

WESTERN CONNECTICUT'S VARIED MINERAL-FORMING GEOENVIRONMENTS

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INTRODUCTION

Connecticut boasts a broad range of mineral forming geoenvironments and thus a long list of mineral species that have long attracted miners, researchers and collectors. The mindat.org Connecticut page lists 770 mineral species, series, group or variety names. The state is so rich in minerals, both in number and distribution, that any exposure will reveal something of interest and often quite different from others nearby. This great variety and distribution was noticed right away by colonists, who in their drive to find riches scrutinized every outcrop in the increasingly denuded landscape using what was essentially a haphazard, bottom up approach to resource prospecting. They were missing “the big picture” that would allow a predictive, top down approach, therefore, much of their effort was wasted due to lack of understanding. Today we can make sense of the variety of mineral occurrences by viewing them in the context of the geoenvironments they occur in, which resulted from the state’s long and complex geologic history. That history, of repeated terrane accretion with coeval compressive deformation, metamorphism and plutonism from the Proterozoic through Permian, to extension and coeval sedimentation, volcanism and hydrothermal activity in the early Mesozoic, is well told elsewhere and is alluded to here only as necessary. Given the regional scale of these events and tectonic terranes, most major types of mineral forming geoenvironments in the state are not unique to one locality, thus a selection from each can represent a range of places, but with local, sometimes unique variations.

Mineral occurrences are a unique aspect of geology because they appeal to a variety of human interests: economic (ore mineral resource exploitation), scientific (research, preservation), and mineral collecting (aesthetics and investment). These interests are not undertaken in isolation and a mineral occurrence can commonly be pursued by all 3 interests simultaneously or at different times as each interest provides information that is of value to the others, even if their activities are sometimes at odds. A brief historical review of Connecticut mineral interests demonstrates their symbiotic relationship over the past 300 years or so.

From the beginning of colonial days there was a local imperative and a desire by the Crown to exploit geological/mineralogical resources to better the standard of living and to increase financial coffers, respectively. Colonists were typically untrained in both the nascent science of mineralogy and the art of mining, it took many decades for knowledge about deposits to spread beyond the locals and for effective technology and expertise to arrive. From the early period, the best known figure in both respects was first Connecticut Governor John Winthrop (the Younger) (1606–1676) who started the state’s first iron manufacturing (from bog ore), mined gold near Great Hill, and found the first columbite crystal (probably in Haddam). Copper mining in what was then Simsbury began in 1707 and in the late 1730s Samuel Higley minted the first (technically illegal) American coins. By 1734, exploitation began of the goethite iron ores of the Salisbury area. The Revolution spurred interest in lead mines, for obvious reasons of defense, with the State taking over the mine in Middletown. There were many other smaller, less well known prospects, most poorly documented and operated or of limited potential, but their abundance suggested greater riches. These initial efforts began to expose the state’s mineral diversity and set the stage for great expansion in mineral research and economic exploitation during the 19th century.

Following the War of 1812, the desire for economic self-sufficiency and better military defense resulted in stone quarrying for fortifications and drove the nation and state to sponsor systematic surveys of mineral and geologic resources by qualified researchers. These initial efforts culminated in Charles Shepard’s 1837 *Report on the Geological Survey of Connecticut* and John Percival’s 1842 *Report on the Geology of the State of Connecticut*. These are still the go-to works on the state of mining and resource knowledge up to that time, but they were only single documents, what was really needed were journals that could keep up with contemporary local discoveries.

The political, economic and military motivations of the early 19th century coincided with the rise of the industrial revolution and its technological advances. This in turn placed demands on the education system driving the expansion of local colleges from mainly teaching theology, legal practice, agriculture and medicine into the fields of natural science, including chemistry, mineralogy and geology. Initially, most mineralogical knowledge came from study abroad, the European scientific journals and private mineral “cabinets” of local specimens. Again,

a desire for a home-grown, enduring and quality outlet for mineral knowledge lead to Archibald Bruce's relatively short-lived *American Mineralogical Journal* (1810-1814), which was followed up at Yale in 1818 by attorney turned chemist/mineralogist Benjamin Silliman's *American Journal of Science*. Successively edited through the 19th century by Benjamin, his son Benjamin, Jr., then James D. Dana and his son Edward S. Dana, and helped by Yale's proximity to mineral occurrences, the *Journal* is filled with early, and sometimes the only, documentation of many Connecticut minerals and occurrences, highlighted by the state's 13 type minerals (and a few others that should be!).

The presence of varied deposits so close to major colleges and universities such as Yale, Harvard, Wesleyan, Amherst, and Columbia provided specimens for study by many early luminaries. Mineral specimens from Connecticut are preserved in the museum collections at Greenwich, Middletown, New Haven, and Kent, Connecticut; plus Cambridge and Amherst, Mass.; New York City; Washington, DC and beyond. Preservation of specimens can be at odds with mining interests as demonstrated by the conflict between mid-19th century operators of the Bristol Copper Mine who wanted to smelt them and Benjamin Silliman, Jr. and other researchers who wanted to study the unique chalcocite and bornite crystals from there. Luckily for posterity many were saved, perhaps because Silliman, Jr. and other "Yale people" were investors and promoters of the mine, too (Jones, 2001).

While private mineral specimen collecting in 19th century America had been a pastime among a small cadre of wealthy and/or highly educated gentlemen (usually clergymen, attorneys or doctors), by the early 20th century it was taken up by middle class urban men and women. By now general interest in "natural history" was soaring, the economy was expanding and transportation technology, especially light rail and later automobiles, allowed easy access to the hundreds of diverse and interesting collecting sites "out in the country".

From the middle 19th century several Connecticut pegmatites were worked for microcline as a source of ceramic glaze. During the Great Depression many more were worked as a supplementary source of income. During WWII and the subsequent Cold War, the search for domestic supplies of strategic minerals such as muscovite, beryl, and uranium ores expanded or opened up even more pegmatites. After the war, these became favored collecting sites for local hobbyists. Connecticut's mineral diversity inspired a plethora of amateur collectors who took advantage of the available scientific and government literature generated by the war, but who lacked formal scientific training. By the 1950s, scientific and economic interest in minerals had largely shifted westward to larger and more accessible deposits with relatively little published about local mineralogy. Government sponsored works shifted toward detailed geologic mapping and tectonic history. This left the specimen collector with the remaining major interest in Connecticut minerals, who have been left with decreasing scientific information available about collecting sites.

The increase in collector interest did spur the creation of hobby oriented publications (such as *Rocks & Minerals* magazine starting in 1926), which published descriptions about localities and field trips, and of numerous field guides – both as general formal publications by experts (such as Dr. Frederick Pough's 1953 *A Field Guide to Rocks and Minerals*) and as local, privately published documents by hobbyists circulated within the growing mineral and gem clubs. The later tended to be somewhat rudimentary, with crude sketch maps, simple (often flawed) mineral lists, brief descriptions of habits and assemblages (if any), and no photographs. However, the works of Ronald Januzzi of Danbury, CT/Brewster, NY; Richard Schooner of East Hampton, CT, and Edward Force of Windsor, CT, who had access to analytical testing equipment, outside expertise and/or were keen field observers, and were more skilled than most in writing descriptions (and later at photography), stand out. They incorporated information from many other collectors as well, and while lacking the formal scientific necessities such as data appendices and references that allow independent verification of information (especially for the more unlikely claims), their works are geographically and historically comprehensive in scope (a big job considering the hundreds of state localities and species) if not always correct in detail.

By the 21st century, the Internet allowed easy access to information, and the creation of mineral oriented web sites such as mindat.org in 2000 provides a world-wide, user-populated database where the location, history, mineralogy and literature regarding any locality can be preserved and continuously updated via text, graphics and photographs. While its focus is toward the collector, and indeed most users and contributors are amateurs (as is the creator Jolyon Ralph) or mineral specimen dealers, the information is managed by professionals so that it maintains a more scientific, verifiable level of quality. For Connecticut mineral localities, there is a great backlog of information being added to it from the 300 or so years of documentation described above and, with the ease of mineral photography via digital cameras, a veritable flood of specimen photographs making up for their previous scarcity. Mining this database allows geospatial analyses and reveals the distribution of a particular mineral or

paragenesis that can be correlated with geological maps to delineate the geoenvironments they formed in, and with temporal data, their geologic history. A short description and list of Connecticut's major mineral forming geoenvironments can be found at the Connecticut mindat.org web site: www.mindat.org/loc-15903.html.

Knowing the particular geoenvironment greatly reduces the possible mineral species that a collector, miner or mineralogist may encounter at any locality, although there are always exceptions and surprises, and helps the researcher work out the paragenetic sequence and apply genetic hypotheses to explain origins. Although most localities have been studied enough and the general geologic history of Connecticut is known enough to place each into one of them, despite two centuries of study at local to regional scales, many of these specific geoenvironments have not been studied in detail beyond the properties of the minerals present and their basic field relationships. Most of the scientifically detailed locality studies are from the 19th or early 20th century and are missing results from modern analyses such as radiometric dating, detailed chemical, isotopic and/or thermal histories; or even geological maps. Much of the knowledge of many is based on brief notices in journals, mineral lists or simple descriptions from privately-published amateur field guides or hobby publications. Consequently, much can still be learned about each geoenvironment and how it fits into, or alters, “the big picture”.

Besides showcasing each locality's minerals and their field relationships where still visible, the focus of this year's NEIGC trip is to discuss the known and unknown aspects of their distribution, timing and genesis and to spur interest in modern research before they are lost, as is happening with increasing frequency. Many old sites are built over, have been over collected, or are no longer accessible. Most new localities are construction sites with short exposure time or active quarries with very limited access. This field trip visits 4 localities in the western Connecticut highlands that provide representative examples of some of the various geoenvironments and the degree of understanding at each. These include:

1. shallow- and deep hydrothermal systems and a scheelite-rich amphibolite (northern Trumbull area). These are geoenvironments that were studied and mined in the 19th century but which only collectors have been interested in since then. So many new discoveries, both spatially and mineralogically, have occurred here that the area cries out for new research.
2. mineralization in basalt flow gas vesicles and along faults (Pomperaug Basin in Southbury). These geoenvironments are well understood and have been well researched fairly recently.
3. granitic pegmatites (Thomaston Dam area). While pegmatites in general are now fairly well understood and those in eastern Connecticut have been well studied and collected, those found in western Connecticut have been neglected.
4. neocrystallization of kyanite, staurolite, garnet and ilmenite mega-porphyroblasts in metamorphic rocks and associated bull quartz veins and masses (northeastern Litchfield). Another area with old mines that were poorly documented but with new discoveries that beg for study, especially regarding megascopic minerals that do not fit nicely into thin sections.

Each stop, selected to best illustrate these geoenvironments, is discussed in detail below.

STOP 1 - NORTHERN TRUMBULL AREA

Introduction

The northern Trumbull area, known politically as Long Hill, is in many ways a uniquely mineralized part of Connecticut. In particular, the topographic hill known locally as Long Hill or Saganawamps (more or less after the Paugussetts' term for “on the side of the hill” (Sullivan, 1985) in allusion to a large vein there of white “bull” quartz used as a resource by Native Americans), became a locus for prospecting, quarrying and mining from about 1800-1900. The mineralization is co-located with perhaps the best exposures of the so-called basal member of the Siluro-Devonian The Straits Schist that crops out in a complex geological zone. This member includes marble, a rock highly sought after for agricultural purposes, which lead to its quarrying and an increase in rock and mineral exposures there in the early 19th century.

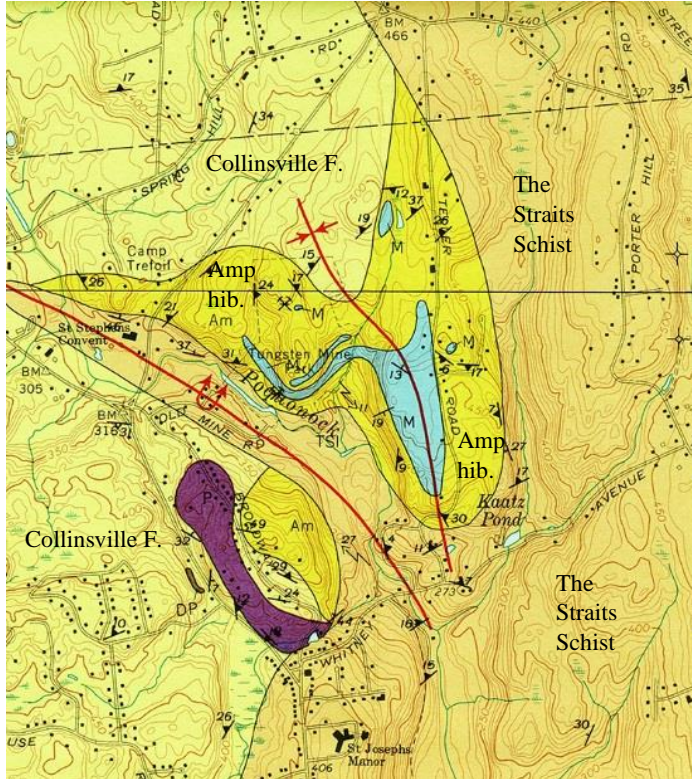


Figure 1. Portion of the Long Hill quadrangle-scale geological map by Crowley (1968) showing amphibolite (Am – yellow) and marble (M – pale blue) that comprise what is now called the “basal member” of the Siluro-Devonian The Straits Schist. The Straits Schist (TSI – tan) and the discontinuous basal member lie unconformably on older rocks, such as the Ordovician Collinsville F. (C – pale yellow), here at upper and lower left. Dark purple pluton is a pegmatite, and smaller pluton (DP) is a “dacite porphyry”. Area shown is about 3 km across.

The history of the various players in the mining activity is long, complex and confusing. It is best told by Sullivan (1985) and is only briefly summarized here. The marble in the basal member was quarried and burned for quick lime, in great demand for agricultural use, especially in areas like this where such rocks were scarce. The Lane family worked a mineral-rich outcrop in the early to mid-19th century. In the 1870s-1880s, Brooklynite Thomas Hubbard hoped to find for copper, lead and silver but did not find much. When demand for tungsten to alloy with steel surged after 1855, a serious but bungled attempt

to mine tungsten occurred here in the late 19th century and was described in detail by Gurlt (1893) and Hobbs (1901). The abandoned mill buildings were destroyed by fire in 1916. In lieu of unpaid taxes, the town took over the property in 1937, creating “Old Mine Park” in 1940. During WWII, the tungsten potential of the park was assessed, but was found, after a rather cursory investigation, to be insufficient (Sullivan, 1985).

The interesting minerals in the marble, amphibolite and veins (such as scheelite, ferberite, topaz and fluorite) were studied at Yale during 1819-22 by chemist/mineralogists Benjamin Silliman and George Bowen, who were sold many specimens by prospector Ephraim Lane of Monroe. Until the 1870s, Silliman and Yale received many specimens of Trumbull minerals from the Lane family, who also operated 3 other small mines in Monroe. Because Silliman and Bowen were more interested in the chemistry and crystallography of the minerals than their exact origin, and because the Lanes sold specimens in batches that typically did not differentiate such origins, many Trumbull specimens are misattributed to Lane's Monroe mines. Thus the scientific and collector literature is replete with errors that are difficult to correct after the fact, though some were clarified by Hitchcock (1826, 1828).

The park has been a famed collecting locality with several field guides, mineralogical articles, and collector magazines listing or describing the minerals, but almost no scientific research about the mineralogy has been undertaken since the 1840s. Localities in northern Trumbull (Long Hill) are detailed at www.mindat.org/loc-246208.html, which includes a mineral database, site photographs, and mineral photographs, plus links to the numerous sublocalities.

