# *GEOLOGY & MINERALOGY*
## *OF THE*
# *OLD MINE PARK AREA*
## *TRUMBULL, CONNECTICUT*

State Geological and Natural History
Survey of Connecticut

**GUIDEBOOK No. 11**

**DEDICATION**

This field guide and map is dedicated to Ronald Everett Januzzi (1930-2018), mineral shop owner, writer, and collector/conserver of mineral specimens from Connecticut including many excellent Old Mine Park ferberites. And also to Allan Sacharow, teacher and mentor in astronomy, photography, and minerals. Without his early guidance and encouragement this guide would not have been created.

**COVER PHOTOGRAPHS**

Upper left – ferberite pseudomorph after scheelite crystal in altered amphibolite, Harold Moritz collection (former Julian Sohon and Earle Sullivan specimen). Lower right – topaz crystal, Harold Moritz collection (found by Earle Sullivan in 1939). Center – tightly folded amphibolite near the Champion Lode vein, Old Mine Park, Trumbull. Harold Moritz photographs, copyright 2021.

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DEEP Store
79 Elm Street
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(860) 424-3555
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Geological Society of Connecticut
PO Box 94
Hadlyme, CT 06439
geosocietyct@gmail.com
www.geologicalsocietyct.org

**STATE GEOLOGICAL AND NATURAL HISTORY SURVEY OF CONNECTICUT**
**GUIDEBOOK No. 11**

# GEOLOGY AND MINERALOGY OF THE OLD MINE PARK AREA, TRUMBULL, CONNECTICUT

By

**Harold Moritz**
*East Haddam, Connecticut, fritzandsheila@pobox.com*

**Robert P. Wintsch**
*Wesleyan University, Middletown, Connecticut, rwintsch@wesleyan.edu*

**William Devlin**
*Rock Bottom Research, Southbury, Connecticut, bd8@icloud.com*

**Ryan J. McAleer**
*U.S. Geological Survey, Reston, VA, rmcaleer@usgs.gov*

**Shinae Lee, SookJu Kim, Keewook Yi**
*Div. Earth and Environmental Sci., Korea Basic Science Institute, 162 Yeongudanji-ro, Ochang, Cheongwon, Chungbuk 363-883, Republic of Korea*

Contributors
**Ian Hillenbrand**, *Connecticut Geological Survey, now with U.S. Geological Survey*
**Chusi Li**, *Indiana University*
**Chris Fitzgerald**, *Indiana University*

Editors
**Margaret A. Thomas**, **Connecticut State Geologist**
**Taryn J. Isenburg, Geoscience Resource Assistant**
*Connecticut Geological Survey*
*Department of Energy and Environmental Protection*

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**Katie Dykes, Commissioner**
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# INTRODUCTION

Old Mine Park, in the northern Trumbull area (also known as Long Hill) of southwestern Connecticut, is a recreation area encompassing the mineral-rich hill of "Saganawamps" and owned by the Town of Trumbull. Most of its 72 acres are wooded, rocky and undeveloped but it is surrounded by dense infrastructure and transportation, residential, retail, and commercial development (Figure 1). It preserves the first tungsten mine operated east of the Mississippi and the first topaz locality identified in the USA (Hitchcock and Silliman, 1825), as well as the type locality for the mineral *tungstite* ($WO_3 \cdot H_2O$). Hiking and biking trails cross the property and continue beyond the park along the former New Haven railroad line that parallels the Pequonnock River, which flows through the southern part of the park. Access is from the south via Old Mine Road, or from the north via Corporate Drive. During the mining era and for many decades after its creation the park was a famous source of mineral specimens. In 2016 the Trumbull Parks and Recreation Commission suspended collecting of any kind.

## BRIEF SUMMARY OF GEOLOGY AND MINERALOGY

The northern Trumbull area geology primarily consists of highly deformed metamorphic rocks. The dominant lithologies of mica schists and gneisses were originally deposited as muds and sands in the Silurian and Devonian Periods. Other metamorphic lithologies include amphibolite, marble, and minor quartzite, originally deposited as basaltic lava flows, limestone, and sand, respectively. The close association of the amphibolite and marble requires a unique tectonic and depositional setting. The names, stratigraphic relationships, metamorphism, and deformation of these rocks are briefly summarized below.

The Trumbull Old Mine Park area encompasses perhaps the best exposure of Rodgers' (1985) lithologically heterogeneous basal member of the Silurian-Devonian The Straits Schist (see regional geology map on Plate 1). State-wide, the discontinuously exposed basal member includes amphibolite, quartzite, marble, and calc-silicate gneiss. However, at Long Hill, the interval consists of a thick, well-exposed section dominated by amphibolite and marble that is unique enough in western Connecticut that we informally refer to it in this guide as the Saganawamps section. Hatch and Stanley (1973) recognized that this unique package of rocks represented an important lithostratigraphic and potentially chronostratigraphic marker and correlated the interval with the Russell Mountain Formation in southern Massachusetts. Rodgers (1985) interpreted The Straits Schist to overlie a regional (Silurian-Devonian) unconformity above Cambrian-Ordovician Rowe-Hawley Zone rocks. This unconformity may be interpreted as a post-Taconian (Middle to Late Ordovician), post-Llandovery erosional surface. The rocks exposed in the Old Mine Park area and the expansive road cuts along the Route 25 expressway are interpreted to occur above this regional unconformity and are some of the youngest Paleozoic sediments preserved in western Connecticut.

The main body of The Straits Schist is an erosion resistant unit that crops out in a N-S belt across all of western Connecticut (see regional geology map on Plate 1). The protolith of the schist was quartz-rich aluminous mudstone, and detrital zircons indicate derivation of the unit from multiple sources, including peri-Gondwanan and Ordovician arc components (Wintsch et al., 2014, 2015, 2017). All the rocks in western Connecticut were metamorphosed to upper amphibolite facies conditions exceeding 650 ºC and 8000 bars (~28 km depth) during the Acadian orogeny (~400-360 Ma, e.g., Dietsch et al. 2010). Folds in these rocks formed during the Acadian when the rocks were hot enough to bend without breaking. Although the Saganawamps section stratigraphically underlies The Straits Schist in the northern part of the field area (Corporate Drive, Stop 1), it is also observed to be structurally thrust over The Straits Schist along a zone of granitic pegmatites and incorporated metamorphic rocks we call the Pequonnock River migmatite zone (Stop 10).

The local rocks host multiple, distinct episodes of overlapping mineralization, some unique to the state and even to the Appalachians, that make the Old Mine Park area uniquely worthy of study (see mineral list in Appendix IV). Long before prospecting by European settlers, the term Saganawamps (more or less after the Paugusetts' term for "on the side of the hill" (Sullivan, 1985)) alluded to the location of a large vein of white "bull" quartz used as a resource by Native Americans. Based on information from them, the hill became a locus for prospecting, quarrying, and mining from about 1800-1900. Initially the hill was quarried for agricultural lime, then for scientific specimens as North America's first discovery of topaz and the tungsten minerals scheelite and ferberite (Sullivan, 1985) and the type locality for tungstite (Silliman, 1822a, b). Later it was the draw of traces of copper and lead mineralization, but subsequent quartz and tungsten operations were the final (unsuccessful) commercial mining activities. The tungsten mineralization, with associated concentrations of quartz, albite, clinozoisite, iron sulfides and scapolite, is hosted by metasomatically altered Saganawamps section amphibolite, which occurred during a later Alleghanian heating event likely associated with the emplacement of local igneous plutons such as the Permian Pinewood Adamellite (aka Granodiorite; Sevigney and Hanson, 1993) 4 km to the southeast. Topaz occurs mainly with quartz, muscovite and fluorite in cross-cutting, high-temperature veins crystallized in brittle fractures formed during deformation after the host rocks cooled from very high Acadian temperatures. Similar veins show albite-chlorite-dominant, and rarely, calcite-dominant mineralogy with emerald green beryl along the contacts of the latter type. Although not well exposed, Mesozoic age (~180 Ma) brittle faults host low-temperature (~200 ºC) hydrothermal mineralization consisting of calcite, fluorite, quartz, sphalerite, galena, and pyrite. How, why, and when these minerals crystallized, and their geologic distribution are questions addressed in this guidebook and map.

## MAPPING HISTORY

For 2 centuries Long Hill has been a famed mineral specimen collecting area. Some of the earliest publications by pioneering Yale mineralogist Benjamin Silliman describe minerals from here (Silliman, 1819a, b, c; 1822a, b) including the new mineral tungstite. Eventually the mining area would be the subject of numerous scientific and amateur collector articles (Bartsch, 1942a, b; Blatz, 1938; Bowen, 1822; Gold; 1838; Gurlt, 1893; Hiller, 1969; Hitchcock, 1828; Hitchcock and Silliman, 1826; Hobbs,1901, 1903; Jones, 1963; Shannon, 1921a, b; Shelton, 1967), mineralogical compendiums and surveys (Cochrane, 1896; Hess, 1917; Januzzi, 1994; Jones, 1960; Kerr, 1946; Manchester, 1931; Percival, 1842; Robinson, 1825; Sanford and Stone, 1914; Schairer, 1931; Schooner, 1961; Shepard, 1837; Sohon, 1951; Weber and Sullivan, 1994; Whitney, 1854) and several amateur mineral collector guides (Januzzi & Seaman, 1979; Hiller, 1971; Ryerson, 1976; Shelton and Webster, 1979; Sullivan, 1985; Trumbull Historical Society, 1966; Webster, 1978). Despite this large body of work, most of these publications just describe and list minerals identified, repeat, or update the knowledge on their occurrence, or speculate on their origins. There are also errors in the early literature that, despite written corrections, went largely unnoticed and were unfortunately perpetuated. Very little of the body of work is original scientific research on the genesis of the local mineralogy and its relationship to the geology. As documented by Kerr (1946), the Old Mine Park area encompasses the largest scheelite deposit in eastern North America and besides Fisher's (1942) pioneering work no one has comprehensively determined the scheelite's extent, nor seriously examined why it occurs here.

Early work on the geology by Hitchcock and Silliman (1825), Hitchcock (1828) and Percival (1842) established the basic geological framework in descriptive terms but lacked mapping. The first real geological maps of the area were produced by Hobbs (1901) and Kerr (1946) (see Appendix I) and show the interlayered amphibolite and marble. Hobbs' detailed plane-table map is limited to just the mining area, but served as the basis for collector guide sketch maps. His smaller scale map of the wider amphibolite and marble area, based on the late 1800s 15-minute quadrangle topographic mapping, is also a first, but is crude compared to the similarly scaled map in Kerr (1946) and the 7.5' quadrangle-scale photogrammetric map used by Crowley (1968), which served as the basis for Rodgers' (1985) state bedrock map in this area. Although similar in certain ways, these older maps do not agree in detail and were limited by topographic mapping quality and the availability of outcrops.

With the construction of the Route 25 expressway in the late 1970s, commercial and retail development of the area around the junction of Routes 25 and 111 increased greatly, and the park has slowly become an island of open space between the expressway to the south, the development to the west and north and residential housing to the east (Figure 1). Despite all of the more recent blasting, no work had been done to remap the geology of the park area, and many of the rock exposures at developments were transient and are now covered. However, several large and useful exposures not available to earlier workers remain along the expressway, at accessible facilities along both sides of Route 111 west of the park (e.g., The Home Depot – formerly Old Mine Plaza), and along Corporate Drive to the north. The areas of development also exposed mineralogy similar to that found within Old Mine Park and many specimens were collected with good locality documentation and enough matrix to recreate at least the type of rock exposed. The newer exposures reveal many more mineralized veins and show that the area of mineralization is more widespread than the well-known veins within the park.

## PURPOSE OF THE GUIDEBOOK

This guidebook is a companion to Plate 1 - Bedrock Geologic Map of the Old Mine Park Area, Trumbull, Connecticut, by Harold Moritz, William Devlin, Robert Wintsch, Ian Hillebrand, and Zachary Kläng (2019). It is available as a download from the Connecticut Department of Energy and Environmental Protection web site. In conjunction with the map, the guidebook's purpose is multi-fold:

- Highlight and differentiate the many unique and overlapping aspects of the local geology and mineralogy of these rocks.
- Correct errors in the literature that lead to false conclusions about the geology and the distribution and origins of the mineralogy here.
- Update geologic mapping using new LiDAR base maps with new outcrops
- Provide a revised conceptual model of the stratigraphy, structure and history and its relationship to the region, and the extent and origins of both the stratabound, amphibolite-hosted scheelite and the cross-cutting, vein-hosted mineralogy.
- Publish new findings and inspire additional geologic investigations.

This guide is not intended to include a comprehensive list and description of all the minerals found in this area. Such dynamic information is best found on www.mindat.org - a continuously updated, world-wide mineral database where many contributors post relevant locality and mineral specimen information and photographs – far more than can be included here. Browsing it while using this guide is encouraged, specifically the pages about mineral localities in northern Trumbull (Long Hill), www.mindat.org/loc-246208.html. Links to other mindat.org pages are included in this guide.

## CONTRIBUTIONS & ACKNOWLEDGEMENTS

This guidebook and its companion map (Plate 1) could not have been completed without the valuable contributions made by many individuals and organizations. Much of the work was done without remittance for labor and expense solely in the interest of furthering geologic knowledge and understanding and without the intent of financial gain.

New geological field mapping was undertaken by Harold Moritz, William Devlin, Robert Wintsch, and Ian Hillenbrand using custom LiDAR hillshade base maps derived from public data available from Connecticut Environmental Conditions Online (CT ECO). The availability of the extremely detailed LiDAR derived mapping (down to individual boulders and stone walls!) greatly increases the precision of geological mapping at all scales. It has long been the desire of one of the authors (Moritz) to prepare a new map of the geology and mineral occurrences of this unique but small area and the availability of LiDAR data finally provided the impetus. The mappers are also most grateful for the efforts of Margaret Thomas, Connecticut State Geologist of the Connecticut Geological Survey, Department of Energy and Environmental Protection, and capable staff: Ian Hillenbrand, Zachary Kläng, Tom Nosal, and Melissa (Luna) Mostowy for assistance in creating, editing, and preparing the final map for publication.

The guidebook was drafted by Harold Moritz, Robert Wintsch and William Devlin with contributions by others here acknowledged. Harold Moritz also compiled historic and mineralogical information from professional and amateur sources and photographed mineral specimens and outcrops. Shinae Lee, SookJu Kim and Keewook Yi at the Division of Earth and Environmental Science of the Korea Basic Science Institute mounted and analyzed titanites by SHRIMP to establish the time of the last foliation in the amphibolites and Ryan McAleer at the U. S. Geological Survey contributed new geochronologic data, which meaningfully improved our geologic interpretation of this area (Appendices II and III, respectively). Chusi Li helped with electron microprobe analysis at Indiana University. Chris Fitzgerald with colleagues established that no conodonts survived metamorphism in the marbles, thus removing the possibility of establishing the age of deposition by paleontological means. Chris with Dave Bish analyzed topaz from Stop 1 with XRD and Rietveld Refinement to establish its unit cell dimensions and thereby its fluorine content. Our thanks go to reviewers Art Merschat and Peter Valley at the U. S. Geological Survey, whose contributions improved this document. Margaret Thomas and Taryn Isenberg with the Connecticut Geological Survey, DEEP, managed editing, review, and publication of the guidebook. Thanks go to Cooper Surgical for access to the rock cuts on their property at 50 Corporate Drive. Thanks also to the many rockhounds who alerted Harold Moritz to new mineral occurrences and rock exposures and who saved thousands of specimens from many locations now covered or no longer accessible. Most importantly, gratitude is extended to the Town of Trumbull for preserving Old Mine Park and making it accessible for geological study and recreation.

## MINING & PROSPECTING HISTORY

The history of land ownership at Saganawamps Hill and the various players in the mining activity is long and complex. It is best told by Sullivan (1985) but is summarized here.

### MARBLE QUARRYING

The marble here was quarried and burned for quick lime, a resource in great demand for agricultural use, especially in areas where such rocks are scarce. This began before 1803 when Philo and George Sherman leased the right, "at a place called Shaganawamps for transporting lime from any part of the land to the kiln or the place where lime has usually [been] burnt" (Sullivan, 1985). The quarry at the southwest side of the hill (Stop 7) may have supplied a kiln that was later buried in the bank west of the park's footbridge, while another kiln was set up next to a series of smaller quarries on the east side of the hill where the marble is coarser grained and purer (see Plate 1). By the time Shepard (1837) made his survey this activity had ended, but the ruined foundation of the eastern kiln is still extant.

### MINERAL SPECIMEN MINING

What amounted to an era of mineral specimen mining was undertaken by the Lane family of Monroe and has led to a lot of confusion and errors in the literature that persist over 200 years later. Sulfide minerals and native bismuth found in a quartz mass on the Lane's Elm Street property in Monroe became of great interest to Dr. Archibald Bruce, who published it in the initial volume (1810) of his short-lived American Mineralogical Journal. The Lanes acquired other mineralized properties (see regional geology map on Plate 1) and brought or sent various samples from them to Benjamin Silliman at Yale. Descriptions of “wolframite” (an old term for the ferberite-hübnerite iron-manganese tungstate solid solution series – Silliman’s initial analysis showed them to be the Fe-rich end-member ferberite) and scheelite exactly matching the Trumbull occurrence (especially the rare pseudomorphs of ferberite after scheelite, Figures 2 through 6) appear in Silliman (1819a, 1819b, 1819c) and in Bowen (1822). Silliman (1822a, b) made the initial description of the new mineral tungstite from its alteration of ferberite crystals matching those from Trumbull. All these specimens were purchased from and shipped by Ephraim Lane for “a reasonable compensation”, they were not field collected by Silliman or Bowen, and were generically attributed in the earliest literature to “Lane's Mine” or just “Monroe”. It was not until 1825 that Edward Hitchcock visited the Trumbull locality, identified the marble/amphibolite geology where they were found in Trumbull “four miles south of what is usually called Lane’s mine [Monroe]” (Hitchcock and Silliman, 1825). Specimens of topaz, newly discovered in North America, were obtained from Ephraim Lane, and were also initially, generically attributed to “Lane’s Mine”. Hitchcock (1828) notes that the topaz was found in veins traversing marble at a location “three and a half miles southwest of [Lane’s Monroe] mine” and that they were “connected with the Wolfram.” Hitchcock purchased 300 or 400 specimens from various places from Mr. Lane “at a reasonable rate”, who keeps them “on hand, for the accommodation of mineralogists.” (See text posted by HM on www.mindat.org/loc-23342.html and www.mindat.org/loc-14012.html).

But the obscure 1825 and 1828 corrections went unnoticed by many later publishers, including Shepard (1837) and even by Yale’s James Dana when compiling his famous System of Mineralogy, and as a result the International Mineralogical Association still incorrectly lists Lane’s Mine, Monroe as tungstite’s type locality. There are *no* tungsten minerals or topaz at Lane’s Mine in Monroe, which still exists within a residential neighborhood at the corner of Pequonock Ridge and Flint Ridge Roads. Moreover, most of the amateur mineral guidebooks misattribute many minerals, particularly the tungsten ones, to the Monroe mine (but do include them also for the Trumbull mine) and so it has become difficult to attribute some minerals to either place without trustworthy samples. But the error did not get past Professor Adolph Gurlt (1893), who in his report on the Trumbull tungsten deposit, referring to earlier reports by Silliman, Percival, and Shepard, stated (in Sullivan, 1985, p. 21):

> On the authority of these explorers, some statements about the occurrence of wolfram [tungsten] minerals have been widely spread through American and European scientific literature, frequently, however, with slight inaccuracies as to the locality, which is sometimes placed in Monroe and sometimes in Trumbull parish. As a fact, the [tungsten] deposit lies in the latter; and the error may be explained by the circumstance that the owner at that time, a certain Charles [brother of Ephraim] Lane had been mining in both parishes, --in Monroe for lead and bismuth, which occurred in association with magnetic iron pyrites on a quartz-lode traversing gneiss, and in Trumbull at the above-mentioned place.

## MINERAL VEIN MINING

Ephraim Lane purchased or leased many acres in and around the hill for mining and prospecting until 1854 when he sold them all to his son Ambrose. According to Gurlt (1893) and Hobbs (1901), Ephraim’s brother Charles also worked there. Based on the timing of mineral descriptions in Hitchcock (1826) and Shepard (1837), it was during the Lane era that most of the prospecting along the cross-cutting mineral veins was conducted. During this period many specimens went to museums and collectors, however, Shepard noted that the “proprietor of the topaz-vein supplied a considerable quantity of the [fluorite]…at sixty dollars the ton” to the Phoenix Mining Company for “smelting of the copper-ores of Granby”. How lucrative a business this was is unrecorded, but the mining of the largest vein, the Native American quartz source, or so-called Champion Lode, for use in wood filling or processing, apparently took place around 1900 (Hobbs, 1901). This was done probably by or for the Bridgeport Wood Finishing Company, which had a large mill on the Housatonic River in New Milford and obtained quartz from many places in western Connecticut around that time (Pawloski, 2006).

## TUNGSTEN MINING

In the 1870s-1880s, Thomas Hubbard of Brooklyn, NY purchased all the land that would eventually become Old Mine Park (Sullivan, 1985) in hopes of finding copper, lead, and silver. According to Gurlt (1893) he did not find much. Not until demand for tungsten (for hardening steel) surged after 1855 was the deposit described in detail by Gurlt (1893), who estimated (with caution) that the ore bed contained 2- 3% "wolfram" with a potential yield of 90-130 lbs./yd$^3$ of rock. This apparently inspired serious but bungled attempts to mine tungsten here in 1898-1901 first by the Rare Minerals Mining Company and then by the American Tungsten Mining and Milling Company of West Virginia. That company undertook an extensive building program, including a mill and tramways to carry ore from the mine pit at the top of the hill to the mill at the bottom adjacent to the larger marble quarry (a borrow quarry just north of this marble quarry may have been the source of fill for the tramway). This activity and the mine area are described and mapped by Hobbs (1901, 1903) and summarized by Shannon (1920) and Sullivan (1985). As with many Connecticut mining attempts, it was long on facilities but short on proper mining and milling techniques or mineral expertise. The effort was focused on a localized zone along one of the contacts between marble and amphibolite where ferberite was prevalent, rather than on the more abundant scheelite present in the bulk of the amphibolite (though they apparently were not aware of this at the time). They exposed this zone at the upper mine pit and at the base of the quarry, but based on the limited physical and temporal effort, never worked very deeply into the deposit. Hobbs noted that "The pits had been sunk vertically through the ore bed into the gneiss and then had been abandoned instead of following the bed, which dips east 20° to 25°." In the end it reportedly was doomed by an inability to separate pyrite from the ore concentrate without additional processing cost. The abandoned mill buildings were destroyed by fire in 1916 (Figure 7, more photos of the mill complex before, during and after the fire can be viewed at www.trumbullhistory.org/photographs.html). In lieu of unpaid taxes, the town took over the property in 1937, and stated that the "portion of it which was formerly worked and exposed during mining operations will be left open to residents and non-residents who are interested in Geology or Mineralogy for the study and removal of specimens" (Whitney, 1938). "Old Mine Park" was named in 1940 (Sullivan, 1985).

During WWII, the tungsten potential of the area was investigated by the Strategic Minerals Commissions of Connecticut and of New England, with Earl Sullivan as their guide. Outcrops were examined during the day and at night with an ultraviolet lamp, but the Commissions concluded that there was an insufficient amount of ore to justify the mining (Sullivan, 1985, pages 14-15).

Scheelite is one of the brightest, intrinsically fluorescing minerals when illuminated by shortwave ultraviolet (SW UV) light, a property that is used very successfully by prospectors, but under daylight scheelite can be very difficult to discern (Figure 8). Inexplicably, the Commissions did not include the Bureau of Mines or mining geologists experienced in its exploitation. However, as part of the war effort, Kerr (1946) compiled a survey of known tungsten deposits in the United States. The vast majority are in the Rocky Mountains, but a spattering of other occurrences are found east of the Mississippi, though most are very minor. Of these, only the Trumbull deposit merited a few pages plus a figure based on a map by Fisher (1942), which included the first survey map of scheelite using a portable UV light. Whether this work was related to that of the Commissions is unknown. The results are discussed under the mineralogy section below.

Finally, there are a few vague references to feldspar mining from the local pegmatites (Sullivan, 1985). Such activity must have been unimportant because only a few drill holes are visible in pegmatite.

# GEOLOGY

## PREVIOUS WORK

There are several historic versions of the general geology of the park area. The geology was first studied by Hitchcock (1828, 1835), who noted interlayered, nearly flat-lying marble and amphibolite. Hobbs (1901) produced a crude "vicinity" geological map, based on the 15' quadrangle topographic maps of the time, showing a roughly 1.5 x 3-mile lenticular area of interlayered marble and amphibolite surrounded by a "schist and gneiss complex". His detailed plane-table topographic and geologic map shows a major and a minor marble layer sandwiched between an upper and lower amphibolite. Although inferred, he could find no exposed contacts between the amphibolite-marble layering and the surrounding schist/gneiss. Hobbs' 1901 map, which focused on the area of mining operations, was the best available geologic map of the area until now (Appendix I: Historical Maps; www.mindat.org/photo- 884272.html).

Fisher's 1942 map (Appendix I) depicts the first UV light survey of the distribution of scheelite. It presumed a horizontal layer-cake stratigraphy, with pegmatite as a basal layer and amphibolite-marble-amphibolite layers progressively up section. Fisher's 1942 map extends well beyond the park boundaries to the west, north and south into areas now heavily developed.

The northern Trumbull area on Crowley's 1968 Long Hill 7.5'quadrangle bedrock map (relevant portion in Appendix I) includes the Collinsville Formation in the west and his lower member of The Straits Schist (DSt) in the east. The lower member of The Straits Schist occurs in a north-south trending belt and is described by Crowley as "uniform, medium- to coarse-grained, rusty weathering garnet-plagioclase- biotite-muscovite-quartz schist", (mineral abundances listed in ascending order). West of the The Straits Schist belt, Crowley assigned the discontinuous amphibolite-marble layers of the Saganawamps section to the upper part of the Collinsville Formation. He described the Collinsville as "crudely laminated, medium- to coarse-grained feldspathic biotite gneiss locally bearing microcline augen, with finer-grained garnet-mica schist and calc-silicate gneiss being locally important." He noted the absence of amphibolite, except near the contact with The Straits Schist. Crowley did not differentiate the marble and amphibolite complexes as a separate stratigraphic unit but mapped and described them in his report. In the Old Mine Park area, he showed 3 marble outcrop areas within a larger zone of amphibolite flanked to the east, south and southwest by his lower member of The Straits Schist. The Collinsville Formation lies to the northwest. Crowley noted the greater thickness of amphibolite at the park area compared to other localized areas of this rock along the Collinsville/The Straits Schist contact.

As part of a sub-regional structural analysis of The Straits Schist, Dieterich (1968) recognized that the amphibolite/marble interval mapped by Crowley on the western edge of his lower member of The Straits Schist was unique and could potentially serve as a structural marker horizon. Based on this insight he interpreted a string of amphibolites that Crowley mapped along the eastern edge of his lower member of The Straits Schist as being equivalent to the amphibolite/marble section to the west. Correlation of these amphibolites created a stratigraphic symmetry on either side of the lower member of The Straits Schist, a relationship that Dieterich used to interpret a series of regionally developed, refolded recumbent folds. A consequence of Dieterich's reinterpretation of the stratigraphy was that Crowley's upper member of The Straits Schist had to be structurally and stratigraphically situated beneath the lower member of The Straits Schist in a stratigraphic position similar to the Collinsville Formation. Dieterich's reinterpretation found its way onto the state map of Rodgers (1985) and Crowley's upper member of The Straits Schist was incorporated by Rodgers (1985) into the Trap Falls Formation (see regional geology map on Plate 1).

