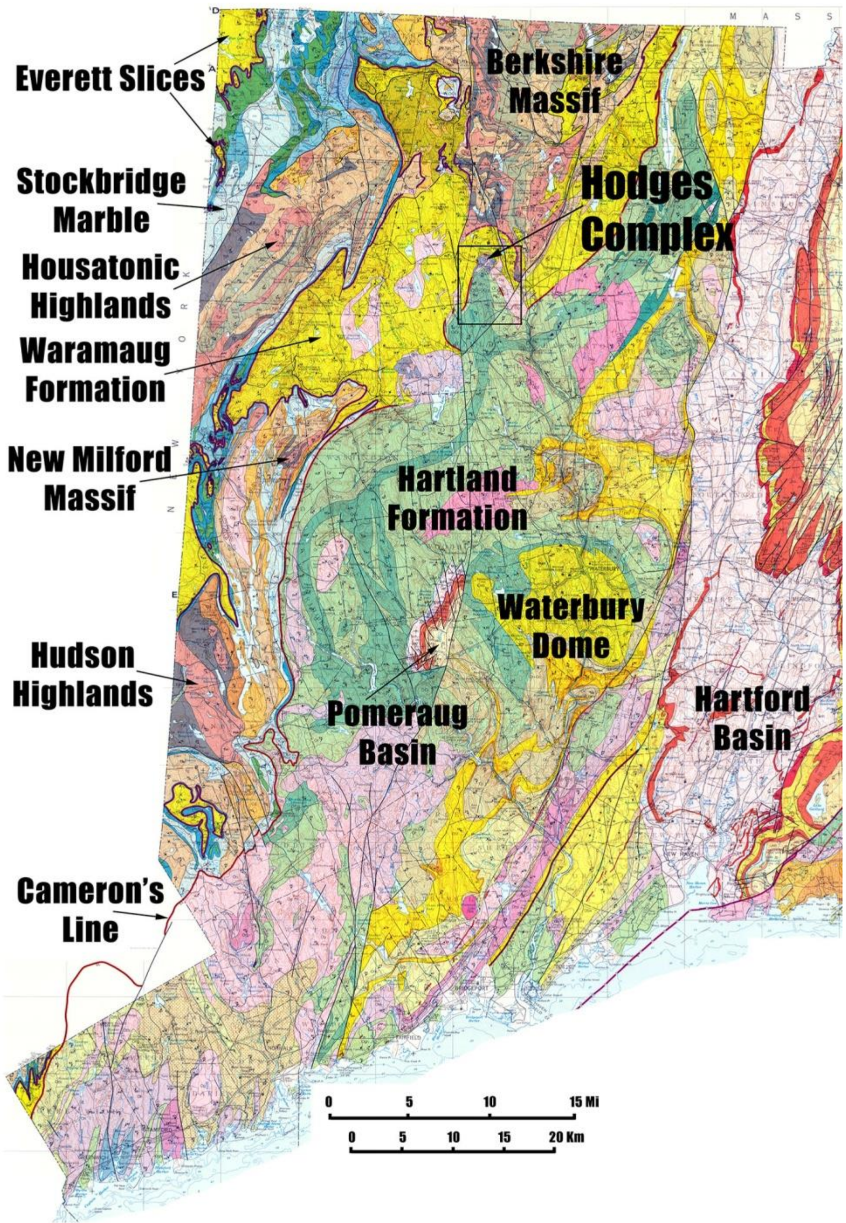
Wallrocks of the Hodges Complex and Tyler Lake Granite, West Torrington, Connecticut



Geologic map of western Connecticut showing from NW to SE, the basement + cover sequence, Cameron's Line (red) and the bounding Hartland Formation. (From Rodgers et al., 1985.)

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by

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State Geological and Natural History Survey of Connecticut

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ACKNOWLEDGEMENTS

A fieldtrip of this type can never be accomplished without the help of many people. The author has always had a soft spot in his heart for western Connecticut – the land, the rocks, and mostly the people. A gentle folk, down to earth and ready to be friendly. In that connection this guidebook is dedicated to my dear friends in western Connecticut whose humor and love for the rocks and minerals spawned a deep interest in CT geology. Thus, I acknlowledge the lasting spirits of the late **Dr. John E. Sanders, Dr. Leo M. Hall, Dr. John Rodgers, John A. Carter, Burritt Curtis, Sr., Sterling E. Parker, Earle C. Sullivan, and Ray and Dick Wadhams.**

In 1972, I was introduced to the Hodges Complex by **Dr. Nicholas M. Ratcliffe** during my Master's thesis work at City College of New York. His guidance then and friendship over these many years has been a great benefit to me personally.

For this trip, I acknowledge the help of **NE Utilities** for arranging access to the Soapstone quarry, **Jim Wright** for allowing access to the Hodges Complex and his kind friendship over many years, and **Damien and Anna Oswarek** for preserving the long-lost Old Litchfield Mines, keeping them available for study and accessible for this trip. Recent collaboration with **Harold Moritz** and **John A. Pawloski** has provided new insights into the geology and mineralogy of the region and their input and friendship is much appreciated. I thank the staff at Duke Geological Laboratory including **Genevieve Glasson** and **H. Manne** for thier efforts in helping put together this guide. Finally, I am grateful for a thorough edit by **Margaret A. Thomas** that improved the field trip guide.

Charles Merguerian

Disclaimer

Most of the rock viewing localities listed in this guide are generally not open to the public and this guide in no way condones or unintentionally serves to facilitate trespassing or rock collecting on private or public land. We recommend that readers **always** take the time to identify land owners and ask permission **<u>before</u>** you set foot on their property.