Geology

The geology was first studied by Hitchcock (1828, 1835), who noted that the topaz and fluorite occurs in veins cross-cutting interlayered marble and amphibolite, and that the latter rock type is the host for scheelite and ferberite. Along with his geological description, Hobbs (1901) produced a crude area map (Figure 2), but a fairly detailed site map showing a synclinal feature plus mining locations and minerals found at each. The quadrangle-scale geological map was done by Crowley (1968) (Figure 1), who also proposed a NW-plunging synform but with a complementary tight antiform to the SW. Regional mapping over many quadrangles (see Rodgers, 1985) supports the hypothesis that the Siluro-Devonian The Straits Schist lies unconformably upon deformed Ordovician rocks (locally, the Collinsville Formation), an idea not adopted by Crowley. Quartzite, calc-silicate rocks, amphibolite and/or marble

comprise a discontinuous basal member identified at scattered locations along the unconformity in western Connecticut and thought to represent an important litho- and time-stratigraphic marker as a regional unconformity (Hatch and Stanley, 1973). Due to the old marble quarrying and intense commercial and retail development in the area around the park, the exposures of the basal member here are among the best in the state.

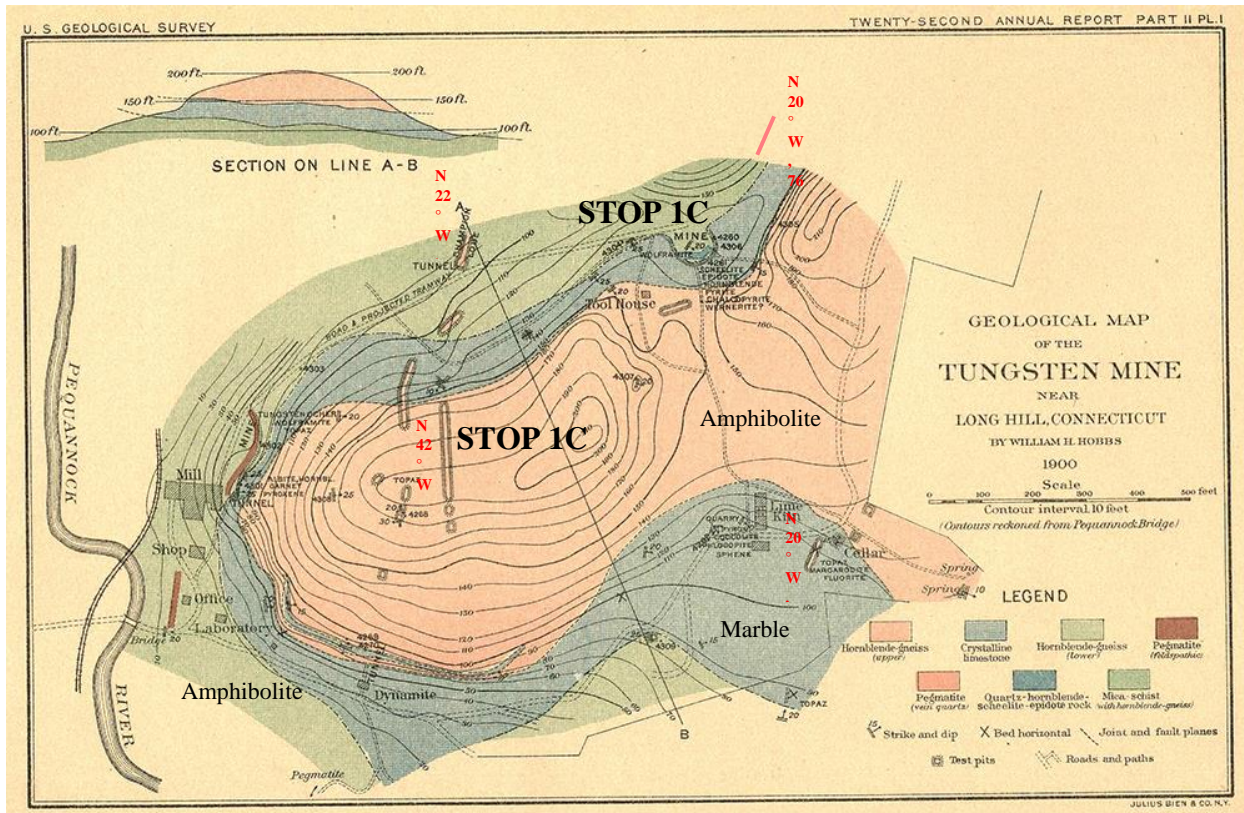


Figure 2. Hobbs' (1901) geological map of "Long Hill". Marble is blue, green and pink units are amphibolite. Here the units are generally flat-lying. Elongated, narrow features are workings along various steeply dipping veins of quartz, topaz, chlorophane, muscovite, albite, etc. with some strike and dips added. Stop 1C includes 2 of these veins, and the northern W mine pit. North is to the upper right.

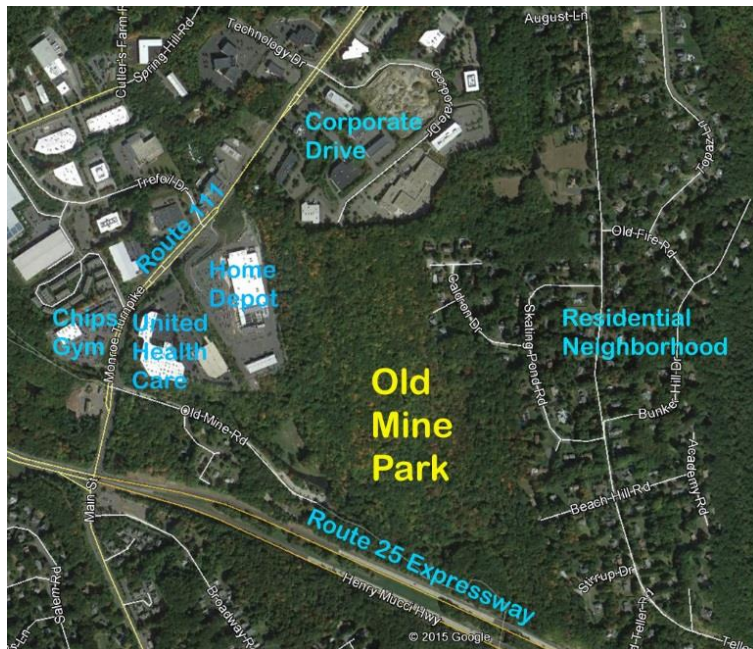


Figure 3. Developments near Old Mine Park that exposed bedrock.

Since Crowley did his mapping, several bedrock exposures have resulted from these developments as shown on Figure 3. Despite all of the more recent blasting, no work has been done to remap the geology of the park area and much of the rock exposures at developments was transient and is now covered and lost. The areas of development also exposed mineralogy similar to that found within Old Mine Park and due to the very active specimen collector community, probably thousands of specimens were saved, many

with good locality documentation and enough matrix to recreate at least the type of rock exposed. In some places, photographs were taken by one of the authors (Moritz). The newer exposures provide a broader context for the mineral-forming geoenvironments first identified within Old Mine Park and show that they are mostly much more widespread and varied than those found in the park, as discussed below.

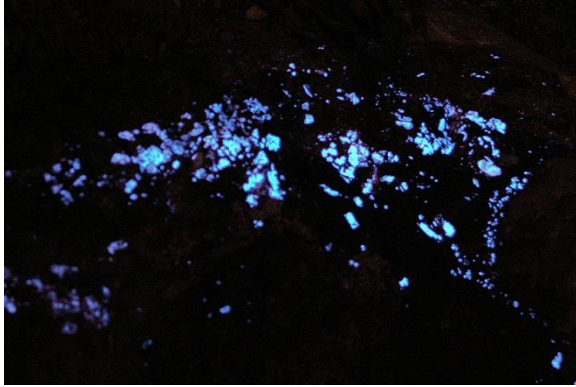


Figure 4. Nighttime photo of amphibolite behind The Home Depot. Scheelite fluoresces bright blue-white under short-wave ultraviolet light. This ~1 m view shows a very high concentration of crystals. (H. Moritz photo.)

Amphibolite-hosted minerals

In general, the amphibolite has the typical composition (based on petrography) of “hornblende” plus albite variety oligoclase to andesine with varying amounts of “biotite”. Ilmenite, sphene, pyrite and quartz are accessory phases. What makes the amphibolite of greater interest are the megascopic accessory minerals that are too large for thin section but are readily apparent in outcrops and hand samples. Most famous is scheelite, which occurs as small to large anhedral to euhedral crystals (up to about 8 cm) with a distribution varying from isolated to concentrated in zones or layers to nearly pure pods, typically with quartz (Figure 4). Though initially noted within Old Mine Park, to date it has been found, with the aid of short-wave ultraviolet lamps (all scheelite shows very bright blue-white fluorescent), in every place the amphibolite crops out in the Long Hill area. The Home Depot site was particularly prolific. However, in some exposures, such as at The Home Depot and along Corporate Drive, the amphibolite hosts concentrations and boudins of very coarse-grained, white to pale green albite, white to pale green marialite (in radiating masses over 40 cm long), and pyrrhotite and pyrite, the latter rarely as coarse-grained spherical crystal aggregates. The amphibolite also displays alteration, especially near the marble contact within Old Mine Park, where it is replaced by coarse-grained, clove-brown, clinozoisite and quartz. Within Old Mine Park, at the north end location of the old Lane or Hubbard workings, much of the scheelite in this zone is famously pseudomorphed (Figure 5) by very-fine-grained aggregates of ferberite (referred to as “wolframite” in older literature). Some of these pseudomorphs had in turn altered to a waxy yellow tungsten oxide called tungstite. These and other tungsten minerals unearthed in the early 19th century have been misattributed to one of the Lane’s family mines in Monroe with one of them still incorrectly given as the tungstite type locality.



Figure 5. Black ferberite pseudomorphs after bipyramidal scheelite crystals in amphibolite altered to quartz/clinozoisite. These crystals were confusing to early 19th century chemist/mineralogist Benjamin Silliman (1819a) because they had the wrong chemistry for their crystal shape. (H. Moritz photo.)

The origin of the scheelite and other accessory minerals in the amphibolite has not been studied. The widespread distribution of the mineral within the amphibolite, in both altered and unaltered portions, in layers and scattered within it, and its absence in other local rocks suggests it is primary although secondary recrystallization along joint and fault surfaces was observed during our pre-trip research. Ferberite pseudomorphs are a localized phenomenon found only in Old Mine Park. While much of the amphibolite shows alteration to or contains concentrations of very coarse-grained marialite, albite, pyrrhotite, pyrite and clinozoisite, these do not appear to uniquely correlate with the presence of scheelite. When or why the alteration of the amphibolite occurred is unknown. If scheelite (or at least tungsten) is a primary syngenetic constituent of this amphibolite, does it occur in any of the other basal member amphibolite outcrops around western Connecticut? Has anyone looked (a UV light is recommended)? If not, then

what is unique about this amphibolite? What does it say about the petrogenesis of the basal member? Obviously, we have far more questions than answers.

The bungled mining attempt in the late 19th century was doomed for a number of reasons, but it and the cursory assessment of tungsten resource potential done during WWII (without the aid of UV lamps) were hampered by tunnel vision regarding its extent. Using UV lamps, scheelite is present in all places where the amphibolite has been exposed, though in varying quantities, and with this knowledge a better resource assessment starts with an accurate map of the formation's extent. Absent that, Crowley (1968) mapped an area of roughly 1.5 km² and Hobbs' (1901) cross-section gives a minimum thickness of about 16 meters, for a volume of $24 \times 10^6 \text{ m}^3$, or weight of 6×10^7 tonnes of amphibolite (at 2.5 tonnes/m³). The average scheelite concentration is difficult to estimate ex-situ, but a conservative average 0.1% scheelite (based on UV lamping of hand samples) gives 6×10^4 tonnes of scheelite, a potentially decent deposit! And that is in a generally flat-lying rock at or near the surface that could be easily strip-mined, plus more amphibolite should extend eastward and southward under The Straits Schist. Sadly, given all the development that has occurred in the area since WWII, there is really no chance this deposit could be mined now.

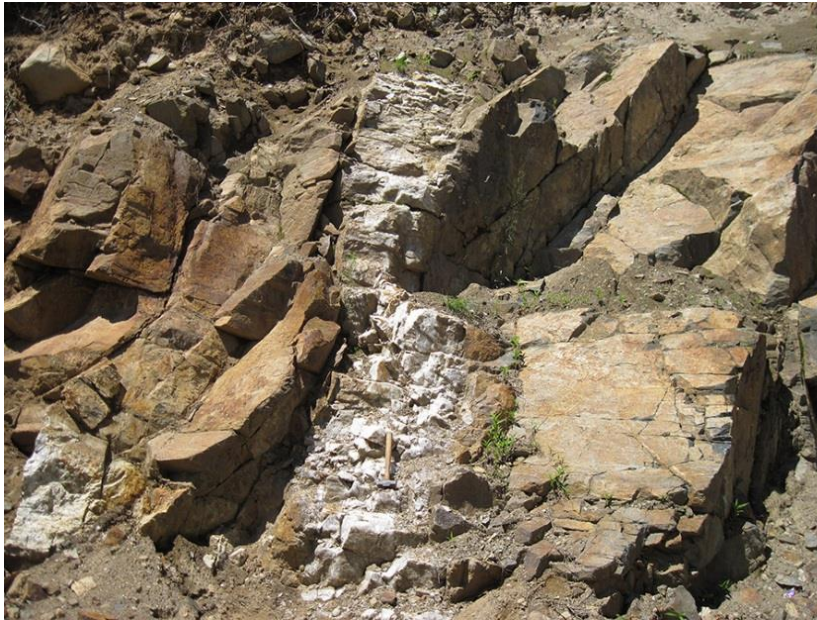


Figure 6. Stop 1A. Excellent exposure of quartz-rich hydrothermal vein N22°W, 74°SW cross-cutting amphibolite foliation N65°W, 74°NE. This one is mostly quartz with albite, chlorophane, and muscovite along the contact. (H. Moritz photo.)

Cross-cutting Hydrothermal Veins

Numerous cross-cutting, steeply-dipping, +/-1m thick, hydrothermal veins crop out in Old Mine Park and surrounding areas (Figure 6). They are apparently emplaced along joints and are undeformed. Their mineralogy varies, but the most common ones contain a very coarse-textured core assemblage of quartz+/-topaz+/-fluorite var. chlorophane (reddish to smoky to colorless) with a coarse to medium-textured sub-parallel muscovite-rich wall zone (a few cm or so). The veins can be large enough that a predominantly quartz-cored vein in Old Mine Park, called the Champion Lode, was mined solely for quartz (Hobbs 1901). In some veins, the topaz, which may commonly have a coarse muscovite coating, has altered to a very soft, compact and granular to peripherally parallel-fibrous or lamellar habit of margarite. Some veins contain albite in place of topaz and some veins are composed of mostly albite+/-clinochlore+/-marialite. Rarely, veins are composed predominantly of very-coarse-textured calcite, with clinochlore and with a wall zone rich in marialite, pyrrhotite, fluorite and beryl (some with color tending toward emerald green). Though the veins can laterally extend over 30 m, outcrops are generally limited (Figures 6 & 7) and the veins may in fact grade in composition between these extremes both laterally and vertically as some show a mix of these compositions.

Regardless of composition, the veins show a similar metasomatic alteration of the host amphibolite to fine-grained, brownish phlogopite/marialite (Figure 8). Where they cross-cut marble or schist, little wall rock alteration is obvious. The veins generally have a simple slab geometry, with parallel walls, little in the way of pinching and swelling and there is no associated fracturing or brecciation. No offsets of wall rock features are obvious. Typically steeply dipping, they are oriented parallel to a major joint set in the local outcrop. Indeed, some joints in the amphibolite show the same characteristic alteration in the surrounding rock, but display little more than a thin layer of the muscovite wall zone as "vein" mineralization.

