

A Guide to the Betts Manganese Mine

By Sara J. Powers

ABSTRACT:

This study was performed to help create a guidebook for minerals at the Betts Manganese Mine. Through various methods including scratch tests, streak tests, and acid tests, an assortment of mineral samples were identified. These specimens were used as references to create the guide, which provides an in-depth explanation on how to identify a wide variety of Betts minerals. Although it was hypothesized that the guide would help collectors distinguish any mineral at Betts while in the field, some minerals proved to be too difficult to identify without lab analysis.

INTRODUCTION:

The Betts Manganese Mine, formerly known as the Taconic Mines, is a manganese ore deposit in Plainfield, Massachusetts. Located on the Hawley Mineral Belt, the site is a rich area host to a wide array of minerals. This variety makes the locality exciting for collectors, yet it also makes it difficult to identify different specimens due to the large assortment.

Through various methods involving the optical and physical properties of minerals, a guide can be created to elucidate the differences between certain minerals, allowing even inexperienced eyes to identify any specimen at the Betts Manganese Mine. In most cases, this identification shouldn't require analysis beyond visual cues, or methods including acid testing and streak testing. However, in cases that are difficult to identify, more advanced analytical techniques (such as X-ray fluorescence, X-ray diffraction, or scanning electron microscopy) must be used.

X-ray fluorescence and X-ray diffraction are both testing methods used in labs to determine the chemical makeup of specimens; however, they operate in different ways. X-ray fluorescence, commonly called XRF, reports the ratio of elements (in parts per million) of the specimen. However, it only detects elements heavier than oxygen, which leaves room for ambiguity. X-ray diffraction, commonly called XRD, measures the angles and intensities at which a beam is diffracted through a powder made from the sample being tested. The results of this are recorded as a graph, and compared

with a database of mineral information. Because each mineral species has its own unique graph, the results can be paired with existing data. (Dutrow, Clark 2020) (*See Appendix A*)

Scanning electron microscopy, abbreviated to SEM, is an analytical technique designed to identify and characterize mineral samples. A beam of high-energy electrons is focused on the sample, and the resulting reactions between the electrons and sample reveal information about the specimen. This information can help determine the chemical makeup of the sample (Swap 2021).

This write-up is meant to serve as a guidebook for collectors who visit Betts. Rather than making assumptions and potentially mis-identifying minerals, collectors will be able to reference a comprehensive list of the most commonly collected Betts minerals with descriptions.

GEOLOGICAL SETTING:

The Betts Mine is located in Plainfield, Massachusetts, close to the bordering town of West Cummington. This area is considered part of the Hawley formation, an Ordovician-age body of rock that comprises the eastern side of the Berkshire mountains (Jordan, Cernak, Richardson 2019). It consists of deformed shales, graywackes, and volcanic rocks that have undergone repeated metamorphism over time. The relatively consistent regional schistosity dips steeply and trends north-northeast, yet the multiple stages of deformation have caused some variation (Hickmott 1982). Hickmott's

studies have shown that the area has experienced two periods of metamorphism, and two stages of deformation.

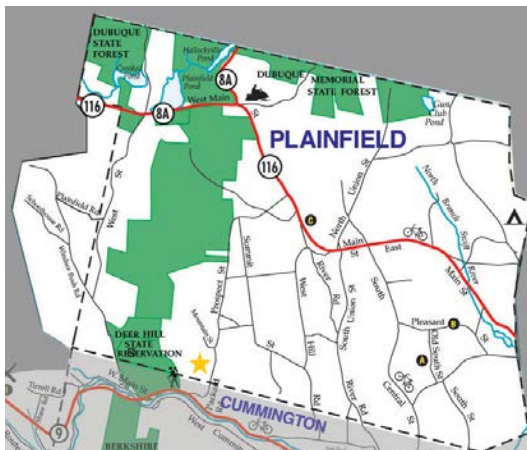


Figure 1: Map overview of Plainfield and the northern border of Cummington. The Betts Mine is located directly above the Cummington line, and is marked by a yellow star on the map.

According to Hickmott, the Hawley Formation is comprised of plagioclase-hornblende-chlorite-epidote-ankerite amphibolite, which is interlayered with quartz-muscovite-biotite-garnet-chlorite phyllite. Some of its primary minerals include amphibole, epidote, ankerite, quartz, chlorite, and oligoclase. Alongside these main minerals: garnet, biotite, muscovite, and magnetite are prevalent. Rutile and pyrite are considered “accessory” minerals, meaning they occur in relatively small quantities (Quinn 1945).

The Betts Mine itself is a “stratabound massive sulfides deposit” (Hickmott 1983) which sits on the Hawley Mineral Belt. The ore zone consists of manganese-rich boulders (Hickmott), likely with much of the manganese deposit yet to be uncovered. Extraction of the low-grade manganese carbonate ore began in 1848, peaking in the early 1940s under supervision of Anson G. Betts (Jordan et al. 2019).

In 1943, the United States Bureau of Mines drilled a total of four holes to retrieve core samples from the area. (Franks 1953). The first and second holes were drilled near the

North pit, while the third and fourth were drilled near the South pit. (*See Appendix B for drill hole map and core sample*)

A brief analysis of each drill hole is as follows:

1. Hole 1 faced northwest, at an inclination of 40°. Samples taken from 224 to 264 feet deep on the incline averaged at 0.58% Mn, 7.66% Fe, and 60.87% insoluble.
2. Hole 2 faced southwest, at an inclination of 45°. Samples taken from 157 to 183 feet on the incline averaged at 7.43% Mn, 7.7% Fe, and 30.6% insoluble.
3. Hole 3 faced northwest, at an inclination of 40°. Samples taken over a length of 140 feet on the incline averaged at 9.9% Mn, 5.3% Fe, and 54.7% insoluble.
4. Hole 4 faced northwest, at an inclination of 70°. However, the inclination deflected through schist and resulted at an angle of 53°. Samples taken from 123-125 feet deep on the incline averaged at 8.08% Mn, 4.47% Fe, and 63.3% insoluble. More samples taken at a 150 feet vertical depth averaged at 9.0% Mn, 9.5% Fe, and 52% insoluble.