Wallrocks of the Hodges Complex and Tyler Lake Granite, West Torrington, Connecticut

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INTRODUCTION

This one day field trip to West Torrington, Connecticut is intended to introduce participants to the bedrock stratigraphy of wallrocks of the Hodges Complex, a 446 Ma mafic ultramafic intrusive situated astride a major tectonic boundary - Cameron's Line. Ample time will be spent examining and discussing separation of the subunits of the Hartland and Waramaug formations on either side of Cameron's Line, a folded Taconian plate boundary suture. Ductile structures and lithologies associated with Cameron's Line and contact relationships with crosscutting plutons will also be examined. The trip in various forms has been conducted numerous times. Field data for this study was initially acquired during Master's research (1977 ms) and for the NEIGC (1985) and then to legions of undergraduate students during my "held-over" 35-year engagement at Hofstra University. I provide the following links for download:

Merguerian 1977 ms:
http://www.dukelabs.com/Publications/PubsPdf/CM1977ms_HodgesComplex.pdf
http://www.dukelabs.com/Publications/PubsPdf/CM1977ms_HodgesComplex_Plate1.pdf
http://www.dukelabs.com/Publications/PubsPdf/CM1977ms_HodgesComplex_Plate2.pdf
Merguerian 1985:
http://www.dukelabs.com/Publications/PubsPdf/CM1985d_NEIGC_HodgesComplex.pdf

Nine stops have been selected to best illustrate the geology of the quadrangle paying particular attention to the Hodges wallrocks. So, before we delve into the details of the individual stops, it is customary to describe the regional geology and set the trip stops into proper context. The following section serves to accomplish this task.

GEOLOGICAL BACKGROUND

The major geological elements of western Connecticut have been under scrutiny for nearly two centuries leading to a modern tectonostratigraphic framework that has allowed focused investigations to refine structure, metamorphism, age and tectonic sequencing. Future radiogenic dating and geochemical investigations in this region will take us to the next level of understanding, though I have very little of this type of data from the West Torrington quadrangle. Since the 1980s my work has been rediewcted to New York City geologic investigations. Hopefully, this GSC fieldtrip, a classic hammer and handlens experience, will outline problems and solutions for new students and active researchers.

The crystalline bedrock of western Connecticut consists of a sequence of metamorphosed Mesoproterozoic to Lower Paleozoic rocks that converge southward as the Manhattan Prong (Figure 1). The highly deformed tectonostratigraphic elements of western Connecticut include Mesoproterozoic and younger basement gneiss and attached lower Paleozoic cover rocks (quartzite/marble/graphitic schist) which are mostly found to the west and northwest of Cameron's Line, a major Taconian suture that separates the ancestral Laurentian basement+cover rocks from those of former oceanic parentage forming the Hartland Belt. Indeed, most workers envision the middle Ordovician Taconian orogeny the result of collision between an amalgamated arc complex and the passive margin of North America, resulting in continentward overthrusting of the Taconic sequence. In New York City and western Connecticut the upper plate includes sheared aluminous metasedimentary rocks and intercalated mafic and felsic metavolcanic rocks. Together they form the Hartland Belt, interpreted as a subduction complex consisting of off-scraped oceanic strata associated with Taconian subduction, imbrication and suturing (Merguerian 1983).