Across western Connecticut, several other Connecticut 7.5' quadrangle mappers recognized the occurrence of a relatively thin, discontinuous package of amphibolites, marbles, and/or quartzites beneath The Straits Schist, but none of these mappers broke it out as a separate unit. USGS mappers in adjacent Massachusetts also recognized a unique lithologic assemblage of calc-silicate gneiss and quartzite beneath the Goshen Formation (The Straits Schist in Connecticut) where it was called the Russell Mountain Formation (Hatch et al., 1970). Hatch and Stanley (1973) utilized the repeated occurrence of this interval below The Straits Schist to propose a regional correlation from Massachusetts across all of western Connecticut essentially using the Russell Mountain-The Straits Schist relationship as a stratigraphic datum. These authors did not directly propose to call this interval the Russell Mountain Formation in Connecticut although they clearly indicated stratigraphic equivalence in their correlation table. The correlations proposed by Hatch and Stanley (1973), consistent with those of Dieterich (1968), essentially formed the basis for the western Connecticut stratigraphy represented on the state-wide compilation of Rodgers (1985). Rodgers (1985) did break out this unique interval on the state map but opted to place the amphibolite/marble/quartzite section in a new unit called the "basal member" of The Straits Schist (see regional geology map on Plate 1), acknowledging in his map legend that it is a stratigraphic equivalent of the Russell Mountain Formation. Recent studies utilizing detrital zircons from units above and below The Straits Schist contact (Wintsch et al., 2017, 2019; Fitzgerald et al., 2018) have prompted the suggestion that the Russell Mountain Formation is a more appropriate designation than "basal member" of The Straits Schist for this lithologically unique section.

Petrologically, Hobbs and Crowley found the amphibolite to be generally unremarkable, consisting of hornblende and plagioclase, the latter in the oligoclase to andesine variety range. Crowley (1968) gives modal analyses of 2 amphibolite samples in the Long Hill quadrangle: hornblende 49 to 65% and plagioclase 31 to 41% with up to 4% biotite and accessory calcite, titanite, muscovite, chlorite and fluorapatite. Hobbs noted more biotite, in some places up to 1/3 the amount of hornblende, plus traces of ilmenite, pyrite and quartz. He assumed that the amphibolite was originally intrusive diorite. Energy dispersive electron microprobe analyses of 1 sample from the Old Mine Plaza site show a range of compositions clustered on magnesio-hornblende, typical of other amphibolites around the state (Moritz, 2018). This composition is confirmed in this study by wavelength dispersive analyses of a sample from Corporate Drive (Stop 1) also used for dating. The results show that the amphiboles are zoned with slightly tschermakitic cores and magnesio-hornblende rims. Plagioclase is also zoned from An28 cores to An35 rims. Titanite has limited solid solution with 1.0 to 1.3 wt. % $Al_2O_3$ and 0.1 to 0.3 wt. % F. This sample also contained disseminated pyrrhotite and chalcopyrite. The pyrite contained <0.4 wt. % Ni and <0.2 wt. % Co. The chalcopyrite was essentially pure Cu-Fe sulfide. This occurrence opens the possibility that the sulfides in some veins were locally derived, unlike the W and F minerals. Mostly what makes the amphibolite interesting is its localized alteration/recrystallization and the remarkable presence of scheelite and ferberite [see Mineralogy section].

Hobbs describes the coarsely crystalline marble near the eastern kiln as "nearly 92 per cent carbonate of lime and almost free from magnesia, the residue being largely silica…At the quarry near the lime kiln the rock contains pink, blue, and black calcite, and is very coarsely crystalline (up to 10 cm). It abounds in blades of a brown mica and actinolite, and contains crystals of pyrite, pyroxene, etc." It does, however, speak to a very clean limestone as a protolith: something challenging to interpret associated with metabasalts. But this is atypical, and the authors agree with Shannon (1920) that the rock is mostly "thinly laminated white crystalline marble, containing bedded lines of metamorphic minerals throughout" that are difficult to visually identify. Rarely are there collectible coarse-grained minerals here, but at a now covered spot near the southern end of the neighboring Old Mine Plaza site (before The Home Depot construction), collectors recovered many specimens of calc-silicate-rich marble containing excellent orange-red grossular and green diopside crystals with albite and quartz (Figure 9).

Another rock type mapped by Hobbs (1901), Fisher (1942) and Crowley (1968) is granite pegmatite (Appendix I). A few small pegmatite dikes are noted on Hobbs' large-scale mining area map. These cross-cutting pegmatites have the common mineralogy of albite-microcline-quartz-mica with a trace of accessory minerals (schorl) and no internal textural or compositional zoning. They are not unique to this area as they occur throughout western Connecticut. Fisher's map joins other local pegmatite outcrops into essentially a continuous nearly horizontal layer underlying the amphibolite-marble layers, which we describe later in this guidebook as a zone of migmatite and thrusting (see Geology section). Not far outside this study area Crowley mapped a large body nearly 1 km long on the west flank of Parlor Rock, south of Old Mine Park and Route 25 that may be a continuation of Fisher's layer.

The aeromagnetic map of the Long Hill quadrangle (USGS, 1973) shows no anomaly in the Old Mine Park area.

## NEW MAPPING

A new detailed geologic map accompanies this guidebook (Plate 1). Although geologic units are consistent with earlier work, more extensive outcrop coverage has allowed for clear observations of contact relationships, enabling mapping in greater detail and identification of structural repetition of units. For the first time, the northwest, east and southeast parts of the park are mapped in detail and the members of the Saganawamps section traced to their exposures in the central and southern park areas previously mapped by Hobbs. The new map also includes a structural column and cross-section. In honor of the pioneering scheelite survey work by Joseph Fisher, who was killed in action during WWII (Kerr, 1946), the authors have named the steep slope along the southeast edge of the park "Fisher's Ridge".

### *Stratigraphy*

The stratigraphic relationships displayed on Plate 1 are generally consistent with earlier maps, but the stratigraphic section and outcrop patterns are modified and expanded compared to Hobbs' and Crowley's maps. The following units identified by previous mappers are maintained. In ascending order, they include a lower amphibolite member, marble member, upper amphibolite member, and The Straits Schist (DSt). However, important new findings reported here include the following:

- An additional upper marble member is identified between the upper amphibolite member and The Straits Schist. The upper marble is capped by a 30-cm-thick quartzite immediately below The Straits Schist in the map area.
- The Straits Schist is mapped in the low-lying ground in the southeast corner of the park as well as in the high ground in the northeast corner of the park and along Corporate Drive to the north.
- The Straits Schist mapped in the southeast occurs below the lower amphibolite member, requiring a newly identified thrust fault in this portion of the park.
- Several outcrop-scale boudins are mapped, the most accessible of which involves the upper amphibolite member and is observed on both the east and west sides of Saganawamps Hill.
- The lower amphibolite member in the small drainage east of Saganawamps Hill contains an isolated marble layer. The extent and thickness of this marble is unclear due to limited outcrop.
- Several thin marble layers, typically <1 m, but locally up to 2 m thick, are newly identified and mapped within the lower portion of the upper amphibolite member modifying the single thin marble body mapped in the amphibolite by Hobbs (1901).
- The 4 amphibolite and marble units are herein collectively designated the Saganawamps section after the old name for the park's hill.
- The base of the lower amphibolite is so densely intruded by migmatite that it is mapped separately as a "zone of migmatite." It is well exposed along the base of Fisher's ridge, in the same locality as a zone mapped by Fisher (1942) as pegmatite.
- Outcrops show migmatite intimately mixed with isolated, typically conformable, unaltered, and altered portions of the lower amphibolite indicating magma intruded the amphibolite without totally disrupting the continuity of the section. This intrusive relationship is extrapolated across the alluvial lowlands in the south of the park based on similar observations in isolated outcrops across this area and is interpreted as a zone of thrusting over The Straits Schist.

The layers of the Saganawamps section progress down section from north to south but much of the lowermost amphibolite is either migmatitic or covered by alluvium along the Pequonnock River and adjacent lowland within the park. The contact of the lowermost amphibolite with Collinsville Formation was not found. Further to the south and southeast, exposures of The Straits Schist occur along the Pequonnock River and Route 25 expressway.

***Saganawamps Section (amphibolite & marble)***

The upper marble member of the Saganawamps section occurs primarily at the excellent outcrops at 50 Corporate Drive (Figure 49) and vicinity (Stop 1). A contiguous section that includes the upper part of the upper amphibolite member, the upper marble member, and the lower part of The Straits Schist (DSt) (Figure 10) is well exposed at this location. Note that “marble” is used here as a field term to describe the calcareous rocks in the section. Modal analyses based on X-ray diffraction data and Rietveld refinements (Fitzgerald et al. 2018) indicate that some marble is rather pure with <3% plagioclase, some contain actinolite (~3 wt.%), plagioclase (~2 wt.%), and biotite (~1 wt.%). However, the upper ‘marble’ at Corporate Drive contains only 49 wt.% calcite, with quartz (32 wt.%), plagioclase (12 wt.%), actinolite (3 wt.%), and microcline and biotite (3 wt.% each). At this locality, the upper marble is capped by a 30-cm-thick quartzite that in turn is overlain by The Straits Schist at the north end of the outcrop. However, the marble is structurally truncated at the base of The Straits Schist along the southeastern wall of the exposure and The Straits Schist directly overlies both altered and unaltered amphibolite at the south end of the outcrop. The upper marble member is observed at another outcrop on the east side of Corporate Drive, again overlain by a thin quartzite succeeded by The Straits Schist. The upper marble unit is also mapped at 2 minor outcrops at the park’s north edge (near Stop 3). Further south, within the park, the marble is lost in an area lacking outcrop.

The northwest section of the park is underlain mostly by the upper amphibolite, lower marble, and lower amphibolite members. The lower marble was traced from its northernmost exposure east of The Home Depot to the upper mine pit area. Contacts with both the lower and upper amphibolite are observed in places along the strip of lower marble outcrop. At the upper mine pit area (Stop 4), it is exposed in the pit wall (Figure 11), in a small shaft south of the pit, at the north end of a trench just to their east, and in the lower portion of an outcrop along the west-facing slope east of the mine dump area. Except for a low ridge of fractured lower amphibolite just north of the upper mine pit dump, the lower marble is interpreted to underlie the floor of the topographic basin north of the pit.

The lower marble and lower amphibolite members also crop out along Fisher’s Ridge and are traced to the marble quarries on the east side of Saganawamps Hill. The sharp lower marble/lower amphibolite contact is well exposed in 2 long outcrops along the ridge.

The new mapping adds detail to Hobbs’ (1901) map of Saganawamps Hill. South of the upper mine pit area, the lower marble’s outcrop area is similar to that mapped by Hobbs, showing it wrapping around the southern nose of Saganawamps Hill, but with a few differences. The bottom contact of the lower marble was reportedly exposed at the base of the marble quarry cliff (Stop 7), but now appears to be covered. The exposed section of lower marble is about 8 m thick here (Figure 12). From the marble quarry, the lower marble can be traced in a series of small cliffs around the southern and eastern sides of the hill but thins because of local deformation (see discussion further below) on the hill's eastern and western slopes (Figure 17, Stops 6 and 8). It is well exposed again in a series of smaller marble quarries on the northeastern slope, especially the large quarry next to the old kiln ruins (Stop 11). It shows up in the cut for the “topaz” vein a little further east before crossing the south-flowing stream on to Fisher’s Ridge along the southeastern edge of the park. The lower marble also forms a thin cap on the northwestern corner of the migmatite cropping out south of the southeastern corner of Saganawamps Hill (Stop 8).

In several areas around the south end of Saganawamps Hill where exposures are particularly good, 1 to 3 marble layers, typically <1 m, but up to 2 m thick, occur in the lower part of the upper amphibolite (Figure 13). The interlayering is more extensive than the single thin marble mapped by Hobbs (1901).

The marble layers were traced as far as outcrop would allow, although the lowermost marble interlayer was observed to pinch out just east of the southwest marble quarry (Stop 7). A thin layer of amphibolite, < 30 cm thick, was noted within a few lower marble outcrops, but was too small to map.

The relationship of 3 isolated exposures of marble to the main units at Saganawamps Hill is uncertain. There is a short section of marble in the rock cut on the eastern side of The Home Depot, it is <1 m thick and ends abruptly laterally. It appears to be down section from the lower marble layer mapped on the park land to the east. During construction of The Home Depot, most of the bedrock exposed was all lower amphibolite member, just as it is in the long cut to the west and downhill from The Home Depot at 48 Monroe Turnpike (Figure 50). Prior to the construction of The Home Depot, mineral collectors reported a limited exposure of marble in a small knoll near the southern end of the development. However, there are no data on its structural orientation and the outcrop is now leveled and covered. A second marble exposure is present at 2 small, isolated outcrops in the southwest corner of the park just below the rip-rapped slope leading up to The Home Depot. Most of the larger outcrop there is deformed marble with an amphibolite contact on the southwest side, and a smaller amphibolite outcrop to the west. Riprap placed along the southeastern and southern sides of the The Home Depot property and along the southwestern side of 48 Monroe Turnpike cover the area between these marble outcrops and any exposures formerly present along the Pequonnock River in that area. The marble outcrop at the base of the rip-rapped slope, along with the "temporary" marble outcrop described by collectors in the former Old Mine Plaza before The Home Depot construction, align with a zone of deformed marble on both the west and east sides of Saganawamps Hill. As described below in the structure section, the zone of deformed marble is interpreted to occur at the northern end of a large, outcrop-scale boudin structure. Although the boudin structure has been removed by erosion in the valley west of Saganawamps Hill, the trend of the deformed marble is interpreted to reflect its presence across Old Mine Park prior to erosion of the valley. Finally, a third isolated marble exposure along the south-flowing stream in the valley east of Saganawamps Hill is separated from the main band of lower marble outcrop on the hill by a single outcrop of amphibolite further upstream. The relationship of this marble exposure to the rest of the stratigraphy is not obvious because there is no continuity with the main lower marble exposures. The isolated exposure in the stream bed is interpreted as a marble layer within the lower amphibolite member, however the possibility that there is structural repetition of the lower marble at this locality cannot be excluded.

Of note is the absence of any kind of obvious mineral variation at the many contacts seen between the multiple layers of marble and amphibolite (Figure 13). All contacts are sharp. One anomaly occurs in outcrops along the upper portions of Fisher's Ridge. In these exposures an intermittently occurring rusty-weathering quartz layer up to 40 cm thick is observed at the base of the lower marble. This layer is associated with clinozoisite, iron sulfides and possibly scheelite (Fisher, 1942), but otherwise the rocks on either side of the quartz layer are not unusual (Figure 14). The position and character of this quartz-clinozoisite-iron sulfide layer is similar to that present at the upper mine pit where ferberite pseudomorphs after scheelite occur.

A previously undescribed aspect of the lower marble member and thinner marble layers alike is the ubiquitous presence of laterally persistent pegmatitic quartz-albite layers. Individual pegmatite layers are typically < 10 cm thick but can be thicker locally. In the thicker marbles, multiple thin pegmatites are commonly seen to be grouped into their own layers or "bands" of pegmatite. Differential weathering causes these layers to stand out in relief, which along with an affinity for deep green moss to grow on the marble, aids in mapping the marble layers. The pegmatite layers are best seen in the face of the marble quarry on the southwest side of Saganawamps Hill (Stop 7; Figure 12). In the quarry face, the albite-quartz layers are vertically separated in what appears to be several packages of closely spaced, multiple pegmatite layers separated by areas of marble, with the uppermost sequences having the thickest albite-quartz layers near the unit's middle part. One of the thinner marble layers mapped in the upper amphibolite has a characteristic single quartz-albite layer near its upper contact with amphibolite (Figure 13). These features are schematically depicted in the structural column on Plate 1.

### *The Straits Schist*

The Straits Schist (DSt) is mapped in the southeastern corner of the park as well as in the high ground in the northeast corner of the park and along Corporate Drive to the north (Figure 49). This unit is well exposed at the rock cut at 50 Corporate Drive (Stops 1 and 2) and is seen to dip to the west towards Route 111 (Figure 49). There are no existing outcrops between Corporate Drive and Route 111, but The Straits Schist probably underlies much of this area. Outside the mapping area, along Trefoil Road, west of Route 111, there are 2 more outcrops of The Straits Schist, the only other outcrops in this area. However, amphibolite is exposed just to the south of these outcrops in the rock cut behind Chips restaurant and Edge Fitness (Moritz and Merguerian, 2015) (Figure 27). Crowley (1968) showed an outcrop of The Straits Schist on the banks of the Pequonnock River just south of 48 Monroe Turnpike, but it has since been covered by riprap. Although The Straits Schist overlies the Saganawamps section north of the park, it appears again below the Pequonnock River migmatite zone at the south end of Fisher's Ridge (Stop 10; Figure 15). The bedrock area along the Pequonnock River is mostly obscured by alluvial deposits, but 2 outcrops of The Straits Schist were mapped near where the river passes under the Route 25 expressway. Road cuts in the expressway immediately south of the park also expose The Straits Schist.

### *Pegmatite and Migmatite*

The only intrusive rock in the park area is granite pegmatite. Most prominent are 2 massive, slightly zoned (coarser-grained toward the center) pegmatites just north of the Pequonnock River. One is exposed at the very south end of 48 Monroe Turnpike and along the western park boundary, the other forms a hill jutting southward from the southeastern corner of Saganawamps Hill (Stop 9; Figure 16). Several smaller, isolated pegmatite bodies are scattered around the park, another is located just off of the northwestern corner of the park. These pegmatites are undeformed and appear to crosscut the metamorphic rocks so are interpreted to be no older than Late Devonian.

In between the 2 massive, cross-cutting pegmatites described above, and best exposed along the lower, steep slopes of Fisher's Ridge, is a concentration of subhorizontal pegmatites that extensively intrude the lower amphibolite member. They contain inclusions of unaltered and altered amphibolite ranging in size from <1 m to tens of meters long. The included amphibolites for the most part maintain structural continuity with the foliation in the overlying Saganawamps Section. Consequently, we interpret these amphibolite bodies as representing parts of the contiguous lower amphibolite member isolated from the larger body by multiple injections of migmatite. These sill-like bodies have intruded without totally disturbing the continuity of the amphibolite unit and are co-deformed with it and so must be Devonian in age. This zone, named the Pequonnock River migmatite zone (Dprmz), is extrapolated from the ridge westward across the alluvial lowlands based on similar observations in isolated outcrops of mixed amphibolite and migmatite across this area. In 1 outcrop on lower Fisher's Ridge near the river (Stop 10), the migmatite is found in contact with The Straits Schist. The 2 massive, undeformed pegmatites appear to cross-cut rocks of the Pequonnock River migmatite zone.

The migmatite continues southeast beyond the mapping area and is exposed in a road cut along Teller Rd. where it also contains included remnants of amphibolite and overlies The Straits Schist. This relationship is similar to that observed at the south end of Fisher's Ridge and provides evidence for along-strike continuation of an interpreted thrust fault zone described below.

## GEOLOGIC STRUCTURE

The Saganawamps section members and the Pequonnock River migmatite zone are mostly laterally continuous, gently dipping units, with a few local variations within the map area. In the northern and southeastern parts of the field area the rock layering typically dips northeast to east from 10 to 25 degrees. In the valley east of Saganawamps Hill the dips are close to horizontal, and on Fisher's Ridge in the southeast part of the park, dips are again gentle to the east. It is easy to see how previous mappers interpreted the section as basically flat-lying layers (Hobbs, 1901, Fisher, 1942). However, our recent mapping recognizes structural repetition within this "layer-cake", as well as the substantive role of ductile deformation in the area's structural history. Ductile deformation is manifested at many scales:

- In the penetrative foliation observed at grain scale within the amphibolite, marble and migmatite.
- In the transposition of layering into the dominant foliation including rotation of thin, interlayered pegmatites parallel to layering.
- In the ubiquitous presence of boudinage on scales ranging from several centimeters to 10+ meters.
- In meter-scale tight to isoclinal folding.

### *Small-scale Deformational Structures*

At the grain scale, amphibole crystals in the interior of amphibolite bodies are coarse-grained >2 mm, blocky, and in near random orientation. On the upper and lower margins of the bodies, amphibole grains become longer, flatter, and better aligned. We attribute this to ductile deformation at the contacts of these amphibolite bodies, with the coarser-grained interior textures preserving an earlier (Acadian) fabric.

In addition to this fabric change, the most conspicuous evidence of ductile shear strain is expressed as boudinage, particularly boudinage of the thin pegmatitic layers in the marbles. Shear strain of the pegmatites is expressed in any given outcrop as a continuum of extensional deformation that can range from pinch and swell of the layers, varying degrees of necking, boudinage - where layers can either maintain some continuity or detach as individual boudins from the parent pegmatite layer, and total extensional dismemberment of pegmatite into trains of remnant quartz-albite fragments within the foliation. In the extreme case, dismemberment of the pegmatite can proceed to a point where isolated, individual quartz and albite grains are surrounded by marble matrix. No matter the expression of deformation, the host marble is always seen to have ductilely flowed around whatever shape the deformed pegmatite takes, including thickening into boudin necks where gaps have been left in the original pegmatite layer. The main marble quarry on the southwest side of the hill (Stop 7) provides an excellent exposure to observe the range of pegmatite deformation in marble.

### *Outcrop-Scale Boudinage*

Larger scale boudinage is expressed in 2 exposures in the upper reaches of Fisher's Ridge. These outcrop-scale boudins occur in the upper part of the lower amphibolite member at the contact with the lower marble member. The amphibolite boudins are at least ~4-5 m thick and best expressed where there is well-exposed thickening of the marble into the thinned neck region of the amphibolite boudin (Figure 20). Conversely, the marble thins dramatically onto the amphibolite ranging from ~4 m at its thickest to ≤1 m over a distance of ~3 m. Over this short distance layers within the marble clearly diverge (thicken) into the neck region and converge as they thin onto the amphibolite, attesting to ductile flow during the boudinage. The geometry of the amphibolite boudins is not necessarily expressed as classic "lens-shaped" bodies in that they look to be asymmetrical in cross-section and can display abrupt structural termination of the amphibolite foliation against marble along the boudin margin. This relationship indicates boudinage occurred after formation of most of the foliation as part of a continuum of deformation affecting the section.

A larger scale boudin of upper amphibolite is mapped on the southeast side of Saganawamps Hill (Stop 8). As mapped, this structure is at least 10 m thick and about 100 m long. On its south end, a continuous layer of lower marble with a typical thickness of ~4 m is abruptly terminated against amphibolite over a distance of only ~2 m (Figure 17). Two thin marbles are observed immediately north of, and structurally higher than the terminated lower marble layer. The upper thin marble is the lowermost of the thin marbles mapped in the lower amphibolite layer. However, the thin marble beneath this one, <0.5 m thick, is interpreted as the dramatically thinned lower marble member that has been ductilely stretched over the top of the amphibolite boudin. The trace of both of these thin marbles projects into the air as exposure is lost to the north. However, exposures of the amphibolite boudin continue and near its interpreted northern terminus a thick section of lower marble reappears beneath it and the uppermost thin marble reappears above it. The ductilely thinned lower marble member is interpreted to pinch-out above the amphibolite boudin and is not present at the boudin's north end. Also observed at the northern terminus of the boudin are localized, meter-scale, tight to isoclinal folds in both the thin marble above, and the lower marble immediately below the boudin. These structures are interpreted as local deformation of the marble layers related to formation of the boudin and consequent disruption of the adjacent marbles during ductile flow.

The expression of this large, outcrop-scale boudin on the west side of Saganawamps Hill is not as obvious but several lines of evidence indicate its presence. At its interpreted southern terminus is the main marble quarry where the lower marble is anomalously thick, ~8 m, which is twice the normal thickness observed throughout the park (Figure 12). On the north end of the quarry, the thick marble section abruptly ends north of a zone of mild structural disruption. Outcrops are poor in this zone, but it is clear that a thick section of amphibolite has taken the place of the marble over a distance of a few meters and along strike with what should be a continuation of the lower marble member at this structural level. The only marble observed north of the disrupted zone is a thin patch of outcrop at the base of the borrow quarry exposure. The anomalous thickness of marble in the quarry, its abrupt termination to the north, and comparison with the geometry at the southern terminus of the boudin on the east side of the hill suggests that the quarry marble represents a ductilely thickened section at the southern terminus of an outcrop-scale boudin of upper amphibolite. The geometry and thickness relationships are also identical to those represented by the marble surrounding the boudins on Fisher's Ridge, but twice the scale. Further, if one stands back to view the thick section of marble at the quarry, a slight convergence of the layers is seen on each side, same as in the thickened marble "neck" sections described on Fisher's Ridge (e.g., Figure 20).

North of the borrow quarry the lower marble member is absent until one reaches the small valley southeast of the Champion Lode (Stop 6). At this locality, the relatively continuous lower marble trending from the north abruptly changes strike from SSE to WNW, the dips steepen from about 20° E to > 60° N and the normal 4 m of marble thins to about 1 m thick. There is no marble outcrop south of these structural changes until just north of the marble quarry as described above. We propose that it is either truncated along the northern margin of the interpreted boudin or it exists as a thin, stretched marble neck below the amphibolite boudin but covered by the fill along the road. Such dramatic changes in the thickness and attitude of the lower marble are consistent with deformation and thinning at the terminus of a boudin structure. The observations are similar to those described above from the other mapped boudins.

The lack of lower marble member exposures between the outcrops described above hinders our ability to accurately define the upper and lower boundaries of the boudin on the west side of the hill because all contacts of the boudin with the surrounding rock in this area are amphibolite on amphibolite. However, the 3 thin marble layers mapped in the lower part of the upper amphibolite member abruptly terminate on both the east and west sides of Saganawamps Hill where we interpret the upper boundary of the boudin structure. Overall, the observations described above at the southern and northern terminus of the interpreted boudin, the similarity in scale and location with the boudin structure on the east side of the hill, the disruption of structurally "well-behaved" lower marble member outcrops to the north and south, and consistency of interpretation from one side of Saganawamps Hill to the other are offered as evidence for an outcrop-scale boudin structure in this area.

In addition to the larger structural features described above, a couple of local, small-scale structures are observed in the map area and are mentioned here for completeness. The deformation is meter-scale, involves tight to isoclinal folds, and affects both marble and amphibolite. Outcrops of deformed marble occur in the wall immediately above the upper mine pit (Figure 11) and in adjacent outcrops to the south, and in the lower marble at the north end of Fisher's Ridge. An outcrop of deformed upper amphibolite member is well-exposed southeast of the Champion Lode (near Stop 5; cover photo of this field guide) in the vicinity of the northern boudin neck on the west side of the hill.

***Pequonnock River Migmatite Zone Thrust Fault***

There are no topping indicators preserved in the Saganawamps section to indicate a normal stratigraphic succession or an overturned section. The only indication of stratigraphic "tops" comes from the The Straits Schist (DSt) overlying the upper marble member in the outcrops along Corporate Drive. This contact relationship is regionally consistent with published mapping from western Connecticut and neighboring Massachusetts and serves as the "stratigraphic up" reference datum for the amphibolite and marble member stratigraphy in this area. The lower amphibolite and lower marble members are easily mapped in the upper reaches of Fisher's Ridge and the contact between them is well exposed. In the lower slopes at the southern end of Fisher's Ridge The Straits Schist appears again, but here it is beneath the Pequonnock River migmatite zone. There is no evidence for an inverted repetition of upper marble member in contact with The Straits Schist. The migmatite zone is present there instead and is not part of what we consider a normal stratigraphic succession.