(McHenry 1949)

Today, the collection sites consist of the mine dumps from when the mine was active; based on location and differing mineral varieties, the Betts Mine has been split into four alphabetically-labelled “zones” A-D.

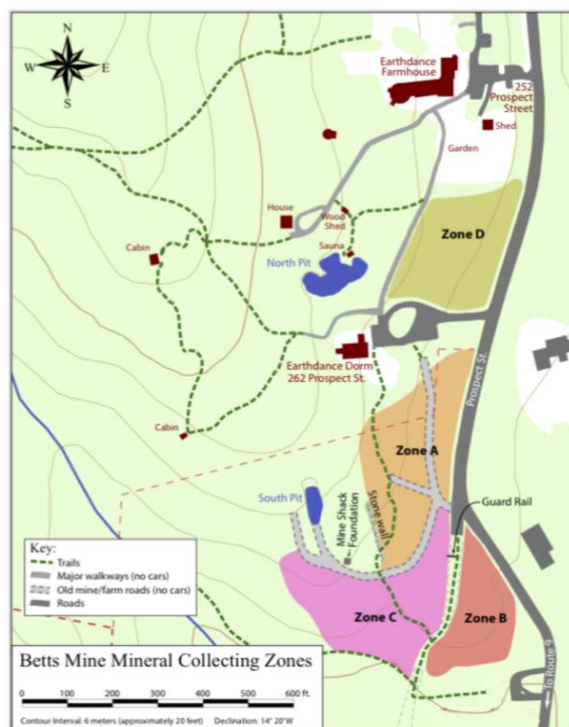


Figure 2: Map overview of the Betts Mine © Earthdance Minerals

The locality also contains two quarry pits. The North Quarry Pit is located closer to the farmhouse, which is now on Earthdance property. It has been depleted of commercially-suitable ore, and is now filled with water which can exceed 20 feet in depth. The South Quarry Pit is within the collecting zone, but is also off-limits to collectors. Like the North pit, it is also filled with water, which can exceed 10 feet in depth.



South Quarry Pit (left) and North Quarry Pit (right) © Rick Cernak

MINERALS:

A field guide to the most commonly-collected minerals at the Betts mine is as follows. The minerals are categorized by the major mineral groups, and are otherwise in alphabetical order.

CARBONATES:

Calcite -- CaCO_3 (Carbonate)

Calcite has recently been confirmed to be at Betts, using cold acid tests. It is found in massive form, with a vitreous, resinous, or waxy luster. At Betts it is typically white, and is found alongside other minerals, especially rhodochrosite. Calcite has a hardness of 3 on the Mohs scale, and a white streak. It also fizzes in cold acid, being an especially soft carbonate. (See methods section for more information regarding acid testing.)



Betts Mine calcite © Rick Cernak

Kutnohorite -- $\text{CaMn}^{2+}(\text{CO}_3)_2$ (Carbonate)

Kutnohorite is a very common carbonate at Betts, and is often found alongside other manganese minerals. It appears white, light pink, or beige, and is found in massive form. It has a white streak, and a hardness of 3.5-4 on the Mohs scale. Its luster is sub-vitreous or resinous.

In previous studies performed by Alonzo Quinn, kutnohorite was believed to be

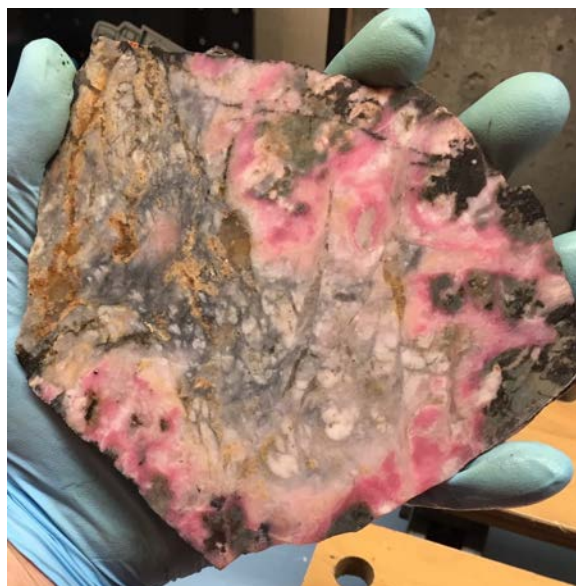
another endmember of the dolomite group, ankerite (Hickmott 1982).



Betts Mine kutnohorite (beige)

Rhodochrosite -- $MnCO_3$ (Carbonate)

Rhodochrosite, like rhodonite, is a manganese ore. It is found by breaking open the black oxide-covered rocks that are on the ground, and will likely be found in the same specimen as other manganese minerals. It appears pale to deep pink or red, making it easily confusable with rhodonite. It has a vitreous luster, and appears more red when there is less iron present. When looking through a microscope or loupe, rhodochrosite crystal faces will appear platey. Being a carbonate mineral, rhodochrosite will fizz in warm muriatic acid.