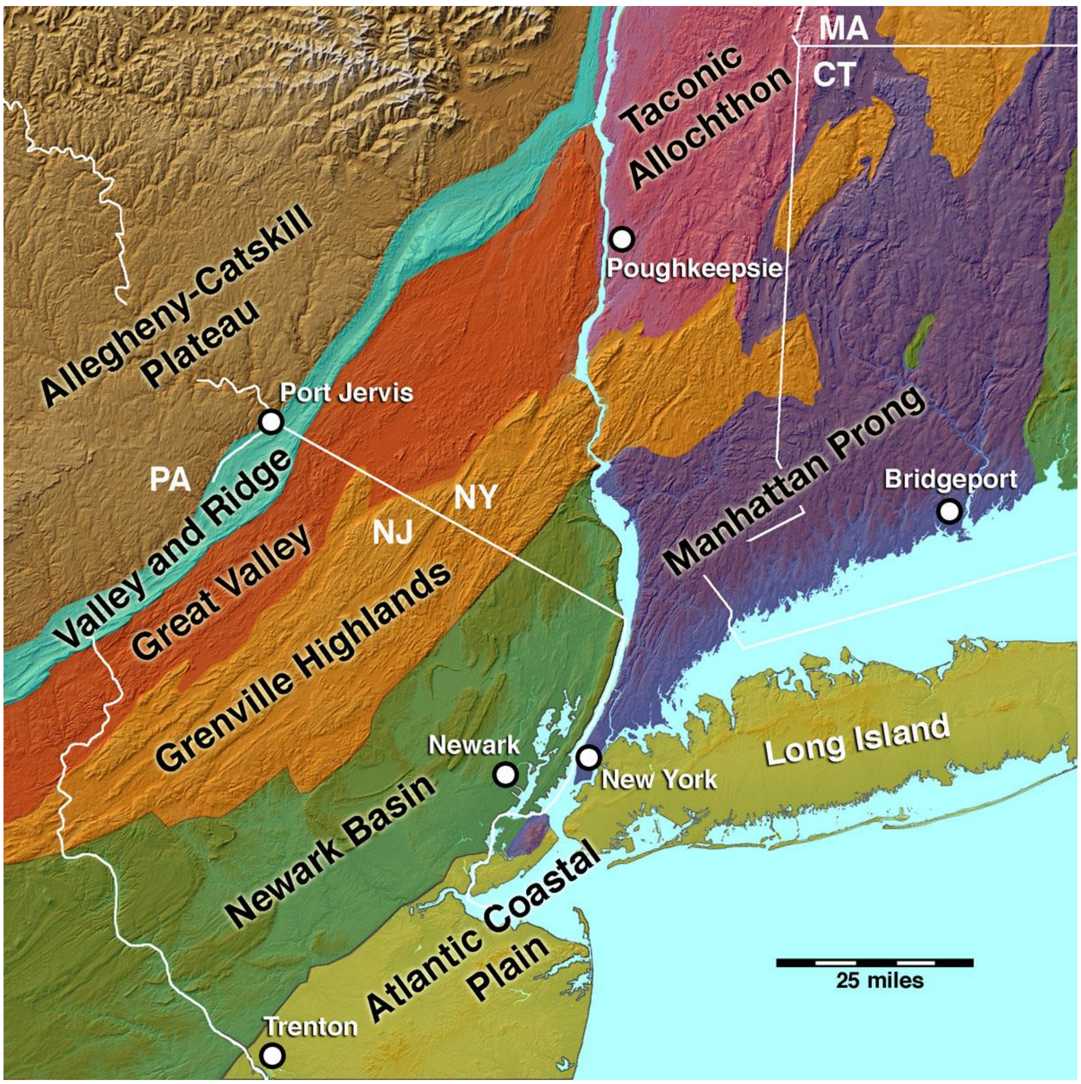

Figure 1– Physiographic diagram showing the major geological provinces in southern New York, western Connecticut, and northern New Jersey. (From Bennington and Merguerian, 2007.)

The Geology of Western Connecticut

The mineral-rich lower Paleozoic crystalline terrain of western Connecticut consists of a diverse assemblage of Proterozoic to lower Paleozoic metasedimentary and metaigneous rocks of the Hartland Formation which can be traced from New York City northward into the Connecticut Valley-Gaspé synclinorium (Figure 2). The Hartland Formation (Cameron, 1951; Gates, 1951, 1952; Merguerian, 1977 ms) consists of aluminous metasedimentary and interlayered metavolcanic rocks. They are bounded on the west by **Cameron's Line** and to the east, are overlain by metamorphosed rocks of probable Silurian and Devonian age (Hatch and Stanley, 1973). The Hartland Formation constitutes the bulk of the highlands of western Connecticut and is a metamorphosed sequence of eugeosynclinal rocks (formerly deposited in deep water on oceanic crust). (See Cover Figure.)

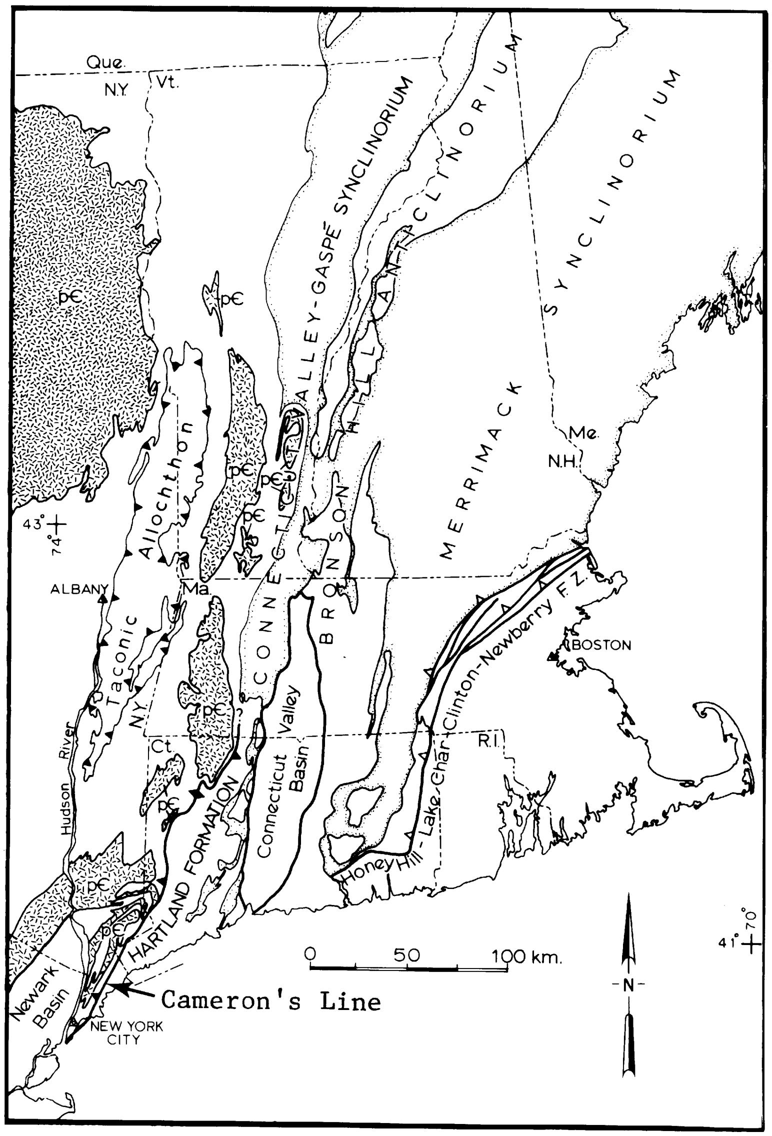

Figure 2 – Tectonic sketch map of southern New England showing the major geotectonic provinces. (From Merguerian, 1983).