A high degree of localized deformation is present in the Pequonnock River migmatite zone. Inclusions of altered amphibolite and schist within it can exhibit contorted fold geometry both in outcrop and in numerous blocks of talus at the base of the hill. The stratigraphic relationship described above, and its highly ductile character led us to interpret it as a thrust fault zone that places the Saganawamps section over The Straits Schist, with migmatitic melt intruding the weakened fault zone. This map-scale feature visibly continues southeast beyond the map area (and is inferred to continue to the northwest under overburden). Reconnaissance beyond the park, to the SSE along a road cut on Teller Road, identified amphibolite, soaked in migmatite, overlying a schistose interval that is contiguous with widespread exposures of The Straits Schist in this area. Thus, the interpreted Pequonnock River migmatite zone thrust structure has lateral continuity. This newly identified structural relationship requires further study to unravel its potential regional significance.

# MINERALOGY

This section combines information from old descriptions of mineral finds, of extant specimens in collections from Old Mine Park and adjacent areas, from photographs and observations of now covered outcrops and from this new mapping effort. The focus of this section is on minerals occurring in the Saganawamps section other than the normal rock-forming ones, and in the various cross-cutting veins.

## AMPHIBOLITE-HOSTED MINERALS

***Distribution and Origin of Scheelite***

What makes the amphibolite of great interest are the accessory minerals that are readily apparent in outcrops and hand samples. These include a suite of minerals in portions of the amphibolite exhibiting metasomatic alteration. Most well-known is scheelite, which occurs as small to large anhedral to euhedral crystals (up to 8 cm) distributed as isolated grains, concentrated in zones or layers, or in pods commonly in greenish amphibolite in which the hornblende is locally altered to actinolite; but scheelite is also typically associated with quartz, clinozoisite and calcite in a tough, non-foliated, light brown rock. Euhedral crystals occur where associated quartz is also abundant. White to green marialite (as determined from 1 Raman spectroscopic analysis) occurs in large compact, radiating masses over 40 cm long (Figure 21) or as discrete crystals along joints, with pyrrhotite and pyrite.

Altered amphibolite occurs in several places, most notably at:

- The Old Mine Plaza (now The Home Depot) site where many large scheelite crystals were collected.
- The well-known occurrence at the upper mine pit just below the lower marble.
- Along Fisher's Ridge in the same stratigraphic position with the lower marble as in the upper mine pit.

Hobbs (1901, p. 16 & 18) described how the amphibolite changes in the metasomatized zone (Figure 22). Overall, the altered amphibolite is paler, more gneissic, contains less magnesio-hornblende, and is coarser-grained than the unaltered rock. The magnesio-hornblende crystals are changed from large single individuals to "frayed at the edges, in radial bundles of fibrous crystals, or in a closely matted web of long columnar to acicular crystals" (the actinolite noted in this study) with more titanite present that was likely formed from Ti released from the parent magnesio-hornblende when replaced by actinolite. The alteration includes other retrograde minerals such as clinozoisite (up to 75 % by volume), calcite, quartz, pyrite, a "radial variety of scapolite" and scheelite "irregularly disseminated and often concentrated in crystalline masses which are, sometimes as large as the fist".

Although the quartz-clinozoisite rock just below the lower marble is no longer easily viewed at the upper mine pit, it is well exposed on Fisher's Ridge. A layer consisting predominantly of quartz is present intermittently along the contact there, varying from a few cm up to ~40 cm thick. The quartz is locally boudinaged and in places slightly penetrates up into the lower marble. Locally it also exhibits weathering - rusty and/or yellow-staining - and microcrystalline gypsum crusts are observed under protected ledges (Figure 14). These are probably the result of chemical weathering of iron sulfides. Subhedral clinozoisite is abundant and scheelite is present according to Fisher (1942). In both places there are small cavities in the quartz lined with crude quartz crystals lacking surface striations indicating they formed in contact with another mineral, likely calcite, which subsequently weathered out.

Another variation in the amphibolite mineralogy includes pods and boudins, approximately 0.3 m thick, of very coarse-grained, white to pale green albite and quartz with a thin rind of biotite. The pods and boudins are concentrated in 2 subhorizontal zones exposed near the top and middle of the long rock cut in the amphibolite at 48 Monroe Turnpike, west of The Home Depot, and were seen in rock blasted during the construction (Figure 50). They are accompanied by deformation and shearing. Scheelite was found in 1 of these pods.

The first documented attempt to survey and map the distribution of scheelite was conducted by Fisher (1942), whose work was published in Kerr (1946) (see Appendix I). Surveying was done at night with a portable UV light, a tool first available in the 1930s, that takes advantage of scheelite's intrinsic, bright fluorescence. Fisher reported it at the upper mine pit area and at the marble quarry by the former mill site (either detected or from historic reports). The greatest extent of scheelite was mapped within the lower amphibolite member outcrops along Fisher's Ridge.

Our reconnaissance surveys along Corporate Drive and near The Home Depot using a UV lamp at night show the amount of scheelite to be quite impressive, with large crystals > 4-5 cm and concentrations > 25% of a rock face, particularly in the lower amphibolite member at the The Home Depot site (Figure 24). Along Corporate Drive, in the upper amphibolite member, the size and concentration of scheelite crystals are smaller, <1 cm and up to a few percent (Figure 8). But in both places the light color and similarity of scheelite to the common minerals quartz or albite, plus any staining on the rock faces due to weathering of iron sulfides in the amphibolite, can completely mask its presence in daylight. Sullivan

(1985, p. 24) reports that scheelite "was seen in bedrock at the intersection of Broadway and Parlor Rock Road", which is in amphibolite 600 m southwest of the park on the opposite side of the Route 25 expressway. No scheelite was found within amphibolite exposed behind Edge Fitness west of Route 111, however. (Moritz & Merguerian, 2015).

The cause of this metasomatism has not been studied in detail but it is undoubtedly a retrograde, post-Acadian paragenesis. One important finding from UV light surveys is the absence of scheelite from the upper and lower marble members. On outcrops, and in hand samples, primary scheelite grains are found only in amphibolite adjacent to marble contacts, but not within the marble (Figure 25). Kerr (1946) states that "all types of [tungsten] deposition is believed to be connected with marginal or end-stage phases of igneous invasion". Thus, he proposed a contact metamorphic origin for Trumbull's scheelite based on an association of the local pegmatites with scheelite.

Kerr based this hypothesis on the many scheelite deposits he surveyed in the western USA where quartz veins or contact metamorphism of limestones by plutons is a common tungsten ore setting. Many of the minerals associated with western tungsten deposits are present in this field area, such as quartz, calcite, fluorite, topaz, clinozoisite, garnet, muscovite, and albite. Kerr's understanding of the overall mineralogy and the specific occurrence of the scheelite at this deposit was apparently influenced by some of the literature errors described above, such as significant tungsten mineralization occurring in the topaz-rich veins (which we did not find, see below). Because many western deposits have scheelite hosted by limestones but emplaced by plutons, he placed the Trumbull tungsten mineralization at the base of the lower marble rather than in the amphibolite and considered the local pegmatites responsible for the ore formation, perhaps via the topaz-rich veins. Our fieldwork finds that the pegmatites long predate the amphibolite alteration and vein formation (see Geologic History section below).

Another potential genesis of scheelite deposits is greisenization, but although the Trumbull deposit shows some similarities to greisens, there are significant differences, too (see discussion under origin of the cross-cutting "topaz" veins below), which cast doubt on that mechanism. The apparent uniqueness of this amphibolite-hosted, metasomatic scheelite occurrence clearly requires additional research to unravel.

***Ferberite Pseudomorphs after Scheelite***

Ferberite (aka wolframite) pseudomorphs after scheelite have been known from the upper mine pit (Stop 4) area since the early 19th century. Despite the much more widespread scheelite-quartz-clinozoisite amphibolite association, the ferberite pseudomorphs are confirmed only from this 1 location, where associated quartz is abundant and precursor scheelite crystals are especially well formed. Why they occur only in this 1 spot and when the replacement happened is unknown. These pseudomorphs are very rare. They have not been found elsewhere in the USA and are documented only from at least 7 other worldwide locations (www.mindat.org/forum.php?read,6,392615,page=3). Kerr (1946) noted their absence in the many western tungsten deposits.

An examination of many pseudomorph specimens from this area shows that they are of the classic replacement type, where many very tiny ferberite crystals nucleated at multiple sites within a single scheelite crystal and grew until the scheelite was fully or partially replaced. Zones of remnant scheelite within pseudomorphs are common (Figure 5) and boundaries between ferberite and remnant scheelite are very sharp. Rarer are voids within pseudomorphs showing tiny terminations of the myriad replacing ferberite crystals (Figure 4). The well-preserved tetragonal bipyramidal scheelite crystal form baffled Silliman when he first described them (Silliman 1819a, b, c) as the literature on pseudomorphs then was scant and he was still new to the science. They are classic specimens found in many museums and private collections.

When Gurlt visited the locality in 1887, he had workers open up this zone and provided one of the best descriptions of the bed and in-situ crystals, which is now not well exposed (Hobbs, 1901, p.14-15):

> In its principal mass the ore bed consists of vitreous, translucent quartz of an entirely different character from that of the Champion and topaz veins. It usually forms a compact mass, containing cavities or druses studded with quartz crystals that are frequently covered by a thin film of yellow wolfram ocher [tungstite]. The quartz penetrates through crevices and fissures into the [lower marble] and the amphibole gneiss, both of which near the contact must therefore be taken as part of the ore bed. The quartz also contains iron pyrites, [clinozoisite], calcite, mica, and the wolfram minerals, scheelite and wolframite. The latter occur embedded not only in the quartz, but in the adjoining metamorphosed beds of the country rock as well-shaped crystals or solid lumps and strings. The crystals are numerous and often of considerable size. It is remarkable that the wolframite crystals never show the peculiar crystallization of this mineral, but always that of scheelite. They are really pseudomorphs and indicate that the original wolfram mineral was scheelite or tungstate of lime, which was subsequently altered into tungstate of iron and manganese. The crystals are sometimes only partially converted, showing both minerals in the same individual. Both the crystals and lumps are usually loosely embedded in the matrix, and easily detached.

His description of the rock along the contact is very similar to that seen along Fisher's Ridge. Cavities are present in the quartz there, too, and there is potential for ferberite pseudomorphs in that area based on this passage from Hobbs (1901, p. 19):

> An occurrence of some interest, because so far removed from the mining property, is that on the Burnett place [probably now the cellar hole near the stream east of Saganawamps Hill], which is east of the road that runs north and south and is about a half mile distant in a northeasterly direction. The locality is at the lower contact of the [lower marble] belt, which at this point dips to the westward, and the minerals found are similar to those that occur at the mine, viz, hornblende, scapolite, fluorspar, chalcopyrite, and in addition a trace of malachite. Wolframite crystals have been reported from this locality, and there is no reason to suppose that they have not been found here, although the writer was unable to discover any in his examination.

During the recent mapping, an old prospect pit was found in a small outcrop near the northern end of Fisher's Ridge in very rusty amphibolite where the overlying marble is tightly folded (Figure 23). The associated mine dump is devoid of recent disturbance. This may well be the place alluded to by Hobbs (1901).

Tungsten mining efforts were focused on these pseudomorphs and on this particular stratigraphic zone. Many old, small trenches and pits were dug around Saganawamps Hill in search of it, but none show any attempt at mining the contact. Many other contacts between these 2 Saganawamps Section members elsewhere in and around the park do not show any unusual mineralogy. If the miners had concentrated on the more widespread scheelite, they may have been more successful.

## HIGH-TEMPERATURE MINERAL VEINS

### *General Character and Composition*

Numerous cross-cutting, steeply-dipping, <2 m thick veins, many rich in topaz, famously crop out in Old Mine Park and surrounding areas. The veins generally have a simple planar geometry, with predominantly straight, parallel walls, and minor if any branching, pinching, and swelling. Although the veins are in fact fracture fillings, they themselves lack brittle fracturing or brecciation. No offsets of wall rock features are obvious, and they show no evidence of deformation after emplacement. Most vein exposures in the park are where they cross-cut Saganawamps section amphibolite and/or marble but they can be difficult to see in the old trenches and prospect pits. Excellent recent exposures of veins in near vertical rock cuts occur at Corporate Drive (Figure 49). Nine identified veins reach up to ~30 cm thick in the upper marble and upper amphibolite but thin to <10 cm thick where they cut the overlying The Straits Schist (Figure 26) (Stops 1 and 2). Another recently exposed vein is located behind Edge Fitness, west of Route 111 from The Home Depot (Figure 27).

A plot of vein orientations (Figure 28) shows what is obvious from the map, that most veins are oriented around N30-40°W (azimuth 330), with a lesser set nearly 90° to the principal trend. Typically, steeply dipping (75° to 90°), they are usually oriented parallel to a major joint set in the local outcrop.

The mineralogy of the veins varies, but the most common ones contain a very coarse-textured core assemblage of quartz ± topaz ± fluorite var. chlorophane (dubbed here "topaz" veins) with a coarse to medium-textured wall zone a few cm thick of subparallel muscovite crystals arranged roughly perpendicular to the contact (much literature refers to the muscovite under the historic varietal name margarodite) (Figures 29 and 30) (Stops 1, 2, 3 and 6). Shannon (1921a) describes the wall zone as "Veinlets of coarse foliated margarodite, made up of interlocking crystals". Very coarse-grained and internally zoned veins have a pegmatitic appearance, but some veins consist of little more than the muscovite wall zone, which is one of the main defining characteristics. Rarely veins consist mostly of a thick mass of generally fine-grained muscovite, with subordinate, scattered, small pods (a few cm wide) of topaz and fluorite and very rarely fine-grained black tourmaline (Stop 9). These very limited occurrences can resemble greisens but are not derived from a granite mass and lack greisen's typical tin mineralization. Primary sulfides are rare, mainly sphalerite, galena or pyrrhotite (first noted by Shepard, 1837). Tiny fluorapatite grains may be present near the contact, but are only visible via their yellow SW UV fluorescence, and may have formed as a reaction with the wall rock. Some veins were large enough to support 19th century fluorite or quartz mining.

Many well-formed crystals of topaz have been collected from the veins. Where enclosed in later-forming quartz or fluorite, topaz crystals can be quite large (15 to 20 cm in diameter, 8 to 17 cm long), though they are rarely gemmy or terminated as they typically impinge on other topaz crystals (Figure 30). They can be difficult to free from the hard quartz without splitting along their perfect basal cleavage. Open spaces within the veins are typical but limited in size such that most terminated, euhedral pocket crystals are small (<1 cm) (Figure 31). Color varies from colorless, white, pale yellow, and pale green, to orange-brown. In some veins, the topaz, which commonly has a coarse muscovite coating, has altered to a soft, compact, and granular to peripherally parallel-fibrous or lamellar habit of margarite (Shannon, 1921a) (Figure 32) (Stop 6). The margarite and muscovite are commonly in contact and can show some interesting textures in samples (Figure 33).

The primary fluorite in these veins is the rare variety chlorophane, which is famous for its thermoluminescence, fluorescence and phosphorescence (Figure 34). Legend has it that the variety was discovered when chunks placed around a fire at night started to glow green. This property is easily replicated (see videos on Youtube.com). But chlorophane fluoresces the same green color under SW UV light, with a blue-green residual glow (phosphorescence) after the light is removed. (If left out in the daylight for a long time it loses all these properties). Under long-wave (LW) UV light it shows the same blue-purple fluorescence as most "normal" fluorite, which is permanent and caused by a divalent europium impurity (Robbins, 1994). The causes of its SW UV fluorescence and phosphorescence and the thermoluminescence have not been worked out, but other divalent and trivalent rare earth element impurities may play a role. At Trumbull, the chlorophane is always massive, with color ranging from colorless, smoky, pink, and red to nearly black. Its occurrence here is particularly noteworthy because it is usually only found elsewhere in complex, rare-element granitic pegmatites.

***Other Vein Compositions***

Other veins show different compositions. Though not as well documented because of their lower economic or specimen interest, some veins contain mostly very coarse-grained albite in place of topaz (e.g., 50 Corporate Drive, Stop 1; the Champion Lode dump) and other veins are composed chiefly of albite ± clinochlore ± marialite (dubbed herein "albite" veins). The formula of marialite, $Na_4Al_3Si_9O_{24}Cl$, can be rewritten as $3NaAlSi_3O_8{\cdot}NaCl$, emphasizing that this mineral is a close chemical cousin of albite that includes dissolved halogen (in this case Cl), but still associated with another halide (F) mineral fluorite. The clinochlore can occur in voids as micaceous aggregates up to 1.5 cm shaped like "double cones applied base to base" (Shepard, 1837) or generally spherical. Euhedral albite and clinochlore crystals are found in small voids in these veins or where they formed in contact with chlorophane (Figure 35). The marialite is typically present along the vein contact with the host amphibolite as compact radiating aggregates of white crystals that fluoresce pink under SW UV. Rarely, veins are composed predominantly of very-coarse-textured calcite, with a wall zone rich in clinochlore, albite, quartz, marialite, beryl, and pyrrhotite (Figure 36) (dubbed herein "calcite" veins). The beryl has color tending toward emerald green, initially reported by Shepard (1837). Nevertheless, Sullivan (1985) mistakenly attributed these rare beryls either to misidentification of topaz or as actually occurring in the pegmatites. The best such vein was exposed and exploited for years at the abandoned Old Mine Plaza development but was not well documented in-situ before it was obliterated by the subsequent construction of The Home Depot.

Although exposures for most veins are limited, individual veins can vary in composition vertically or horizontally. The veins exposed in vertical cuts above and below Corporate Drive show mostly chlorophane, quartz, albite, and muscovite lower down, but mostly quartz, topaz, and muscovite higher up (Stops 1 & 2). Similarly, the Champion Lode vein, which is the longest that can be traced horizontally, also shows variable composition. The waste dump downhill from the thicker, quartz-rich, mined-out portion contains abundant discarded blocks that are rich in albite. In the narrower part to the vein to the southeast, in the trench on the western slope of Saganawamps Hill, it is instead topaz and margarite-rich (Stops 5 & 6).

***Wall Rock Metasomatism***

Within 10-30 cm of the vein contacts, the host amphibolite exhibits metasomatic alteration to fine-grained, brownish mica and marialite, regardless of the vein's composition, even where the vein is only a layer of muscovite (Figures 29 to 31, 36, 37) (Stops 1, 2, 3, 5 and 6). Alteration may also occur on either side of joints where no vein is present, showing that the hot, aqueous, halogen-rich fluid penetrated and reacted with the minerals in the amphibolite beyond the veins. In the field, the color contrast in the amphibolite helps identify the presence of veins not well exposed, and the altered matrix attached to specimens in collections identifies their occurrence. In contrast, marble or schist hosts show little or no obvious alteration, suggesting that any hot fluid there did not react with those wall rock compositions.

Thus, vein fluids were rich in $H_2O$, fluoride, chloride, $Na^+$, $CO_2$, S, and at one time $WO_4$. Al and Si are especially soluble in F-rich solutions and $WO_4$ is soluble when complexed with $Na^+$. The intrusion of these fluids into the Saganawamps Section, rich in amphibolite and marble, may have led to the precipitation of scheelite and fluorite that released $Na^+$. This may have led to the precipitation of now less soluble Al as topaz and albite and less soluble Si as quartz. The margarite replacement of topaz requires the addition of Ca but preserves the Al:Si ratio of 2:1 in each mineral.

Scheelite can also be present as very tiny grains in the vein wall zone, with or without scheelite in the host amphibolite rock. These tiny grains are essentially invisible without their bright SW UV fluorescence (Figure 37). They are also present along joints in the amphibolite exposure behind Edge Fitness west of Route 111 but only along the joints where the rock shows the metasomatic alteration. This relationship suggests that vein fluids mobilized a small amount of $Ca^{++}$ from the amphibolite and deposited it along the walls of the vein and in joints as scheelite.

***The Emerald Controversy***

Whether the beryls found along the contact zone of the "calcite" veins can rightly be called emerald is controversial. It may seem like a trivial argument, but there are few American emerald localities, and their presence could point to an economic resource (assuming they could be exploited) and add to the body of scientific knowledge. A purely mineralogical emerald requires $<2$ % Cr, V and/or Fe as chromophore impurities to produce the strong green color (Giuliani, et al, 2002). While some have derided the Trumbull crystals as too pale, that is a gemological perspective rather than a mineralogical one. Crystals at many emerald localities show a great variation in color, down to almost colorless (Figure 36), which of course never reach the market as gemstones.

Geologically, emeralds tend to form in geoenvironments different from other kinds of beryls. Thus, emeralds and other beryl varieties are not found together. Generally speaking, a source of Cr, V and/or Fe bearing rocks (ideally ultramafic or mafic rocks), and a source of Be must be present under the right P/T environmental conditions to form emerald. In some settings it is pegmatitic or greisen formation in phlogopite schist. Others involve the juxtaposition of phlogopite schist or carbonate talc schist against serpentinite by faulting coupled with hydrothermal metasomatism. The Be comes from mica-rich rocks and the chromophores from the mafic rocks. The emerald-rich zones can include carbonates, phlogopite, quartz, chlorite, and pyrite, a remarkably similar assemblage to the Trumbull occurrence. The famous Colombian emeralds, formed by hydrothermal activity in brecciated zones cutting black shale, occur in veins with albite, calcite, and pyrite. In that geologic setting, Na-rich hydrothermal brines metasomatically leached Be, Cr and V from the black shale (Giuliani, et al, 2002). Although formation of the Colombian emeralds occurred at a lower temperature (300 °C) than the beryl at Trumbull (perhaps about 400 °C, see below), the circumstances of formation and the resulting assemblages are remarkably similar. So what's the problem?

***Vein Distribution and Origin***

Most of the veins are concentrated in the Old Mine Park area, but this may be partly due to the availability of exposures of the Saganawamps Section in addition to removal by 19th century prospecting. The veins penetrating The Straits Schist (DSt) are narrow, so they may be less obvious in this rock, which is also not well exposed in the park area. Moreover, some of the vertical veins at 50 Corporate Drive pinch out beneath The Straits Schist (Stops 1 & 2). Only 1 vein was found cutting The Straits Schist along the lower slope of Fisher's Ridge, near its exposed contact with the Pequonnock River migmatite zone (Stop 10), although a few fragments of vein rock were seen loose in the talus. The azimuth 330 orientation of the veins is subparallel to the trend of the ridge, reducing the chance of finding vein/host rock intersections there. If present, they are likely covered by the abundance of large migmatite boulder scree. A few are known beyond the study area (see regional geology map on Plate 1). Outcrops west of Route111 are very scarce and poor, other than the large rock cut behind Edge Fitness, where 1 excellent ~2-m-wide quartz-rich vein is exposed. A sample of albite-chlorophane-clinochlore was found loose there. Historically, veins were reported during construction at the cul-de-sac of Quartz Lane just east of the park, and further east as far as Porter Hill Road (all residential now). A vein reported by Sullivan (1985) to the southeast on Whitney Avenue is perhaps the same one seen by the authors cutting The Straits Schist just east of where Whitney Avenue passes under the Route 25 expressway. Another was found during this study within rock cuts on Teller Road just north of Whitney Avenue. Where known well-enough to plot, covered historic vein locations are indicated on Plate 1.

Hypotheses for the origin of these hydrothermal veins have been largely speculative. The veins' steep dips and generally similar strikes of N 30-40°W (Figure 28) and the possible topaz-forming geo-environments must be considered by any genetic hypothesis. Topaz can form in several environments such as in rhyolite; in cavities in granites and pegmatites, greisens, veins and skarns; and over a wide range of temperatures - 850 (volcanic) to 200 °C (low hydrothermal). In topaz, OH can substitute for F and their ratio varies with the temperature, so a measure of the OH content will limit the hypotheses. OH/(OH+F) varies from about 0.10 to 0.20-0.30 in highest to lowest temperature topaz, respectively (Menzies, 2011). In 1 sample from the road cut above 50 Corporate Drive, X-ray diffraction showed a topaz unit cell to be consistent with an OH/(OH+F) of 0.16, indicating an intermediate temperature of formation such as in a pegmatitic or elevated hydrothermal environment range.

One genesis for all the minerals present proposed by some writers such as Kerr (1946) is greisenization. This is a process of hydrothermal or pneumatolytical (550 to 300 °C) alteration of a granite pluton where feldspar and muscovite are converted to an aggregate (greisen) of quartz, topaz, and muscovite or lepidolite by the action of water vapor containing fluorine. Tourmaline, fluorite, rutile, cassiterite, and ferberite-hübnerite are common accessory minerals. The simple listing of many of these minerals found in the study area would seem to favor that mechanism. But as described above, the quartz, mica, topaz, and fluorite are present at Trumbull in a distinctly different environment (discrete, steeply dipping veins) than the ferberite (a replacement of scheelite as an amphibolite accessory). Greisens occur within granite masses, not discrete veins. There is no granite, rutile or cassiterite and only very scarce tourmaline here, so this potential origin does not fit the data.

A pegmatitic origin is another possibility and the veins' mineral textures and internal zoning are similar to many pegmatites. Many study area veins include chlorophane, which is a rare and uniquely fluorescent type of fluorite. Many world-wide occurrences (www.mindat.org/min-948.html) are pegmatitic (450-350 °C), so the local occurrence is intriguing. The absence of brittle faulting along the veins and the presence of chlorophane and topaz suggests a similarly high temperature to pegmatites but a shallow enough depth to allow fracturing. The vein mineralogy, wall alteration, and fracture filling occurrence, however, suggest that the veins are hydrothermal not pegmatitic. The presence of abundant fluorite - variety chlorophane - indicates a relatively high temperature of formation for these veins. If the local pegmatites were a source of fluids for the veins, then there should be a physical connection of the veins to the pegmatites. This was not observed. A thin, poorly exposed, cross-cutting quartz-fluorite-muscovite vein intersects the southeast corner of the pegmatite promontory south of Saganawamps Hill (Figure 38) (Stop 9), which demonstrates that the pegmatite is older than and apparently not the source of the fluids producing the veins.

Hydrothermal veins originating from granitic plutons seem to be the most likely explanation. They tend to be steeply dipping and those producing topaz have a temperature range of around 400-200 °C (Menzies, 2011). The topaz's OH/(OH+F) ratio of 0.16, the alteration of the host wall rock, and the presence of chlorophane favor the higher end of this temperature range for the topaz in the veins found in the park area. Because the wall rock is altered in the same way adjacent to veins of albite or calcite dominant composition, they are inferred to have the same formation temperature as the topaz rich veins.