Betts Mine rhodochrosite, polished (pink) © Rick Cernak



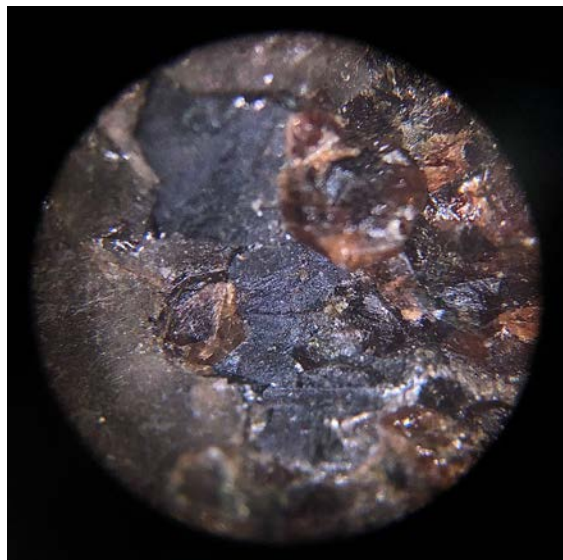
Betts Mine Rhodochrosite, magnified © Rick Cernak

OXIDES:

Ilmenite -- $FeTiO_3$ (Oxide)

Small crystals of ilmenite are relatively common among quartz-embedded spessartine garnets. They appear as very small, metallic black crystals that may be confused with rutile when viewed at certain angles. However, while they can be similarly-colored and found in the

same place, rutile crystals will be striated, while ilmenite crystals will not. Ilmenite scores a 5-6 on the Mohs Scale, and has a black streak.



Betts Mine ilmenite alongside spessartine garnets, magnified

Jacobsite -- $Mn^{2+}Fe^{3+}_2O_4$ (Oxide)

Jacobsite, similar in appearance to arsenopyrite, can also be found at Betts. These metallic black crystals are octahedral as well, and have a hardness of 5.5-6.5 with a reddish black streak. In addition to streak, a good way to differentiate from arsenopyrite is using magnets. Jacobsite is weakly magnetic.

Magnetite -- Fe_3O_4 (Oxide)

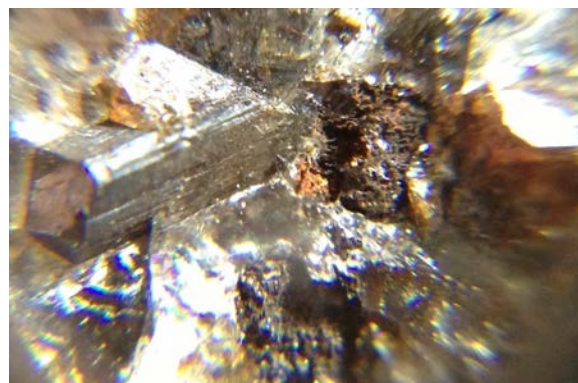
Certain rhodonite specimens can be marbled with magnetite. It can easily be mistaken with the black manganese oxide that forms on rhodonite, as they look similar. Magnetite has a metallic luster, a hardness of 5.5-6.5, and a black streak, but the easiest way to determine its presence in a rhodonite sample is using magnets. As the name suggests, magnetite is magnetic, and rhodonite specimens containing the mineral will be weakly to strongly magnetic as well.



Betts Mine rhodonite with black magnetite mottling (note the magnet in the center) © Rick Cernak

Rutile -- TiO_2 (Oxide)

Rutile is a rare mineral at Betts, so far only found in certain rocks around Zone D. It has been found among spessartine garnets, and looks like a small, striated, tube-like crystal. It is mainly tinted dark brown at Betts, but can appear reddish or black as well. Rutile has an adamantine or metallic luster and a hardness of 6-6.5 on the Mohs scale. Its streak can appear Greyish black, pale brown, or light yellow.



Betts Mine rutile, magnified © Rick Cernak

Hematite -- Fe_2O_3 (Oxide)

Hematite is often found as a coating on other minerals. Most often it is seen on pyrite, giving the cubes a reddish tint. In massive form which is less common at Betts, it can appear blackish. A clear indicator of hematite is its deep

red streak. It has metallic luster, and a hardness of 5.5-6.5.

PHOSPHATES:

Fluorapatite -- $\text{Ca}_5(\text{PO}_4)_3\text{F}$ (Phosphate)

Fluorapatite is the fluorine-rich endmember of the apatite group, and can be found within carbonate at Betts. It is primarily grayish or slightly green, and has a resinous luster. It has a white streak, and scores a 5 on the Mohs scale. The apatite at the Betts mine is difficult to identify without shortwave fluorescent light. It will fluoresce yellow.

SILICATES:

Almandine Garnet -- $\text{Fe}_3\text{Al}_2\text{Si}_3\text{O}_{12}$ (Silicate)

Almandine garnets are another easy mineral to identify. They form a solid-solution series with spessartine garnets, and are the iron-rich endmember of this series. They are found all around the mine, but appear most often in Zone D, and Zone A's "metallics pit," a small mine dump towards the eastern side of Zone A. Like all garnets, they typically have a dodecahedral crystal habit, but often have a trapezohedron habit as well. These iron-aluminum garnets can appear deep red, maroon, or black. They commonly form along contact lines between schist and quartz, and look like small, round crystals.

In the metallics pit, excess iron can cause garnets to form in "rust balls," making it difficult to tell if they are garnets at all. Rubbing off the rust on a rust ball with a brush or gloved hand may reveal high-quality garnets underneath. These "rust-ball" garnets are likely a mix of the solid-solution series containing almandine and spessartine garnets, meaning they may share qualities of both garnet varieties. For reference in streak and scratch tests, almandine garnets have a white streak, and score a 7.5-8.5 on the Mohs scale.