In northwesternmost Connecticut, broad tracts of land are underlain by metacarbonate rocks (both dolomitic- and calcite marble) of the Cambrian to Ordovician Stockbridge marble, a thick sequence of deformed marble that is depositionally above the gneisses and granitoids of the Laurentian craton. These deposits have been mined for hundreds of years for use as building stone and for use in smelters in support of the iron industry that flourished in the region in past centuries. Evidence for this industry comes in the form of iron prospects, marble quarries, and the huge roasting ovens and kilns that dot the landscape – icons of a different era of history.

Occurring immediately to the west of Cameron's Line is a sequence of massive gneissic rocks known as the Waramaug Formation (Neoproterozoic? to Ordovician) which is correlative to the north with the Hoosac Schist and to the south with Manhattan Schist unit Є-Om of New York City (Clark 1958; Merguerian 1983). This sequence is interpreted as a continental slope/rise deposit that was situated between the depositional sites of the passive continental margin and deep water eugeosynclinal deposits. Thus, on either side of Cameron's Line, strongly disparate sequences of equivalent age occur with lower-plate continental-shelf, -slope, and -rise rocks and upper-plate oceanic rocks juxtaposed along a major zone of mylonite (ductile shear zone).

Cameron's Line

According to Eugene Cameron (of Cameron's Line fame) in a confidential personal communication with CM at a GSA meeting in the 1980s, the geologic relationship of Cameron's Line was first noted by William Agar who shared the concept with E. Cameron. According to EC - *"I don't know why they called it Cameron's Line at all, it should have been called Agar's Line!"* In any case, Cameron's Line delimits the easternmost exposures of autochthonous Proterozoic Y and Z gneiss and overlying lower Paleozoic cover rocks deposited originally on continental crust of proto-North America.

In western Connecticut, the Hartland Formation or Complex of Merguerian (1983) is interpreted as an internally sheared imbricate thrust package that marks the former site of a deep-seated accretionary complex or subduction zone. (See Figure 2.) It consists of a thick sequence of interlayered muscovite schist, micaceous gneiss and granofels, amphibolite, and minor amounts of calc-silicate rock, serpentinite, and manganiferous- to ferruginous garnet-quartz granofels (coticule) (Merguerian, 1981). Hartland rocks are correlative with metamorphosed eugeosynclinal (deep-water deposition) Cambrian to Ordovician rocks found northward along strike in New England and southward in the southern Appalachians.

Numerous lower Paleozoic alkalic mafic-ultramafic plutons occur in western Connecticut. According to Ratcliffe and others (2012) these are tightly constrained in age from about 446 to 454 Ma and as such represent Taconian intrusives emplaced across Cameron's Line and associated ductile faults (Figure 3). Near West Torrington, Connecticut, the Hodges mafic-ultramafic complex and the Tyler Lake Granite were sequentially intruded across Cameron's Line (Merguerian, 1977 ms; Merguerian and Ratcliffe 1977). Because of the formerly elongate shape and because the regional metamorphic fabrics related to the development of Cameron's Line in both the bounding Waramaug and Hartland formations display contact metamorphism, the Hodges pluton is interpreted as late synorogenic. The recognition of significant medial

Ordovician plutonism stitching across Cameron's Line (Mose, 1982; Mose and Nagel, 1982; Merguerian and others, 1984; Amenta and Mose, 1985; Ratcliffe et al., 2012) establishes a Taconian age for the formation of Cameron's Line and the syntectonic development of regional metamorphic fabrics in western Connecticut. Comparison of metamorphic minerals in the regional fabric to contact metamorphic assemblages peripheral to the Hodges indicates that the Waramaug and Hartland were juxtaposed along Cameron's Line and intruded by the Hodges and Tyler Lake Granite at depths of roughly 20 km.