Open spaces within the vein filling are typically very limited, and when encountered may represent selective dissolution or weathering of certain minerals rather than true fluid-filled spaces. Still, many well-formed crystals

and specimens originate from the veins (Figures 9, 10 & 11). Where enclosed in later-forming quartz, topaz crystals can be quite large (15 to 20 cm in diameter, 8 to 17 cm long), though they are rarely terminated as they typically impinge on other topaz crystals. They can be difficult to free from the hard quartz without splitting along the perfect basal cleavage. Color varies from white, to pale yellow, to pale green to orange-brown. The chlorophane is always massive, its aesthetics come from the dark red daylight color and/or the bright blue-green fluorescence, which is lost by prolonged exposure to any light (or by heating [thermoluminescence]) and so good specimens need to be kept in a light-tight container. Good albite and clinocllore crystals are found in small voids and emerald-green beryl (Figure 8) can be relatively easily freed from the enclosing calcite.



Figure 7. Stop 1B. One of several narrow topaz-rich veins cross-cutting The Straits Schist with foliation ~N80°E, 11°SE at 75 Corporate Drive. The veins in the outcrop parallel a set of prominent joints that from S to N measure N20°W, 90°; N32°W, 80°SW; N35°W, 61°SW; N36°W, 63°SW; N19°E, 72°NW; N4°E, 90°. (H. Moritz photo.)

The table below lists the major minerals of the amphibolite, its alteration, and the veins. Clearly the veins are rich in volatiles such as water, fluorine, chlorine, CO₂ and sulfur, plus SiO₂, CaO, Al₂O₃ and rare BeO. The amphibolite metasomatism shows the addition of water, chlorine and silica to the amphibolite constituent minerals, while the border zone show both recrystallization of iron-poor amphibolite minerals and new minerals of mixed amphibolite/core zone chemistry. Formation of topaz requires high fluorine and alumina, with correspondingly low calcium and alkalis. This explains the general absence of topaz in veins exposures that are very rich in fluorite, which forms where Ca is high, and albite is abundant. The margarite replacement of topaz suggests a late loss of fluorine and addition of calcium in some parts of the vein. Scheelite was only slightly affected by the hydrothermal activity as only very tiny grains of it could be found in the veins mostly in the wall zone, and along joints, that would be essentially invisible without their bright UV fluorescence.

Table 1 – Hydrothermal Vein Mineralogy (based on review of hand samples)

<i>Host Amphibolite Constituents</i>		<i>Wall zone (coarse to medium texture)</i>	
“Hornblende”	$\square\text{Ca}_2\{(\text{Fe}^{2+}, \text{Mg})_4\text{Al}\}(\text{AlSi}_7\text{O}_{22})(\text{OH})_2$	Muscovite	$\text{KAl}_2(\text{AlSi}_3\text{O}_{10})(\text{OH})_2$
Albite (Oligoclase)	$\text{NaAlSi}_3\text{O}_8$	Albite (Oligoclase)	$\text{NaAlSi}_3\text{O}_8$
“Biotite”	$\text{K}(\text{Fe}^{2+}, \text{Mg})_3(\text{AlSi}_3\text{O}_{10})(\text{OH})_2$	Clinocllore	$(\text{Mg}, \text{Fe}^{2+})_5\text{Al}(\text{AlSi}_3\text{O}_{10})(\text{OH})_8$
Marialite	$\text{Na}_4\text{Al}_3\text{Si}_9\text{O}_{24}\text{Cl}$	Marialite	$\text{Na}_4\text{Al}_3\text{Si}_9\text{O}_{24}\text{Cl}$
Pyrrhotite	Fe_7S_8	Pyrrhotite	Fe_7S_8
Pyrite	FeS_2	Pyrite	FeS_2
Quartz	SiO_2	Fluorite	CaF_2
Scheelite	CaWO_4	Beryl (rare)	$\text{Be}_3\text{Al}_2(\text{Si}_6\text{O}_{18})$
<i>Host Amphibolite Wall Alteration (fine texture)</i>		<i>Core zone (very coarse texture)</i>	
Phlogopite	$\text{KMg}_3(\text{AlSi}_3\text{O}_{10})(\text{OH})_2$	Quartz	SiO_2
Marialite	$\text{Na}_4\text{Al}_3\text{Si}_9\text{O}_{24}\text{Cl}$	Fluorite variety chlorophane	CaF_2
		Topaz	$\text{Al}_2(\text{SiO}_4)(\text{F}, \text{OH})_2$
		Margarite	$\text{CaAl}_2(\text{Al}_2\text{Si}_2\text{O}_{10})(\text{OH})_2$
		Calcite (rare)	CaCO_3
		Sphalerite (rare)	ZnS



Figure 8. a) Close-up of wall zone of rare calcite-rich vein showing calcite (white at upper right), beryl (pale green prisms), quartz (light gray around beryl), and pyrrhotite (brassy grains). b) Same specimen showing altered amphibolite at lower right with phlogopite and marialite grading away from contact. (H. Moritz photos.)

Origin of the Veins

The origin of these hydrothermal veins has not been studied. Topaz crystals of hydrothermal origin (Figure 9) can be distinguished by their much higher OH⁻ mole % substitution (22% to 28%) for F⁻ than in pegmatites and greisens (2% to 6%). Topaz refractive index also increases with OH substitution. These data have not been collected here. Hydrothermal geoenvironments have generally lower temperatures than magmatic ones, but the presence of abundant fluorite variety chlorophane points toward a relatively high temperature for these veins.



Figure 9. Subhedral topaz crystals (pale yellow-green with micaceous coating) in quartz (colorless glassy) from the core zone of a typical vein. (H. Moritz photo.)

Chlorophane is a rare and uniquely fluorescent type of fluorite that fluoresces bright blue-green under short-wave UV light and fluoresces the more common bright blue-purple color under long-wave UV light (Figure 10). However, it is also thermoluminescent and will give off the same blue-green color when heated. Its normal daylight color varies from white to smoky to dark red. The majority of occurrences are pegmatitic (450°-550 °C), so this occurrence is intriguing. The absence of brittle faulting along the veins and the presence of chlorophane and topaz suggests a similarly high temperature and depth of emplacement as pegmatites.

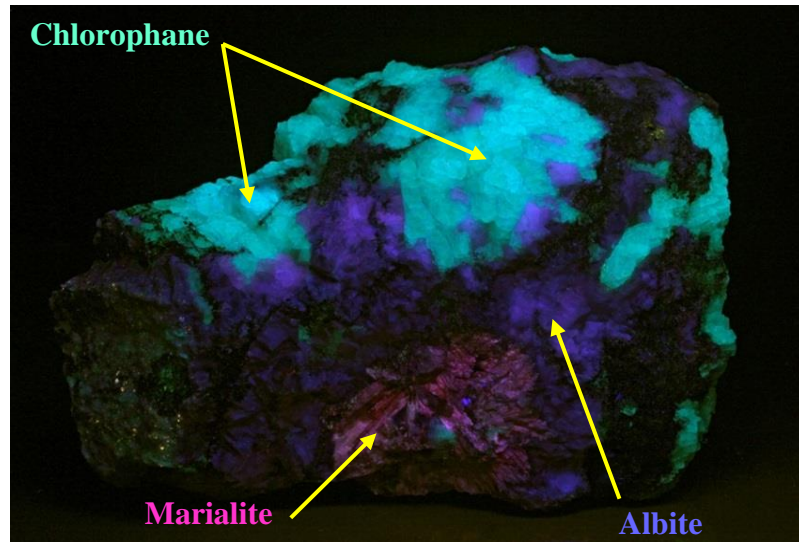
Because the veins are undeformed and cross-cut all local strata, they must be Devonian or younger. Besides numerous pegmatites, which in western Connecticut are Devonian, Crowley (1968) maps two post-Devonian local plutons – the Pinewood Adamellite (291±4 Ma), situated about 4 km SE of Old Mine Park and “dacite porphyry” located about 1 km SSW. These are noteworthy because of their proximity to the unusual-mineralogy of the Old Mine Park area, they are the youngest rocks in the area and are undeformed. The Pinewood Adamellite, also

contains accessory fluorite. However, data are needed to make anything more than a proximal connection between the veins and local plutons. The veins' generally similar strikes of N20°W to N40°W should be considered in any genetic hypothesis.

Figure 10. Specimen of wall zone minerals (fluorescing under short-wave UV light): chlorophane (blue-green), albite (purple), marialite (pink). (H. Moritz photo.)

Veins Associated with Brittle Faulting

In addition to the veins described above, which show no evidence of faulting, there are numerous hydrothermal deposits associated with brittle faulting in the Old Mine Park area. These were best exposed at the Old Mine Plaza/The Home Depot site, from where many specimens were preserved (Figures 12 & 13). These veins typically contain calcite, pyrite (and more rarely other simple metal sulfides), fluorite (normal variety) and quartz. Similar to many brittle fault environments, there are many void spaces hosting excellent mineral crystallization. Calcite shows a variety of crystal forms, from elongated prisms, to rhombohedra, to highly acute "poker chip" habit overgrowths on other calcite crystals. Much of the calcite fluoresces a deep orange-red under mid-wave UV light. Fluorite shows both octahedral and cubic forms, with colors from pale green, yellow and purple. Overall, the mineralization is similar to that found in Mesozoic faults found in



the Hartford Basin and presumably of the same age at Thomaston Dam railroad cut and the Haynes Naugatuck Quarry. The mineralization in the brittle faults also appears to be pervasive in all rock types. They occur as thin films of pyrite, red-fluorescing calcite, and purple fluorite in late fractures of quartz-topaz-chlorophane-muscovite veins. Whatever caused it appears to have "soaked" all the area rocks and not just migrated through the brittle faults.

Figure 11. Specimen from vein at Stop 1A showing white albite crystals surrounding massive, dark gray chlorophane.

The amphibolite found adjacent to brittle faults shows metasomatic alteration different

from that peripheral to quartz-topaz-chlorophane-muscovite veins. The brittle fault contacts exhibit a secondary mineralization to chlorite, albite, clay, quartz, gypsum and/or bavenite. Zeolites are rarely present also. What does it say about their age(s)? Why are faults concentrated here? As with many phenomenon in this area, more data are needed to form a better understanding of what occurred here.



Figure 12. (left) “Poker chip” habit acute rhombohedral calcite overgrowths on “normal” rhombohedra, with purple to green “normal” fluorite (lower left). From a mineralized brittle fault at The Home Depot site. (H. Moritz photo.)



Figure 13. (right) “Normal”, purple tinted, clear fluorite crystals showing complex combination of cubic and dodecahedral forms. From a mineralized brittle fault at The Home Depot site. (H. Moritz photo.)

STOP 2 - O&G INDUSTRIES SOUTHBURY QUARRY

Introduction

The quarry known today at the O&G Industries Southbury Quarry began its life as a sand pit called the Silliman Quarry, after the original owners who were, appropriately, descendants of Benjamin Silliman. It eventually expanded into the trap rock found in the 50 km² area of the Early Mesozoic Pomperaug Basin. This incipient Atlantic Ocean rift basin, part of the Newark Supergroup of basins along the continent’s east coast, was mapped in detail by Burton (2006) and is a stratigraphic miniature of the much larger Hartford Basin to the east and to the Newark Basin to the west. This similarity, and structural features in all 3 basins, argues that they were originally connected before being separated by faulting. Indeed, the character of the many fault-hosted hydrothermal mineral-forming geoenvironments now exposed within the intervening metamorphic/igneous rock highlands require thousands of feet of formerly overlying rock to provide the pressure-temperature conditions for their formation. Hydrothermal mineralization in faults also occurs in the basin rocks and are best exposed in its 2 trap rock quarries. Both the Woodbury (quarried out) and Southbury (active) quarries have operated for decades to feed our state’s voracious appetite for aggregate. The quarries work the middle and thickest of the 3 basaltic lava flows (Oreanaug Basalt of Burton – correlates with the Holyoke Basalt). The quarries expose numerous N to NNE-trending, high-angle, mineralized normal faults and abundant, commonly mineralized gas vesicles. While these mineral-forming geoenvironments are not unique to the Mesozoic rocks of this basin (there are numerous occurrences in the Hartford and Newark Basins), the Southbury Quarry is an outstanding example that is also conveniently proximal to the other trip stops. Benjamin Silliman (1819b) noted the spectacular mineralization, but it received scant attention until it was studied by Garabedian (1998). The mineral photographs in this section, and many others, can also be viewed at www.mindat.org/loc-5370.html.

Mineralization

The host rock is an aphanitic, gray to greenish basalt consisting of about 45% anorthite (labradorite), 40 % augite, 10% pigeonite, and 5% accessories/devitrified glass. These Ca, Mg, and Fe-rich minerals served as ion sources for much of the secondary minerals found in the faults and vesicles (Figure 14), the most common being prehnite, anhydrite (dissolved), calcite, pumpellyite, datolite, apophyllite and the zeolites laumontite, heulandite, and stilbite. A trapezohedral mineral, likely analcime (later replaced), is also common. These minerals occur with ubiquitous chalcedony and quartz. Leaching of ions from basalt around a vesicle resulted in alteration of the host rock to a generally pale green-gray, earthy halo or rind up to several cm from the vesicle wall (Figure 17), which serves as an indicator of unopened vesicles.

Figure 14. Types of mineralogy filling “half-moon” vesicles (Garabedian, 1998).

Garabedian (1998) argues for an initial steam dominated phase followed by a hot water dominated phase of mineralization within the “half-moon” vesicles as the lava cooled (Figure 15). The first vesicle fillings were “water level” crystals (Figure 23) likely precipitated from boiling meteoric water that infiltrated the upper crust before the lava was cold enough to fracture. After it fractured, steam from the base of the flow could circulate, alter the basalt (the glass especially at first), pick up Fe, Mg, silica, alumina, Na and Ca and reprecipitate them in vesicles and fractures higher up as pumpellyite, chalcedony and analcime (Figures 19, 20, 22). Flash boiling events would empty come cavities and precipitate minerals as botryoidal wall linings, then the cycle would repeat adding more mineral layers. With continued cooling, a hydrothermal, saline water dominated system took over, dissolving some early minerals (anhydrite, analcime, chalcedony) out of vesicles and/or pseudomorphing them. The saline waters from below initially appeared to be alkaline, boron rich and silica poor, leading to datolite deposition (Figure 18). As the chemistry changed and temperature dropped, prehnite crystallization dominated (replacing much datolite with prehnite “hearts”), followed by calcite, quartz and eventually low temperature zeolites after burial and diagenesis.