Betts Mine almandine garnets © Rick Cernak

Chlorite --

$(\text{Mg},\text{Fe})_3(\text{Si},\text{Al})_4\text{O}_{10}(\text{OH})_2 \cdot (\text{Mg},\text{Fe})_3(\text{OH})_6$
(Silicate)

Chlorite can be found in the greenish chlorite schist that is throughout the mine. It is a deep greenish-gray, with a vitreous, almost metallic shimmery luster. It has a hardness of 2-2.5 on the Mohs scale, and a pale green to gray streak.

Cummingtonite --

$(\text{Mg},\text{Fe}_{2+})_2(\text{Mg},\text{Fe}_{2+})_5\text{Si}_8\text{O}_{22}(\text{OH})_2$ (Silicate)

Cummingtonite is rare at Betts, but has been found with quartz and spessartine before. It has a unique structure, which looks bladelike or fanlike. It can appear dark green, brown, gray, or colorless, and has a vitreous luster. It has a hardness of 5-6 on the Mohs scale, and a gray or white streak. Recent EDS (energy-dispersive X-ray spectroscopy) lab tests have revealed that cummingtonite found here can be the mineral grunerite, which contains more iron than the cummingtonite of Dewey.



Betts Mine cummingtonite © Rick Cernak

Grunerite -- $Fe_7Si_8O_{22}(OH)_2$ (Silicate)

Grunerite has been found at Betts, and is often mistaken for cummingtonite. It is the iron-rich endmember of the grunerite-cummingtonite series. It can appear brownish, greenish, or gray, with a vitreous to silky luster. It scores a 5-6 on the Mohs scale, and has a colorless streak. Because of its similarity to cummingtonite, lab testing may be required to differentiate between the two.



Betts Mine grunerite (golden-brown) © 2018 Peter Cristofono

Gypsum -- $CaSO_4 \cdot 2H_2O$ (Silicate)

Gypsum is rare at Betts, typically forming as a “crust” on top of other minerals. Small fully formed crystals have been found on the interior of freshly broken rocks, and occasionally on the exterior black oxide coatings on rocks. These crystals are usually yellowish,

white, or clear, have a vitreous luster, and appear rhombohedral or diamond-shaped. Gypsum has a hardness of 2 on the Mohs scale, and a white streak.



Betts Mine gypsum © Rick Cernak

Muscovite -- $KAl_2(AlSi_3O_{10})(OH)_2$ (Silicate)

Muscovite, also known as common mica, can be found in certain areas at Betts. It has been found in Zone A and B, indicating it may have originated in the North Quarry Pit. Often, it is found alongside deformed almandine garnets, rather than perfectly euhedral garnets. It is typically silvery or clear, and appears in muscovite's typical sheetlike form. On its surface, it has a hardness of 2-2.5 on the Mohs scale. Its streak is white, and it has a vitreous, silky, or pearly luster.



Betts Mine muscovite

Rhodonite -- $CaMn_3Mn[Si_5O_{15}]$ (Silicate)

The Betts Mine is famous for its rhodonite, being one of the locality's most abundant minerals. Like the other manganese minerals at Betts, it is found in the black rocks that are seen throughout the mine. Due to

environmental conditions, a crust of black manganese oxide tends to form over most manganese-bearing rocks at Betts. This makes it difficult to discern which rocks contain rhodonite, and which do not. One way to determine this is to check the weight of the rock---a heavy rock is a good indicator that rhodonite is inside.

Rhodonite is typically pink, but at Betts it can appear reddish, purplish, brownish, or gray. In crystal form, it has a thick tabular structure, but at Betts it is most often found in massive form. It has a vitreous luster, which can appear pearly on cleavage. Its streak is white, and its hardness is 5.5-6.5 on the Mohs scale.

Rhodonite is the calcium-rich endmember of the rhodonite group, which contains iron-rich ferrorhodonite and manganese-rich vittinkiite as well. Any sample of rhodonite will contain varying levels of manganese, calcium, and iron, due to the rhodonite group's endmembers containing these elements. (*See conclusion for more information regarding the recent discovery of vittinkiite.*)

It can easily be confused with rhodochrosite, which is commonly pink as well. Looking at the mineral's structure through a loupe or microscope may help distinguish between the two. At Betts, rhodonite grains appear "comb-like," with longer, "finger-like" crystal faces reaching out. In rhodochrosite, the crystal faces will appear platey. If you're still unsure, performing acid tests at home will help identify the mineral. Rhodochrosite, being a carbonate mineral, will fizz in warm muriatic acid, whereas rhodonite---a silicate mineral---will not.



Betts Mine rhodonite © Rick Cernak

Quartz -- SiO_2 (Silicate)

Quartz is a ubiquitous mineral at Betts, found in veins throughout every zone. It has a vitreous luster, but can appear waxy or dull especially in the massive form found at Betts. It is typically colorless or a milky white, and can be found in both boulders and the smaller, oxide-covered rocks on the ground. It usually is found in the same specimen as various other minerals. It has a white streak, and a hardness of 7 on the Mohs scale.



Betts Mine quartz

Spessartine Garnet -- $Mn_3Al_2(SiO_4)_3$ (Silicate)

Spessartine garnets are another variety of garnet found at Betts. They form a solid-solution series with almandine garnets, and are the manganese-rich endmember of this series. They are frequently found within rocks in and around Zone D. Like all garnets, they typically have a dodecahedral crystal habit, but often have a trapezohedron or hexoctahedral habit as well. These manganese-aluminum garnets can appear reddish, orange, or brown. They commonly form along contact lines between schist and quartz, and look like small, round crystals. For reference in streak and scratch tests, spessartine garnets have a white streak, and score a 6.5-7.5 on the Mohs scale.

