture of magnesio and ferro- hornblende. This would make sense due to that in the upper right corner there are elongate, classic amphibole morphology, bright spots that appear to correspond to the garnet hornblende assemblage. However, to double check another run of the EDS will be needed to further confirm this idea.

4. Conclusion

Overall, the mineralogy of the metasedimentary rocks remained consistent with previous studies, and what general knowledge is known about the composition of these rocks. However, re-analyzing the rocks at Mt. Mitchell State Park provided new information on these medium to high grade metasedimentary rocks. Titanium rich biotite, rutile, zircons and monazite are all previously undocumented minerals present in these rocks can provide more detail on their formation. Future research therefore can proceed by dating the zircons, calculating temperature and pressure through garnets, and even structural geology by means of directional forces. Thus, by providing more information on Mt. Mitchell the files and displays can be updated to benefit the park's visitors and for future understandings of the Appalachian Mountains.

5. Acknowledgements

I would like to thank Mount Mitchell State Park for allowing me to collect samples and to do research during the three-month period. I would also like to thank The University of North Carolina Asheville for providing the opportunity of research, Undergraduate Research Grant and for to the Department of Environmental Studies for equipment used to complete the research and support.

6. References

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