Varieties of Half-moon Fillings

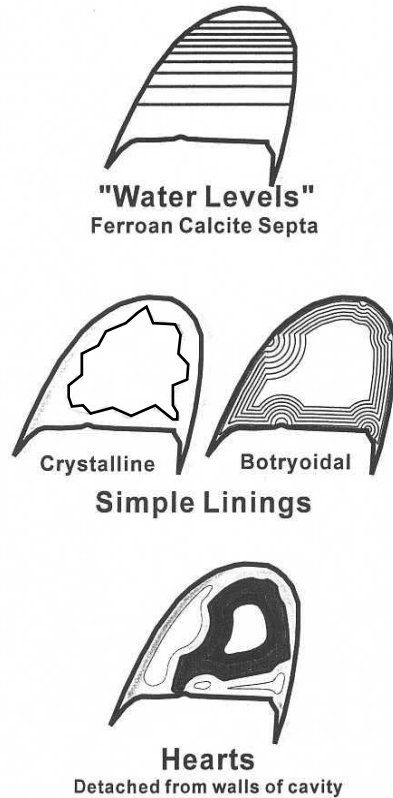
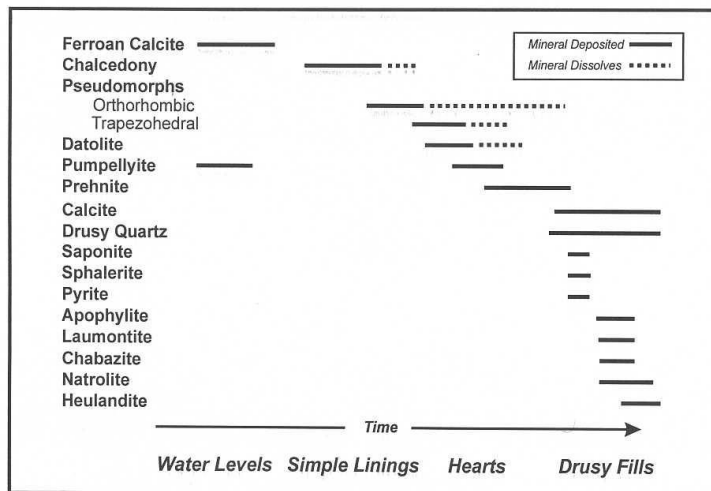


Figure 15. Mineral paragenesis in vesicles according to Garabedian (1998). The “Orthorhombic” and “Trapezohedral” pseudomorphed minerals are anhydrite and the analcime, respectively. “Saponite” is actually pumpellyite or julgoldite.



The locality is well-known for prehnite (Figure 17). Three varieties are found - the standard green, rare yellow, and the extremely rare white (iron-free). Particularly noteworthy and sought after are prehnite floater specimens called "hearts". According to Garabedian (1998) these formed via a 5-step process shown in Figure 16 (see also Figures 18 & 21).

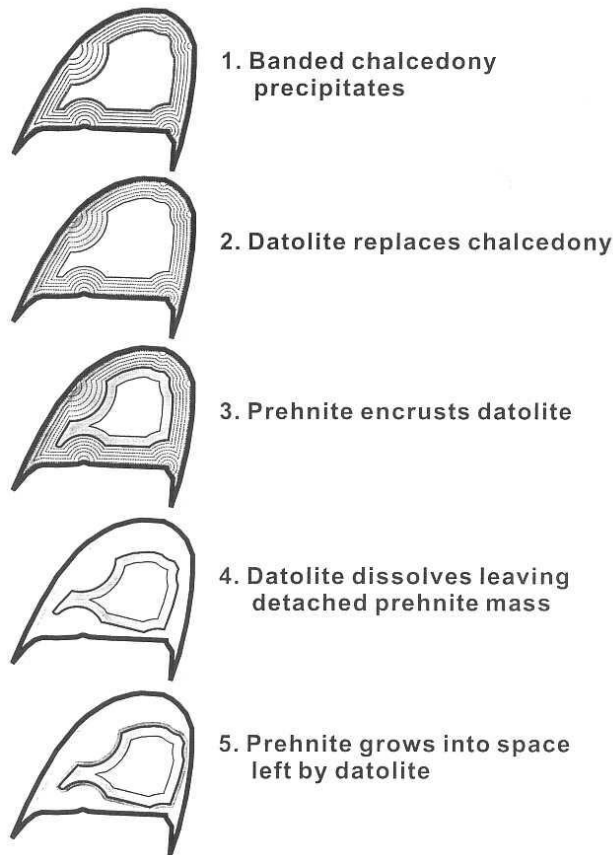


Figure 16. Steps in the formation of prehnite “hearts” according to Garabedian (1998).

Late forming minerals include pyrite, gemmy green sphalerite crystals to about 6mm, calcite as dogteeth or various rhombohedra, fluorapophyllite-(K), babingtonite, julgodite/pumpellyite, drusy quartz (some amethystine) and zeolites (Figures 19 to 23). Regarding the formation of zeolites, Tschernich (1992) provides this summary for a basaltic lava flow, which is generally consistent with many features seen at this locality, though the process discussed below was likely cyclical here and the flow much thicker and slower cooling:

“Given a basalt flow 25 meters thick with an initial molten temperature of 12000 C, after two years the temperature would still be 3000 C at its base, and 1200 C after five years (Robert et al., 1988). If water is present during the cooling stages (from a rain, streams, or a lake), the flow cools at a much faster rate and chlorite/clay minerals will generally line the cavities, followed by high-temperature to low-temperature zeolites as the temperature falls from 2000 to 400 C.

“The interconnected open spaces in the base of the flow allow the fluids to circulate and mix to form a uniform chemical composition and pH. The minerals in this area are commonly the same in all the open spaces. In the dense portions of the flow, each cavity is isolated and acts independently of the others. Heated solutions slowly penetrated the rock and filled these cavities. After the initial filling of the cavities, the fluid became stagnant. The elements needed to form the zeolites in isolated cavities are derived from the walls of the cavity. These alteration rims, or halos, are a few millimeters to several centimeters wide, and are colored gray, brown, black, or red from porous altered rock and clay minerals... Since the temperature of the fluid was nearly the same in all the cavities, small differences in pH, cation composition, and silicon/aluminum ratio produce slightly different species or a lack of mineralization. The fluids in all the cavities have undergone the same decrease in temperature; therefore, the minerals crystallize in the same order, although some species may be absent in some cavities due to insufficient chemical components.”

Figure 17. Typical vesicle showing alteration rind in the basalt and prehnite crystal lining. (H. Moritz photo).



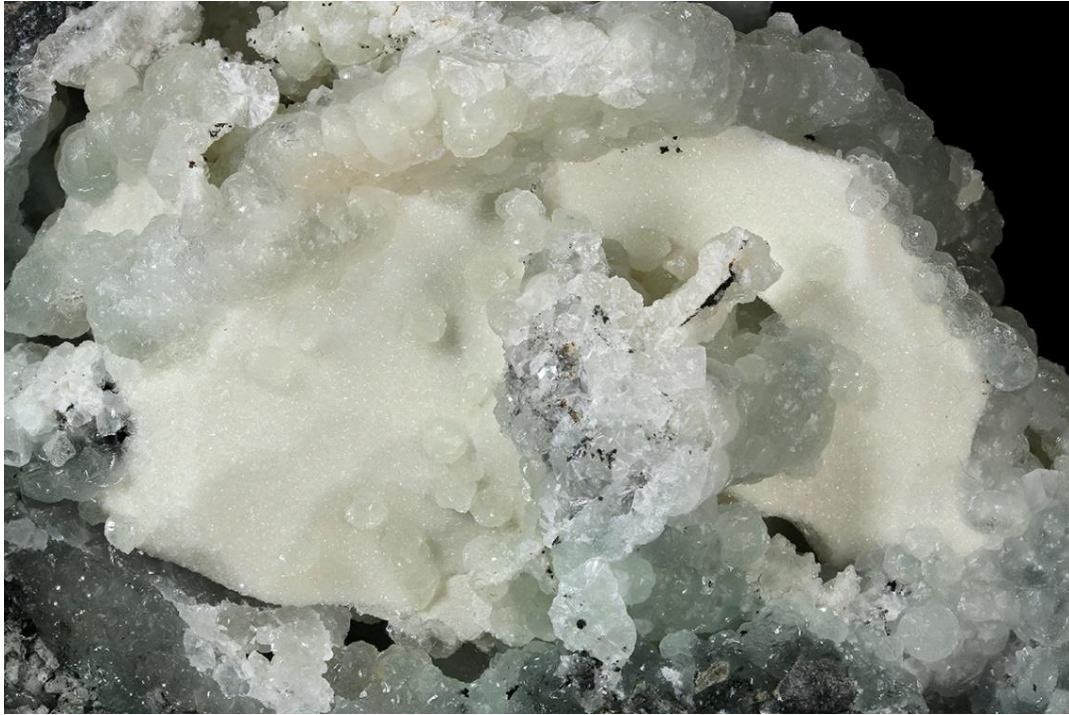


Figure 18. Specimen showing an intermediate step in the formation of prehnite "hearts". A mass of white, very fine-grained, partially dissolved datolite is partially encrusted by botryoidal pale green prehnite. (H. Moritz photo.)



Figure 19. Fan-shaped voids were tabular anhydrite crystals later epimorphed by white chalcedony and amethystine quartz, then the anhydrite dissolved. Late forming tan heulandite crystallized in the voids.



Figure 20. Prehnite epimorphed a trapezohedral zeolite (analcime), which later dissolved, then more prehnite partly filled in the void. These are very sought after specimens. (H. Moritz photos.)

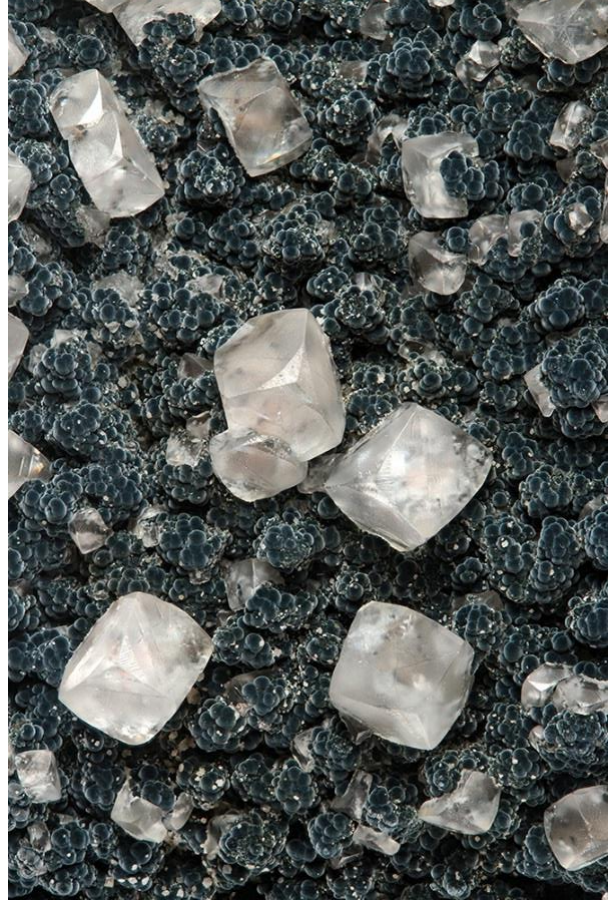


Figure 21. (upper left) Glassy fluorapophyllite-(K) on a yellow-green, botryoidal prehnite "heart".

Figure 22. (upper right) Pseudocubic calcite crystals on blue-green pumpellyite or julgoldite.

Figure 23. (bottom) Ferroan calcite "water level" septa disrupted and encrusted with drusy quartz.

(H. Moritz photos.)

STOP 3 - THOMASTON DAM PEGMATITE

Introduction

A major flood control dam project completed by the US Army Corps of Engineers (US ACOE) in 1960, it was built in response to the devastating flood of 1955 along the Naugatuck and Housatonic River valleys. The 1.5 million cubic-yard earth and rockfill dam is 2000 feet long and 142 feet high (US ACOE, 2014). The dam was completed in 1960 and cost more than \$14 million and is now used as a picnic area and motocross trails. Its placement along the confluence of the Naugatuck River and Leadmine Brook necessitated the movement of the railroad line to a new cut passing through bedrock above the spillway level around the west side of the dam. The dam is mostly made of sand and gravel, but used large pieces of rock blasted at the site, consisting mostly of the Ordovician Ratlum Mountain Schist, Siluro-Devonian The Straits Schist and intruded pegmatites; to armor the dam surface (Figures 24 & 25). There is an excellent exposure of the typical area pegmatites at the east end of the road across the top of the dam, with schist exposure around it and visible in the spillway and railroad cuts below. The railroad cut around the west side of the dam exposes the schist, some pegmatite, and numerous steeply dipping mineralized faults of unknown origin and age. The location is open any day 8 AM to sunset but collecting is not allowed per US ACOE rules and their office is right around the corner from this pegmatite. Plus the walls of the cut are a bit physically unstable.



Figure 24. View of the N side of Thomaston Dam. The surface is armored with large boulders of white pegmatite and gray schist. (H. Moritz photo.)

The principal mineral forming geoenvironment showcased here is a granitic pegmatite pluton (Figure 26). Pegmatites in general are a widespread and important mineral forming geoenvironment in Connecticut, especially for minerals containing rare elements. This pegmatite exposure, although not rich in accessory minerals, is very accessible, well exposed in 3 dimensions, and typical of many in western

Connecticut. For mineral details see www.mindat.org/loc-264534.html.

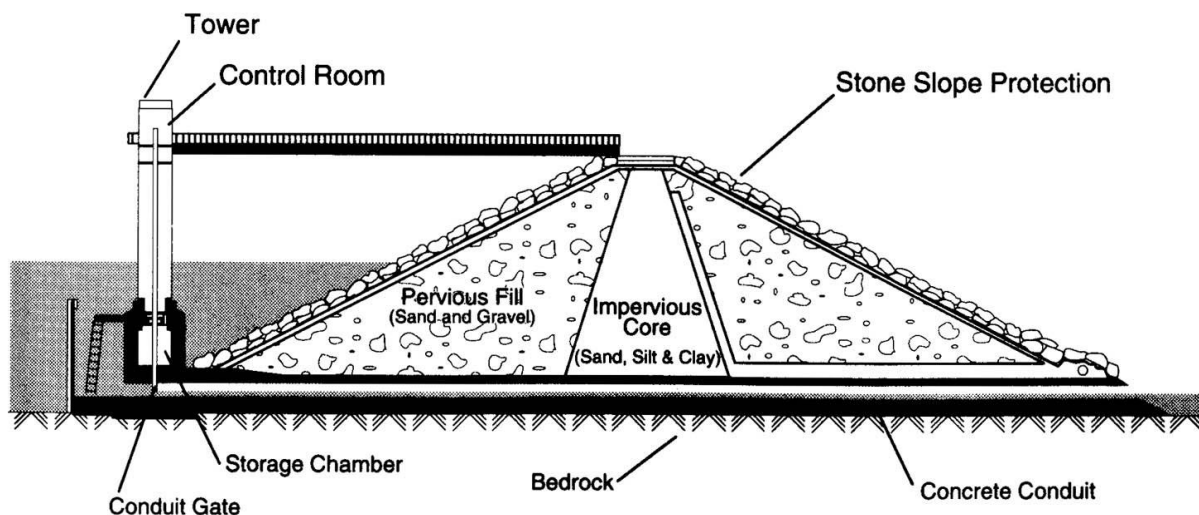


Figure 25. Sectional view of the Thomaston dry dam built after the disastrous flooding of the Naugatuck river valley in 1955. (U.S. Army Corps of Engineers.)



Figure 26. Pegmatite on access road adjacent to spillway cut. It intrudes gray The Straits Schist. (H. Moritz photo.)

Description

A multi-zoned pegmatite with common mineralogy is well exposed in a rock cut where the road across the top of the dam crosses the spillway at the east end of the dam. Most of the pegmatite consists of a white, microcline-rich intermediate zone with obvious, feathery, slightly radiating, muscovite-annite aggregates around 0.25 meters long that point toward the center of the pegmatite (Figure 27). The other major zone is a core consisting of white massive quartz with tan, very coarse-grained microcline (+/- 1 m) and accessory muscovite (Figure 28). A minor fine-grained border zone several cm thick is also present. No other accessories are visible. The pegmatite discordantly intrudes Siluro-Devonian The Straits Schist (Figure 26). A large inclusion of the schist is surrounded by pegmatite at the west end of the exposure and both can be viewed at right angles from across the spillway.

Figure 27. Intermediate zone of the pegmatite showing elongated, feathery, subparallel and inwardly oriented annite-muscovite crystal aggregates common in pegmatites of this area. (H. Moritz photo.)