In the metallics pit, excess iron can cause “rust balls” to form around the garnets, making it difficult to tell if they are garnets at all. Rubbing off the rust on a rust ball with a brush or gloved hand may reveal high-quality garnets underneath. These “rust-ball” garnets are likely a mix of the solid-solution series containing almandine and spessartine garnets, meaning they may share qualities of both garnet varieties.

These garnets are not to be confused with massive spessartine, which is dull brick-red and found in rocks throughout the mine.



Betts Mine garnets in the almandine-spessartine series © Rick Cernak

Tephroite -- Mn_2SiO_4 (Silicate)

Tephroite is a common manganese silicate at the Betts Mine, often found mixed with other manganese minerals. It has been difficult to identify in the past, but appears in massive form, typically brown or grayish-green. It has a greasy luster, and a similar texture to the rhodonite found at Betts. It has a pale gray streak, and scores a 6 on the Mohs hardness scale.



Betts Mine tephroite (grayish-brown) alongside rhodonite (pink).
© Rick Cernak

(See Appendix B for information regarding the testing of this specimen. The areas tested are indicated by the blue and silver tweezers)

SULFIDES:

Arsenopyrite -- $FeAsS$ (Sulfide)

Arsenopyrite can be found alongside carbonate-rich ore at Betts (Hickmott et al. 1983), appearing as silvery micro-sized crystals. These crystals have an octahedral structure that can be seen more clearly under a loupe. Arsenopyrite has a metallic luster, similar to the other sulfides at Betts. Its hardness is 5.5-6 on the Mohs scale, and its streak is black.

Chalcopyrite -- $CuFeS_2$ (Sulfide)

Chalcopyrite is commonly found alongside other sulfides. It can appear similar to pyrite, but it forms scalenohedral crystals rather than cubic crystals. Like pyrite, it is metallic

brassy yellow and has a greenish-black streak. However, it is much softer than pyrite, scoring a hardness of 3.5 on the Mohs scale.



Betts Mine chalcopyrite (brassy), polished

Marcasite -- FeS_2 (Sulfide)

Marcasite is found alongside other sulfides at Betts. It has the same chemical formula as pyrite, but while pyrite has a cubic crystal structure, marcasite has an orthorhombic structure. It is also less dense than pyrite, and more brittle. Marcasite is metallic and has a silvery or brassy color. It has a hardness of 6-6.5, and a dark gray or black streak.

Molybdenite -- MoS_2 (Sulfide)

Molybdenite may be found with quartz and spessartine, as well as other sulfides. It is metallic and can appear black or silvery-gray, and has a blueish-gray streak. It is a very soft mineral, scoring a 1-1.5 on the Mohs scale.

Pyrite -- FeS_2 (Sulfide)

Pyrite is one of the more easily-identifiable minerals at Betts. It is a sulfide mineral typically found in Zone A, in the schist surrounding the outer edges of the South Quarry Pit. Pyrite forms as metallic cubes within the schist; it is typically colored gold, but often appears coppery at Betts. When looking for schist that may contain pyrite, a telltale sign is

yellow staining on the exterior of the rock. This yellow staining may be accompanied by small cubic holes in the rock, remnants of pyrite that had disintegrated over time. Pyrite found in this schist should be easy to identify based on visual cues, but if there's any confusion, scratch and streak tests should help. Pyrite is a 6-6.5 on the Mohs scale, and it has a greenish-black to brownish-black streak.



Betts Mine pyrite © Rick Cernak

Pyrrhotite -- $Fe_{1-x}S$ (Sulfide)

Pyrrhotite is found all throughout the mine, often alongside other sulfides. It has a metallic luster, a dark grayish black streak, and hardness of 3.5-4 on the Mohs scale. It is highly reflective, and can appear silver or a brassy color similar to pyrite. When first exposed, it often appears iridescent.



Highly reflective Betts Mine pyrrhotite that appears green from the reflections © Rick Cernak



Iridescent Betts Mine pyrrhotite © Rick Cernak

METHODOLOGY:

Throughout the study of the mineral suite, we used various techniques and tools to determine the characteristics of mineral samples. The optical, physical, and chemical properties of these samples were taken into account when being tested. The methods used to identify these samples are as follows:

1. Scratch tests
2. Streak tests
3. Acid tests

While the aforementioned methods detail the scientific tests we performed, the obvious visual properties of these samples were

taken into account as well (i.e. color, luster, cleavage planes, etc.). Some samples were tested with XRF analysis, but this data was primarily used as a reference point.

Scratch tests

Scratch tests are performed to determine a sample's hardness according to the Mohs Scale. The Mohs scale runs from 1-10, and indicates a mineral's resistance to being scratched by harder materials. Each mineral has a characteristic hardness. In this test, we used a metal dental pick and 7 minerals that aligned with the range of mineral hardness found at Betts. The range of minerals is as follows:

- A. Gypsum (hardness of 2)
- B. Calcite (hardness of 3)
- C. Fluorite (hardness of 4)
- D. Apatite (hardness of 5)
- E. Feldspar (hardness of 6)
- F. Quartz (hardness of 7)
- G. Topaz (hardness of 8)
- H. Corundum (hardness of 9)

When testing the mineral suite, each sample was initially scratched with a metal dental pick, which has a hardness of 5.5. If the sample was scratched by the pick, it would then be tested with softer reference minerals, until it was no longer being scratched. Conversely, if the sample was not scratched by the pick, it would be tested with harder reference minerals until it became scratched. For example, if the sample was scratched by the dental pick and the apatite, but not the fluorite, its hardness would lie in the 4-5 range. These measurements were a solid indicator of which samples were carbonates (which typically have lower hardness levels) and which samples were silicates (which typically have higher hardness levels).