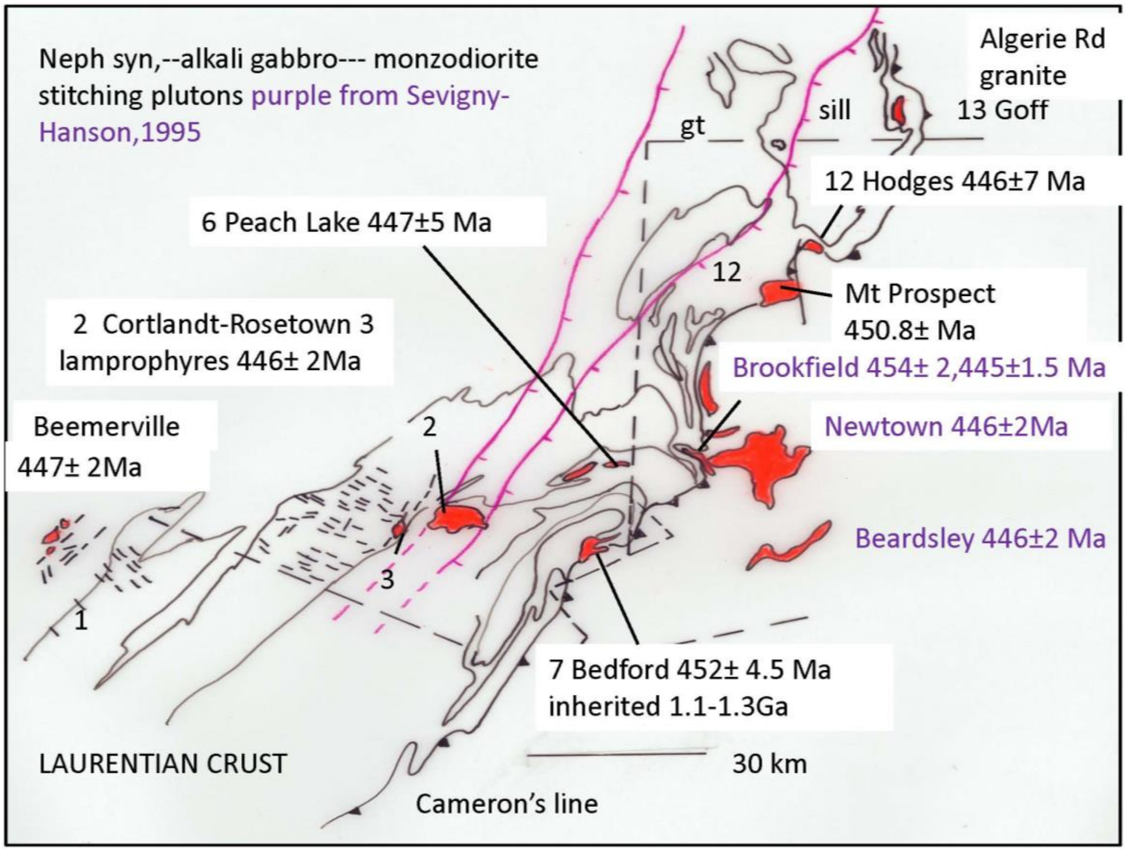

Figure 3 – Map of the major mafic-ultramafic plutons in western Connecticut and New York showing their relationship to Cameron's Line (east-dipping barbed line) – the Taconian suture. Regional sillimanite (sill) and garnet (gt) isograds shown in purple. (Unpublished map from Ratcliffe et al., 2012.)

The force behind such deep-seated deformation presumably resulted from a collision between an amalgamated volcanic-arc terrane and the passive continental margin of Laurentia. At present, the arc terrane is exposed in the Bronson Hill Anticlinorium and its extension southward into Connecticut. (See Figure 2.) The Hartland Belt forms the deeply eroded roots of an uplifted accretionary complex marking the former trench into which the raw edge of North America was subducted.

Much of the bedrock in western Connecticut is therefore interpreted to be allochthonous (a fancy term intended to confuse the layman which simply means transported from somewhere else or not deposited where currently found!). In this model, Cameron's Line marks a fundamental plate-tectonic boundary (suture) between continental and oceanic realms and may demark the root zone for much of the allochthonous Taconic sequence in eastern New York State and for the Everett slices in NW Connecticut and Massachusetts.

I have selected nine stops to best illustrate the results of mapping and research. My detailed maps (1:12,000 scale) can be downloaded at the links provided above (p. 1).

Our Planned Stops:

01 - Hartland Formation (upper member) granofels, schist, and amphibolites [West Torrington Q – all stops]
02 - Hartland Formation (lower member), amphibolite and subsidiary D_2 shear zone
02a - Soapstone quarry (Optional)
03 - Hartland Formation (lower member) muscovite-kyanite-staurolite schist
04 - Sheared amphibolite, and folded dismembered ophiolite of Cameron's Line
LUNCH STOP: South of dam, Brass Mill Dam Road: Waramaug Formation
05 - Waramaug Formation and contact with Hodges Complex diorite
06 - Mafic and ultramafic rocks of the Hodges Complex
07 - Mafic and ultramafic rocks of the Hodges Complex, Hodges Nickel Mine and prospects
08 - Tyler Lake Granite
09 - Old Litchfield Mines

The road log (below) and descriptions of individual stops will follow after a brief summary of the geology of the West Torrington quadrangle.

Wallrocks of the Hodges Complex and Tyler Lake Granite

Two major formations are intruded by the Hodges and Tyler Lake Granite - the Waramaug and Hartland formations.

Waramaug Formation

The Waramaug Formation of Gates (1952) forms a belt up to 10 km wide from Torrington southward to New Milford, Connecticut where Clarke (1958) correlated the Waramaug and Manhattan formations. In the vicinity of West Torrington, the Waramaug (p€-Owg) crops out west, north, and northeast of the Hodges Complex (Figure 4) and consist of a heterogeneous assemblage of -rusty-, -gray-, and locally maroon-weathering biotite gneiss, schist, and granofels with subordinate amphibolite gneiss, amphibolite, and calc-silicate rocks (Stops 04, Lunch Stop and Stop 05). Often magnetic, outcrops are massive and indistinctly layered with a nubby weathered surface resulting from resistant clusters of quartz and aluminosilicate minerals that may have been segregated during metamorphism. Waramaug rocks are generally massive, indistinctly layered, coarse- to medium-textured, gneissic, and granular to foliated; quartz, biotite, and plagioclase are the dominant minerals. Muscovite is typically present but not as abundant as in the Hartland. The Waramaug contains thin layers of amphibolite and amphibolitic gneiss, which typically are granular and gray-green to black in color, and rare tremolite-quartz calc-silicate layers.

Mapping by Jackson (1980ms), and Jackson and Hall (1982) near Kent, Connecticut; by Alavi (1975) near Bedford, New York; by Hall (1968a, b) in White Plains, New York; and by Merguerian and Baskerville (1987), Merguerian (1995) and Merguerian and Merguerian (2004) in New York City support this correlation. The Waramaug Formation is correlative and physically continuous between Connecticut and Massachusetts with the Late Proterozoic (?) to Cambrian Hoosac Schist (Hall, 1971, 1976; Hatch and Stanley, 1973) and can be traced southward to the name locality of the Manhattan Schist in New York City, at the terminus of the Manhattan Prong. The formation is interpreted as metamorphosed slope/rise sediments, initially deformed during the Taconic orogeny (Merguerian 1983).