Discussion

Unlike the Middletown pegmatite district in eastern Connecticut, where dozens of pegmatites were quarried and many studies were undertaken, few western Connecticut pegmatites have received similar attention. The 10 or so quarried are widely separated with no concentrated western Connecticut pegmatite mining district. However, the dearth of quarries does not imply a scarcity of pegmatites in general and pegmatites similar to this one are common in the area and well exposed at the railroad cut at the west end of the dam (0.8 km WNW), at the intersections of state Routes 8 and 222 (1.5 km SSE) and along Route 109 (5.6 km SW). Most of these pegmatites are dominated by the mineralogy and texture of the intermediate zone seen in this pegmatite, with the obvious, long, subparallel oriented mica crystals and almost no significant core zone or rare accessory minerals.

In most cases, the most complex mineralogy in pegmatites is found toward the core or along the intermediate zone/core zone boundary. Pegmatites crystallize rapidly, in days to months depending on their size, because their melt is enriched in water and fluxing ions that minimize nucleation sites, lower viscosity and reduce the melting

point. As crystallization progress inward from the fine-grained, chilled wall zone the flux elements further concentrate resulting in increasing crystal size and inwardly oriented, expanding crystals. Finally incompatible elements that do not fit into ionic sites in the more common minerals will form rare minerals closer to the core, especially when the fluxing ions crystallize out. A core of nearly pure quartz will form last if there is enough excess silica in the melt.

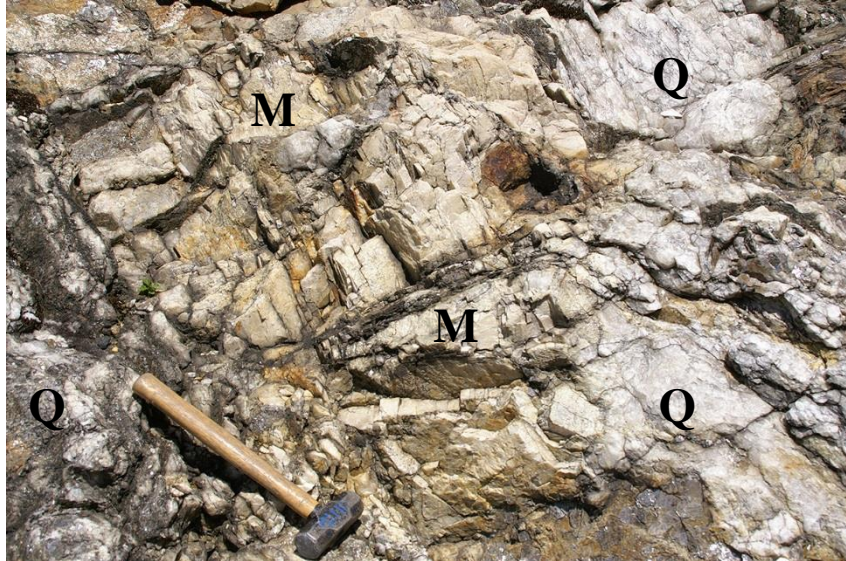


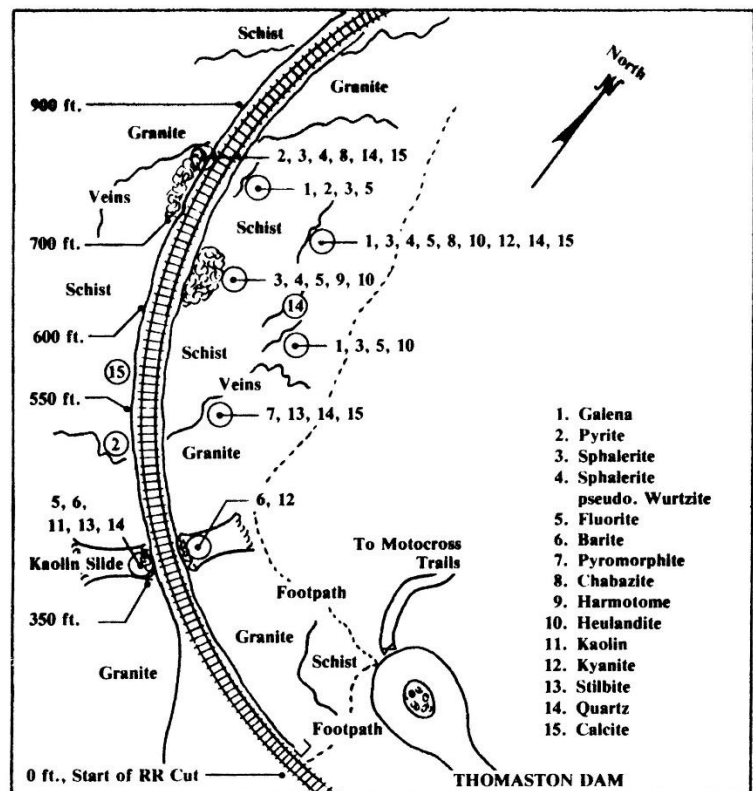
Figure 28. Core zone of the pegmatite showing tan, blocky cleaving microcline (M) and white quartz (Q). (H. Moritz photo.)

The specific age of this pegmatite is unknown. Few pegmatites in western Connecticut have been radiometrically dated. One of the first was the Fillow Quarry at Branchville in far western Connecticut, dated at about 368 Ma (Lane, 1935), which is late Devonian. Considering that the Thomaston Dam pegmatite cross-cuts the Siluro-Devonian The Straits Schist, it may be related to the Devonian Nonewaugh Granite (383 ± 10 Ma, Mose and

Nagle, 1982), which is widespread just to the north and west of the dam site and SW of Thomaston as 4 large and many smaller separate plutons. The Nonewaugh is described by Gates (1954) as having accessory muscovite and biotite and includes pegmatitic zones exhibiting graphic microcline-quartz intergrowths and plumose muscovite crystal aggregates. He describes dikes and sills emanating from the main plutons and maps many small isolated stocks. One of these was quarried for rock for the Morris Reservoir Dam in East Morris. Pegmatitic layers exposed there include miarolitic cavities with exceptional smoky quartz and microcline crystals similar to those from plutons near North Conway, NH. Research and detailed mapping is needed to establish any genetic connection between the pegmatites and the Nonewaugh plutons.

Figure 29. Map of the mineralized area at the railroad cut just west of the dam. From Segeler and Molon (1985).

Along the railroad cut a magnificent transect through the country rocks is visible. Here, dikes and sills of the Nonewaugh granite are clearly intrusive across the regional foliation of the Siluro-Devonian The Straits Schist. The rocks are well-foliated and dip 37°NW with a strike of N12°E. A strong intersection lineation plunges 37° into N75°W. The metamorphic rocks are light to silvery gray schist and gneiss, rich in muscovite with subordinate biotite, plagioclase, quartz,



and locally impressive concentrations of almandine and graphite. Elliptical quartz pods flattened within the foliation contain biotite and bluish gemmy kyanite. More details on the minerals here at: www.mindat.org/loc-4525.html.

A map of the former collecting site is shown as Figure 29. Mineral collectors try to identify veins peripheral to the granite that cut, commonly along joints or faults, across the foliation of host rocks. During the late stages of magmatic crystallization, large, typically incompatible elements complex with the fluoride and chloride ions and, driven by high vapor pressures, purge through the surrounding country rock leaving well-crystallized mineral samples as vug- and fracture fillings. The hydrothermal minerals reported found at Thomaston are similar to the late, fault-hosted veins at northern Trumbull (Stop 1) including banded fluorite and fluorite crystals (in various colors), quartz, galena, sphalerite, pyrite, pyromorphite, wulfenite and a host of zeolite minerals including stilbite, harmotome, heulandite, and chabazite. The mineralized vein is about 1 m wide and is oriented $\sim N15^{\circ}W$, $85^{\circ}SW$ to 90° . Of particular interest to mineral collectors is polysynthetically-twinned sphalerite (long misidentified as wurtzite). It occurs as bronze, sub-metallic pseudo-hexagonal crystals that look like small concertinas standing on end. Another interesting discovery was a dense barium feldspar (var. celsian $BaAl_2Si_2O_8$) within the main mass of the granite, just south of the mineralized area described above. The ultimate source and age of the hydrothermal system here is unknown, but it appears similar to the Mesozoic aged systems in the Hartford Basin.

Although mineral collecting is no longer permitted, mineral collecting was quite active during the construction phase and for a few decades after until the rock slope was destabilized and USACOE ended it to safeguard the railroad below. Some of the many wonderful specimens found here are shown in Figures 30 to 32.



Figure 30. (upper left) Galena (dark crystal at center) with sphalerite (smaller dark crystals) in white quartz vein cutting schist. (www.Dukelabs.com specimen 0286.)

Figure 31. (upper right) Quartz crystal (www.Dukelabs.com specimen 0407.)

Figure 32. (left) Banded fluorite. Cross-cutting veins of solid fluorite were on the order of 1 m thick here, but are collected out and covered to stabilize the slopes above the railroad tracks. (www.Dukelabs.com specimen 0432.)

STOP 4 - OLD LITCHFIELD MINES**Introduction**

Gigantic kyanite (to 40 cm) and ilmenite (to 20 cm) porphyroblasts were discovered in 2012 during some landscaping activity at this location. The locality is situated in NE Litchfield along U.S. Route 202 (Torrington Road) near the border with Torrington (Figure 33). The owners excavated, cleaned and set aside boulders exhibiting these crystals (Figure 34) and saved many smaller specimens. They also unearthed and preserved two shallow, vertical mine shafts (Figures 40 & 43). There are other indications of historic, largely undocumented mining on the property. It is an area historically known for similar crystals that are no longer available or accessible. Despite the large size of abundant kyanite and ilmenite crystals, the mining apparently was for Cu and explains several brief, vague and mysterious 19th century reports of Cu prospecting in Litchfield during the late 18th to mid-19th centuries. The site is private property and is only accessible during this NEIGC field trip by permission of the owners.

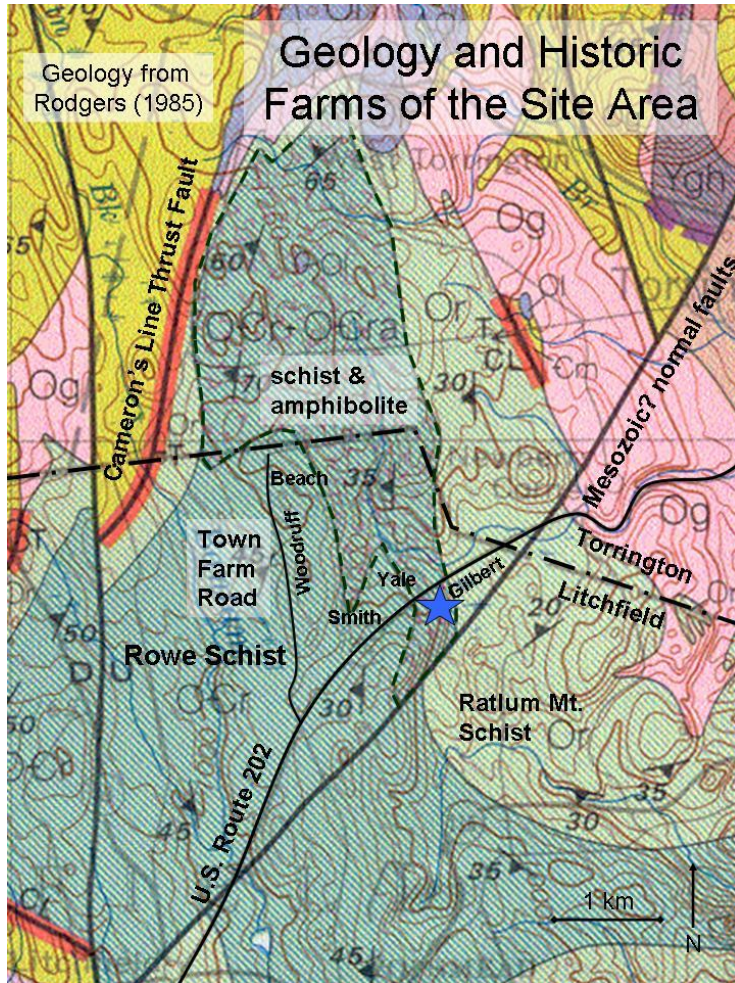
The geoenvironments here exemplify Barrovian regional metamorphism of protoliths of the Cambro-Ordovician Rowe Schist, which consisted of pelagic and volcanoclastic sediments and intercalated basaltic volcanics. During an accretionary phase of Taconian and younger orogenesis, the protoliths were transformed into polyphase deformed metamorphic rocks containing distinctively large index minerals including kyanite, staurolite, garnet, and ilmenite. Indeed, kyanite and ilmenite are widespread in western Connecticut. However, this site exposes at least two different modes of ilmenite and kyanite crystallization; one hosted in schist and concordant boudins and the other involving discordant masses of bull quartz whose field relationships and crystal habits suggest extensional genesis. The latter mode has received scant attention despite hosting spectacular crystals. The relatively high abundance of Fe, Ti, Cr and Cu (and perhaps other metals) in the schist suggests more went on here than just simple pelagic sedimentation – perhaps some enrichment from hot spring exhalation? Coticules, interpreted as manganeseiferous chert associated with itabirites and massive sulfides, have been reported in the Rowe in this area and in regions to the north and south (Merguerian 1980, 1981, 1983). Post-orogenic geoenvironments include retrograde metamorphism, and brittle faulting and fracturing that host quartz, calcite and zeolites common in western Connecticut. A comprehensive mineral list and many more photos are at www.mindat.org/loc-254549.html.

Property Description

The part of the property where the kyanite and ilmenite are found consists of a relatively level area, about an acre or so, within an otherwise generally NE descending, heavily wooded upland area with elevations over 1,000 feet that slopes steeply down to a large wetland at elevation 870 feet. The level area has been cleared and graded recently, but in doing so the owners noticed that it had been leveled before, with large boulders pushed downslope into a steeper area of bedrock outcrops. While grading the area, the owners uncovered a large in-place mass of white quartz attached to muscovite schist, and a hummocky area of angular quartz fragments mixed in with soil bordering a small wet area that appears natural. Upslope from these areas are scattered outcrops of schist and amphibolite. In the downslope area, among the boulders and outcrops of schist and calc-silicate rock, was a suspicious depression. Old junk and slag or cinders were found in the downslope area as well.

Geology and Mineralogy

Originally mapped by Gates and Christensen (1965) the region to the north of Route 202 was remapped by Merguerian (1977) and similar rocks and minerals were found there. The area is underlain by metamorphic bedrock consisting of the Cambro-Ordovician Rowe Schist, originally pelitic siltstone/subgreywacke and shale; interbedded black or mottled, massive amphibolite and hornblende gneiss, representing ocean floor basalt; and lenses of calc-silicate rock, originally impure carbonates (Figure 33). The schist is discussed in more detail below. Loose boulders of "hornblende" (unspecified dark amphibole) gneiss and schist have been found around the property, typically as slabs broken along the foliation. It exhibits layers rich in hornblende as isolated, thick prismatic crystals to 1-3 cm, many in subparallel arrangement within a quartz-rich layer, or as flabellites of thin crystals to about 5 cm in more micaceous layers. The amphibolite is generally fine to medium-grained, well foliated and composed of hornblende and albite (An₃₀) with minor accessory biotite, quartz, titanite, chlorite, clinozoisite, ilmenite and magnetite. Some of it is altered to epidote, typically forming a thinly banded, pistachio green and black rock, with fine-grained, specular hematite in joints. The minor calc-silicate lenses contain generally massive actinolite, grossular, albite, scapolite, epidote, titanite, quartz. These rocks underwent Barrovian prograde metamorphism to



amphibolite facies (staurolite grade) during the Ordovician Taconian and Devonian Acadian orogenies. Merguerian (1985) documents 2 metamorphic events, with the larger porphyroblastic crystals discussed below formed during the second event. Retrograde metamorphism is also evident, best exemplified by abundant hematite, chlorite, epidote, very fine-grained muscovite pseudomorphs after kyanite and very fine-grained hematite, magnetite and rutile pseudomorphs after ilmenite.