Streak tests

Streak tests are used to determine a mineral's color in powdered form, also known as its streak. Due to impurities, a mineral specimen

can appear as a variation of colors. However, when a streak is produced, the specimen is broken into microscopic pieces. Since the impurities become microscopic as well, they no longer affect the color of the streak. This is why streak tests are useful; they are more consistent than a specimen's apparent color.

In streak tests, a specimen is dragged across a surface known as a "streak plate." The streak plate is typically made of unglazed porcelain, but many flat surfaces will work, provided they are harder than the minerals being tested. After the sample has been dragged to reveal its streak, the color of the streak is recorded and compared with the known streak of other minerals at Betts. However, since most silicates and the carbonate rhodochrosite have white streaks, it was difficult to make any judgements using streak tests alone.

Acid Tests

Acid tests are especially useful in determining whether or not a mineral is a carbonate. At Betts, a good way to discern between rhodonite and rhodochrosite is to perform an acid test using warm acid; rhodochrosite will fizz, but rhodonite will not. By altering the temperature of the acid solution, acid tests can be used to distinguish between specific carbonates; while rhodochrosite will fizz in warm acid, calcite will fizz even in cold or ambient-temperature acid.

Acid tests rely on a reaction that occurs between the carbonate and the acid, which results in the precipitation of a salt, the formation of water, and the release of carbon dioxide gas. The release of this gas causes bubbles to form; this "fizzing" is a telltale sign of a carbonate.

To perform acid tests, we began by breaking off dime-sized samples from specimens we wanted to test. We weighed these samples, and recorded their weights. Then, we placed them inside of a plastic ice cube tray, recording

which samples were in each cell. Using a small dropper bottle and wearing safety goggles and gloves, we added 20% hydrochloric acid to each cell, enough so that each sample was covered. When diluting acid at home, be sure never to add water to acid, only add acid to water. This will prevent harmful chemical reactions from occurring. We then recorded which samples fizzed at ambient temperature (likely calcite samples), and took pictures. Then, we heated a pot of water to nearly boiling, poured a small amount in a flat tray to approximately 1 cm maximum depth, and placed the ice cube tray in this shallow bath of hot water at a minimum temperature of 140°F. We recorded which samples fizzed when heated, and took pictures. Once the samples were done fizzing, we gently removed them from the cells, and rinsed each sample to observe the effects under a microscope. This process can be repeated one to two times, depending on how long it takes for the samples to cease fizzing.



Warm acid test setup

CONCLUSION:

This study has shown that while a good portion of Betts minerals can be identified in the field, many require lab analysis. Because of this, it was infeasible to make an entirely comprehensive guide to all Betts minerals; instead, field-identifiable minerals became the focal point of the project. The different testing

methods that were used had varying degrees of helpfulness. Some methods worked better with certain types of minerals, but were impractical with others.

Scratch tests, for example, enabled us to distinguish between softer minerals (which were more likely to be carbonates) and harder minerals (which were more likely to be silicates.) However, it was less useful when trying to identify specific minerals, since many of the Betts minerals have similar hardness. For example, rhodochrosite and kutnohorite both score a 3.5-4, a range that comprised the majority of the scratch test results.

Streak tests were only helpful in certain situations, since it is very common for minerals to have a white streak. Most minerals that have a streak other than white can be identified more easily by other means (for example, magnetite has a black streak which sets it apart, but it is easier to identify magnetite by using a magnet).

Acid tests were instrumental in identifying different minerals. Not only did they indicate which minerals were carbonates, they allowed us to easily distinguish between different carbonate minerals as well. For example, if there was confusion between rhodochrosite and calcite, the temperature at which each specimen reacted eliminated that confusion; while rhodochrosite would fizz only in warm muriatic acid, calcite would fizz at ambient temperature. Acid testing also enabled us to isolate silicates; since there were no carbonates left over after the reaction, we were able to examine pure silicates without wondering if there was any carbonate mixed in with the samples.

Although the different methods may not have been enough to identify minerals on their own, combined, they provided a solid foundation on which to base our conclusions. However, to ensure the accuracy of this guidebook, both XRF and SEM analysis were used. While we recognize that these methods are

unrealistic for the typical field collector, they were necessary in correctly identifying some minerals. Tephroite in particular was difficult to specify, since there weren't many previous references at Betts to examine. However, it was verified using SEM analysis. (*See Appendix C*)

Through our XRF data, we discovered that every rhodonite specimen we tested contained a substantial amount of calcium. This aligns with the recently revised chemical formula for rhodonite. Previously, it was believed to be MnCO_3 ; however, it was determined that the formula $\text{CaMn}_3\text{Mn}[\text{Si}_5\text{O}_{15}]$ is more accurate, since rhodonite is now considered the calcium-rich endmember of the rhodonite group. This group has two other endmembers: iron-rich ferromanganoite ($\text{CaMn}_3\text{Fe}[\text{Si}_5\text{O}_{15}]$), and the recently discovered manganese-rich vittinkiite ($\text{MnMn}_3\text{Mn}[\text{Si}_5\text{O}_{15}]$). The outdated formula is comparable to vittinkiite's formula, as it contains only manganese and silicate. (Shchipalkina et al. 2019)

Even with the use of lab testing, some minerals have yet to be confirmed by this study. Although listed on Hickmott's mineral list under relatively common presence at Betts (Hickmott et al. 1983), we have been unable to identify barite, sonolite, and neotocite. Furthermore, due to their rarity, many minerals that appear in trace amounts at Betts were not confirmed in this study. Nevertheless, the majority of commonly-collected Betts minerals were identified and accurately described in this guidebook.