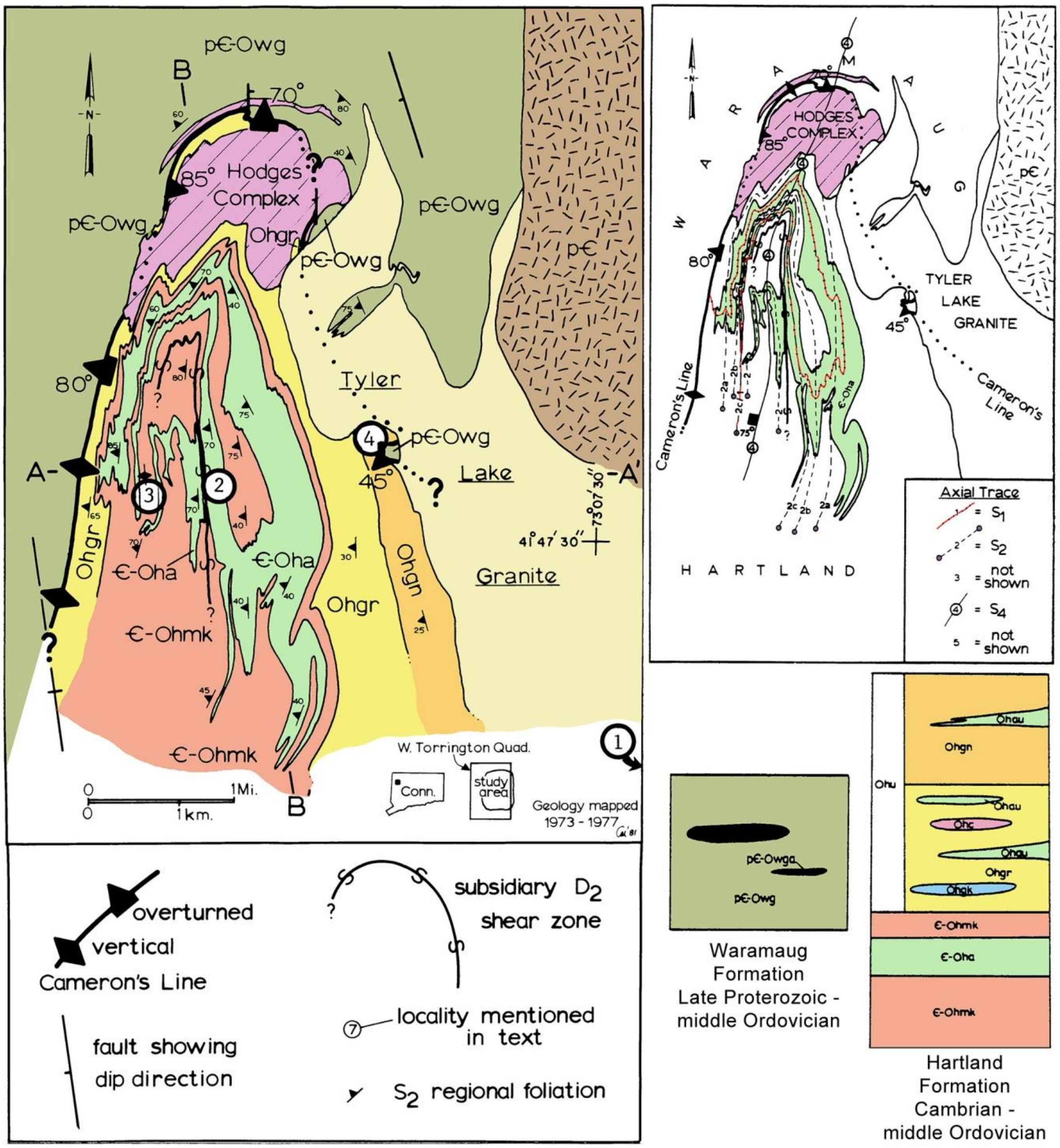

Figure 4 – Simplified geological map (showing Stops 01, 02, 03, and 04), axial-surface map, and stratigraphic column of a part of the West Torrington quadrangle. (Colorized from Merguerian, 1985, fig. 4, p. 415.)

Hartland Formation

In western Connecticut, the Hartland Formation consists of a thick sequence of well-layered muscovite schist, micaceous gneiss and granofels, amphibolite, and minor amounts of calc-silicate rock, serpentinite, and manganiferous garnet-quartz granofels (coticule). The rocks are very rich in muscovite and quartz and, to a lesser extent, plagioclase; they contain thin- to thick layers of greenish amphibolite.Hartland rocks are correlative with metamorphosed eugeoclinal Cambrian(?) to Ordovician rocks found along strike in New England. They can be distinguished from the Waramaug because Hartland rocks tend to weather gray.

Because the Hartland is overlain by Silurian and Devonian metamorphic rocks east and southeast of Torrington and the dominant regional foliation in the Hartland is truncated by the 446 +/- 7 Ma Hodges gabbro (Ratcliffe et al 2012), an Ordovician minimum depositional age for the sequence is indicated. Rocks mapped as Hartland extend from New York City (Seyfert and Leveson, 1969; Baskerville, 1982; Merguerian 1983, Merguerian and Baskerville, 1987) through southeastern New York (Hall, 1968a; Pelligrini, 1977) and western Connecticut, northward to the Massachusetts state line (Hatch and Stanley, 1973).