Because the veins are undeformed and crosscut all local foliations, they are post-Early Mississippian in age (see Appendix II, titanite). Crowley (1968) maps 3 post-Devonian intrusive bodies southeast of Old Mine Park – the Permian Pinewood Adamellite (291 ± 4 Ma, Sevigny and Hanson, 1993), situated about 4 km southeast, a small body of "dacite porphyry" located about 1 km SSW of the park, and a "rhyolite porphyry" containing fluorite in the northern Bridgeport quadrangle (see regional geology map on Plate 1). These are noteworthy because of their rarity and proximity to the unusual mineralogy of the Old Mine Park area; they are the youngest dated rocks in the area and are undeformed. The Pinewood Adamellite also contains accessory fluorite (Crowley, 1968). Recent work on the Pinewood Adamellite by Rebekah Kennedy (Kennedy and Wintsch, 2021) reveals abundant similar, cross-cutting hydrothermal veins within and immediately adjacent to the pluton. The veins consist primarily of quartz but with the same muscovite wall zone observed in the Old Mine Park area veins. Minor calcite and fluorite variety chlorophane are also present. A recent $^{40}Ar/^{39}Ar$ cooling age for a muscovite sample from a vein at Corporate Drive of 266.7 ± 1.4 Ma (McAleer and Wintsch, 2018, see Appendix III) gives the minimum age for the veins. How these ages relate to the overall geological history is discussed below.

## FAULT-HOSTED HYDROTHERMAL MINERALS

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. Sullivan (1985) reports that during "excavation work to the east of the Old Mine Park entrance road [circa 1983], pyrite, purple fluorite, pyrrhotite, sphalerite, and specks of scheelite were found". In the late 1970s, a mineralized brittle fault was discovered in the Route 25 expressway rock cuts north of Daniels Farm Road overpass (see regional geology map on Plate 1). But more recently, such veins were best exposed at the Old Mine Plaza site during the 1990s-2010, where many specimens were collected. In fact, brittle fault hydrothermal mineralization was not distinctly recognized as occurring in this area until these outcrops were exposed.

These veins typically contain primary calcite, pyrite (and more rarely other simple metal sulfides), fluorite and quartz, plus many secondary minerals. A good list of minerals and many photographs are at www.mindat.org/loc-105689.html, see also Appendix IV. Although some veins can be massive without voids, being that they formed in a brittle fault environment, others can have void spaces hosting well-formed euhedral minerals (Figure 39). 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 best under mid-wave UV light (Figures 40, 41). In contrast to the always massive and typically colorless, smoky to red-shaded chlorophane variety, the fault-hosted fluorite is usually crystallized in octahedral, dodecahedral, and cubic forms, with colors of pale green, yellow or deep purple, even reported by Shepard (1837) as a "few examples of druses of small rich purple, and in variegated cubes with beveled edges" (Figure 42 and 43). Much of the pyrite found in the amphibolite and marble (Figure 44), and a vein of quartz crystals exposed by blasting in 1988 just east of the park (www.mindat.org/photo-222604.html) may have originated from this hydrothermal activity.

Unfortunately, there are no longer extant exposures of most of these veins, but specimens exist in collections, many of which are now out of context. A prospect trench dug along an E-W-oriented brittle fault rich in clinochlore and quartz crystals is in the park uphill and east of the Champion Lode (between Stops 5 and 6). This is the only mappable brittle fault that is still visible in the study area. Overall, the assemblage is consistent with epithermal mineralization similar to that found in numerous brittle faults found in the Hartford basin and Western Highlands of Connecticut, implying they are Mesozoic.

Mineralization like that found in the brittle faults is also pervasive along joints and mineral grain boundaries in all rock types. They can occur as thin films of pyrite, orange-red-fluorescing calcite, and purple fluorite in late fractures within the "topaz" or similar veins. These occurrences were noted by Shannon (1921a) in the "topaz" vein wall zone muscovite "where deep purple fluorite forms thin plates between the plates of mica" (easily found still today) (Figure 31), but they attributed this mineralization to the host topaz veins they were found in. The hydrothermal fluids appear to have pervaded all the area rocks and not just migrated through the brittle faults.

Amphibolite found adjacent to brittle faults also shows alteration, but it is different from the alteration peripheral to "topaz" or similar veins. The rocks hosting the brittle faults are commonly etched and include secondary mineralization such as chlorite, albite, smectite (?), quartz, and gypsum (Figure 43).

## SECONDARY MINERALS

Weathering produces many secondary minerals; most interesting here are those formed from the breakdown of iron sulfides – pyrite, pyrrhotite and marcasite – all are reported here and are typically found near the bottom of the marble near its contact with the amphibolite. Their weathering produces brown iron hydroxide (goethite) and sulfuric acid, which reacts with the marble to produce yellowish hydrous iron sulfate (jarosite) and white hydrous calcium sulfate (gypsum). Brown, yellow, and white stains and crusts of microcrystals of these minerals, particularly gypsum (Figures 46 & 47), can be found under protected ledges near the contact, such as at the upper mine pit (Stop 4), the base of the southwestern marble quarry (Stop 7), and along the upper slopes of Fisher's Ridge.

Tungstite (formerly 'yellow tungstic ochre') is a rare secondary mineral formed from weathering of scheelite and as the old name sounds is a yellowish, waxy to earthy mineral. Silliman (1822a, 1822b) and Bowen (1822) both note that it was "disseminated through the tungstate of lime [scheelite]...in cavities and fissures in the ferruginous tungsten [ferberite] of Mr. Lane's mine" (Stop 4). The presence of tungstite with the unique ferberite pseudomorphs after scheelite, and unaltered scheelite, can only mean the specimens came from Lane's Mine of Trumbull (not his Elm Street, Monroe mine as mistakenly perpetuated). Yale Peabody Museum has the very meager type material. It was rare to begin with and is difficult to find now because the weathered zone where it apparently occurred has long been mined out.

# GEOLOGIC HISTORY

The history of the mineralization in this fascinating area is best understood in the context of the geological history of the host rocks. Metamorphic structures and cross-cutting relationships tell us about the relative timing of events. These rocks reached upper amphibolite facies metamorphic conditions, up to 650° C and 7 kb, in the park area (Moecher et al., 1997; Matthews et al., 2008). This places the rocks in the staurolite-kyanite zone consistent with the generation of migmatites and granitic pegmatites. The rocks of the Saganawamps section are all foliated, including many of the pegmatites that intrude it, showing that the metamorphism was part of a dynamic orogenic mountain-building event. The dominant foliation is mostly parallel to observed lithologic layering. Syn-kinematic quartz-albite pegmatites were intruded into the section fairly early and were subsequently transposed (rotated by shearing) and boudinaged to become sub-parallel to both layering and foliation as the deformation persisted during falling metamorphic temperatures. This is well displayed at the large marble quarry on the southwest side of Saganawamps Hill where boudinaged to partly dismembered pegmatites are transposed into layers within the marble parallel to the dominant foliation. Localized intense shearing also produced outcrop-scale boudins of amphibolite that display meter-scale tight to isoclinal folds focused at the ends (necks) of the large-scale boudins. Both scales of deformation are observed at several field locations. This localized deformation involves the dominant foliation, so it must have occurred while the rocks were still ductile, but after the dominant foliation-forming event. Larger scale, syn-kinematic migmatite intrusion is represented by the Devonian Pequonnock River migmatite zone, best seen on the lower slopes of Fisher's Ridge, which locally contains foliated amphibolite bodies. The migmatites penetrated and infiltrated foliated amphibolite along the interpreted thrust fault between the Saganawamps Section and The Straits Schist (DSt). All these units are crosscut by poorly zoned, non-foliated, diapiric, Late Devonian pegmatite, such as the topographically prominent one southeast of Saganawamps Hill. It only displays a crude, spaced cleavage that is likely a consequence, in part, of its coarse grain size.

Within this context we observe the scheelite and its associated clinozoisite, quartz, calcite, pyrite/pyrrhotite and marialite alteration of the host foliated amphibolite, which also form euhedral crystals within it. These altered areas can also exhibit small vugs. Thus, the mineralization is younger than the host rock foliation because the high pressures accompanying the high-grade metamorphism would also have closed the fluid-filled vugs. The "topaz" (and related) veins clearly cut all the foliated rocks and include marialite and scheelite along their contacts with the host rock. These features, plus the wall rock metasomatic alteration, indicate these veins formed after, but under similar conditions to the scheelite-bearing amphibolite alteration. The veins also have rare vugs indicating post- deformational shallower emplacement.

The youngest mineralization is probably represented in the brittle, fault-hosted hydrothermal veins. The vuggy nature of these late veins, along with the associated brittle host rock deformation, indicates relatively low pressures, perhaps < 2 kb, or shallower than ~8 km.

The addition of numerical geochronological and thermochronological data to the relative order of geologic events described above establishes the specific temperature – time (T-t) path the local bedrock followed (Figure 48) and illustrates the timing of The Straits Schist and Saganawamps section metamorphism relative to the timing of the park's unique mineralization. Rodgers (1985) denotes an Ordovician age for the gneiss of the Collinsville Formation and an unconformity between it and The Straits Schist Silurian-Devonian section. However, zircons that were deposited as detrital grains in original The Straits Schist sediments indicate the main body of The Straits Schist is likely restricted to the Early Devonian and that the progenitor volcanics and sediments of the basal member (Saganawamps section) are Silurian in age (Wintsch et al, 2014; 2017; 2019). The progenitor sediments were metamorphosed into schist, amphibolite, and marble during the Acadian Orogeny (~400-360 Ma, e.g., Dietsch et al. 2010) when prograde metamorphism to upper amphibolite facies conditions exceeding 650º C and 8000 bars (~28 km depth). Monazite crystals from The Straits Schist in the Long Hill area probably crystallized during the generation of migmatitic liquids in The Straits Schist and grew at ca. 380 Ma

(Lanzirotti and Hanson, 1995; Millonig et al. 2020) during peak metamorphic conditions. The principal foliation, boudinage, migmatite intrusion and thrusting along the Pequonnock River migmatite zone occurred when rocks were hot enough to bend without breaking as the Acadian Orogeny culminated. The undeformed, diapiric pegmatites intruded these rocks in the later Devonian after movement on the Pequonnock River migmatite zone ceased.

The retrograde path from peak metamorphic temperature is partially constrained by the $^{40}Ar/^{39}Ar$ cooling age of amphibole from the upper amphibolite unit at Corporate Drive (see Appendix III; McAleer et al., 2022). This age of 355±3 Ma establishes the time of cooling below middle garnet zone metamorphic conditions of ~500° C. The age of the latest foliation in the upper amphibolite unit at Corporate Drive is defined by the syntectonic age of the retrograde titanite associated with that foliation (see Appendix II). The titanite age of 346 ± 13 Ma constrains the foliation as being Early Mississippian, and thus, all the mineralization is younger than this age. A muscovite cooling age from a “topaz” vein at Corporate Drive of 266.7 ± 1.4 Ma (middle Permian, Guadalupian; Appendix III) marks the time of entrance of these rocks into the lower greenschist facies (~350° C). The regional waning of metamorphic conditions after the Permian is not well defined by geochronometers, but the Middle Triassic nonconformity above these rocks (and exposed along the western margin of the Hartford basin) shows that the rocks were quite close to the surface by ~220 Ma (Wintsch et al, 2003).

The retrograde path of dropping temperature during post-Acadian exhumation is interrupted by a spike of heat produced by intrusion of the nearby Pinewood Adamellite and adjacent small intrusions, including dacite and rhyolite porphyries (Crowley, 1968) (see regional geology map on Plate 1). Together these intrusions constitute the Pinewood Adamellite suite, with an age of 291 ± 4 Ma (Sevigny and Hanson, 1993). This suite of intrusions shows that melts were generated in the early Permian (Cisuralian), and the fine grain size of the 2 smaller porphyritic intrusions shows that the country rocks now at the present erosion surface were relatively cool (Figure 48).

These data, and the T-t path they produce (Figure 48) lay the framework against which the timing of the mineralization must be placed. The scheelite and associated mineralization post-dates the foliation, and the “topaz” veins cut the foliation as well, so both must be Early Mississippian or younger. But the minerals in the veins are coarse grained, so the veins probably crystallized above 400° C, or before about 275 Ma, with the veins cooling down to below 350° C by about 267 Ma (Figure 48). This temperature is consistent with the OH/(OH+F) content of the topaz. This makes a very strong case for the mineralization during the Alleghanian orogeny, potentially produced by a local heating event associated with the intrusion of the Pinewood Adamellite suite. The absence of similar late intrusions probably explains the absence of mineralization in other exposures of the “The Straits Schist basal member” amphibolites of Rodgers (1985).

There is structural evidence for this genetic relationship. The strike of most topaz veins is ~N40°W (Figure 28). This is parallel to the strike of the Pinewood Adamellite suite. A line with a strike of ~N40°W can be drawn from the rhyolite porphyry near Nickols in the Bridgeport quadrangle, through the Pinewood Adamellite, through the unnamed tonalitic ‘gneiss’ at the Hillandale Country Club, and through Old Mine Park joins this intrusive suite (see regional geology map on Plate 1). This regional alignment was noted by Crowley (1968) and Altamura (2005). All the “topaz” veins are weakly foliated to non-foliated, and 3 contain accessory fluorite. This establishes a chemical and structural correlation between middle Permian (Guadalupian) intrusive bodies and the mineralization in the “topaz” veins of the park. We thus speculate that a body of felsic rock of similar age underlies the park, and fluids rising from it invaded fractures associated with its emplacement, bringing late mineralizing fluids to the park area.

Brittle faults later cut the rocks of the Saganawamps section and The Straits Schist. Their open cavities between brecciated host rock fragments show they were shallow and their mineral cements of mostly quartz, calcite, fluorite, and metal sulfides with clinochlore along some of the walls show they were filled with warm aqueous fluids. These fluids also pervaded the host rocks leaving behind traces of these minerals in joints, small voids, and interstitial mineral spaces. The similarity of these open veins with known Mesozoic structures in the Hartford and Pomperaug basins suggests that these veins are also of Mesozoic age (Figure 48) and caused by early Mesozoic crustal extension. Indeed, Gray (1988) places the Hartford basin mineralization at Middle Jurassic (180 Ma), which coincided with the tail end of a higher geothermal gradient that peaked at 200 Ma. Pirovane and Evans (2014) found that New Britain area faults within the Hartford basin show 3 groups of fluid inclusions in quartz corresponding to trapping temperatures of 188 to 207 °C, 148 to 174 °C and 106 to 138 °C, in calcite at 106 to 172 °C, and in barite at 115 to 120 °C. These data reflect epithermal conditions. Vein mineralization in faults within western Connecticut was a bit hotter (deeper). Evans and Lemmons (2017) concluded that early quartz from the large siderite vein in Roxbury was formed by low salinity, $CO_2$-rich hydrothermal water at between 280 and 304 °C at 7.0 to 8.3 km depth. These observations are all in keeping with the inferences of the thermal history of western Connecticut of Roden-Tice and Wintsch (2002) and Wintsch et al. (2003). Zeolite mineralization in joints and brecciated faults occurred during cooling after the Jurassic heat pulse.

Erosion slowly cut down the rocks for the next 180 million years until they reached the surface at which point, they were affected by repeated Pleistocene glaciation and subsequent weathering.

## FUTURE RESEARCH OPPORTUNITIES

Many questions about this unique area have been addressed by previous studies and this guide, but further investigations are warranted and highly encouraged. Detailed mapping of the rest of the Saganawamps section and adjacent rocks is needed to work out the broader structure. A short list of lingering questions includes:

- What were the protoliths and depositional settings of the Saganawamps section members? A depositional model is needed to explain the interlayering, including the presence of quartzite in other exposures.
- What is the origin of the tungsten in the altered amphibolite? Why was just the amphibolite metasomatized? Were other amphibolites affected?
- What is the extent and distribution of scheelite in this study area and beyond? A comprehensive, night-time UV light survey is needed. Why does the scheelite pseudomorphed by ferberite occur in only 1 small area and when did that happen?
- If the veins are related to intrusion of the Pinewood Adamellite, then why are the veins (apparently) clustered in the park area? The veins tend to be very narrow in The Straits Schist, so did they simply pinch out higher in the section and thus are mainly visible in this lower stratigraphic window? Or is there another local pluton just below this area?
- What is the vein geochemistry and what explains variation in vein composition despite similar alteration of host amphibolite wall?
- What is the more regional structure, particularly, what is the extent of the Pequonnock River migmatite zone beyond the mapped area? Crowley's map and rockhound reports suggest a repetition of the Saganawamps section and additional veins south of Route 25. Also, the extensive rock cuts along the Route 25 expressway south of Route 111 have not had a detailed study.
- The area west of this study area, where the Collinsville Formation was mapped by Crowley, also needs remapping. Although outcrops are scarce, they suggest that The Straits Schist underlies most of it. How does the amphibolite exposed west of Route 111 connect to the area mapped by this study and beyond?

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Figure 1 (left). Old Mine Park and developments around it that exposed bedrock. The Home Depot site was built over a never completed development called Old Mine Plaza where many specimens were collected. The former United Health Care office is at 48 Monroe Turnpike.

Figure 2 (below). Exceptional, large (7 cm), tetragonal bipyramidal scheelite crystal in quartz in lower amphibolite member of the Saganawamps section (Ssla) from the Old Mine Plaza/ Home Depot site. Most scheelite crystals are associated with quartz and clinozoisite in localized zones of altered amphibolite. (H. Moritz photo).

Figure 3. Black ferberite pseudomorphs after tetragonal bipyramidal scheelite crystals (to 23 mm) with quartz and clinozoisite in greenish altered amphibolite within the lower amphibolite member of the Saganawamps section (Ssla). This mineralized zone is just below the Ssla contact with the overlying lower marble member (Sslm) at the upper tungsten mine pit. It is the only confirmed place for these pseudomorphs and was the locus for mining because the greater extent of scheelite was not known. The tetragonal bipyramidal crystal form of scheelite ($CaWO_4$) shows well here, but the composition is ferberite ($FeWO_4$), which normally has orthorhombic symmetry. These crystals were confusing to early 19th century chemist/mineralogist Benjamin Silliman (1819a) because they had the wrong chemistry for their crystal shape so he thought they might be a new mineral species. Former specimen of Julian Sohon (author of *Connecticut Mineral – Their Properties and Occurrence*, 1951) and Earle Sullivan (author of *History and Minerals of Old Mine Park (Saganawamps)*, 1985). (H. Moritz photo.)

Figure 4. Close-up of a void in a pseudomorph fragment showing tiny terminations of myriad ferberite crystals replacing the original scheelite crystal (FOV 12 mm). (H. Moritz photo).

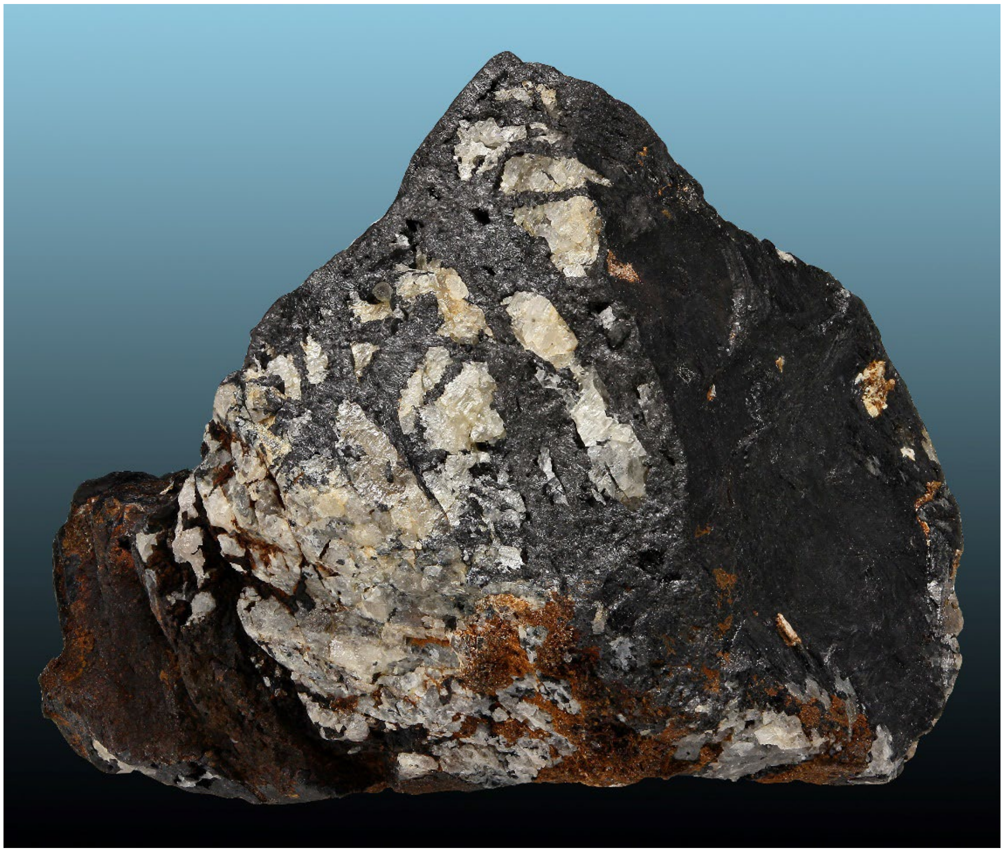


Figure 5 (left). Fragment of a ferberite pseudomorph after scheelite showing remnant patches of white scheelite. Former Earle Sullivan specimen, 35 x 45 mm. (H. Moritz photo).

Figure 6 (below). Large ferberite pseudomorphs collected by Ronald Januzzi, crystal at left is 4.5 cm. The specimen still has the typical rusty iron oxy-hydroxide coating that is usually cleaned off. (H. Moritz photo).

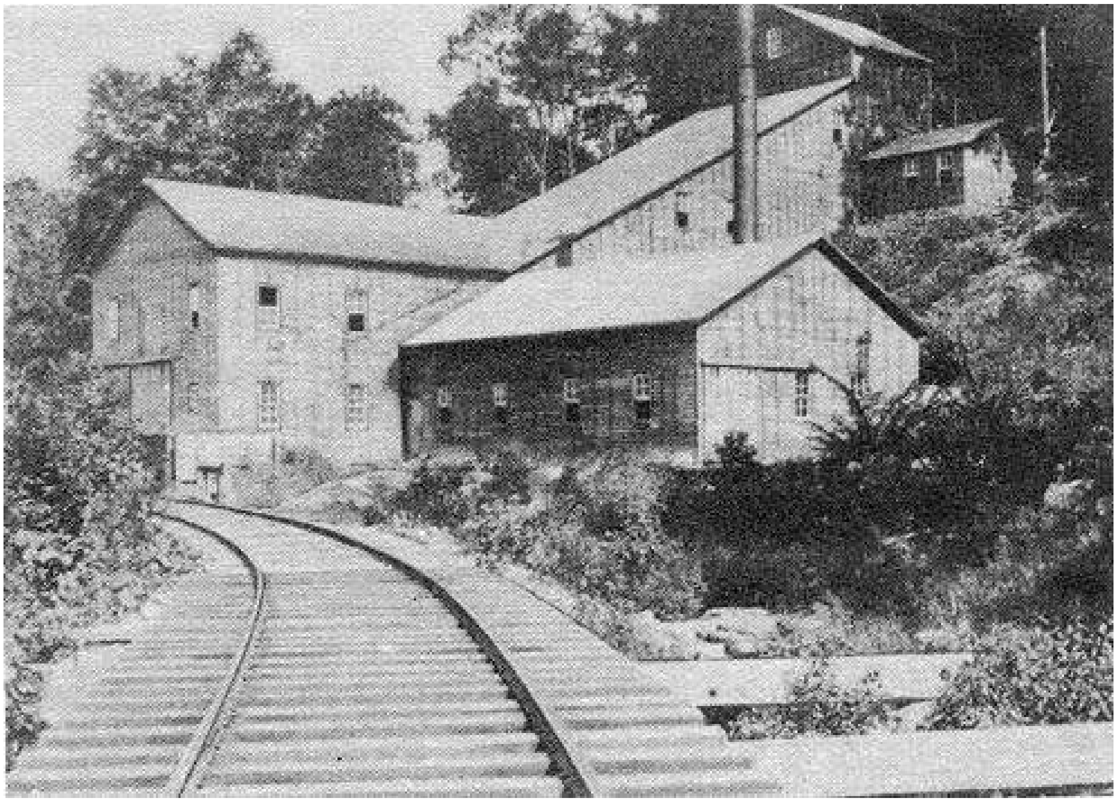


Figure 7. American Tungsten Mining and Milling Company mill circa 1900 situated below the marble quarry at the SW corner of Saganawamps Hill. The mill used a dry process that left pyrite in the concentrate. The failed mining effort seemingly focused on the very limited ferberite zone, where there was also some scheelite, but failed to determine the much greater extent of scheelite in the widespread Saganawamps section amphibolite. Public domain photo. More historical photographs: www.trumbullhistory.org/photographs.html.

Figure 8. Spot the scheelite. Most scheelite occurs as small anhedral grains that in isolation can look like common quartz or albite grains, or can hardly be seen at all in daylight (left) but fluoresce a bright blue-white under short-wave ultraviolet light (right) as shown in this 25 cm x 25 cm sample of amphibolite. Portable UV lights became an indispensable tungsten prospecting tool beginning in the 1930s, too late for the mining effort here, however. Note brown and green color of altered amphibolite. From Corporate Drive. (H. Moritz photos).

Figure 9. Well-developed and relatively large grossular crystals in a matrix of coarse-grained calcite, quartz, albite, and diopside. Mostly the calc-silicate minerals are fine grained and exist in layers and bands within the lower marble (Sslm). From former Old Mine Plaza site. FOV 2.6 cm. (H. Moritz photo).

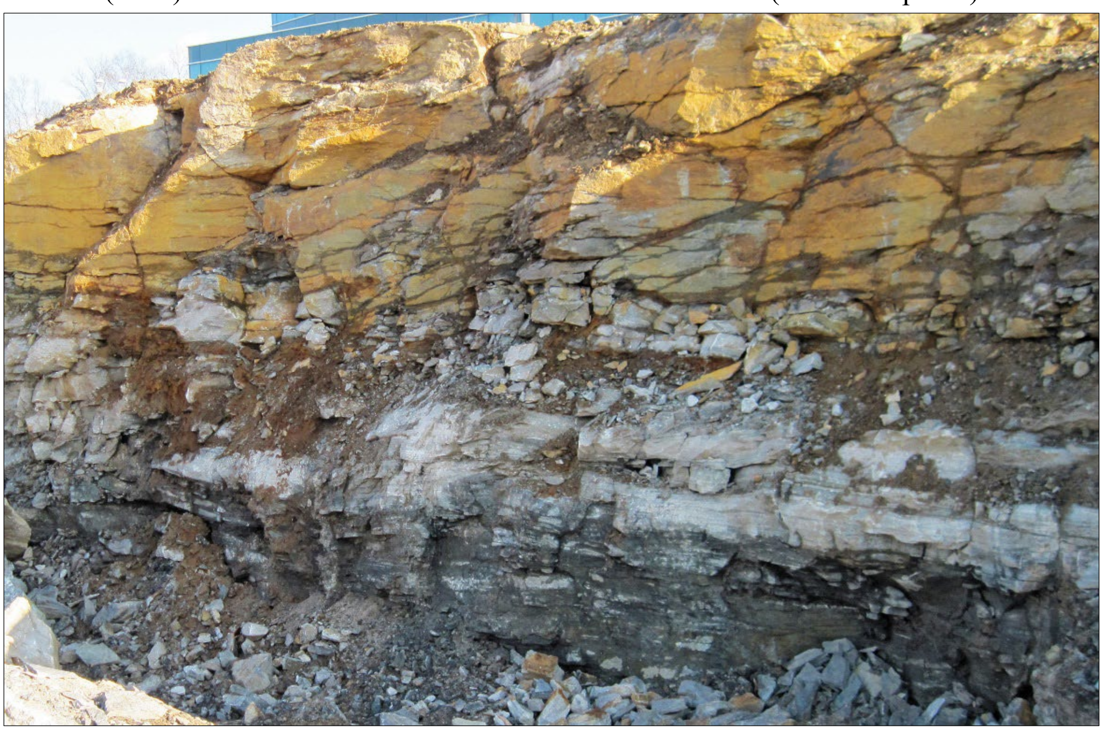


Figure 10. Rock cut (6 m high) during construction at 50 Corporate Drive showing rusty The Straits Schist (DSt) (at top) overlying white siliceous upper marble/quartzite (Ssum) (middle) and dark gray upper amphibolite (Ssua) (bottom) members of the Saganawamps section. An exposure of these rocks in contact with The Straits Schist is very rare. These are the stratigraphically highest units in the park area. (H. Moritz photo).