Ultimately, although this guidebook does not contain every mineral that has been confirmed at Betts, it will serve as a solid introduction to mineral collecting at the Betts Manganese Mine.

APPENDIX A

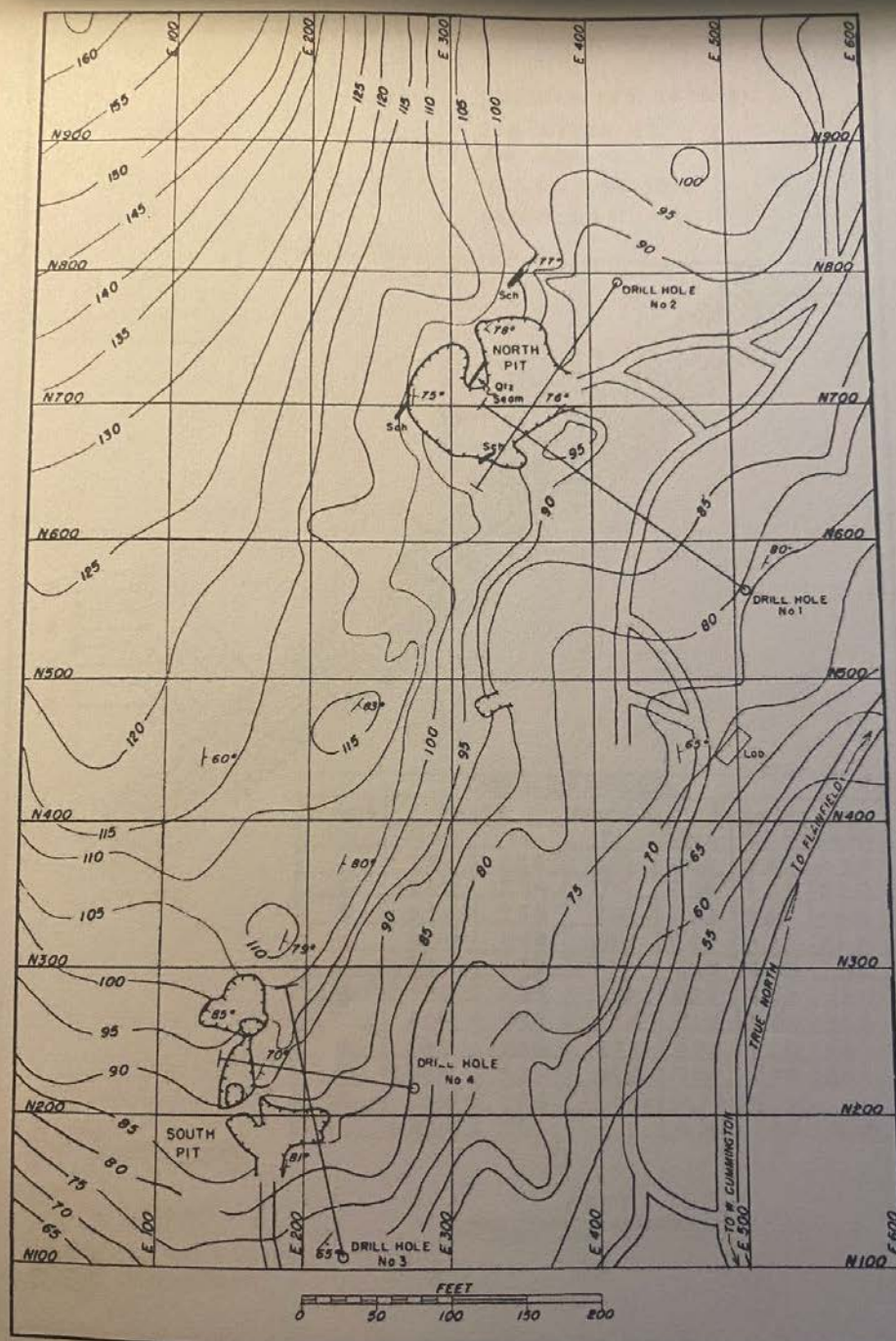


Figure 2. - Betts manganese mine, West Cummington, Mass.