Figure 33. Geology and historic farms of the area where large kyanite and ilmenite crystals were found. Site is marked by blue star. Modified from Rogers (1985).

Many of the boulders that had apparently been pushed just downslope are composed of white quartz with huge kyanite crystals, and some with ilmenite and other large crystals, that piqued the owners' interest. These were cleaned of soil and placed in a rock garden area near the large in-place quartz mass which also shows some ilmenite crystals (Figure 34).

Pyrite and chalcopyrite are very minor constituents of the local rocks. One very small (about 1 cm) chalcopyrite mass is seen within a zone of coarse biotite and albite in

quartz proximal to one of the large pure quartz masses, but several pods have been found in loose rocks. It is only obvious due to the halo of bright green secondary malachite staining the rock around it. Thin green films of malachite are also seen on schist, not very distinct from the more abundant green fuchsite mica, with no indication of the original sulfide. Indeed, Brunet (1977) noticed this also at the Yale Farm locality. These minerals, and perhaps others, appeared to inspire 18th and 19th century prospecting at this site, and others nearby, as discussed later.

Figure 34. Mineral rich boulders and bull quartz mass. (H. Moritz photo.)

Rowe Schist Porphyroblasts

The Rowe Schist is primarily (>50%) muscovite and quartz, with subordinate biotite and albite. Zones of emerald green muscovite variety fuchsite (with 0.56% chromium oxide) are abundant, these were noticed by the owner during excavations and are not mentioned in the literature. Within the schist are porphyroblasts of kyanite, ilmenite, staurolite, albite,



biotite, and almandine. Merguerian (1977, 1985) notes that the schist contains “large (up to 10 cm) porphyroblasts of garnet, biotite, staurolite, and kyanite”. Gates and Christensen (1965) noted the prevalence of kyanite in the site area (Figure 35), but make no mention of the large bull quartz masses, which here are up to 2 meters thick and ~10 meters along strike (Figure 34). Discordant, white, pure quartz masses are common in western Connecticut but are scarcely mentioned in the geologic literature. Nor do they mention conformable quartz boudins rich in kyanite, ilmenite, and albite porphyroblasts (Figures 34, 36, 37).



Figure 35. Concentration of blue-grey, smaller kyanite porphyroblasts with albite in schist. (H. Moritz photo.)

Historically the porphyroblastic minerals are well-known, especially in quartz masses. For example, Brace (1819) reports that kyanite (aka cyanite or sappare in the then commonly used French) was found in Litchfield:

Cyanite or Sappar [sic], are found in great quantities, especially in Harwinton and Litchfield. A crystalline mass of this was found a few years ago, weighing probably 16 cwt. [1600 pounds]; it lay on mica slate [schist] ridge, and undoubtedly had been formerly imbedded [sic] in the slate.

Though kyanite was recognized as a species long before 1819, ilmenite ($\text{Fe}^{2+}\text{TiO}_3$) has a more complicated history. Called by several names going back to the late 18th century, it was formally described and named by Adolph Theodor Kupffer in 1827 after the locality in the Ilmen Mountains of Russia. Shepard (1842) formally described a mineral with the same composition he named “washingtonite” after the Connecticut town and for patriotic reasons. He makes mention of the already described, similar mineral “crichtonite” in Shepard (1835 and 1837) from localities in Washington and South Britain, and in 1838, from Litchfield, too (Gold, 1838). Gold described the “crichtonite” crystals, within the Woodruff Farm on Town Farm Road north of US Route 202:

in short hexagonal prisms, with the alternate angles replaced by single planes, inclining upon the base at an angle of 121° , and upon the lateral planes at an angle of 134° . The largest of the crystals are about three-quarters of an inch in length, and two and one quarter inches in diameter. It is found imbedded in fragments of quartz and mica-slate.

He also noted staurolite crystals up to 4 inches long. Indeed, this area includes “coarse staurolite schist” mapped by Gates and Christensen (1965). Shepard considered “washingtonite” distinct from ilmenite and “crichtonite”, but these and other minerals were eventually shown to be identical and the names besides ilmenite were discredited. Later references, such as Schairer (1931) or Sohon (1951) provide only very general information on these minerals, such as ilmenite being: “Common throughout Litchfield County in the quartz veins.” In any case, this black, heavy, submetallic mineral is widespread and locally common and was likely found and misidentified by

many during the late 18th and early 19th centuries due to the lack of experience and descriptions. By the late 19th century, Gaines (1887) described specific ilmenite localities in Litchfield (Figure 33), in this case on the Yale and Smith farms on the NW side of U.S. Route 202, just SW from this locality and east of Town Farm Rd., where:

a mass of white quartz rock can be seen standing out conspicuously in the open field. Fine crystals of washingtonite were found in this mass itself as also in the blocks on the slope below that had fallen from it...near the top of the same ridge...the mica schist crops out in a small grove of hickory trees. Here a number of plates of washingtonite, without well defined angles, were found in the rock, associated with well preserved crystals of staurolite of a dark brown color.

Brunet (1977) describes collecting at the Yale Farm locality (Figure 33), which he calls a quartz mine:

In the cliff area of the first Gaines location, large detached masses of ilmenite were found in the dump in front of the workings and after considerable rock shifting and excavating, a number of fine crystals common to the area were found—one giant coarsely-shaped crystal being all of 2 1/2 inches by three inches and 1/2 inch in thickness, in an 8" by 5" by 4" matrix. Other smaller, sharper angled crystal specimens and plates and masses were also found. Interestingly enough, in the feldspar found sparingly in the dumps, balls of chalcopyrite and associated malachite films were located, while in the rocks down slope, staurolite crystals of four to six inches were found in good though somewhat weathered condition. Also found were rocks of almost solid staurolite masses which after breaking were found to contain beautiful clean, perfectly shaped staurolite crystals. Most of the adjoining dumps were left unexplored but will be examined for further evidence of ilmenite, as well as other minerals.



Figure 36. Huge kyanite porphyroblasts in massive bull quartz. (H. Moritz photo.)

The kyanite and ilmenite crystal concentrations and sizes at this new locality certainly match or exceed the historical finds. Indeed, the kyanite-rich boulder described by Brace (1819) is a dead ringer for those at this site. Such concentrations were not mapped by Gates and Christensen (1965), though they do mention that a belt of "distinctive kyanite-bearing rock...only 50 to 200 ft wide" within the Rowe Schist may extend along its eastern contact with the Ratlum Mountain Schist but they were unable to trace it in the field opting to use the symbol "X" on their maps to designate the occurrence. This belt includes the site area as well as the ilmenite localities to the north described by Gold (1838) and Gaines (1887). The kyanite porphyroblasts at the site were found in loose boulders and typically occur in 2 modes.

One mode is as grey crystals to 5-10 cm concentrated in layers in the schist, where they are mostly randomly oriented (Figure 35). Boulders like these have a very rough surface due to myriads of exposed kyanite crystals, which due to their high hardness tend to be exposed by weathering. Crystals of this size were noted by Gates and Christensen (1965), which they dubbed "spectacular". Anhedral,

lumpy, white albite porphyroblasts to about 10 cm can be an associated mineral (Figure 35).

The other mode is more impressive due to better color, size, orientation and association, and given the descriptor applied to the smaller crystals by Gates and Christensen (1965), they must not have noticed crystals of this mode. These crystals are tinted mostly light blue with dark blue cores and can reach to over 40 cm long, with most in the 15-30 cm range. They also tend to have parallel orientation and to occur in pure concentrations 10s of cm thick enclosed in massive pure white quartz, less commonly with quartz and subordinate schist, in boulders on the order of a meter or more in size (Figure 36). Combined with these kyanite's tendency to terminate separately in

the pure quartz, these boulders have strongly columnar to wedge or conical shapes due to preferential parting along the prismatic cleavage of the oriented kyanite crystal concentrations. The most impressive ones resemble giant snow cones, the cone part composed of pure, radiating kyanite capped by pure white quartz snow. These boulders certainly recall the 1600-pound "crystalline mass" mentioned by Brace (1819).



Figure 37. Concentration of warped, thin, platy ilmenite crystals in quartz/albite boudin boulder. (H. Moritz photo.)

Ilmenite, too, can occur in the schist, generally as smaller, less obvious porphyroblasts to a few cm hidden with associated dark green, almost black, fine-grained chlorite and coarse-grained biotite. But ilmenite associated with white, very coarse-grained albite and massive quartz is, due to its black color and larger size, much more obvious. These crystals can occur as thin, warped plates only a few mm thick and up to 10 cm across, especially where discontinuous and boudinaged, albite and/or massive quartz is intermingled with schist (Figure 37). Warped ilmenite can be found within a thin layer of

schist enveloping loose quartz boudins that resemble and are about the size of turtle shells. Even more obvious are tabular, undeformed, euhedral crystals found within the perimeter of large, semi-conformable bull quartz masses (Figures 38, 40, 41). These crystals can be mm-scale thin also, but many are a few cm thick and can reach 20 cm across. They tend to occur rooted in concentrations of fine-grained chlorite just outside the quartz and extend into the quartz perpendicular to the contact with the schist.



Figure 38. Sample of the contact between discordant, white, bull quartz (top center) and schist (lower left). Dark green, fine-grained chlorite (commonly with fluorapatite and magnetite) lies in between them, with a flat, undeformed, euhedral ilmenite crystal at right, rooted in the contact. The very brittle ilmenite crystals are mostly found as fragments in mine waste. (H. Moritz photo.)

Discussion

A geological sketchmap of Stop 4 (Figure 39) shows 5 sub-stops that we will visit in order to examine the regional geology including the quartz veins, faults

and mine workings of the area (Figures 34, 40, 43). The rocks consist of Rowe Schist with local amphibolite and are internally folded by isoclinal F_1 and F_2 folds and warped by late SW-plunging crenulate folds of the foliation as shown by the warping of the S_2 foliation form lines. The schist is cut by two quartz veins (yellow in Figure 9) which vary in thickness from 3-4 m (northern vein) to ~2 m thick (southern vein). The northern vein is discordant to the S_2 regional foliation, trends $N40^\circ E$, is steep to vertical and shows some slight variation in dip from NE to SW and an $N65^\circ E$, 90° offshoot at Stop 3 (Shaft #2). This vein is cut along its NW margin by a major fault highlighted by a healed fault breccia which trend $N40^\circ E$, 90° between sub-stops 2 and 3. The quartz vein has been exposed in both open pit shafts (sub-stops 3 and 5) in search of ore minerals.

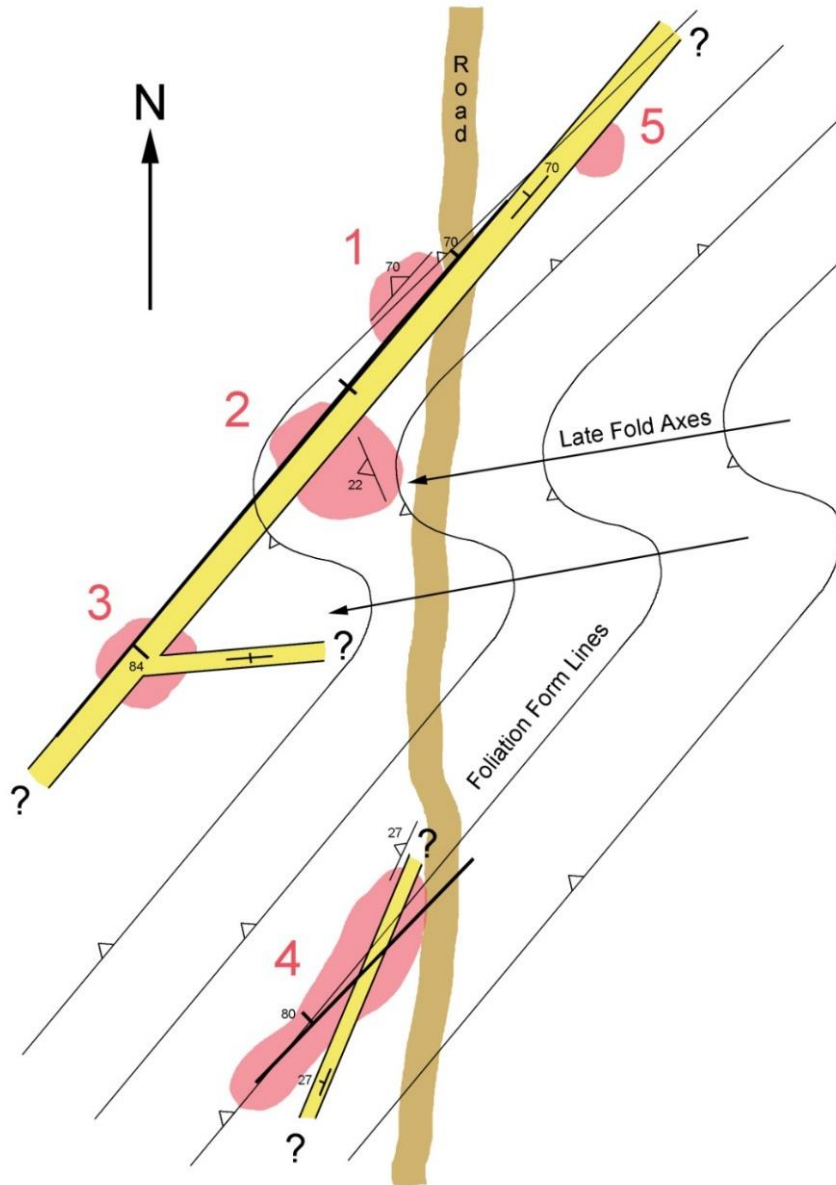


Figure 39. Geological sketchmap of the area of Stop 4 showing the five sub-stops to be studied during our visit. Pink areas show the five numbered sub-stops. Note that Shaft #1 (as described in text) is sub-stop 5 and Shaft #2 is sub-stop 3. Also indicated are the quartz veins (yellow), the major faults (bold black lines with dip bars showing dip direction), S_2 foliation form lines (fine black lines with foliation symbols), and the axes of late, crenulate folds of the S_2 regional foliation. The access road is shown in tan. Map is an initial draft, not to scale - for overview of site only.