Figure 11. Deformed lower marble member (Sslm) exposed at the upper mine pit. Most marble outcrops are coated with a bright green moss and show differential weathering causing the thin albite-quartz layers to stand out in relief. The sub-horizontal, ferberite-scheelite-bearing, quartz-clinozoisite zone at the top of the lower amphibolite member (Ssla) that was the focus of tungsten mining was present approximately where the standing water is. At the left end of the face is a vuggy quartz mass (yellow line) along what appears to be a brittle fault. (H. Moritz photo).

Figure 12. Wall of the marble quarry SW side of Saganawamps Hill showing nearly the full 8-meter thickness of the lower marble member of the Saganawamps section (Sslm). Multiple packages of white albite-quartz layers can be traced along much of the hill's adjacent outcrops. The impure marble appears grayish from the presence of calc-silicate minerals such as diopside, grossular, actinolite and phlogopite. At lower right is a cavity excavated by the tungsten miners in search of the ferberite-rich layer at the top of the underlying amphibolite. The mill complex was located opposite this approximately 15 m wide view. (H. Moritz photo).

Figure 13. Outcrop of 1 of 3 smaller marble interlayers within the upper amphibolite (Ssua) and above the lower marble (Sslm). The marble is the moss-covered, 40-cm-thick layer above the field book and includes a laterally persistent albite-quartz layer near the top, here showing boudinage. Note the sharp contacts devoid of alteration and/or quartz. (H. Moritz photo).

Figure 14. Layer of quartz (the slightly rusty boudin) between lower marble (Sslm) (top) and lower amphibolite (Ssla) (bottom) present in the outcrops along the SE edge of the park and similar to that described at the upper mine pit. The zone also shows secondary minerals (rusty yellow sulfate mineral crust near center) from the weathering of iron sulfides. However, the amphibolite shows no signs of the alteration found at the upper mine pit area, nor were any ferberites seen here. However, Fisher's 1942 map (Kerr, 1946) shows scheelite in these amphibolite outcrops. Card is 20 cm tall. (H. Moritz photo).

Figure 15: Five meter high outcrop of The Straits Schist (DSt) on the lower reaches of Fisher's Ridge near the Pequonnock River. The layering is subhorizontal and impregnated with many small quartz boudins. Behind and above, it is talus from the Pequonnock River migmatite zone (Dprmz). (H. Moritz photo).

Figure 16: Close-up of the Pequonnock River migmatite zone (Dprmz) near its contact with the large pegmatite exposure SE of Saganawamps Hill. The Pequonnock River migmatite zone is deformed and includes here a rusty fragment of altered amphibolite above the hammer, a zone of migmatite behind the hammer, and a fragment of unaltered amphibolite below the hammer. (H. Moritz photo).

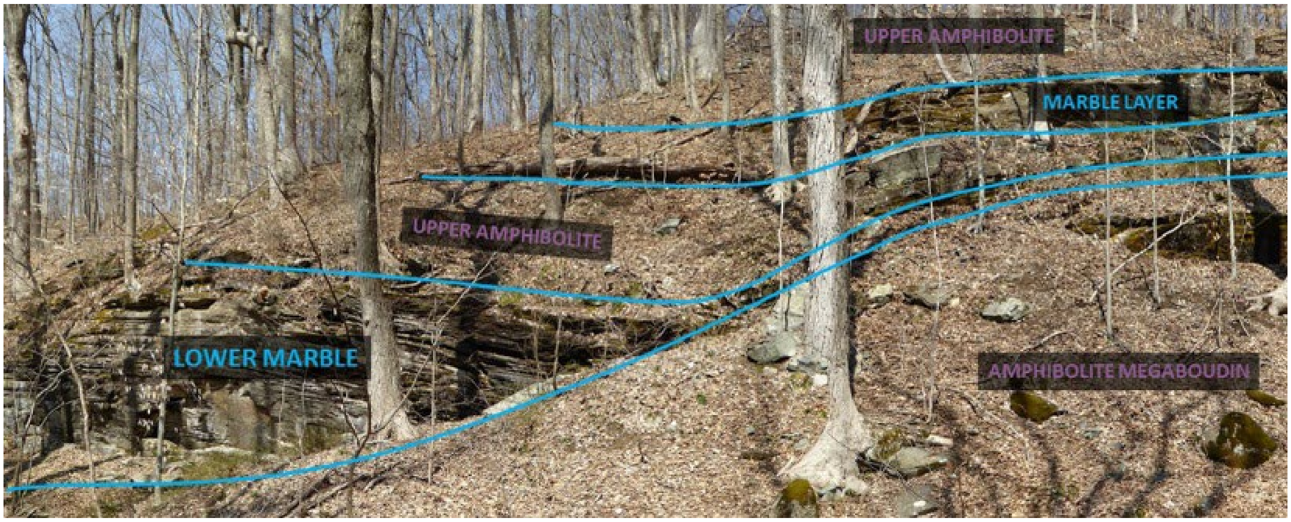


Figure 17: The SE side of Saganawamps Hill showing where the gently dipping lower marble member (Sslm) at lower left and interlayered marble and amphibolite of the upper amphibolite member (Ssua) above it are deformed adjacent to the southern terminus of an outcrop-scale boudin of the upper amphibolite member (Ssua). FOV about 25 m. (H. Moritz photo).


Figure 18: Ductile deformation in lower marble member (Sslm) situated in the neck region between two very large upper marble member (Ssua) amphibolite boudins. Location is north (right) of the view in Figure 17. 18-cm hammer head in moss at bottom for scale. (H. Moritz photo).

Figure 19: Portion of the lower amphibolite member (Ssla) (blocky outcrop) included within the base of the Pequonnock River migmatite zone (Dprmz). Bill Devlin is standing where the Pequonnock River migmatite zone is in contact with The Straits Schist (DSt) (lower left) on the lower reaches of Fisher's Ridge near the Pequonnock River. (H. Moritz photo).

Figure 20. Nose of a very large amphibolite boudin in the lower amphibolite member (Ssla) (dark gray rock lower left of hammer) with a deformed lower marble member neck wrapping over it (light gray rock at right and in upper left background). Located on the upper slope of Fisher's Ridge. (H. Moritz photo).

Figure 21. Mass of radiating marialite (based on Raman spectroscopy) 20 x 14 cm from a pod in altered lower marble member (Ssla) shown under normal light (top) and short-wave ultraviolet light (bottom). Dark areas in the top photo are pyrrhotite, which is also present in masses. (H. Moritz photos).

Figure 22. Sample of altered lower amphibolite member (Ssla) showing zones of dark greenish actinolite, brown acicular clinozoisite and white calcite (which commonly weathers out exposing the clinozoisites in "pockets") and quartz. Scheelite is typically found in this altered rock mineral assemblage suggesting a common metasomatic origin. (H. Moritz specimen and photo).

Figure 23: Small prospect pit in very rusty lower amphibolite member (Ssla) immediately below folded lower marble member (Sslm) at the North end Fisher's Ridge. Is this the other ferberite location mentioned by Hobbs (1901)? Old dump is under leaves in foreground. (H. Moritz photo).

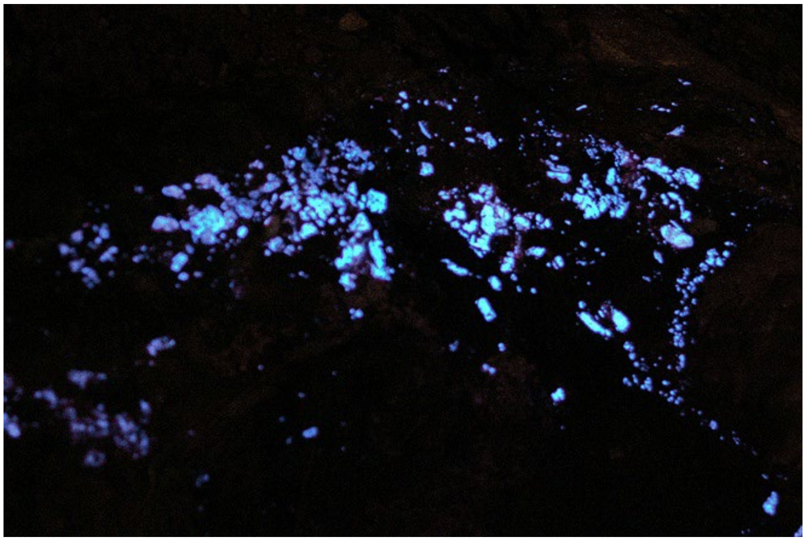


Figure 24. Nighttime photo of in-situ lower amphibolite member (Ssla). This ~1 m view shows a very high concentration of scheelite crystals fluorescing under SW UV light, but not all areas are like this. (H. Moritz photo.)

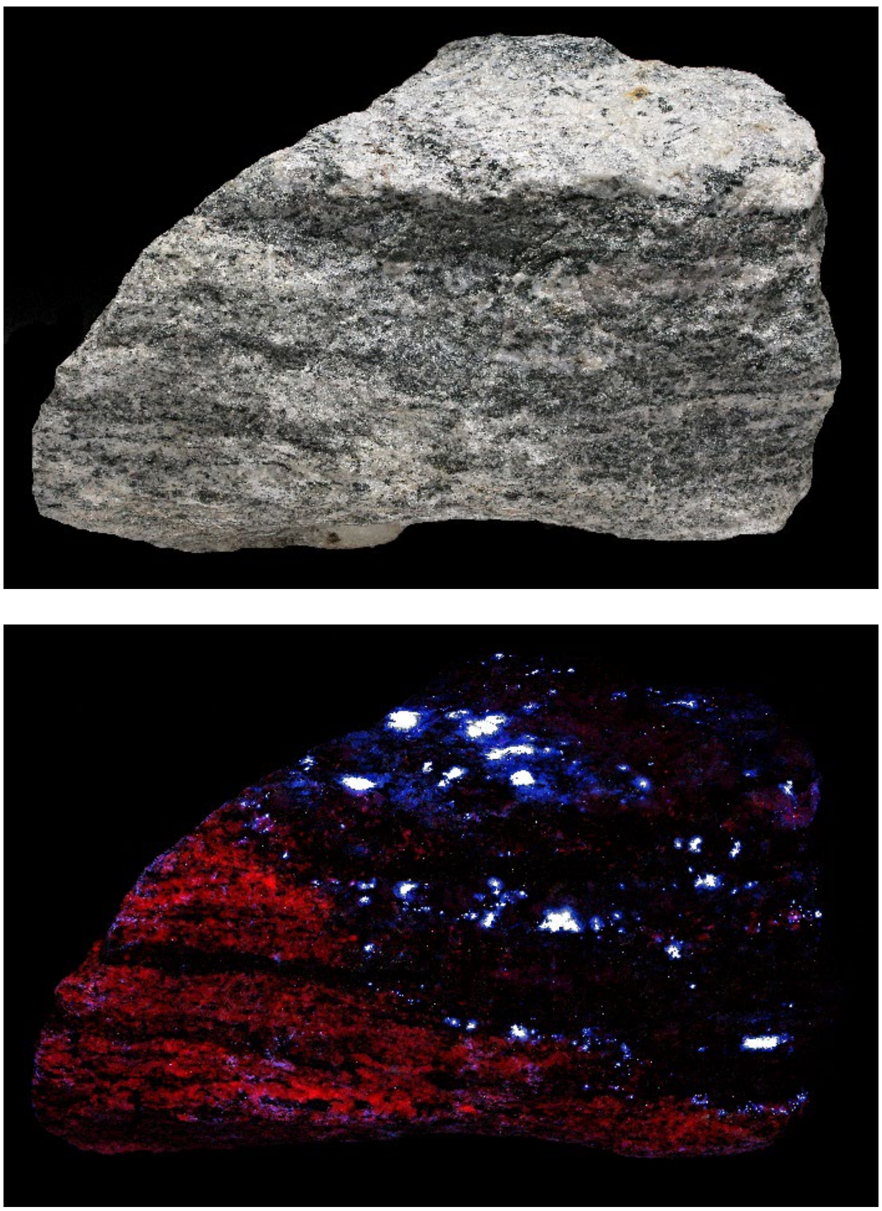


Figure 25. Normal light (upper image) view of a 20 cm sample of ordinary-looking rock from Corporate Drive. It does, however, have an unusual diagonal contact between impure upper marble (Ssum) (lower left) and a dark green amphibolite gneiss (upper right and top). Under SW UV light (bottom image) the contact is obvious and many grains of otherwise inconspicuous, bright blue-white-fluorescing scheelite are visible in amphibolite gneiss but not the marble (orange-red fluorescence). The gneiss has a few grains of calcite and clinozoisite and appears to have replaced the marble. This is an atypical sample and unfortunately was not found in-situ. (C. Merguerian specimen, H. Moritz photo).

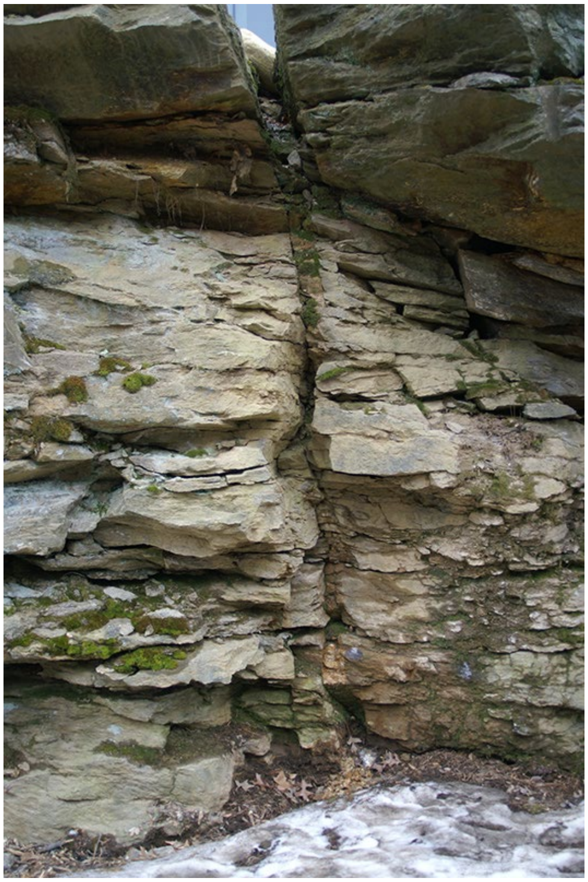


Figure 26 (left). One of several narrow, high-temperature mineral veins cross-cutting The Straits Schist (DSt) within a road cut on Corporate Drive, above the veins exposed in the 3 m high cut at 50 Corporate Drive below the road. The veins in the outcrop parallel a set of prominent joints. Veins tend to be much thinner cross cutting The Straits Schist than in the Saganawamps section (as shown in Figure 27) and some veins in the latter vertically pinch out below The Straits Schist, as seen at the 50 Corporate Drive rock cut below this one. (H. Moritz photo.)

Figure 27 (below). Excellent exposure of about 1 m wide high-temperature mineral vein oriented N22°W, 74°SW cross-cutting amphibolite foliation oriented N65°W, 74°E. It is located in a cut into amphibolite outside the study area behind 41 Monroe Turnpike west of Route 111. This vein is mostly quartz with albite, chlorophane, and muscovite along the contact and is similar to what the vein in the mined-out Champion Lode in the park would have looked like. (H. Moritz photo.)

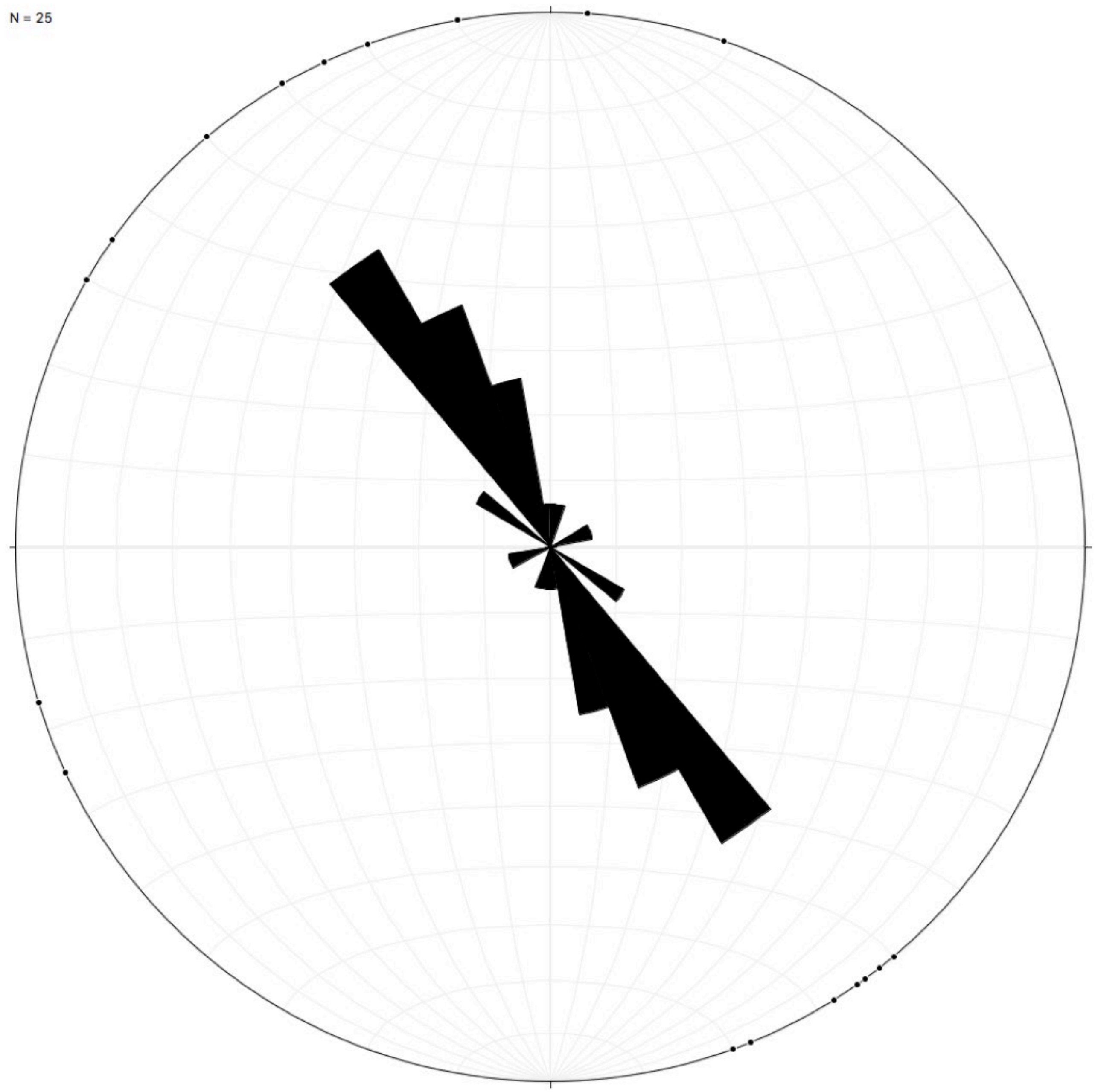



Figure 28: Rose diagram showing the strike orientations of 25 high-temperature mineral veins within and near the study area. All are steeply dipping (see Figure 27). Most orientations are strongly clustered around azimuth 330. Although this result could be due to exposure bias, most bedrock outcrop areas have a generally similar orientation as the veins, which would tend to reveal veins oriented NE-SW, but few of these were found. Plus, because of the strong interest in their minerals, any vein exposures were further opened by prospecting, especially at the former Old Mine Plaza site where the few ENE-WSW oriented veins were found. The rock cuts at 50 Corporate Drive, which are cut both NE-SW and NW-SE, expose only dominant vein orientations. The veins' opening directions imply a push from the SE (150°), which is the push direction of the Alleghanian orogeny about 280 Ma, as determined in the Avalon Terrane (Wintsch and Sutter, 1986).

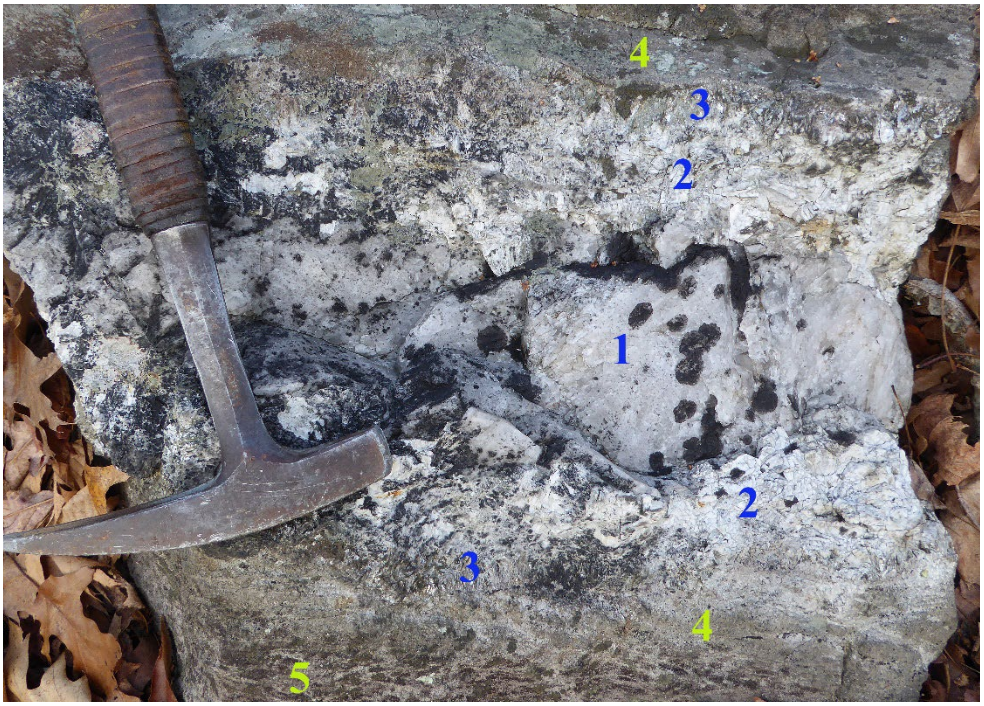



Figure 29. Boulder showing the typical major features of a high-temperature mineral vein cross-cutting upper amphibolite member (Ssua). From the center are:

1. Core zone of massive milky quartz.
2. Outer core zone of chalky white, very coarse-grained albite crystals (in others mostly topaz and fluorite).
3. Muscovite wall zone (with some marialite, hard to see here).
4. Altered amphibolite contact zone of fine-grained marialite and phlogopite. 5. Unaltered amphibolite. At a minimum, a high-temperature vein can consist of just the muscovite wall zone and the altered, host amphibolite contact zone. Besides the planar geometry, these features distinguish the veins from the many granitic pegmatites, which do not show them. Hammer head is 18 cm. (H. Moritz photo).

Figure 30. Section of a typical topaz-rich, high-temperature mineral vein showing subhedral yellow-green topaz crystals in massive gray quartz on a wall zone of prominent, subparallel muscovite folia. The altered host amphibolite at the bottom, FOV is 8 cm. From former Old Mine Plaza site. (H. Moritz photo).

Figure 31. A parallel growth of rare, terminated and gem-quality topaz crystals on muscovite, specimen is 8 cm wide. Note the touches of dark purple fluorite, which formed in between topaz and muscovite grains. This is an old specimen likely from the initial North American topaz discovery vein excavation near the old lime kiln. (H. Moritz photo.)

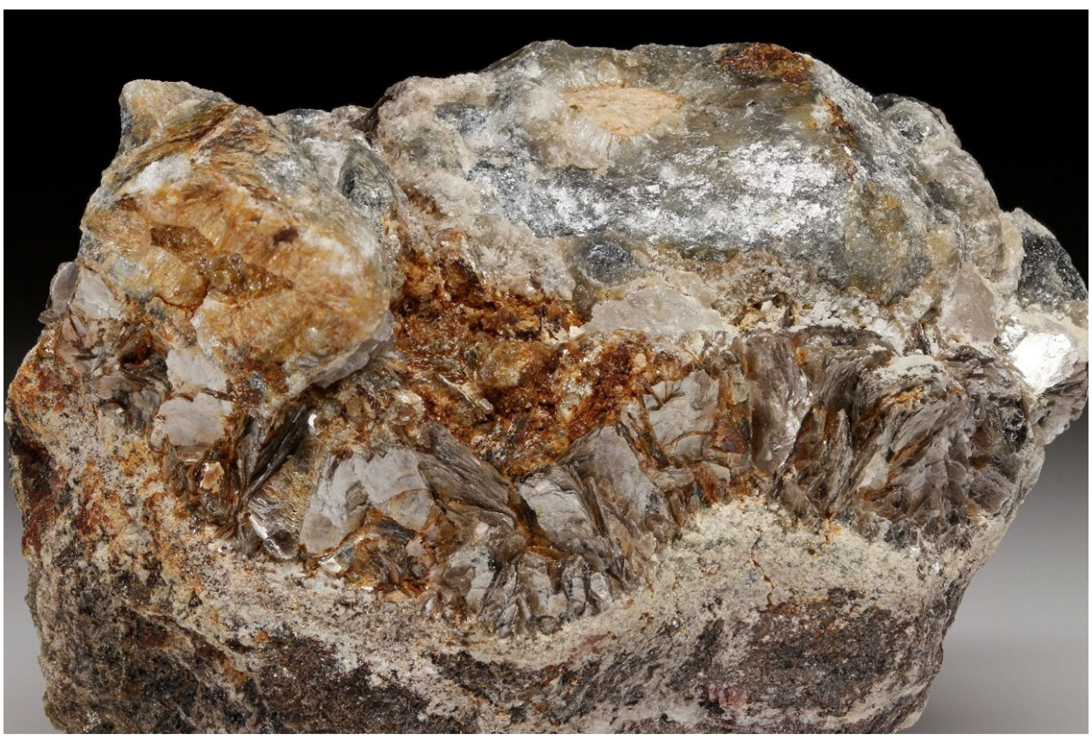


Figure 32. Margarite replacing topaz at upper left and upper center with remnant topaz cores showing through broken portions of fibrous margarite (with pearly surface). View is a cross-section of a topaz-rich, high-temperature mineral vein showing well the coarse, subparallel muscovite of the wall zone and the altered amphibolite at the bottom, FOV 8 cm. (H. Moritz photo.)

Figure 33 (left). Field photo of a margarite replacement of topaz surrounded by coarse-grained muscovite wall zone of a high-temperature mineral vein. Specimen is broken parallel to the vein wall so the margarite pseudomorph looks like an egg, another is to its upper left. FOV 16 cm. (H. Moritz photo).