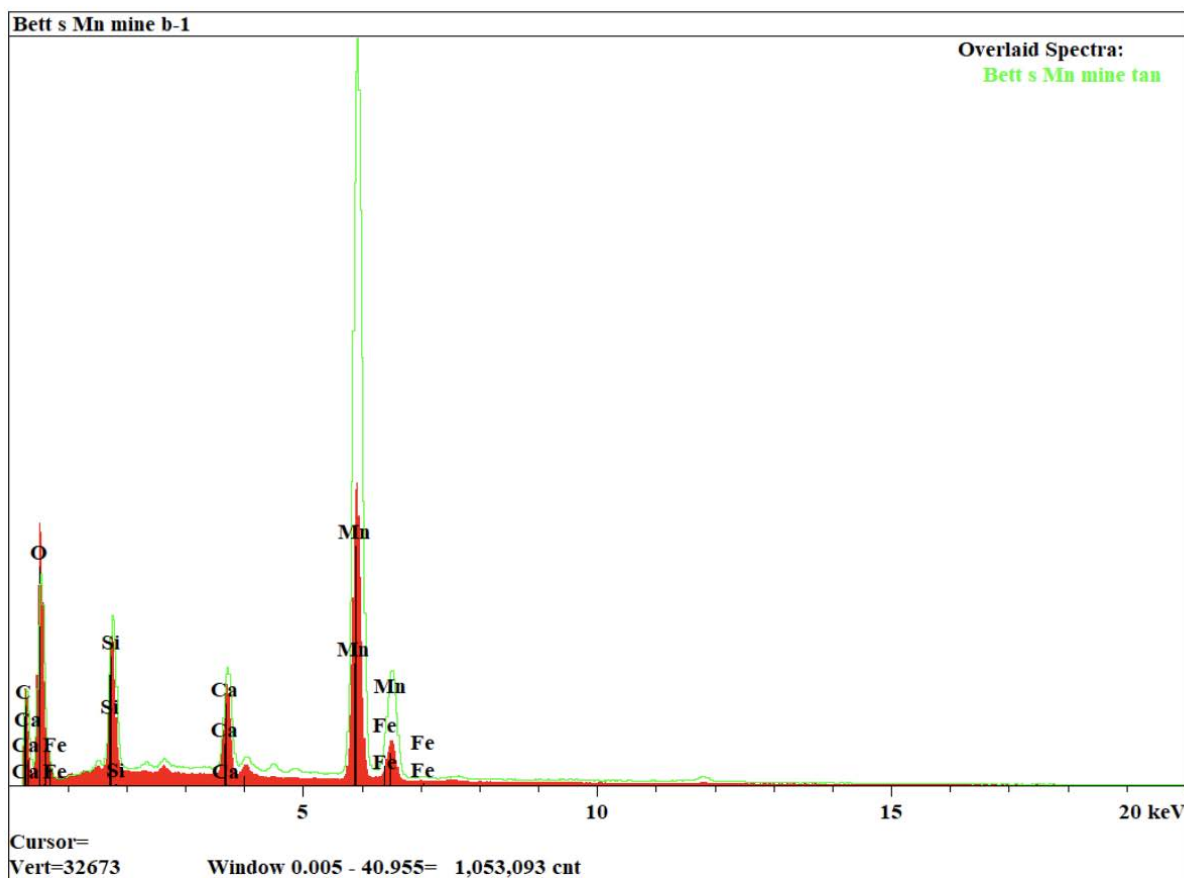
Map overview of the Betts Mine, with drill hole indicators (McHenry 1949)



Core sample from the U.S. Bureau of Mines study in 1943 © Rick Cernak

APPENDIX C

An AMRAY 1830 was used in the investigation of a Betts Mine specimen, and operated with an acceleration potential of 25 kV. Spectra and images were collected using Iridium Ultra, an integrated analytical package by IXRF Systems, Inc.



Overlay of the energy dispersive spectra of the pink and tan material. The results from the pink material are indicated by the red markings, and the tan material is indicated by the light green markings.

Summary:

The pink material contains roughly half the Mn as the tan material, whereas the Ca content is comparable in both cases. This suggests tephroite for the tan material and rhodonite for the pink. However, there are also other Mn silicates with similar stoichiometry and possibly optics would help to support the conclusion. (Al Falster, Maine Mineral Museum Lab 2021)

Conclusion:

The data from this investigation as well as the optical and physical properties of the tan part of the specimen indicate tephroite, confirming that specimen for use in this guide.

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I am very grateful for Rick Cernak's guidance for the duration of this project, as well as his mentorship over the course of this past year. I appreciate both the Earthdance Creative Living Project and Bruce Hooke for allowing me to spend time researching on the Betts Mine property. I am thankful for the support of Al Falster from the Maine Mineral & Gem Museum, who generously offered to analyze unidentified samples from Betts.

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ABOUT THE AUTHOR:



Sara J. Powers is a 2020 graduate of Marianapolis Preparatory School in Thompson, CT. She was accepted for enrollment in the freshman class at Skidmore College, Saratoga Springs, NY. However, due to the Covid-19 pandemic, she elected to take a gap year and reached out to the Worcester Mineral Club in Massachusetts to inquire about internships, mentorships, or other alternative educational opportunities. Sara's request was answered by Rick Cernak, an active member of the Worcester Mineral Club, the Director of The Betts Manganese Mine in Plainfield, MA, and, through his affiliation with the Department of Geosciences at University of Massachusetts at Amherst, MA, a coauthor of recently published articles in *Environmental Geochemistry and Health* on two former mine sites in western Massachusetts. Sara began working with Rick Cernak in August, 2020 and will be officially

completing the mentorship upon completion of the manuscript, *A Guide to the Betts Manganese Mine*.

During the mentorship, Sara became the editor of the Worcester Mineral Club newsletter, *New Diggings*. She also conducted Zoom presentations on the History and Mineralogy of the Betts Manganese Mine for several Mineral Clubs in New England. She is currently working on two projects as part of a team of four, including her mentor, Rick Cernak; Sara Furbush, Vice President of the Worcester Mineral Club; and Jeff Morrison, President of the New England Mineral Association. These projects are being developed to help promote the betterment of all mineral societies by working to improve their understanding and application of technologies to bring them into the 21st century, enhance their outreach via various forms of media to expand outreach for geosciences education, and to improve the relevance of mineral societies through strategies using new models to replace the obsolete model developed in the mid-twentieth century; a model from which so many societies are finding it difficult to break free and evolve. Most mineral societies are suffering as a result of their resistance to change.

Sara plans to start the fall semester, 2021, at Skidmore College. She plans to continue offering to conduct presentations via Zoom, work as an associate editor of *New Diggings*, the Worcester Mineral Club newsletter, as well as continuing with her commitments on the aforementioned team projects.