In the vicinity of Torrington, based on stratigraphic position and tracing of subunits, the Hartland has been subdivided into upper- and lower members. (See Figure 4.) The lower member (Ꞓ-Ohmk) is a lithostratigraphic correlative with the Rowe Schist (OꞒr) and consists of lustrous gray-weathering muscovitic schist typically containing large (up to 10 cm) porphyroblasts of garnet, biotite, staurolite, and kyanite (Stop 03). A texturally- and mineralogically diverse assemblage of thick, laterally variable amphibolite (Ꞓ-Oha) is interlayered within the lower member (Stop 02). The lower member grades, with some lensing, into the upper member.

The Hartland upper member (Stops 01 and 04) consists of lustrous pin-striped muscovitic gneiss (Ohgn), well-layered quartzofeldspathic granofels and -schist (Ohgr), amphibolite (Ohau), and subordinate quartzite, coticule, and calc-silicate rocks (Ohc) and lenses of muscovite-kyanite schist (Ohmk). The upper member of the Hartland Formation is lithically correlative with the Ratlum Mountain Schist (Or) according to Rodgers (1985) and as shown in Figure 5.

Significant tectonic intercalation at Cameron's Line and intense isoclinal- and shear folding under amphibolite-grade metamorphic conditions create uncertainties in distinguishing between the Waramaug and Hartland formations near Cameron's Line. Elsewhere, their unique lithologic characteristics (as described above) make identification easier.

The absolute ages of the Waramaug and Hartland formations are not known. Nevertheless, most workers (Hall, 1976) consider them to be basically time-stratigraphic equivalents. These two formations are inferred to be products of depositional settings that were predominantly transitional slope-rise (Waramaug) and adjacent deep-sea floor (Hartland). They were deposited in the Early Paleozoic seaward of the North American shelf. Subsequently, they were converted into metamorphic rocks and, during deformation, were juxtaposed at depth along Cameron's Line.

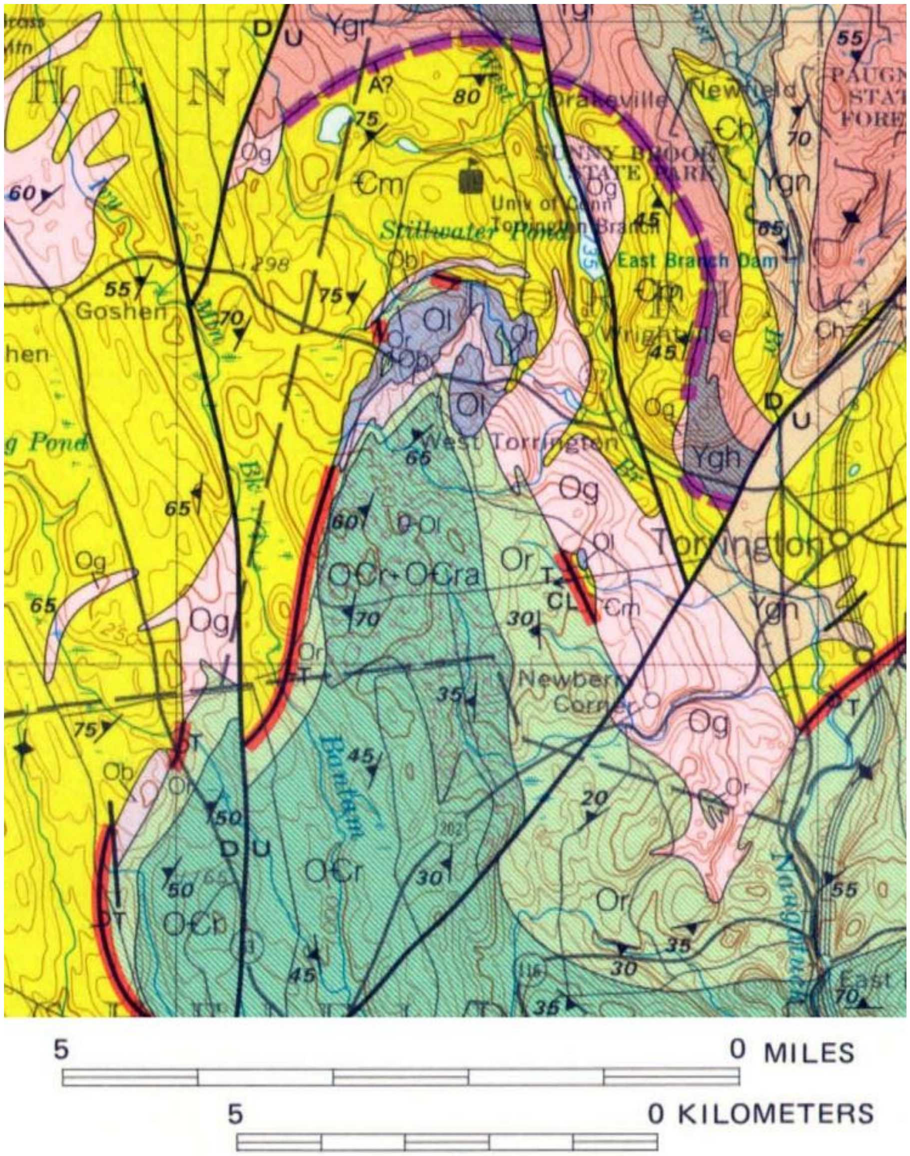

Figure 5 – Geologic map of the Hodges Complex (Ol), Waramaug (Єm), and various Hartland units including the Rowe (OЄr), and Ratlum Mountain Schist (Or). Cameron's Line shown in red. (From Rodgers et al. 1985).