Figure 34 (below). Specimen of high-temperature vein minerals from Corporate Drive fluorescing under SW UV light – fluorite variety chlorophane (blue-green), albite (purple), marialite (pink), fluorapatite (yellow specks at far left). Black areas are non-fluorescent quartz. Specimen is 17 x 11 cm. (H. Moritz specimen and photo).

Figure 35. Specimens from albite-rich high-temp veins showing (left) white albite crystals with massive, dark gray chlorophane with dark green clinochlore (FOV 8 cm); and (above) dark green clinochlore crystal aggregates on albite (FOV 7.5 cm). Specimens were found W of Route 111. (H. Moritz photos).


Figure 36. Specimen from a rare calcite-rich high-temp vein. Cross-sectional view (upper left) shows white calcite and marialite overlying brown, altered amphibolite with fine-grained phlogopite and marialite grading away from contact into unaltered dark gray amphibolite (FOV 6.5 cm). The amphibolite wall alteration visually appears the same regardless of the vein composition. View parallel to the wall zone (upper right) shows calcite (white upper right), beryl (pale emerald green prisms), quartz (light gray around beryl), marialite (very pale yellow-green lower right) and pyrrhotite (brassy grains) (FOV 5.5 cm). At right, another emerald-colored beryl in calcite. Both are from the defunct Old Mine Plaza site, now covered by The Home Depot. (H. Moritz photos.)

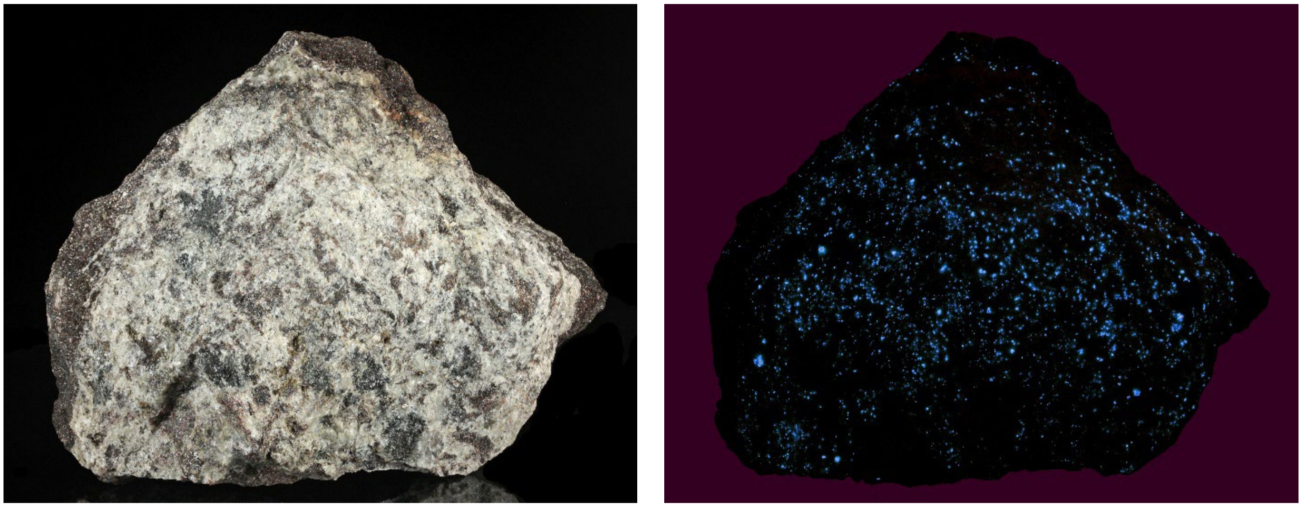


Figure 37. Normal light (left) and short-wave ultraviolet light (right) photos of a high-temperature mineral vein specimen from Corporate Drive broken along the wall contact, 10 x 15 cm. The matrix consists of granular albite, marialite, phlogopite, amphibole, fluorite, and sulfides, nothing particularly unusual. But hidden on it are myriad tiny specks of scheelite detectable only via their fluorescence. This apparently is scheelite that was mobilized from the amphibolite by the vein fluids passing through the latter and recrystallizing scheelite on the wall rock contact farther up the vein. Its presence does not correlate with the presence or absence of scheelite in the local host rock. (H. Moritz photo.)

Figure 38: Quartz-fluorite-muscovite high-temperature mineral vein cross-cutting pegmatite, near the schist and amphibolite fragments shown in Figure 16. This rare occurrence shows that the veins are younger than the pegmatites and the latter are not the source of the veins. Card is 20 cm tall. (H. Moritz photo).

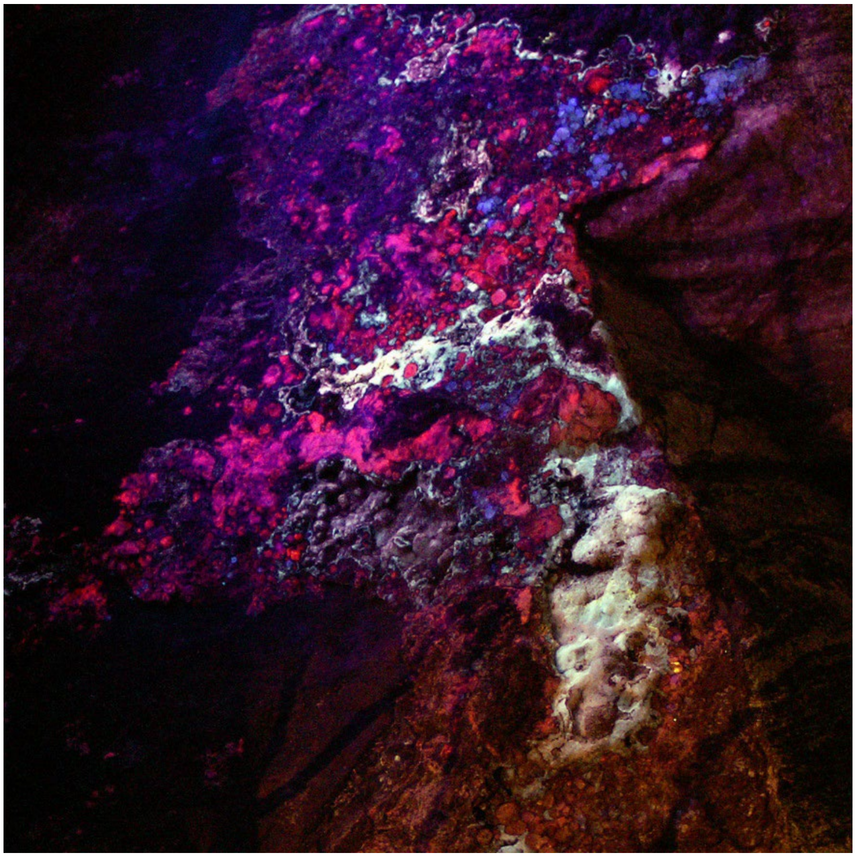


Figure 39 (left). Night-time, short-wave UV light photo of an in-situ joint surface in lower amphibolite member (Ssla) covered with white and red-fluorescing calcite and purple-fluorescing fluorite. This type of mineralization is typical of an epithermal, brittle-fault-associated mineralization event. FOV about 1.5 m wide. (H. Moritz photo).

Figure 40 (below). "Poker chip" habit acute rhombohedral calcite overgrowths on "normal" rhombohedra, with purple to green fluorite. White light illumination (left) and mid-wave ultraviolet light fluorescent view (right). From a mineralized brittle fault at the defunct Old Mine Plaza site. FOV 3 cm wide. (H. Moritz photo).

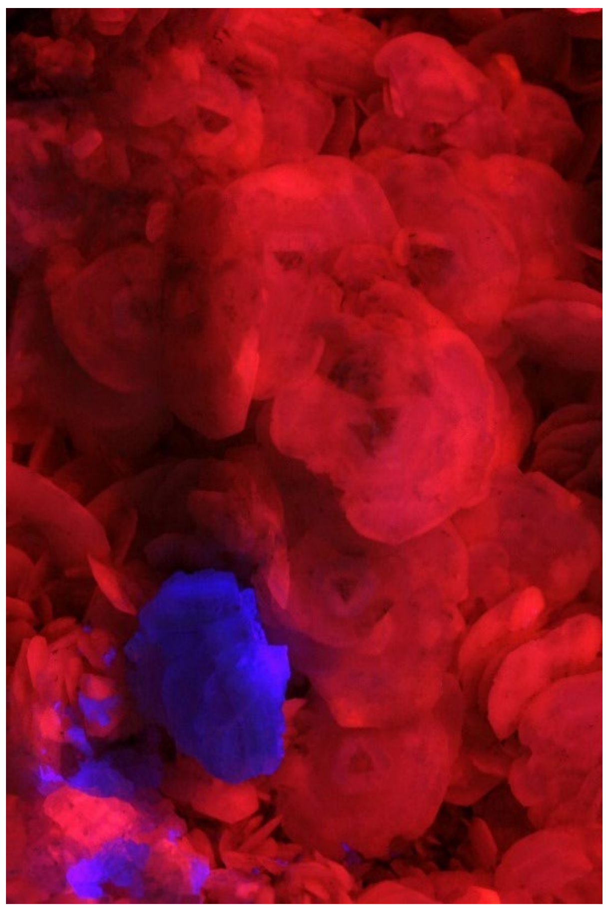


Figure 41. Hexagonal calcite from a mineralized brittle fault at the defunct Old Mine Plaza site. FOV 9 cm. (H. Moritz photo).

Figure 42. “Normal”, purple tinted, clear fluorite crystals showing complex combination of cubic and dodecahedral forms. Shepard mentioned similar crystals in 1837. From a mineralized brittle fault at the Old Mine Plaza site. FOV 1.5 cm. (H. Moritz photo).

Figure 43. Green octahedral fluorite crystals on altered, etched amphibolite matrix with secondary minerals gypsum (gray lower center), albite (white), clinochlore and bavenite. From a mineralized brittle fault at the defunct Old Mine Plaza site. Specimen is 10 cm wide. (H. Moritz photo).

Figure 44: Spherical aggregate of cuboctahedral pyrite crystals 5.5 cm across, from the defunct Old Mine Plaza site. (H. Moritz photo).

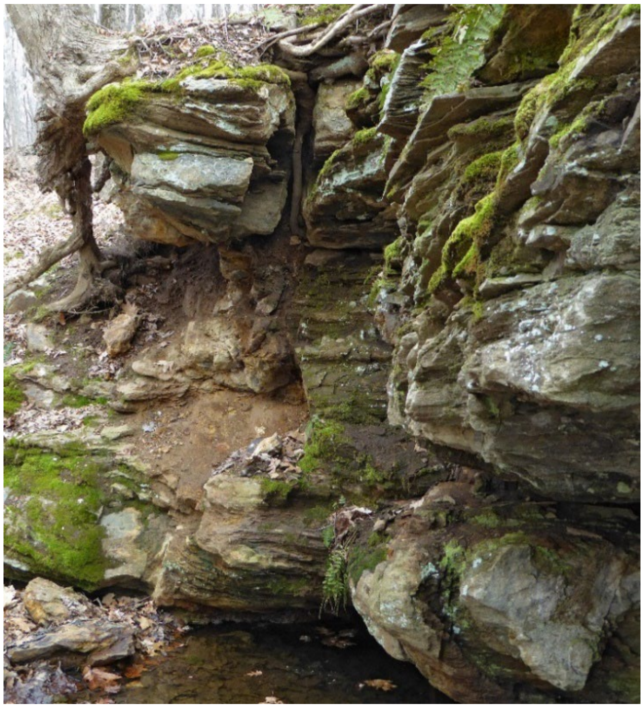


Figure 45 (left): Subvertical zone 3 m high of massive quartz (left with yellow staining) with crude crystals in voids, E corner of the upper mine pit's lower marble member (Sslm) exposure, which seems to match Gurlt's 1893 description of the ferberite-hosting quartz zone – but it has the wrong orientation. Is this a fault zone? (H. Moritz photo).

Figure 46 (above). When the iron sulfides pyrite, marcasite or pyrrhotite (all reported from this area) weather they form sulfuric acid that then reacts with the marble to form hydrous calcium sulfate (gypsum), brown iron oxy-hydroxide (goethite) and hydrous iron sulfate (jarosite). The three are typically found here together as brown and yellow-white coatings and microcrystalline crusts under protected ledges (as shown above), usually near the lower marble member (Sslm) contact with the underlying lower amphibolite member (Ssla). Former Ronald Januzzi specimen. FOV 4 cm high.

Figure 47 (left). Gypsum microcrystals from underneath a ledge at the upper mine pit. Former Januzzi specimen. FOV 17 mm high.
(H. Moritz photos above and left).

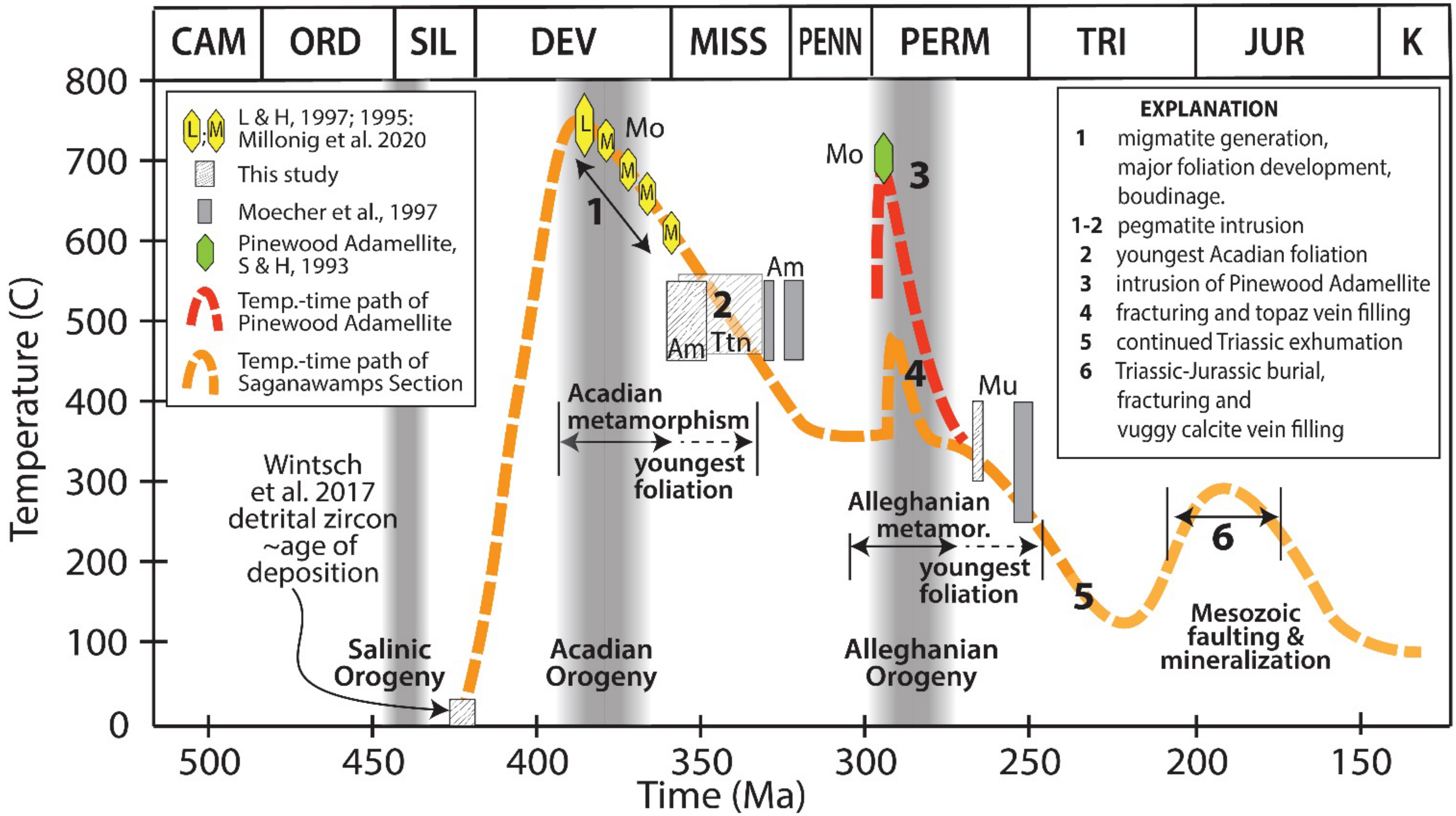
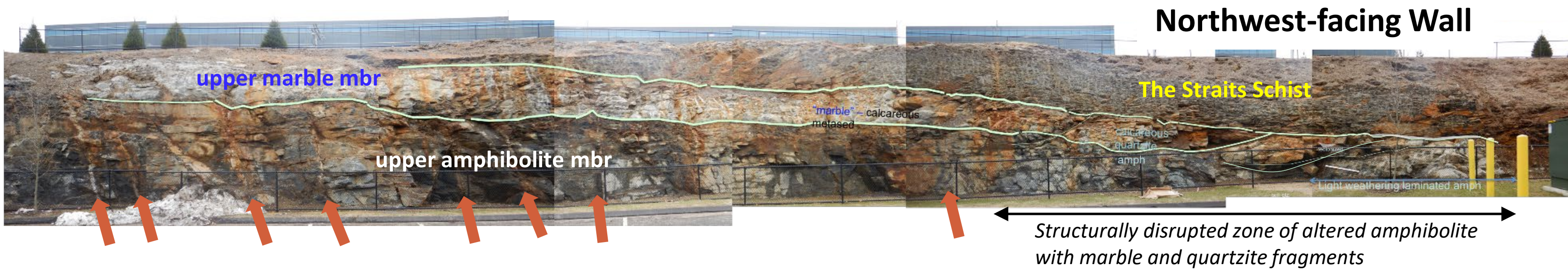
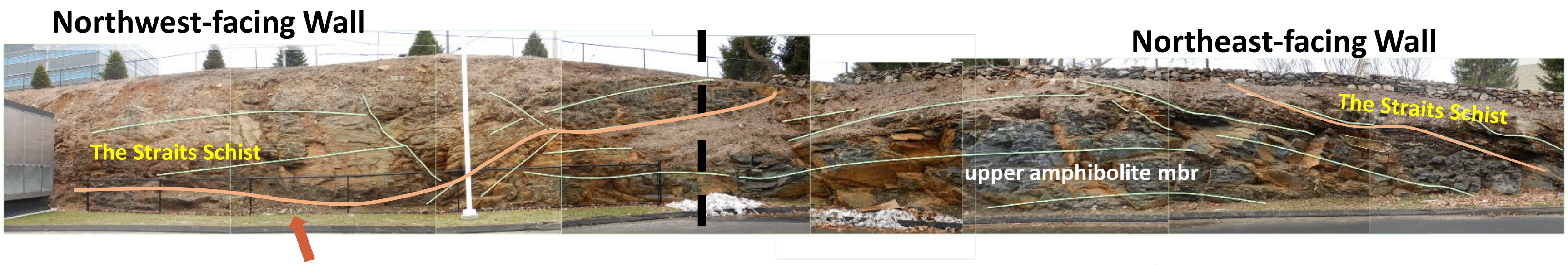
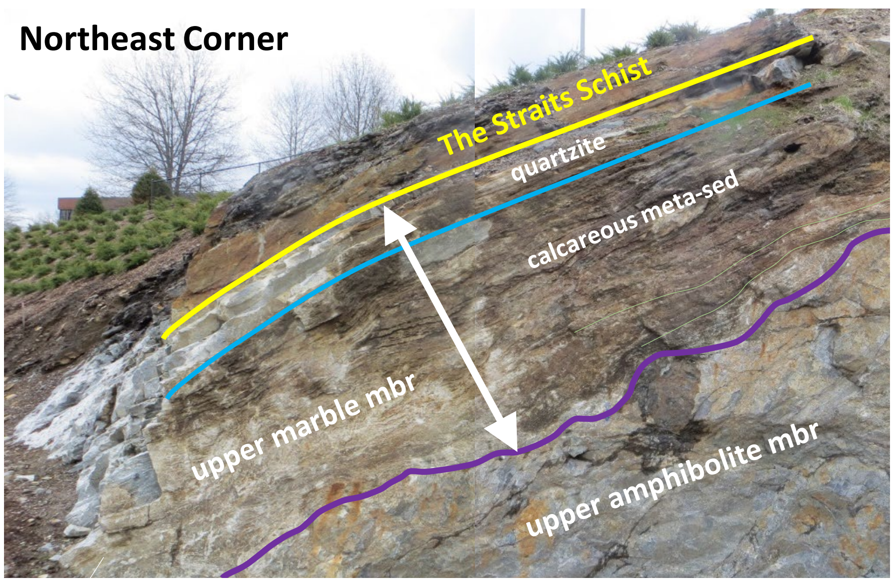



Figure 48. The temperature – time path for the metamorphic history of the rocks of the Long Hill area. It is established by joining the numerical geochronological and thermochronological data from this study (see Appendices II and III) and from the cited literature (see guidebook text) with metamorphic, structural and cross-cutting relationships observed in the field. The time ranges for 3 well-known orogenies are indicated by the vertical shaded zones. Abbreviations: Am – amphibole, Mo – monazite, Mu – muscovite, Tnt - titanite.




## Figure 49 - Rock cuts at 50 Corporate Drive, Trumbull, Connecticut

Photos by Bill Devlin. Private property, accessed with permission.
Do not deface or climb on rock cuts.

This rock cut displays a contiguous vertical section from the base of The Straits Schist (DSt) into the upper marble (Ssum) and amphibolite (Ssua) members of the Saganawamps section. This is the best exposure of the upper marble member, which is a quartz-rich, calcareous metasediment overlain by a 30 cm quartzite at this locality, best examined at the NE corner of the cut. Along the NW-facing wall The Straits Schist is observed to cut down into the underlying stratigraphy, truncating the quartzite and upper marble layers until the schist directly overlies the upper amphibolite member. The latter exhibits local metasomatic alteration and variable scheelite content beneath the truncation.

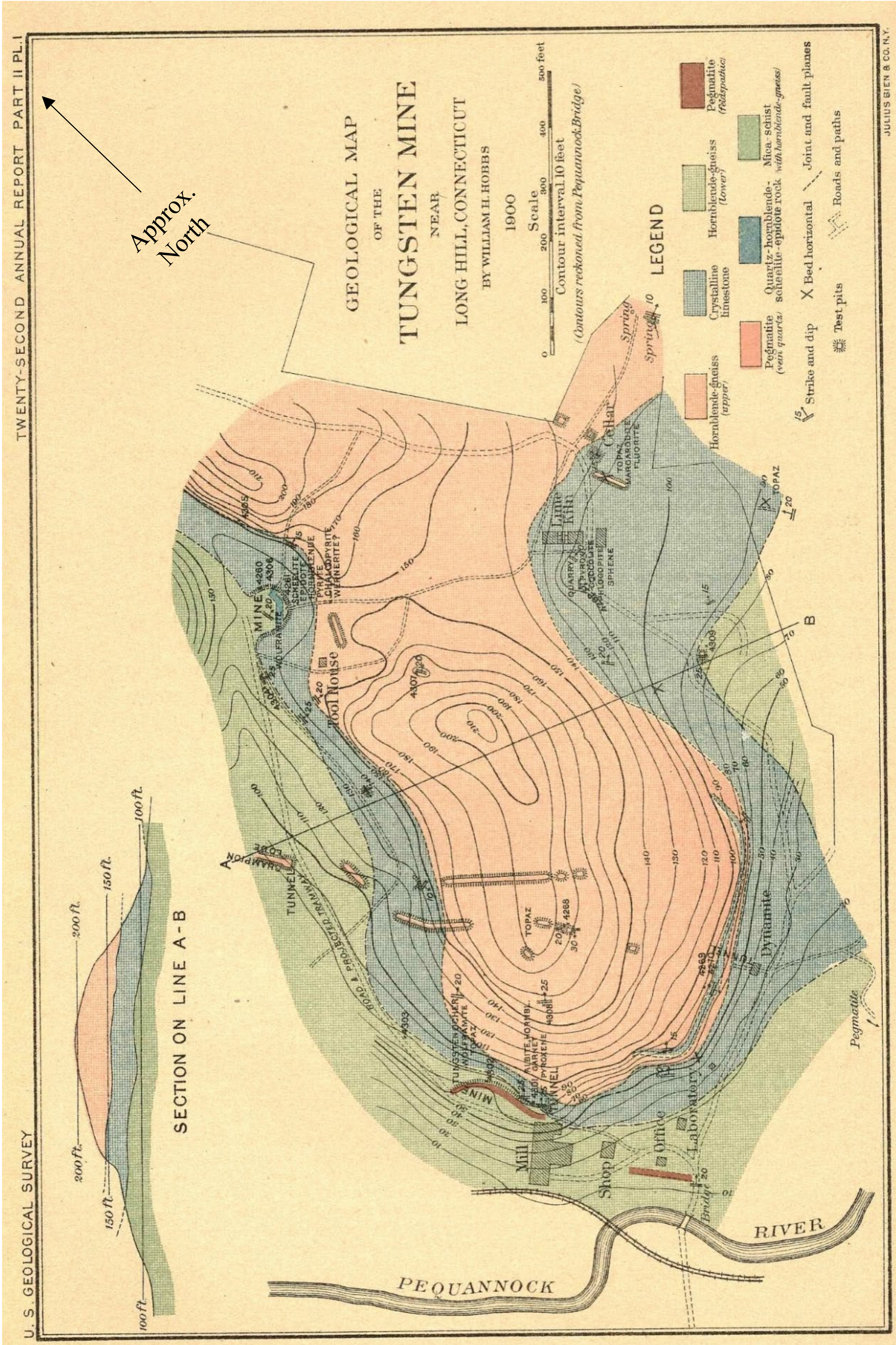
At least 9 high-temperature mineral veins cross-cut all 3 rock types (orange arrows) and 4 of the veins at the left end of the NW-facing wall appear again in The Straits Schist in the cut along Corporate Drive above and behind this view. The veins trend azimuth 320+/-. Their composition is fluorite (chlorophane), +/-quartz, +/-muscovite, +/-albite with minor marialite, fluorapatite, sulfides and tiny secondary scheelite grains along the contacts.