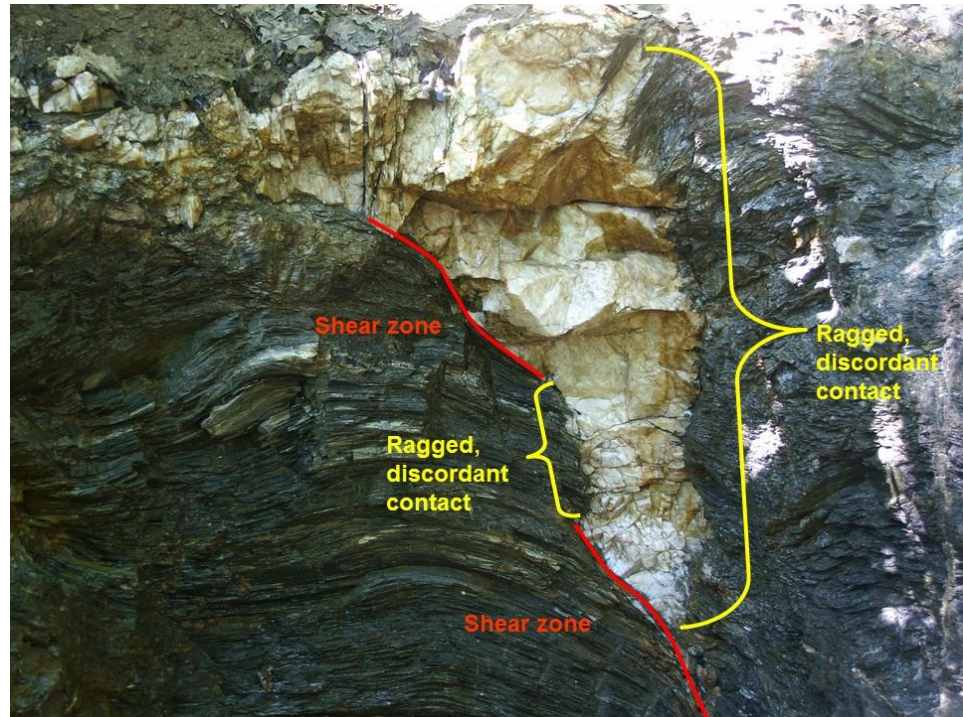
To the south a second, thinner vein is about 2 m thick and concordant to the foliation in a gross sense with a shallow 27° dip to the NW and $N22^\circ E$ trend. It encloses foliated inclusions of the Rowe Schist but is largely injected parallel to the bounding S_2 regional foliation. This vein is also cut by a steeply inclined fault that trends $N41^\circ E, 80^\circ NW$. The fault shows normal oblique-slip slickenlines that plunge 73° into $N10^\circ E$, indication predominately dip-slip offset. Both veins are of unknown

extent parallel to strike.

The deformed kyanite and ilmenite crystallized within the schist and the conformable, associated quartz-rich boudins (Figures 35 & 37) appear related to compressional metamorphism, given the temperatures and pressures required for their formation. Merguerian (1985) suggested they are Taconian, presumably related to regional thermal maxima produced during intrusion of the Hodges Complex which is ~ 450 Ma (Ratcliffe et al. 2012). But the much larger euhedral crystals found in the discordant quartz masses (Figures 36 & 41), although also deep-seated, require a different explanation. Exposures here provide clues to the origin of these discordant quartz masses.

One of the exposures is a vertical cut showing meter-scale quartz masses within the schist. The quartz appears to mostly cross-cut the host schist foliation, with the latter appearing to interfinger and fade into the quartz (Figure 40). A shear zone that extends into and cuts part of the schist as well is present along a portion of the quartz/schist contact. While the sense of motion along the shear is not obvious from this feature alone, the ragged portions of the contact give the impression that the schist was separated by ductile extension.

Figure 40. Detail of the west wall of “Shaft #2” (sub-stop 3) exposing a cross-section of a discordant quartz vein in Rowe Schist. The contact at right is ragged with the schist foliation fading into the quartz. The contact at left truncates a late fold of foliation that exhibits normal shear sense that extends into and disrupts the foliation of the schist. These features suggest the schist was torn open by extension. View is about 2 m wide. (H. Moritz photo.)



Supporting this interpretation is the presence of the large, euhedral ilmenite crystals along some of the contacts (example, see Figure 41). These crystals are rooted in the schist (in a contact zone of pure chlorite) (Figure 38) but must have grown out into an open (liquid-filled) space to have such perfect and undeformed shapes. Eventually the interstitial spaces solidified into massive quartz and remained undeformed. Consequently, in boulders where the quartz has broken away from the contact mostly ilmenite cross-sections are exposed. Removal of intact crystals is extremely difficult because of their good parting, brittleness, relative thinness, and the toughness of the enclosing quartz.

Figure 41. Tabular, undeformed, terminated ilmenite crystal in quartz mass, West Torrington, CT. (www.Dukelabs.com specimen 0063.)

Although ilmenite is described as weakly magnetic, many of the crystals proved to be strongly magnetic or to internally vary from non-magnetic to strongly so. Closer inspection showed that many of the “ilmenite” porphyroblasts are actually partly or completely pseudomorphed by very fine-grained magnetite, hematite and/or rutile (Figure 42). This finding raises the question about the character of ilmenite from other state localities and whether there is any paragenetic relationship between these pseudomorphous minerals and their isolated counterparts in the schist.



When did these quartz masses form? Because the minerals also occur in the schist, the extension must have occurred when the P-T conditions were still appropriate for kyanite and ilmenite crystallization, which would seem to rule out the shallower, brittle Mesozoic faulting event. The contacts where the ilmenites are rooted are rich in presumably retrograde metamorphic chlorite suggesting they formed during early post-orogenic collapse rather than during collision. In any case, hopefully these exposures will spur study of these common but underappreciated geologic features.

Another curious aspect is the relative abundance of metals in the Rowe Schist here. Although ilmenite is certainly a common accessory in this and other similar formations in western Connecticut, it appears to be far more abundant here and along with hematite, magnetite and pyrite accessories demonstrates a local enrichment in Fe and Ti. Cr-rich fuchsite is common and there is more Cu found in the schist as chalcopyrite and malachite than in the more typical hydrothermal vein geoenvironment. These minerals are present **throughout the formation** rather than in a younger, cross-cutting feature and so appear to be part of the protolith, implying enrichment of the sediment, perhaps by syngenetic hot spring exhalation associated with the interbedded amphibolite (basalt)?



Figure 42. Very fine-grained hematite and rutile replaced an ilmenite crystal 9 cm long in massive quartz. (H. Moritz photo.)

Mining

The discovery of two long-abandoned vertical mine shafts on the property and other evidence of mining activity (Figure 39) is interesting from both an historical and geological perspective because both the timing and the reasons for it were (apparently) undocumented and uncertain. However, given the plethora of such small-scale explorations around the state and the presence of Cu mineralization, it is not surprising work was done here. As discussed further below, this site is not as undocumented as initially believed, but the absence of any map with a mine name on it certainly contributed to its obscurity.

One shaft ("Shaft #1" = sub-stop 5 for reference - actual monikers are unknown) was discovered beneath a shallow, suspicious depression and was filled with debris, trash and water-soaked logs and timbers (Figure 43). Its upper part is a pit that passes through 3-4 meters or so of glacial overburden that leads to an approximately 1.25-meter-square vertical shaft about 4 meters deep cut into competent, but mineralogically unremarkable schist with abundant fuchsite. At the base is a very short tunnel, barely more than a meter long, with part of the ceiling still held up by original timbering. Tool marks from drilling and picking are still evident on the walls, floor and ceiling. The owner has since preserved it by constructing a small shelter over the shaft and installing lights and pumps. Connecticut State Archaeologist Nick Belantoni has inspected it and believes the timbering is 200-300 years old.



Figure 43. "Shaft #1 (sub-stop 5) after excavation. Original mine timbering is visible at the top of the short tunnel lit up behind the site owner. The schist contains emerald-green muscovite variety fuchsite, likely mistaken for malachite. (H. Moritz photo.)

The other shaft ("Shaft #2" = sub-stop 3) is also a vertical shaft about 2-meters square and 3-4 meters deep that is surrounded by an area of shallow workings that was covered by schist/quartz debris (Figure 40.) This shaft and workings reveal several large ± 1 m quartz masses within schist with abundant, large ilmenite crystals (or pseudomorphs) in the shaft walls and within the debris, particularly in the quartz in contact with schist and associated with masses of fine-grained chlorite (Figure 38.) Similar to Shaft 1, tool marks are found on the walls here as well.

The mines leave few physical clues about their purpose considering they are sunk into schist, an atypical geoenvironment for mining metals. Most Connecticut metal mines followed brittle fault-hosted hydrothermal deposits that include various metallic sulfide minerals, though typically their quantity and/or the size of the deposit precluded economic success and so they are little more than prospects. The most successful mine, the Bristol Copper Mine, began in 1836 and was in peak production in the 1840-50s. The principal ores there were chalcocite, a heavy, dark gray to black mineral; bornite, with similar appearance; and chalcopyrite. Malachite was also abundant as a secondary mineral, and this was an obvious clue to Cu mineralization anywhere. Malachite is found here but sparingly and not in the shafts. However, while excavating soil and mine waste, the owners report seeing abundant emerald green fuchsite on wet schist in the area of shaft #2 and it is obvious in the schist at shaft #1. This must have been considered exciting news at the time as gold mining operations in California were in full swing and the occurrence of fuchsite within gold+quartz veins were known by miners.

The widespread occurrence of ilmenite but a lack of understanding of its nature may have confused the miners. This heavy, dark mineral could be easily mistaken for chalcocite by 18th and 19th century unschooled prospectors. Even the professionals were fooled. The "broad plates" of supposed, unconfirmed native antimony from Harwinton described by Cleaveland (1822) are likely just ilmenite. In hindsight, chalcocite is not known from the metamorphic highlands of western Connecticut, just from within the Mesozoic Hartford Basin, but those restrictions were not evident at the time. With this perspective, and the discovery of the mining, one of the enduring mysteries of Shepard's 1837 *Report* may be explained (modern mineral names have been added in square brackets):

A number of rich fragments and even crystals of large dimensions of vitreous copper [chalcocite], have lately been forwarded for examination by Mr. ISRAEL COE of Wolcottville, who states that they were found about two miles from that village on rather an elevated ridge of land, among the rubbish surrounding an excavation made by an Englishman prior to the revolutionary war. The tradition is, that the ore obtained was taken to New York and put on board a vessel for England, and that the vessel having been burnt, the enterprise was pursued no farther. Several of the samples are attached to pieces of quartz, and are attended by small quantities of green malachite and chrysocolla. Variegated copper [bornite] likewise occurs to a small extent, blended with the vitreous copper [chalcocite]. Accompanying the specimens, were also sent samples of yellow copper-pyrites [chalcopyrite], associated with iron-pyrites [pyrite] in quartz, and which were stated to have been found within a short distance of the excavation.



Figure 44. SW view from U.S. Route 202 of the hill encompassing the site area rising above a wetland about 2 miles from downtown Torrington. Apparently the "elevated ridge of land" mentioned by Shepard (1837). (H. Moritz photo.)

Shepard's vague and scanty details have caused modern collectors fits. First, the location of Wolcottville is not obvious because it is an old name for downtown Torrington no longer used. Shepard does not state which direction one should travel the 2 miles, but Wolcottville was near the highway to Litchfield (now U.S. Route 202), and a journey of 2 miles SW on that road brings the traveler to elevated terrain

rising abruptly above a large wetland on the SE side of the road, home to this locality (Figures 33 & 44).

The "chalcocite" is described as "fragments" and "crystals of large dimensions" and "attached to pieces of quartz", all consistent with the character and occurrence of ilmenite here. Specular hematite could easily have been mistaken for bornite and the minor chalcopyrite with green secondary malachite is also consistent with the locality's mineralogy. However, the more abundant emerald green but worthless fuchsite was not named (in Europe) until 1842 and so was likely mistaken for malachite for a while after that. But also telling is that Mr. Coe apparently found the minerals "among the rubbish surrounding an excavation", as they can be found there now. This site appears to be a perfect match, once one substitutes ilmenite for chalcocite, but that is not much of a stretch. Besides, a bona-fide chalcocite locality would become well known, yet it disappeared from the literature just around the time

Shepard came to understand the nature of ilmenite. But it may have inspired some prospecting, and solved another less well known mystery, based on this passage from Payne K. Kilbourne's history of Litchfield (1859):

Two miles northeast of the village on the farm of Mr. Beach [on Town Farm Road], a shaft has been sunk twenty five feet in depth by Messrs. Sedgwick and Buell. The vein or lode is fourteen feet in width, composed of pure quartz with a slight mixture of feldspar. In this vein is found a very pure gray copper ore yielding by analysis 79.5 percent of copper. A bevel has been driven 140 feet which, when completed will intersect the vein at 50 feet in depth. In this vein are also found great quantities of small pure garnets.... This vein bearing in a nearly north-south direction, can be traced for a distance of three miles. On the farm of Mr. Gilbert, one-half mile from this location, was recently found an old shaft 15 feet deep which is supposed to have been sunk before the Revolution. This has been cleaned out and sunk 30 feet upon a small vein of iron and copper running together. The quantity of copper found is not yet sufficient to render the digging profitable, the mine having been but partially developed.

The Beach farm on the 1859 map is adjacent to, and may have been subdivided from the Woodruff Farm on Town Farm Road described by Gold (1838). It is also near the Yale and Smith farms (Figure 33) described by Gaines (1887) and later visited by Brunet (1977), who found ilmenite in a mass of pure quartz, garnet, and chalcopryite with malachite. Brunet saw workings and dumps and called it a quartz mine, which apparently had no documentation. Now it seems likely to be prospecting by Sedgwick and Buell, again just substitute ilmenite for "pure gray copper ore" (The analysis is extremely rich and therefore suspect and history shows these to be in most cases bogus and created or enhanced for promotional purposes - or the assayer did not understand the chemistry of ilmenite). The Gilbert house is shown on the 1859 map as located on the south side of the highway near the border with Torrington, but the farm property may have extended SW along the highway, across the wetland and up the hill to this locality. The shafts here match Kilbourne's description, and the original mining period matches Coe's locality in Shepard! It seems that the Gilbert Farm must be this "new" locality (Figure 33).

Another history of Litchfield mining (Hubbard, 1905) describes a locality near the Torrington line where:

...a vein of iron pyrites appears near the Torrington line, and a shaft about 15 feet has been sunk. To the west of this shaft, and at the right of and a short distance from the top of Toll Gate Hill, a number of holes have been dug, apparently by parties seeking ore. It is said that a shaft, begun before, the Revolutionary War, was sunk in this locality on a vein of copper ore, but I have never been able to discover it. The only evidence of mineral in the excavations near Toll Gate Hill are a few crystals of Washingtonite or ilmenite, a commercially valueless [sic] ore of iron, perhaps this was what induced the ancient miners to labor, thinking it of value...There is a large and probably valuable deposit of quartz rock on the farm owned by Dr. J. T. Sedgwick, west of the Torrington road.

The name "Toll Gate Hill" does not appear on modern or historic maps of Litchfield, but the 1859 map shows the toll gate for the Litchfield-Torrington Highway (now U.S. Route 202) just east of this locality and adjacent to, in the words of Shepard, "an elevated ridge of land" rising above the wetland. The descriptions of the prospecting and the minerals found on Toll Gate Hill exactly match this locality. The quartz mining appears to match that documented for the Beach, Yale and/or Smith farms (Figure 33).

The period 1850-1865 was marked by a "mining craze" (White, 1920) in Torrington and Litchfield mainly due to the efforts of Israel Coe, who started Wolcottville's first brass mill in 1834 and was a principal in that expanding business, an industry that spread down the Naugatuck Valley, for decades. As such, and with the contemporary success of the Bristol Copper Mine, he was searching for his own local sources of Cu. This included workings in the Litchfield norite intrusions in W. Torrington and Prospect Hill in Litchfield, which contain grains of chalcopryite and pentlandite. The U.S. Mint was also interested in Ni for coinage at this time, so working the norites for these two metals made sense, though they did not pay, but that is another story. Coe had interests in mines with, and partly financed activities by, Albert Sedgwick and John Buell, who in 1852 took out leases on multiple adjacent properties on the NW side of U.S. Route 202 and adjacent to Town Farm Rd. (Figure 33) (Litchfield clerk's office).

Although all of this information make collective sense, a bit of wrench is thrown into it by this passage from Orcutt (1878) in his History of Torrington:

Specimens of almost pure ore (amorphous), others vitrified, and crystalized [sic], of various colors, have repeatedly been obtained at the summit of Occident hill (Chestnut hill), and afford presumptive evidence of the existence of a rich copper ore bed in that locality. Tradition says that before the revolutionary war an English miner discovered this ore bed; made considerable excavations; obtained valuable products, which he shipped for England, he

going in the same vessel, and that the vessel and himself were lost at sea.