# Figure 50 - Rock cut at 48 Monroe Turnpike, Trumbull, Connecticut

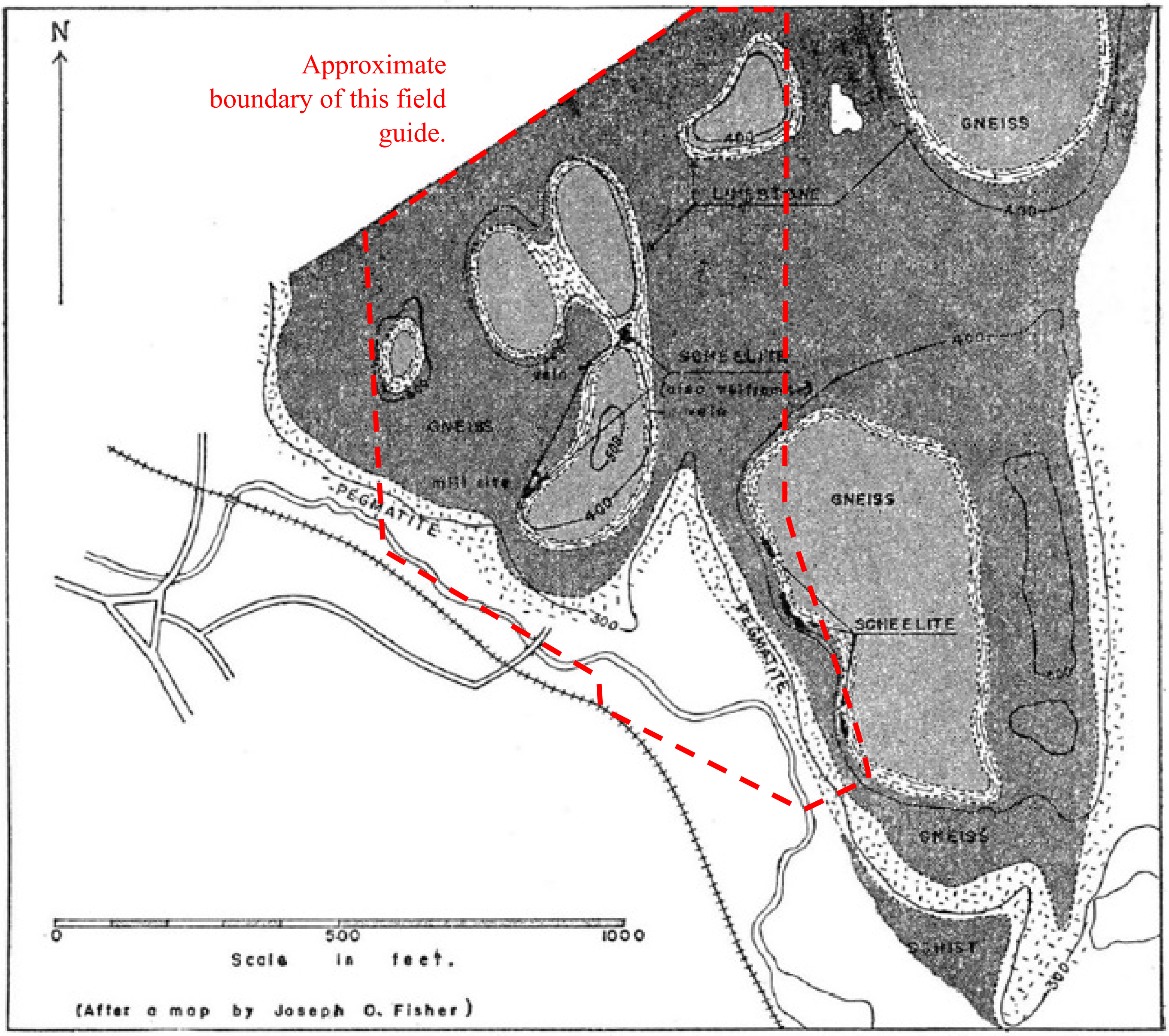
The rock cut exposes the lower amphibolite member (Ssla) of the Saganawamps section and is below the amphibolite exposed at the former Old Mine Plaza/Home Depot development above and behind the image. Most of the exposure is the usual dark, layered amphibolite, but also visible near the top and lower middle are two subhorizontal zones of leucocratic boudins and pods surrounded by possibly metasomatized amphibolite. When exposed at Home Depot, the leucocratic bodies consist primarily of coarse-grained albite and quartz with accessory annite, especially around their perimeters (lower right), or very coarse-grained, radiating marialite with interstitial pyrrhotite (lower left). These zones are cut by numerous steeply-dipping brittle faults that show small off-sets. Similar faults were visible at Home Depot, many were mineralized with calcite, fluorite, quartz and sulfides.


# APPENDICES

## Appendix I: Historic Maps

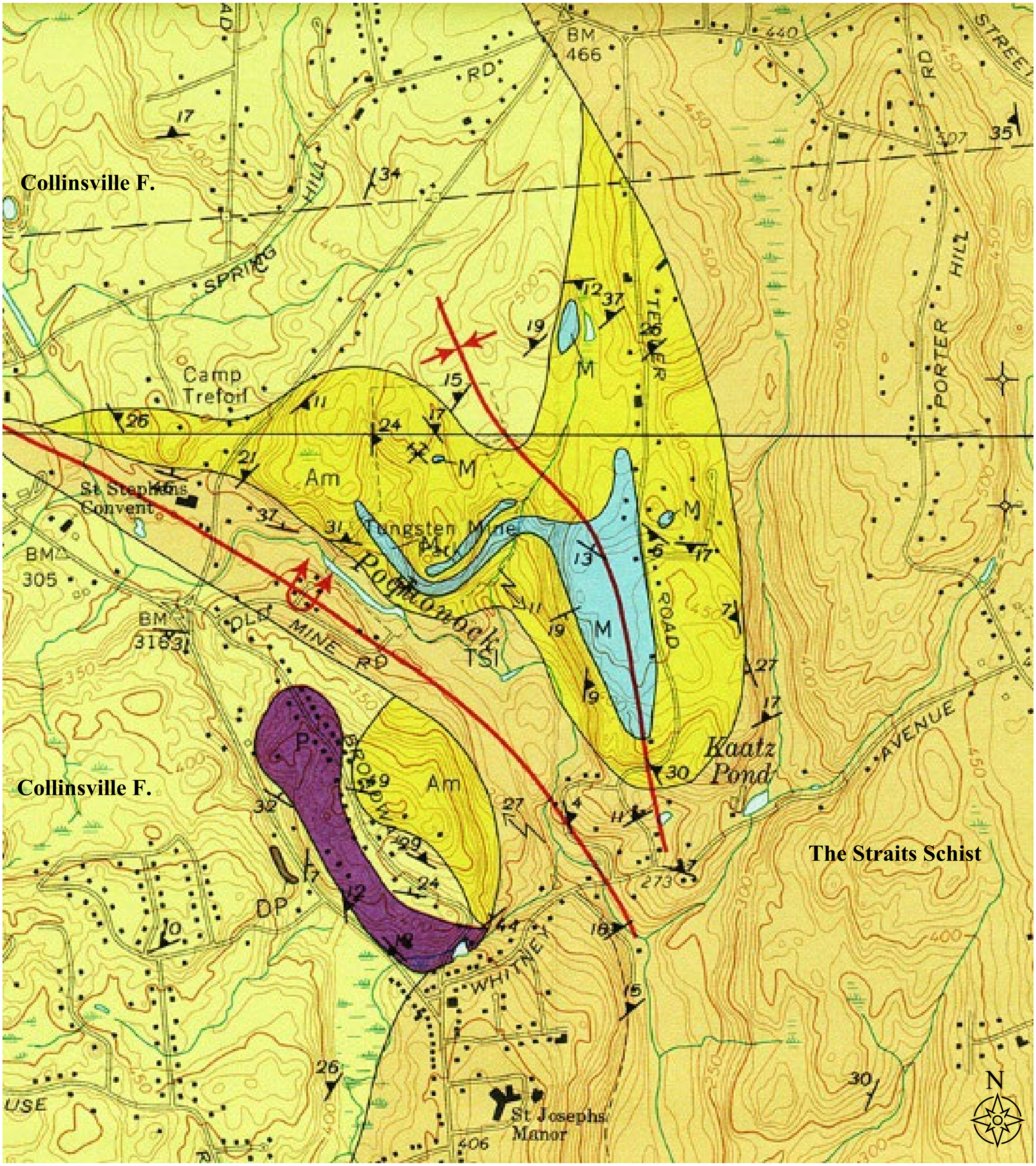



Hobbs, W. H., 1901, The old tungsten mine in Trumbull, Conn.: USGS Annual Report 22: 7-22. Plate 1.




*Scheelite occurrences in limestone above a flat pegmatite Trumbull, Connecticut*

Map of the first ultraviolet light survey of the distribution of scheelite in the Old Mine Park area. From: Kerr, Paul F., 1946, Tungsten Mineralization in the United States: Geological Society of America Memoir 15, Figure 15. Based on work by Fisher (1942). The approximate boundary of this study area is shown in red.




Crowley, William Patrick, 1968, The Bedrock Geology of the Long Hill and Bridgeport Quadrangles, with maps: State Geological and Natural History Survey of Connecticut, Quadrangle Report 24.

**Am – Amphibolite     M – Marble     DP – Dacite Porphyry     P - Pegmatite**

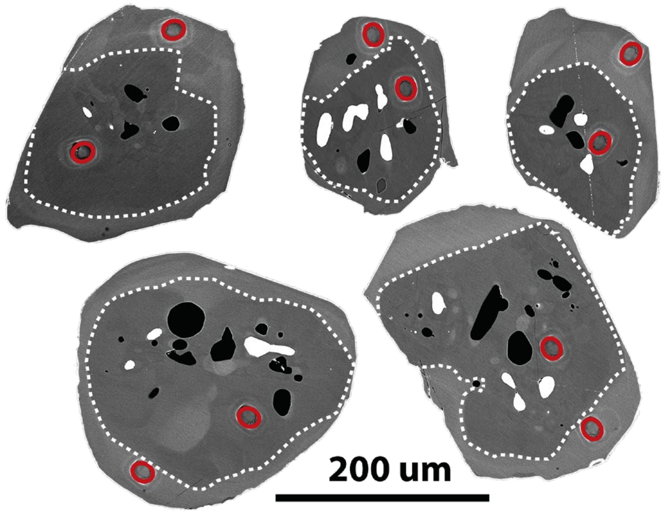



*Fig. AII.1. Backscattered electron images of typical titanite grains in amphibolite from Stop 1. The higher concentrations of U and Th in the rims make them slightly brighter in this imaging and reveals sharp boundaries (dotted lines) between cores and rims that occur as asymmetric overgrowths.*

# Appendix II

## U-Pb SHRIMP analysis of titanite grains define the age of foliation.

Shinae Lee, SookJu Kim, Keewook Yi,
Div. Earth and Environmental Sci.,
Korea Basic Science Institute, 162 Yeongudanji-ro, Ochang, Cheongwon, Chungbuk 363-883, Republic of Korea, and
Robert Wintsch, Wesleyan University, 265 Church St.
Middletown, CT, USA 06459

Titanite grains from the Saganawamps Section upper amphibolite at Stop 1 (Corporate Drive, Trumbull, Connecticut) have been analyzed by sensitive high-resolution ion microprobe (SHRIMP) to constrain the age of the foliation defined by amphibole and biotite. Elongate hornblende grains here define a distinct foliation and are typically 250 µm wide with aspect ratios of 1:3 to 1:4, and up to 1:5. Titanite grains are abundant and form trails of elongate grains (1:2) parallel to this foliation both within and between hornblende grains and rarely within plagioclase clusters. Electron microprobe analyses show that individual grains are slightly zoned along their long axes, with Al-poorer and Fe-richer rims. Sensitive high-resolution ion microprobe (SHRIMP) analysis also shows that the rims are richer in U and Th (Fig. AII.1). However, the Al and Fe contents of titanite grains associated with plagioclase are much higher and lower respectively than those associated with amphibole. This association suggests that the titanite grains crystallized during the development of the foliation and the associated metamorphic differentiation. Thus, their age should closely approximate the time of fabric development.

Zoning in the magnesiohornblende grains shows a progressive drop in $Al_2O_3$ and $TiO_2$ concentrations from core to rim, similar to the patterns found by Stokes et al. (2012). These patterns suggest that the grains in their preferred orientation crystallized by a pressure solution creep mechanism during falling temperatures (Ernst and Liu, 1998; Stokes et al. 2012). The drop in $TiO_2$ concentration also provides a mechanism to produce the titanite:
Ti-rich amphibole → Ti-poor amphibole + titanite.
The observation that the overgrowths are asymmetric is evidence that these grains crystallized during extension and thus formed as part of the fabric in the amphibolite.

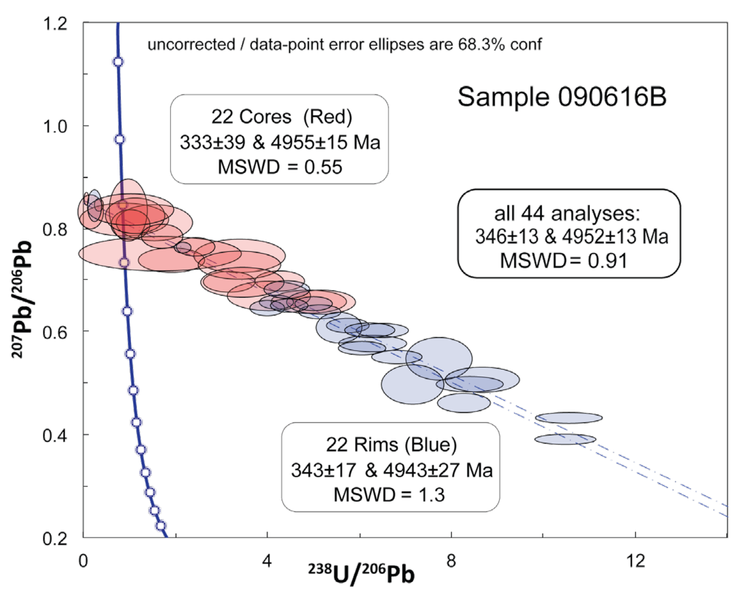



*Fig. AII.2. Tera-Wasserburg plot showing the isotopic results of the analyses of 22 grains of titanite separated from the amphibolite at Stop 1. Analyses from cores (red) and rims (blue) of each grain are plotted separately, and age regressions are given in the figure.*

Titanite grains from this amphibolite were analyzed with a SHRIMP following the methods of Yi et al. (2014). The results (Fig. AII.2) show that the cores contain very little U (<1 ppm) and >85% common Pb, whereas the rims contain up to 5 ppm U and < 80% common Pb. Thus, core analyses plot far from Concordia and rims plot closer to Concordia.

With such high common Pb concentrations, the age of crystallization can be calculated only by regression to Concordia. The core analyses define a narrower range of compositions and thus have a larger error in the Concordia intercept than does the regression of the rim analyses. The best estimate of the age of crystallization of these grains is established by a regression of all 44 analyses. This age (346 ± 13 Ma) shows that these grains crystallized in the Mississippian. Accordingly, the foliation also was established at this time during the waning stages of the Acadian orogeny.

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## Appendix III

## $^{40}Ar/^{39}Ar$ Cooling ages from Long Hill, Trumbull, Connecticut

Ryan McAleer, U.S. Geological Survey, Reston, VA 20192
Robert Wintsch, Wesleyan University, Middletown, CT 06459

In order to establish the cooling history of the rocks at Long Hill, Trumbull, Connecticut, amphibole, and muscovite have been dated by the $^{40}Ar/^{39}Ar$ method. The samples were collected from the rock cuts at Stop 1 at 50 Corporate Drive, Long Hill. With amphibole and muscovite closure temperatures of ~500 and 350 °C, respectively, these two ages should define the time of the end of high-grade metamorphism from amphibolite to greenschist facies. Amphibole and muscovite were separated from samples of Saganawamps Section upper amphibolite and a cross-cutting, topaz-bearing, hydrothermal vein, respectively, using heavy liquids and magnetic separation, and analyzed by the methods described in McAleer et al. (2017). The complete isotopic data can be found in McAleer et al., 2022.

*Amphibole.* Care was taken to avoid amphibolite that was near hydrothermal veins where alteration can be extreme. In our sample, amphibole needles in the amphibolite establish a gently ESE dipping foliation, and a moderate lineation. Electron microprobe analysis (EMPA) of these amphiboles shows that they are zoned with higher concentrations of Al and Ti in the cores and lower concentrations in the rims. Most compositions classify as magnesiohornblende, but some cores are tschermakitic, and some rims are actinolitic hornblende.

The results of the step-heating experiment produced a slight saddle-shaped age spectrum. The first ~10% of the gas released yields low Ca/K ratios and high Cl/K ratios consistent with a minor contribution from a phase richer in Cl but poorer in Ca than hornblende (Fig. App.III 1A). We attribute the relatively young ages (~310-335 Ma) of these steps to small inclusions of biotite that were rarely observed in thin section**,** though the degassing of fluid inclusions is also possible. The remainder of the age spectrum yields fairly uniform Cl/K and Ca/K ratios (see also Fig. Ap III 1B) and the total age range of these steps is 352-358 Ma. The minor variation in age among these steps could reflect slightly different Ar isotopic compositions associated with the chemical zonation observed by EMPA, but we cannot prove this is the case. Nevertheless, the step ages with compositions consistent with the degassing of only amphibole record an age of ~355 Ma. This time overlaps with the Late Devonian ages of nearby titanite reported by Sevigney and Hanson (1993).

These data produce an age slightly older than the 331 ± 2 and 324 ± 3 ages of two nearby samples reported by Moecher et al. (1997). This apparent age discrepancy could be the result of the younger samples being slightly altered, although the chemical compositions of the amphiboles are similar, or to a regional younging trend in the cooling ages to the SE compiled by Matthews et al. (2008). Our preferred interpretation of these results is that an age of 355 ± 3 Ma is the time of cooling of this amphibolite sample below the closure temperature of Ar diffusion in amphibole, while recognizing that this cooling was probably delayed in rocks to the southeast.

*Muscovite.* A small flake of muscovite was separated from a larger muscovite book from a topaz-bearing vein. The muscovite in the foliated The Straits Schist was avoided because we have identified recrystallization in thin section here (also reported by Moecher et al. 1997), and in the younger isotopic ages of the recrystallized material (e.g., McWilliams et al. 2010; Growdon et al. 2013; McAleer et al. 2017). The results of this step-heating experiment on vein muscovite produced a flat age spectrum with a plateau age of 266.7 ± 1.4 Ma (2σ) that includes 70.3% of the $^{39}Ar_K$ (criteria of Ludwig, 2012). This age is also older than the 255 ± 5 Ma isochron age reported by Moecher et al. (1997), but his sample did contain recrystallized phyllosilicates. We interpret the age of 266.7 ± 1.4 Ma as the time of cooling of the host rock below the closure temperature of Ar diffusion at lower greenschist facies conditions.

Together these results show that the high-grade Acadian metamorphic conditions were waning during the later Paleozoic. Staurolite-grade conditions ended by Early Mississippian time, and middle greenschist facies conditions were obtained by the Late Permian.

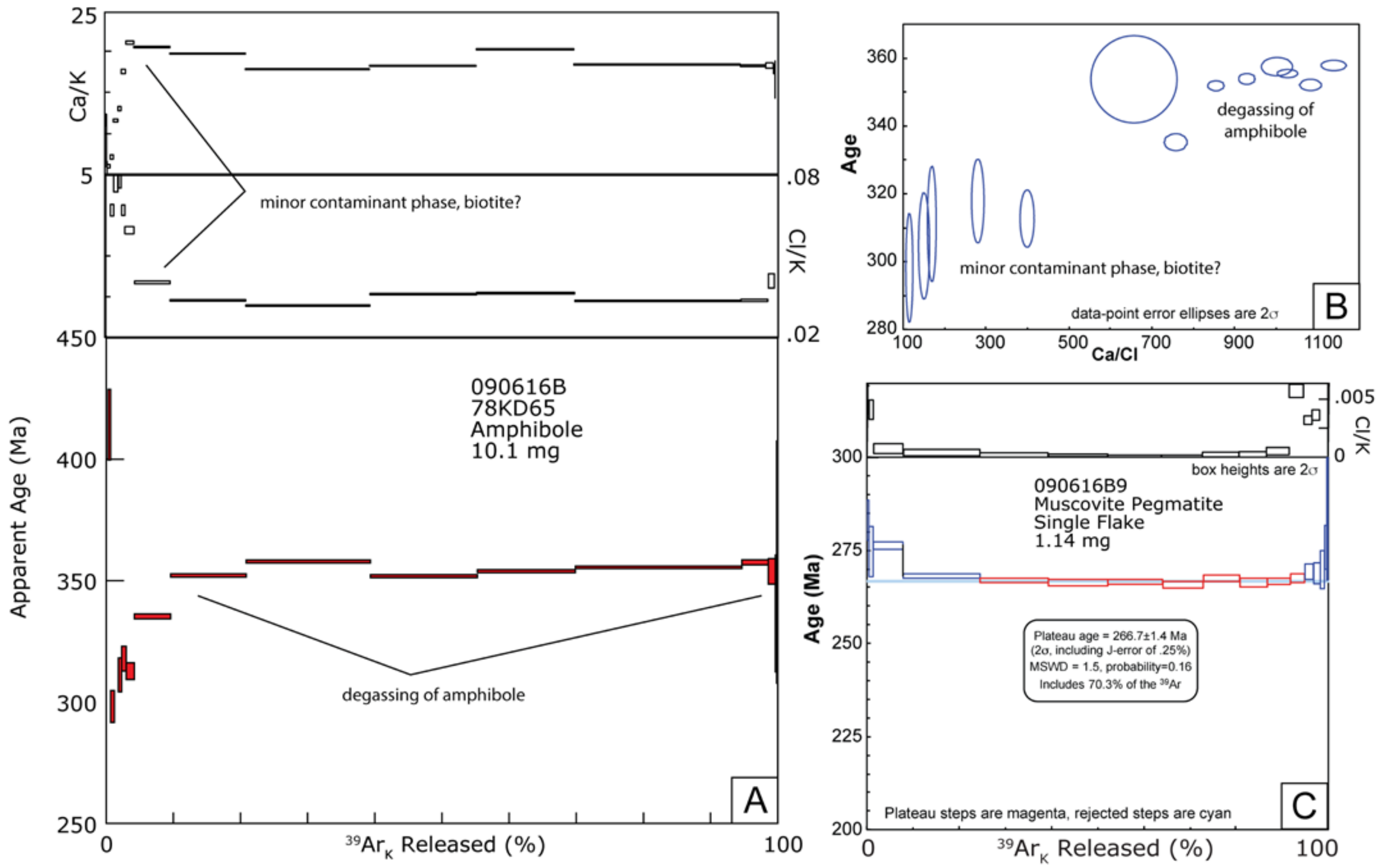


*Fig. Ap III.1 $^{40}Ar/^{39}Ar$ age spectra for amphibole and muscovite separates from Stop 1. A. The age spectrum and Ca/K ratios for amphibole. After 10% of the gas was released, the ages of the steps lie between 352 and 358 Ma. B. The relationship between age and Ca/Cl ratio, showing that young ages correlate with low Ca/Cl, consistent with the presence of biotite. In contrast, the older age steps show the higher Ca/Cl ratios, consistent with amphibole. C. The age spectrum and Cl/K ratios produced by vein muscovite. The 266.7 ± 1.4 Ma plateau age produced by >70 % of the gas from vein muscovite. Older age steps show higher Cl/K ratios and are probably compromised by small contaminating inclusions.*

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## APPENDIX IV - Table of Minerals Organized by Geo-Environment

| Mineral Species[1] and Ideal Formula | | Primary & Accessory | | | High-temp. Vein[2] | Amphibolite Alteration[3] | Brittle Fault Hydrothermal | Weathering/ Secondary | Clefts/ Joints[4] |
|---|---|---|---|---|---|---|---|---|---|
| | | Amphibolite | Marble | Pegmatite | | | | | |
| Actinolite | $Ca_2Mg_{4.5\text{-}2.5}Fe_{0.5\text{-}2.5}(Si_8O_{22})(OH)_2$ | | C | | | A | | | |
| Albite | $Na(AlSi_3O_8)$ | A | C | A | C Fig 34,35 | C | | U | U |
| Anatase | $TiO_2$ | | | | | R | | | R |
| Annite | $KFe^{2+}{}_3(AlSi_3O_{10})(OH)_2$ | C | | | | C | | | |
| Aragonite | $CaCO_3$ | | | | | | | C | C |
| Arsenopyrite | $FeAsS$ | | | | | | R | | |
| Aurichalcite | $(Zn,Cu)_5(CO_3)_2(OH)_6$ | | | | | | | R | |
| Azurite | $Cu_3(CO_3)_2(OH)_2$ | | | | | | | R | |
| Baryte | $BaSO_4$ | | | | | | R | | |
| Bavenite | $Ca_4Be_2Al_2Si_9O_{26}(OH)_2$ | | | | | | U | | |
| Beryl | $Be_3Al_2(Si_6O_{18})$ | | | | U Fig 36 | | | | |
| Bismuth | $Bi$ | | | | | R | R | | |
| Bismuthinite | $Bi_2S_3$ | | | | | | R | | |
| Bismutite | $(BiO)_2CO_3$ | | | | | | | R | |
| Bornite | $Cu_5FeS_4$ | | | | | | R | | |
| Brookite | $TiO_2$ | | | | | R | | | R |
| Calcite | $CaCO_3$ | | A | | U Fig 36 | U Fig 22 | A Fig 39,40 | | U |
| Chalcopyrite | $CuFeS_2$ | | U | | | | U | | |
| Clinochlore | $Mg_5Al(AlSi_3O_{10})(OH)_8$ | | | | C Fig 35 | C | C | | A |
| Clinozoisite | $Ca_2Al_3(Si_2O_7)(SiO_4)O(OH)$ | | | | | C Fig 22 | | | |
| Cobaltite | $CoAsS$ | | | | | | R | | |
| Copper | $Cu$ | | | | | | | R | |
| Cuprite | $Cu_2O$ | | | | | | | R | |
| Devilline | $CaCu_4(SO_4)_2(OH)_6 \cdot 3H_2O$ | | | | | | | R | |
| Diaspore | $AlO(OH)$ | | | | R | | | | |
| Diopside | $CaMgSi_2O_6$ | | C | | | | | | |
| Dolomite | $CaMg(CO_3)_2$ | | | | | | R | | |
| Dravite | $NaMg_3Al_6(Si_6O_{18})(BO_3)_3(OH)_3(OH)$ | | | | | | R | | |

| Mineral Species[1] and Ideal Formulae | | Primary & Accessory | | | High-temp. Vein[2] | Amphibolite Alteration[3] | Brittle Fault Hydrothermal | Weathering/ Secondary | Clefts/ Joints[4] |
|---|---|---|---|---|---|---|---|---|---|
| | | Amphibolite | Marble | Pegmatite | | | | | |
| Epidote | $Ca_2Al_2Fe^{3+}(Si_2O_7)(SiO_4)O(OH)$ | | | | | U | | | |
| Erythrite | $Co_3(AsO_4)_2 \cdot 8H_2O$ | | | | | | | R | |
| Ferberite | $FeWO_4$ | | | | | U Fig 3 to 6 | | | |
| Fluorapatite | $Ca_5(PO_4)_3F$ | U | | R | U Fig 34 | | | | |
| Fluorite | $CaF_2$ | | | | | | A Fig 39,40,41,43 | | C |
| Fluorite var. Chlorophane | $CaF_2$ | | | | C Fig 34,35 | | | | |
| Galena | PbS | | | | | | R | | |
| Goethite | $\alpha$-$Fe^{3+}O(OH)$ | | | | | | | C | C |
| Graphite | C | | R | | | R | | | |
| Grossular | $Ca_3Al_2(SiO_4)_3$ | | U Fig 9 | | | | | | |
| Gypsum | $CaSO_4 \cdot 2H_2O$ | | | | | | U Fig 43 | U Fig 46,47 | |
| Hematite | $Fe_2O_3$ | | | | | | | R | |
| Heulandite-Ca | $(Ca,Na)_5(Si_{27}Al_9)O_{72} \cdot 26H_2O$ | | | | | | | | R |
| Hydrozincite | $Zn_5(CO_3)_2(OH)_6$ | | | | | | | R | |
| Hypersthene | $(Mg,Fe)SiO_3$ | | R | | | | | | |
| Ilmenite | $Fe^{2+}TiO_3$ | R | | | R | C | | | X |
| Jarosite | $KFe^{3+}{}_3(SO_4)_2(OH)_6$ | | | | | | | C Fig 46 | |
| K-Feldspar var. Adularia | $KAlSi_3O_8$ | | | | | | R | | X |
| Langite | $Cu_4(SO_4)(OH)_6 \cdot 2H_2O$ | | | | | | | R | |
| Laumontite | $CaAl_2Si_4O_{12} \cdot 4H_2O$ | | | | | | | | X |
| Linnaeite | $Co^{2+}Co^{3+}{}_2S_4$ | | | | | | | R | |
| Magnesio-hornblende | $Ca_2Mg_4Al(AlSi_7O_{22})(OH)_2$ | A | U | | | | | | |
| Malachite | $Cu_2(CO_3)(OH)_2$ | | | | | | | U | |
| Marcasite | $FeS_2$ | | | | | C | U | | |
| Margarite | $CaAl_2(Al_2Si_2O_{10})(OH)_2$ | | | | U Fig 32,33 | | | | |
| Marialite | $Na_4Al_3Si_9O_{24}Cl$ | | | | U Fig 34,36 | C Fig 21,36 | | | C |
| Melanterite | $Fe^{2+}(H_2O)_6SO_4 \cdot H_2O$ | | | | | | | X | |
| Microcline | $K(AlSi_3O_8)$ | | | A | | | | | |

| Mineral Species[1] and Ideal Formulae | | Primary & Accessory | | | High-temp. Vein[2] | Amphibolite Alteration[3] | Brittle Fault Hydrothermal | Weathering/ Secondary | Clefts/ Joints[4] |
|---|---|---|---|---|---|---|---|---|---|
| | | Amphibolite | Marble | Pegmatite | | | | | |
| Milarite | $K_2Ca_4Al_2Be_4Si_{24}O_{60} \cdot H_2O$ | | | | | | | R | |
| Molybdenite | $MoS_2$ | | | | | R | | | |
| Muscovite | $KAl_2(AlSi_3O_{10})(OH)_2$ | | | A | A Fig 30,32,33 | | | | C |
| Opal-AN | $SiO_2 \cdot nH_2O$ | | | | | | | C | X |
| Phlogopite | $KMg_3(AlSi_3O_{10})(OH)_2$ | | | | C | C Fig 36 | | | |
| Pickeringite | $MgAl_2(SO_4)_4 \cdot 22H_2O$ | | | | | | | X | |
| Prehnite | $Ca_2Al_2Si_3O_{10}(OH)_2$ | | | | | | | | X |
| Pyrite | $FeS_2$ | C | | | R | C | C Fig 44 | | C |
| Pyrrhotite | $Fe_7S_8$ | C | | | R Fig 36 | C Fig 21 | R | | |
| Quartz | $SiO_2$ | | | A | A Fig 27,29 | A | A | | C |
| Rosasite | $(Cu,Zn)_2(CO_3)(OH)_2$ | | | | | | | R | |
| Rutile | $TiO_2$ | | | | | R | | | R |
| Scheelite | $Ca(WO_4)$ | | | | U Fig 37 | C Fig 2,5,8,24,25 | | | U |
| Schorl | $NaFe^{2+}{}_3Al_6(Si_6O_{18})(BO_3)_3(OH)_3(OH)$ | | | R | R | | | | X |
| Siderite | $FeCO_3$ | | | | | | C | | |
| Smithsonite | $ZnCO_3$ | | | | | | | R | |
| Sphalerite | $ZnS$ | | | | R | | C | | |
| Stilbite-Ca | $NaCa_4(Al_9Si_{27}O_{72}) \cdot nH_2O$ | | | | | | | | U |
| Sulphur | $S_8$ | | | | | | | R | |
| Talc | $Mg_3Si_4O_{10}(OH)_2$ | | | | | | | R | |
| Titanite | $CaTi(SiO_4)O$ | U | | | | | | | X |
| Topaz | $Al_2(SiO_4)(F,OH)_2$ | | | | A Fig 30,31 | | | | |
| Tremolite | $Ca_2Mg_5(Si_8O_{22})(OH)_2$ | | U | | | U | | | |
| Tungstite | $WO_3 \cdot H_2O$ | | | | | | | R | |
| Uraninite | $UO_2$ | | | | | | R | | |
| Zircon | $Zr(SiO_4)$ | U | | R | | | | | |

1 – Confirmed or well-documented minerals only, there are other unconfirmed or poorly documented species not listed here (see www.mindat.org/loc-246208.html for latest listings, occurrence details, descriptions, etc.).
2 – From all zones within these veins.
3 – From alteration adjacent to veins and from alteration within the body of the amphibolite (there are many similarities).
4 – Minerals were either seen or are likely in this environment, which was not extensively examined.
Qualitative abundances for minerals: A – Abundant, C – Common, U – Uncommon, R – Rare, X – Undetermined

# Appendix V – Field Stop Descriptions and Index Map

**ALL FIELD STOPS ARE NO HAMMERING AND NO COLLECTING – please preserve access to these rare and important outcrops by staying back from rock cuts at Stops 1 and 2 and refrain from any collecting at any location outside or within the park.**

***A map showing field stop locations and legend follow these site descriptions.***

### 1: 50 Corporate Drive parking lot cut

This excellent rock cut exposes a contiguous section of the upper part of the Saganawamps section right up into the lower part of The Straits Schist (DSt). At the base of the outcrop is the upper amphibolite member (Ssua), overlain by about ~2 m of a quartz-rich calcareous metasediment capped by a 30 cm quartzite in the upper marble member (Ssum) that is in contact with the Straits Schist. At the north end of the cut, The Straits Schist dips down to the west, suggesting that it underlies much of the corporate park towards Route 111 previously mapped as Collinsville Formation by Crowley (1968). Unfortunately, exposures west of the cut are lacking. Along the northwest-facing wall The Straits Schist is observed to cut down into the underlying stratigraphy, truncating the quartzite until The Straits Schist directly overlies the upper amphibolite member (Ssua) (Figure 49). The truncated south end of the upper marble member is a tectonized zone of altered amphibolite and structurally disrupted fragments of amphibolite, marble, and quartzite. The disrupted zone is locally intruded by bull quartz.

At least 9 subvertical, quartz/fluorite/albite/muscovite high-temperature mineral veins crosscut the stratigraphy here. Amphibole and titanite from the northeast end of the cut and muscovite from one vein were dated (Appendix II and III). Scheelite occurs both in the amphibolite as a primary mineral, and as tiny, secondary grains along the vein walls in the marble above (where the scheelite does not occur) apparently mobilized from the amphibolite below by the vein's fluids. Topaz is absent but some veins have an abundance of pyrrhotite. The amphibolite shows zones and pods of coarse-grained albite-quartz and other deviations from the normal mineralogy.

### 2: Corporate Drive rock cut above stop 1

The Straits Schist is well exposed along the roadside here; it underlies the high ground to the north, east and south down into the northeast corner of the park, an area previously mapped as Collinsville Formation by Crowley (1968). Behind the buildings to the east is another exposure of calcareous rock and quartzite of the upper marble member (Ssum) overlain by The Straits Schist, and piles of The Straits Schist float were found near the wetland valley further east. The Straits Schist outcrop along the road contains the same cross-cutting high-temperature mineral veins seen below at Stop 1, except they are very narrow and consist mostly of topaz/quartz with minor muscovite. Notice they tend to be parallel to a major set of joints in The Straits Schist. One sample of topaz was found to have an OH/(OH+F) ratio of 0.16, putting its crystallization temperature within the hydrothermal range.

### 3: Corporate Drive cul-de-sac

At the northeast corner of the circle is a small outcrop of amphibolite hosting a high-temperature hydrothermal vein with the typical topaz/quartz/muscovite mineralogy. The mineral zonation and textures within the veins are well displayed here as is the alteration of the adjacent host rock.

## 4: Upper tungsten mine area

This historic place has many aspects to discuss. It is the site of Ephraim Lane's initial prospecting, which probably looked very different in the early 19th century, where he discovered the rare ferberite pseudomorphs after scheelite crystals that were brought to Yale. This is also the type locality for the rare mineral tungstite. Hubbard worked this area in the late 19th century and finally it was worked by the tungsten miners 1898-1901. Their focus was on the hard quartz-clinozoisite layer where the ferberite and scheelite occur, which contacts the altered lower amphibolite member (Ssla) below. The quartz layer is not a contiguous feature of this contact, though it was searched for all around Saganawamps Hill via small pits and trenches. Because it has a shallow southern dip under the deformed marble here it has been partly mined out and is under water. But it may be visible on the southeast corner of the pit walls. In this corner a quartz vein filling a brittle fault appears to crosscut the marble and the conformable quartz-amphibolite layer. A couple of topaz-rich veins crosscut this location also, though they are not very visible.

The extensive dumps contain all these minerals and rock types; blocks of altered amphibolite are common. The protected ledges under the folded marble shelter crusts of gypsum microcrystals from the weathering of iron sulfides and their reaction with the marble. Just to the east is a trench cut into an albite-rich high-temperature vein. Clinochlore and marialite are present in this type of vein mineralogy. The stratigraphy and geologic structure here are unclear because of an absence of clear contact relationships in the small topographic basin, which is mostly surrounded by amphibolite. The lower marble member (Sslm) layer crops out on the slopes to the west, in the pit, and on the lower parts of a slope to the east. How much of the marble underlies the topographic basin is interpretive. A low ridge of heavily fractured lower amphibolite member (Ssla) rises from the basin's center.

## 5: Champion Lode vein and minerals in its dump

At about 1.5 m this is the thickest vein in the area and is a continuation of the vein visible to the southeast at Stop 6. However, the vein abruptly ends at the northwest end of the trench. It has a large quartz core that was mined out in the late 19th century. A large dump is located downhill from the mine and contains many blocks of the intermediate and wall zones. These show mostly albite in place of topaz in the intermediate zone.

## 6: Test trench on west side of Saganawamps Hill

On the west side of Saganawamps Hill is a prospecting trench following a high-temperature vein. This vein is topaz-quartz-muscovite rich, with bands of fibrous margarite along the contact and replacing topaz. Near the top of the slope the vein is visible in place where it crosscuts the lower marble member (Sslm), which does not appear to have been altered by the vein's intrusion. Compositional zoning within the vein is visible here as well, where the vein is about 40 cm thick. It continues onto the top of the hill and can be traced via small exposures, pits, and trenches.

Along the hillside near this trench a normal thickness of relatively continuous lower marble trending from the north and abruptly changes strike from SSE to WNW immediately south of the above-mentioned vein. Dips in the marble steepen from about 20° E to > 60° N and the normal 4 m thickness of marble thins to about 1 m. These observations are interpreted to be related to deformation at the north end of a large, outcrop-scale boudin of upper amphibolite that extends south to the marble quarry of Stop 7.

## 7: Marble Quarry/Tungsten Mill Site

This 10-m-high quarry wall may have fed a lime kiln now long gone but may also have been cut largely by the tungsten miners to get at the lower contact of the lower marble member (Sslm) where ferberite/scheelite was supposed to be. These minerals were reportedly found in the short adit at the base of the quarry, but that zone is not visible now and those reports lack modern confirmation. The quarry gives the best exposure of the lower marble member (Sslm), an anomalously thick 8 meters here. Three samples of marble were processed for conodonts, but none were recovered (Fitzgerald et al., 2018).

At the north end of the quarry, the thick marble section abruptly ends north of a zone of structural disruption. Outcrops are poor in this zone, but it is clear that a thick section of amphibolite has taken the place of the marble over a distance of a few meters and along strike with what should be a continuation of the lower marble member (Sslm) at this structural level. The only marble observed north of the disrupted zone is a thin patch of outcrop at the base of the adjacent borrow pit amphibolite exposure to the north. The anomalous thickness of marble in the quarry and its abrupt termination to the north across a disrupted zone is interpreted to be the southern end of the outcrop-scale boudin addressed at Stop 6.

Well exposed on the quarry face are what appear to be several "packages" of quartz-feldspar pegmatitic layers in sub-horizontal marble that give a cyclic appearance to the exposure. The quartz-feldspar layers can be traced around the south and east exposures on Saganawamps Hill. As you contemplate them, recognize that the large tungsten mill complex sat at the floor of this quarry, over the dump below and down to the pavilion on the alluvial flat below. Do you think there was enough ore here to support such a large operation? Also note the sections of high-temperature veins, especially the muscovite wall zones, exposed on the boulders along the trail.

**8: Southern and Eastern slopes of Saganawamps Hill**

Continuing around the southern face of the hill, the lower marble member (Sslm) can be traced around to the east. Note the series of trenches in the talus that expose the lower contact – but were not mined. Above the marble is the upper amphibolite member. Wrapping around the southern end of the hill the gently dipping upper amphibolite member (Ssua) is interlayered with 3 thin ($\leq$ 1 m), recessively weathering marbles, difficult to see from down here on the trail. As the trail continues along the east side of the hill, the rocks maintain near horizontal dips until a point opposite the large pegmatite of Stop 9, just east of the former dynamite storage adit. At this point along the hillside there is a sudden discontinuity in the structure where the lower marble member (Sslm) is abruptly replaced by amphibolite at the same structural level. The lower marble member (Sslm) can be seen thinning from ~4 m to $\leq$0.5 m over the amphibolite and across a distance of only 4-5 meters. Continuing up the trail to the northeast, the amphibolite body is replaced by a full thickness of the lower marble member (Sslm). These relationships are interpreted as the expression of an outcrop-scale boudin of the upper amphibolite member (Ssua) ~10 m thick and about 100 m long. At the northern terminus of the boudin, localized, meter-scale tight to isoclinal folds occur in both the thin marble interlayer above and the lower marble member (Sslm) immediately below the amphibolite boudin neck. These structures are interpreted as local deformation of the marble layers related to formation of the outcrop-scale boudin of upper amphibolite member (Ssua) with consequent ductile disruption of the adjacent marbles during emplacement.

**9: Pegmatite**

The path to the south crosses a horizontal surface layer of the lower marble member (Sslm) heavily colonized by bright green moss, a convenient field marker for this lithology. On the south side of Saganawamps Hill is a large pegmatite mass that juts out across gently sloping terrain and alluvium of the Pequonnock River. This pegmatite appears massive, unzoned, and undeformed and cuts surrounding metamorphic rocks. A thin high-temperature quartz-fluorite-muscovite vein with accessory schorl in turn cuts the pegmatite. In several outcrops under the moss-covered lower marble member and around the protruding pegmatite is the mixed amphibolite and migmatite characterizing the Pequonnock River migmatite zone.

## 10: Pequonnock River Migmatite Zone and The Straits Schist again

From stop 9 follow a narrow trail southeast through alluvial terraces until the Pequonnock River comes near a high west-facing slope – this is the base of Fisher's Ridge. In the lower slopes of the ridge is a zone of migmatite with inclusions of amphibolite that appear as if absorbed in place. Higher up on the ridge the lower amphibolite member and lower marble member overly the migmatite. The migmatite forms blocky talus on the lower slopes and remnants of amphibolite are abundant. Outcrops of The Straits Schist containing pegmatite boudins sit below the migmatite and are also exposed south of the river and in rock cuts along the Route 25 expressway immediately south of the park.

Recall that The Straits Schist is the formation overlying the Saganawamps section at the top of the stratigraphic column best exposed at Stop 1 along Corporate Drive to the north. For The Straits Schist to now underlie the Saganawamps section, the latter must be either folded or faulted. Emplacement of the Saganawamps section over The Straits Schist by a thrust fault is the favored interpretation. In this case, the fault is a zone of migmatite that incorporates many conformable fragments of amphibolite and schist – the Pequonnock River migmatite zone. The contact of the Pequonnock River migmatite zone (Dprmz) with the underlying The Straits Schist is visible just above the block of schist near the base of the slope.

One small topaz-rich high-temperature vein is also exposed just north of the block of schist. This is the only vein found along Fisher's Ridge. The dominant orientation of the veins is essentially parallel to the trend of the ridge thus limiting the potential for their exposure along it.

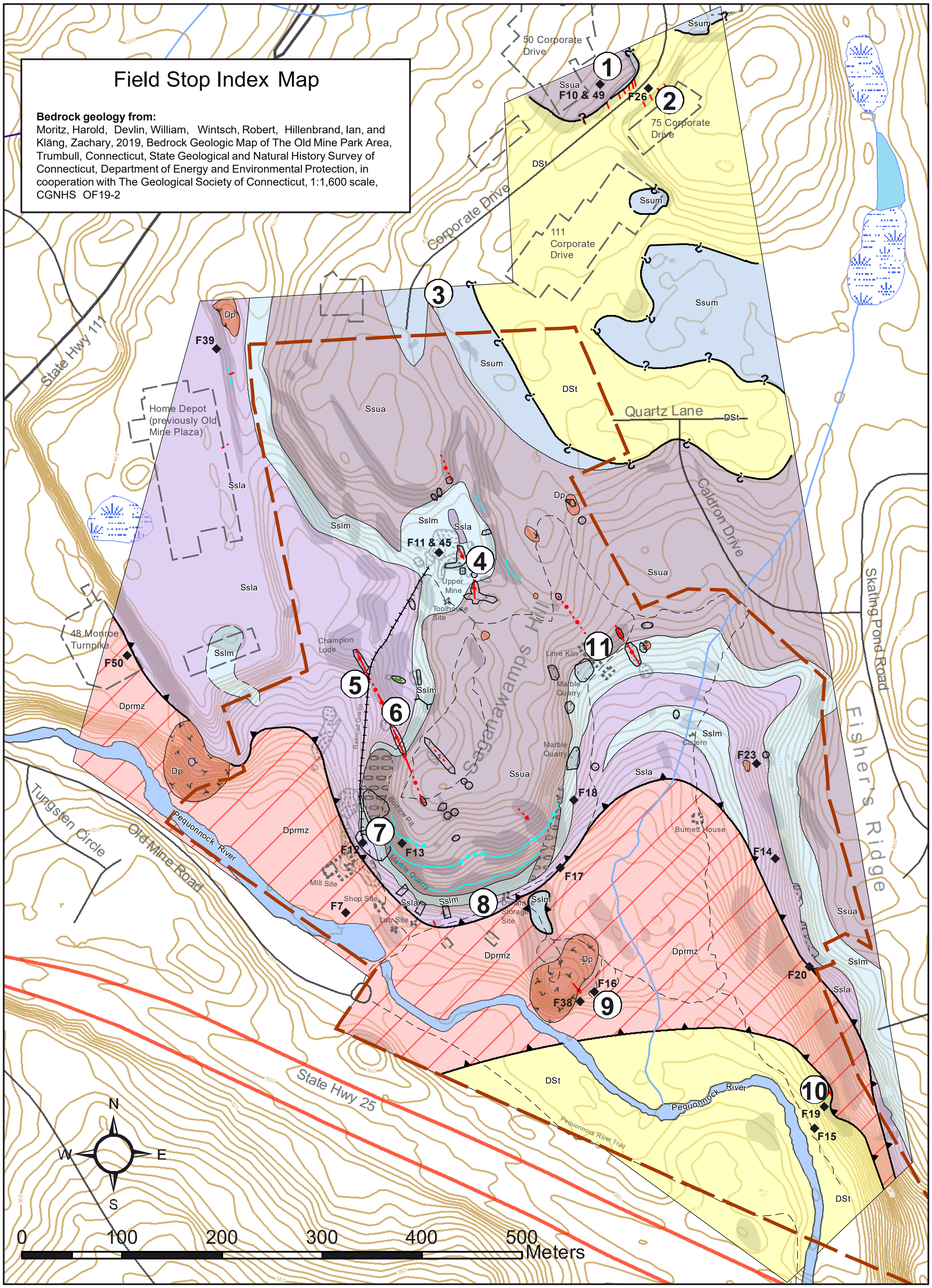
## 11: Old marble quarries, kiln, and trench along topaz vein

Head back to Saganawamps Hill where on the east-facing slopes are a series of small marble quarries in the flat-lying lower marble member here and in the valley to the east. The ruins of an early 19$^{th}$ century lime kiln are located just east of the largest quarry. Quick lime for agricultural use was in great demand at that time and was difficult to obtain outside the "marble belt" in far west Connecticut. Thus, even the relatively impure and limited lime resource was exploited here. The trench on the vein here represents the first location where topaz was identified in North America ca. 1820.

## Optional Exposures: Fisher's Ridge

The high slopes of Fisher's Ridge have no well-established trails, and scrambling along the steep, vegetated slopes should only be attempted with appropriate caution. Consequently, this area is not part of the field trip, but is described here because this area is mentioned little in the literature. The lower marble member (Sslm) and lower amphibolite member (Ssla) contact is well exposed near the crest of the slope. The contact between the two units is marked by a quartz layer (Figure 14) similar to that described at the same contact in the upper mine (Stop 4), including secondary sulfide minerals under protected ledges. While no tungsten minerals are obvious, the UV light survey of Fisher (1942; Appendix I) shows multiple scheelite detections in the amphibolite. If the marble/amphibolite outcrops are followed to the southeast, two well-exposed boudinage structures are outlined by ductilely-deformed marble truncating/wrapping around and over the amphibolite boudins (Figure 20). Further southeast, in very rugged and steep terrain, are deformed migmatites lying between the amphibolite and The Straits Schist close to the river. These migmatites are intruded along the Pequonnock River migmatite zone described at Stop 10.

At the north end of Fisher's Ridge is a small outcrop with a tight fold in the marble (Figure 23). It directly overlies very rusty amphibolite that was prospected, with a small dump of rusty-yellow rubble below. This may be the prospect mentioned by Hobbs (1901) as the one northeast of the Burnett place where ferberite was reported. If so, it would be the only other ferberite locality in the park besides the upper mine.


Field Stop Index Map
Bedrock geology from:
Moritz, Harold, Devlin, William, Wintsch, Robert, Hillenbrand, Ian, and Kläng, Zachary, 2019, Bedrock Geologic Map of The Old Mine Park Area, Trumbull, Connecticut, State Geological and Natural History Survey of Connecticut, Department of Energy and Environmental Protection, in cooperation with The Geological Society of Connecticut, 1:1,600 scale, CGNHS OF19-2
50 Corporate Drive
75 Corporate Drive
111 Corporate Drive
Corporate Drive
Quartz Lane
Caldron Drive
Skating Pond Road
Fisher's Ridge
State Hwy 111
State Hwy 25
Home Depot (previously Old Mine Plaza)
48 Monroe Turnpike
Tungsten Circle
Old Mine Road
Pequonnock River
Pequonnock River Trail
Saganawamps Hill
Upper Mine
Toolhouse Site
Champion Lode
Railroad Grade
Lime Kiln
Marble Quarry
Cistern
Burnett House
Mill Site
Shop Site
Lab Site
Storage Site
F10 & 49
F26
F39
F11 & 45
F50
F7
F12
F13
F14
F15
F16
F17
F18
F19
F20
F23
F38
Ssua
Ssum
DSt
Ssla
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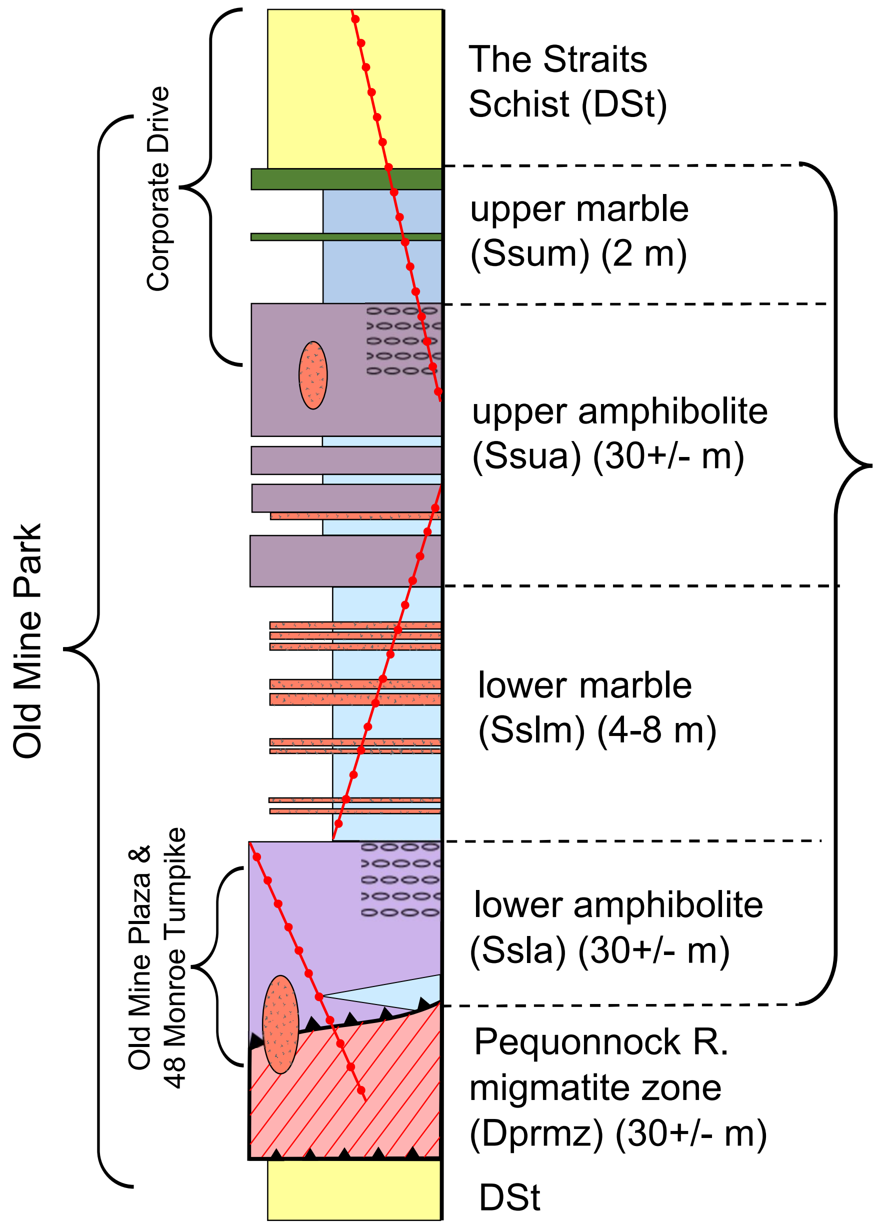
300
400
500
Meters

## Generalized Stratigraphic Column




*thicknesses not to scale*

## Explanation of Units

**Dp** — **Devonian Pegmatite:** Massive, unzoned granite pegmatite.

**Dprmz** — **Devonian Pequonnock River migmatite zone:** Granitic pegmatite bearing fragments of both adjacent map units.

**DSt** — **Devonian – Silurian The Straits Schist:** Rusty-weathering, coarse- grained schist.

**Saganawamps section informal names**

**Ssum** — **Silurian upper marble:** White to grey, fine- to medium-grained marble.

Quartzite to feldspathic quartzite sub-unit.

**Ssua** — **Silurian upper amphibolite:** Dark grey to black, fine- to medium-grained amphibolite to amphibole gneiss.

**Sslm** — **Silurian lower marble:** Coarsely crystalline marble with persistent albite-quartz layers.

**Ssla** — **Silurian lower amphibolite:** Similar to the upper amphibolite unit but includes albite-quartz.

### Legend

- Old Mine Park Boundary
- Trails
- Pits and Quarry Walls
- High-temperature Mineral Vein
- Mineralized Brittle Fault
- Marble Interlayer
- F12 Field Guide Photograph Site
- 1 Field Stops
- Trench
- Outcrop
- Mining Dump
- Boudinage