The copper is found in a mica slate [schist] ledge and associated with quartz distinctively. Some of the specimens are carbonates and of beautiful green crystals [malachite]. The yellow or copper pyrites [chalcopyrite] are also found.

Of course, Occident or Chestnut Hill cannot be found on any map! That aside, it tells the same story of the lost English miner as did Shepard (1837) and Kilbourne (1859). While Shepard did not give a specific town, Kilbourne is referring to Litchfield. The geology and mineralogy given matches that found at this site, however. Bill Domonell (1994) wrote about this "lost" Torrington Cu mine. He makes a strong case that the "Englishman" was none other than Samuel Higley, operator of the Higley copper mine (now in East Granby) and minter of the first coins in America - the Higley copper! Samuel Higley was supposedly lost at sea in 1737 with a shipment of his ore to England. Isaac Higley, Samuel's half-brother, was one of the first Torrington settlers who came there before 1740. There is no direct evidence they did any mining in Torrington (or Litchfield) but the circumstantial evidence is certainly compelling. In any case, Coe eventually found out about it and he and Cyrus Palmer obtained a 999-year lease on the property in 1837, the year Shepard's survey was published. Domonell (1994) states:

When mining operations began, the men hired to sink a shaft failed to find a continuous vein, but they did find a rich sulphurate ore occurring in separate deposits and in small quantities. Whatever ore they did obtain from the undertaking was smelted in one of the brass mill's furnaces and then poured into a mold. The finished product, weighing nearly a pound and consisting of nearly pure copper, was used by Coe as a paper weight on his desk for fifty years, and...was often referred to as Coe's "\$30,000 toy" supposedly representing the amount of money which went into financing his earlier mining venture.

It now appears that this property underwent 3 periods of prospecting, one before the Revolution (perhaps by Samuel Higley before 1737), by Israel Coe around 1837, and finally in 1859-60 by Sedgwick and Buell. Small mines and prospects in Connecticut typically went through cycles, usually a couple of generations apart, of re-prospecting and/or re-promotion for investors, only to fade away again when the ore (always "silver", "gold" or "copper" regardless of the actual mineralogy) or deep pockets were exhausted. But here the 19th century work was done by well-respected men of the local community. The goal was copper, spurred on by the presence of chalcopyrite and malachite, but perhaps enhanced by ilmenite mistaken for chalcocite but more likely fuchsite mistaken for malachite. All operations were apparently short-lived as they obviously would not have paid for the work done. The widespread, but shallow workings have the appearance of prospecting techniques from that era, done with hand tools and some black powder and with rough timbering. The owners have found and saved many artifacts, which appear to be 19th century. But certainly the mines had to be old enough to become forgotten and heavily overgrown by forest, which supports the scant documentation available about their age.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the cooperation of the owners of Tailwaggers Kennel for selflessly, and at their expense, excavating and preserving the minerals and long-lost mines at this site and making them available for study and accessible for this trip. Without them this truly remarkable locality would have remained lost. We are also indebted to O&G Industries and Mr. Ken Faroni for allowing access to the Southbury Quarry during this trip. They recognize that the spectacular mineralization found there is part of the state's heritage worthy of study and preservation. Thanks goes to Martha Gilmore for getting the insurance paperwork to O&G and to her work and all others at Wesleyan University involved in hosting the NEIGC.

ROAD LOG

Mileage (starting point is ConnDOT commuter lot near Rts. 25 & 111, 647846.60 m E; 4572111.76 m N).

- 0.0 From DOT commuter lot turn right onto Broadway Rd.
- 0.1 Turn right onto Route 111.
- 0.3 Follow Route 111 straight through the traffic light at the intersection with Route 25 and continue to entrance to the plaza with Edge Fitness (41 Monroe Turnpike). Turn left into the plaza, drive straight through plaza, turn left behind Edge Fitness and park.

Stop 1A: Edge Fitness. (647694.08 m E; 4572549.65 m N) View and discuss outcrop of amphibolite and cross-cutting hydrothermal vein.

- 0.5 From the exit from Edge Fitness plaza turn left onto Route 111 and follow it to Corporate Drive.

0.3 Follow Corporate Drive through left and right curves and park on right side of road when road straightens.

Stop 1B: Corporate Drive. View and discuss outcrop of The Straits Schist at 75 Corporate Dr. and marble and amphibolite in work site below (not accessible), with cross-cutting hydrothermal veins.

0.2 Drive to circle at the end of Corporate Drive and park on the road.

Stop 1C: Old Mine Park. (648141.75 m E; 4572336.73 m N) Hike into park & view & discuss outcrops of hydrothermal veins, orientation mineralogy, etc. Collect minerals from these veins. Discuss alteration of scheelite to ferberite at upper mine shaft.

0.5 Drive back on Corporate Drive to the intersection with Route 111, left onto Route 111.

0.7 Follow Route 111 to the intersection with Route 25. Turn right onto Route 25.

9.2 Turn right onto Mile Hill Rd / Wasserman Way

1.5 Take ramp right for I-84 East toward Waterbury

6.0 At exit 15, take ramp right for Route 67 North / US 6 East toward Woodbury / Roxbury.

0.2 Turn left onto US 6 / Route 67.

1.6 Turn left onto Route 67 / Roxbury Rd.

0.5 Arrive at entrance to O&G Quarry, 236 Roxbury Rd, Southbury, CT, turn right into quarry and follow winding road about 0.75 miles to quarry office. Park here to wait for all the group to arrive.

Stop 2: O&G Quarry. (648842.72 m E; 4597241.34 m N) Explore quarry for mineralized vesicles and faults. Discuss parageneses of minerals. **Stay away from walls, wear hard hats, gloves and eye protection.**

0.5 From end of quarry entrance road, turn left onto Route 67 / Roxbury Rd and follow to intersection with US 6 / Route 67 / Main St.

1.6 Follow US 6 / Route 67 / Main St. south and take ramp left for I-84 East toward Waterbury.

9.9 At I-84 exit 20, take ramp left for Route 8 North toward Torrington.

9.4 At Route 8 exit 39, take ramp right for East Main St toward Thomaston.

0.2 At end of ramp turn left onto US 6 / E Main St.

0.4 Bear right onto E Main St, and then immediately turn right onto Route 222 / N Main St.

1.0 Follow Route 222 under Route 8 – take note of large pegmatite outcrop in schist on left side of road. Turn right to stay on CT-222 / Hill Rd

0.6 On the left arrive at US Army Corps of Engineers office at entrance to dam. Park here.

Stop 3: Thomaston Dam pegmatite. (661403.10 m E; 4617540.02 m N) View & discuss properties of pegmatite.

0.8 From USACOE office turn right onto Route 222 / Hill Rd. Take ramp left for Route 8 N.

6.4 Take ramp right for Route-118 West toward Litchfield / Torrington.

0.2 At end of ramp turn left onto Route 118 / Litchfield Rd.

2.2 Follow Route 118, turn right onto Clark Rd.

1.6 Road name changes to Peck Rd.

0.4 Turn left onto US-202 / New Litchfield St.

1.0 On left arrive at Tailwaggers, 568 Torrington Rd, Litchfield, CT. Drive straight up past buildings and park beside grassy area and boulders beyond them.

Stop 4: Tailwaggers kennel. (652944.27 m E; 4627008.90 m N) View & discuss metamorphic minerals & mines. Owners have specimens for sale.

References

- Bowen, G.T., 1822, Analysis of the calcareous oxide of tungsten from Huntington: American Journal of Science: s. 1: 5: 118-21.
- Brace, J. P. 1819, Observations on the Minerals Connected with the Gneiss Range of Litchfield Co. American Journal of Science: s.1, 1: 351-355.
- Brunet, William M., 1977, Ilmenite Occurrences in Litchfield, Connecticut: Rocks & Minerals: 52(11): 415-20.
- Brunet, William M., 1988, New Mineral Discoveries in Litchfield County, Connecticut: Abstract for presentation at the 14th Rochester Mineralogical Symposium in: Rocks & Minerals: 63(2): 126-7.
- Burton, William, 2006, Bedrock Geologic Map of the Early Mesozoic Pomperaug Basin Surrounding Basement Rocks, Litchfield and New Haven Counties, Connecticut: USGS Open-File Report 2006-1011.
- Cleaveland, Parker, 1822, Elementary treatise on mineralogy. ed. 2: Cummings and Hilliard. Boston. 2 vols.
- Crowley, William Patrick, 1968, The Bedrock Geology of the Long Hill and Bridgeport Quadrangles, with maps: State Geologic and Natural History Survey of Connecticut, Quadrangle Report 24: 73.
- Domonell, Bill, 1994, Torrington's "Lost" Copper Mine: The Torrington Voice: II(39): (April 28).

- Domonell, Bill, 1997, Nickel Mining - in Torrington??? (Parts I and II): The Torrington Voice: August 28 and September 4.
- F. W. Beers & Company, 1874, Map of Litchfield, Connecticut.
- Fuchs site mineralogical information: <http://www.mindat.org/min-1617.html> accessed July 15, 2015.
- Gaines, M. R., 1887, Notes on some mineral locations in Litchfield, Connecticut: American Journal of Science: 34: 406-07.
- Garabedian, James A., 1998, Secondary Mineralization of Half-Moon Vesicles in the Mesozoic Basalt of the O&G#2 Quarry, Woodbury, Connecticut: University of Connecticut Master of Science Thesis.
- Gates, Robert M., 1954, The Bedrock Geology of the Woodbury Quadrangle: State Geological and Natural History Survey of Connecticut Quadrangle Report no. 3.
- Gates, Robert M. and Nikolas L. Christensen, 1965, The Bedrock Geology of the West Torrington Quadrangle: State Geological and Natural History Survey of Connecticut Quadrangle Report No. 17.
- Gold, T. S., 1838., New locality of crichtonite: American Journal of Science: 1st series, 35: 179.
- Gurlt, Adolf, 1894, On a remarkable deposit of wolfram-ore in the United States: Transactions of the American Institute of Mining Engineers: 22: 236-242.
- Hatch, N. L., Jr.; and Stanley, R. S., 1973, Some suggested stratigraphic relations in part of southwestern New England: United States Geological Survey Bulletin 1380, 83 p.
- Hitchcock, Edward, 1828, Miscellaneous notice of mineral localities. American Journal of Science: series 1: 14: 215-30.
- Hitchcock, Edward and Benjamin Silliman, 1826, Topaz. American Journal of Science: series 1: 10: 352-358.
- Hobbs, W. H., 1901, The old tungsten mine in Trumbull, Conn.: U.S Geological Survey Annual Report 22: 7-22.
- Hopkins, G. M., Jr., 1859, Clark's Map of Litchfield County, Connecticut. Richard Clark, Philadelphia.
- Hubbard, John T., 1905, Litchfield mining ventures lecture to the Litchfield Scientific Association, Dec. 13, 1905.
- Ilmenite mineralogical information: <http://www.mindat.org/min-2013.html> accessed January 24, 2014.
- Januzzi, Ronald E. and David Seaman, 1976, Mineral Localities of Connecticut and Southeastern New York State and Pegmatite Minerals of the World: The Mineralogical Press, Danbury, Connecticut.
- Jones, R. W., 2001, Famous Mineral Localities: The Bristol Copper Mine Connecticut: Mineralogical Record: 32(6):433-450.
- Kilbourne, P. K., 1859, Sketches and chronicles of the town of Litchfield: Case, Lockwood, Hartford.
- Lane, A. C., 1935, Report on the committee on the measurement of geological time: National Research Council, Wash., DC.
- Merguerian, Charles, 1980, Metamorphosed manganiferous sediments (coticules) in the Ordovician of southern New England (abs.): Geological Society of America Abstracts with Programs: 12: 73.
- Merguerian, Charles, 1981, Coticules in New England - Ancient examples of metalliferous sediments (abs.): EOS, Transactions American Geophysical Union: 62: 310.
- Merguerian, Charles, 1983, Tectonic significance of Cameron's Line in the vicinity of the Hodges Complex - an imbricate thrust model for western Connecticut: American Journal of Science: 283: 341-368.
- Merguerian, Charles, 1985, Geology in the vicinity of the Hodges Complex and the Tyler Lake granite, West Torrington, Connecticut, in R. J. Tracy, ed., 77th New England Intercollegiate Geological Conference, New Haven, Connecticut. Connecticut Geological and Natural History Survey Guidebook No. 6: 411-442. http://www.dukelabs.com/Publications/PubsPdf/CM1985d_NEIGC_HodgesComplex.pdf
- Merguerian, Charles, 2015, Geology 143H – Geology, mines and minerals of western and central Connecticut: Field guide for Hofstra University Geology 143H Field Course, 04-10 April 2015, 182 p., Hofstra University, NY.
- Mose, D.G. and Nagel, M.S., 1982, Chronology of Metamorphism in western Connecticut: Rb-Sr ages: in Joesten, R., and Quarrier, S., eds. Guidebook for field trips in Connecticut and south-central Massachusetts, New England Intercollegiate Geological Conference: Connecticut Geological and Natural History Survey, Guidebook 5: 247-263.
- Orcutt, Rev. Samuel, 1878, History of Torrington, Connecticut: J. Munsell, Albany.
- Ratcliffe, N.M., Tucker, R.D., Aleinikoff, J.N., Amelin, Y.; Merguerian, C.; and Panish, P.T., 2012, U-Pb zircon and titanite ages of late- to post-tectonic intrusions of the Cortlandt-Beemerville magmatic belt, CT, NY, and NJ: relation to Iapetan closure in the Taconic orogeny: Geological Society of America Abstract # 200033, Abstracts with Programs: 44(2): 73.
- Rodgers, John, 1985, Bedrock Geological Map of Connecticut: State Geological and Natural History Survey of Connecticut.
- Schairer, J. F., 1931, The Minerals of Connecticut: State Geological and Natural History Survey of Connecticut Bulletin 51.
- Segeler, C. G., and Molon, J., 1985, The Thomaston Dam Site, Thomaston, Connecticut: Rocks and Minerals: 60: 119-124.
- Shepard, Charles U., 1835, A Treatise on Mineralogy: Howe, New Haven.
- Shepard, Charles U., 1837, A Report on the Geological Survey of Connecticut: Hamlem, New Haven.
- Shepard, Charles U., 1842, On Washingtonite (a new Mineral) etc.: American Journal of Science: 1st series, 43: 364-66.
- Silliman, B., 1819a, Additional notice of the tungsten and tellurium: American Journal of Science: series 1: 1: 405-10.
- Silliman, B., 1819b, New localities of agate, chalcedony, chabazite, stilbite, analcime, prehnite, etc.: American Journal of Science 1: 134-135.
- Silliman, B., 1822a, Native yellow oxide of tungsten: American Journal of Science: series 1: 4: 52.
- Silliman, B., 1822b, Massive yellow oxide of tungsten: American Journal of Science: series 1: 4: 187-88.
- Sohon, J. A., 1951. Connecticut minerals, their properties and occurrence: State Geological and Natural History Survey of Connecticut Bulletin 77.
- Sullivan, Earle C., 1985.; History and Minerals of Old Mine Park, 2nd Edition: Trumbull Historical Society, Inc.
- Tschernich, Rudy, W., 1992, Zeolites of the World: Geoscience Press, Phoenix: 14-16.
- US ACOE, 2014, Thomaston Dam brochure NAEPP 360-I-40.
- White, Alain Campbell, 1920 The History of the Town of Litchfield, Connecticut, 1720-1920.

To Cite this publication:

Moritz, Harold; and Merguerian, Charles, 2015, Western Connecticut's varied mineral-forming geoenvironments: p.C1-1-C1-32 *in* Gilmore, M. S. and Resor, P. G. eds., Guidebook to fieldtrips in Connecticut and Massachusetts, New England Intercollegiate Geological Conference, 107th Annual Meeting, Wesleyan University, Middletown, Connecticut, 362p.