The Hodges Complex and the Tyler Lake Granite

Metamorphosed mafic- and ultramafic rocks of the Hodges Complex underlie an area of 2.5 square kilometers (Figure 6). The zoned complex is a steep-walled, folded, mushroom-shaped pluton. The core consists of hornblende gabbro core and the chilled margin, of dioritic rock. A stock-like central intrusive and many smaller separated masses of pyroxenite and hornblendite crosscut not only the main gabbro-diorite pluton but also the foliated amphibolites of the Hartland Formation that extend to the south. As shown in the map and sections of Figure 6, the pluton is in direct contact with both the Waramaug and Hartland formations and is surrounded by a narrow contact aureole.

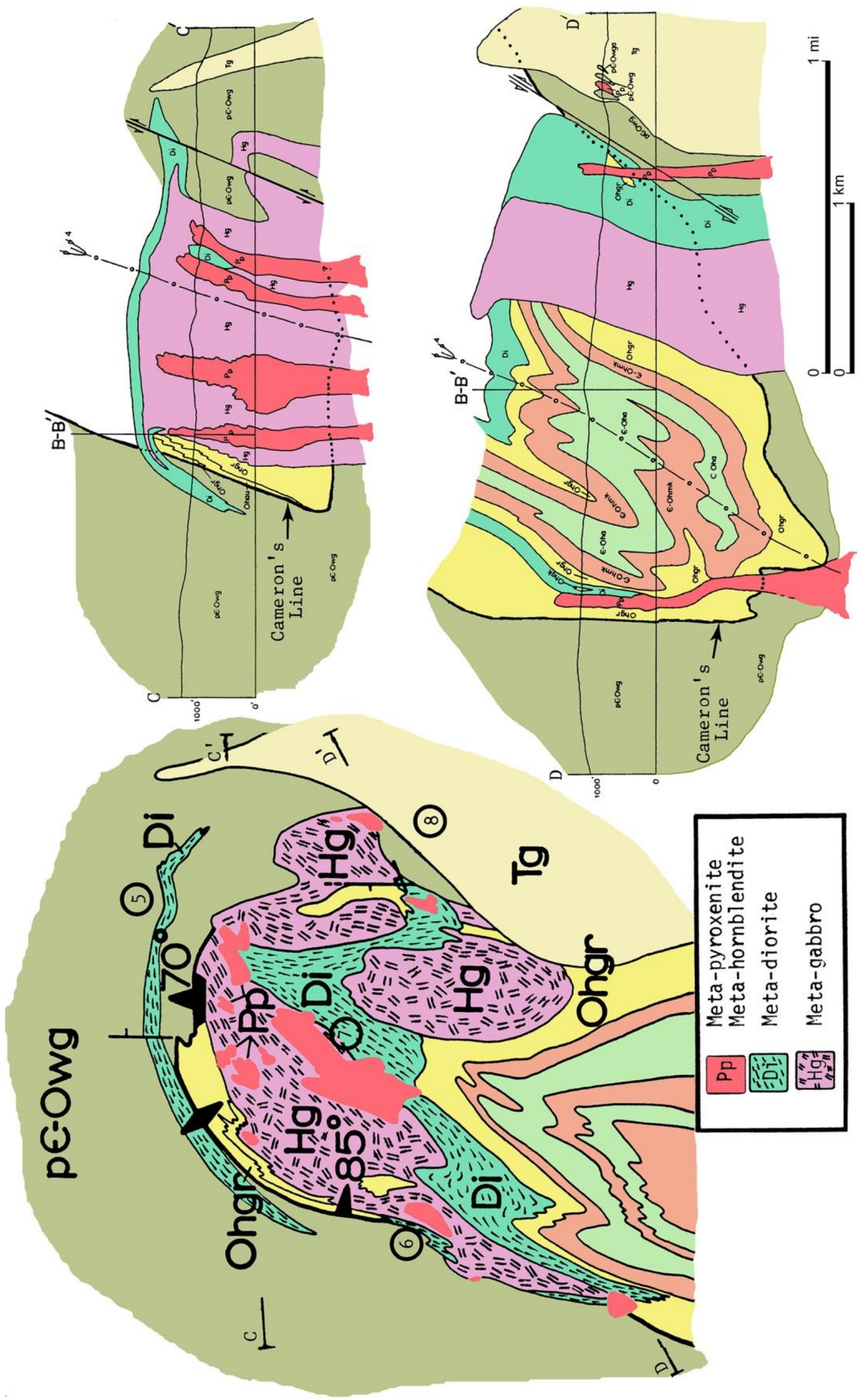

Figure 6 – Geologic map and sections of the Hodges Complex showing Stops 05-08. (Colorized from Merguerian, 1985, fig. 5, p. 418.)

All rocks of the Hodges Complex have been metamorphosed. Their original igneous textures have been overprinted and recrystallized. Relict olivine, enstatite, hypersthene, augite, and hornblende have been corroded and replaced by tremolite, actinolite, anthophyllite, cummingtonite, hornblende, magnesian chlorite, calcite, talc, and serpentine minerals. Gabbros and diorites remain relatively nonaltered but some changes are evident. These include recrystallization of plagioclase and replacement of hornblende by biotite and by chlorite.

The Hodges is subdivided into three mappable metaigneous rock units. These are indicated on the map by the symbols: Pp = pyroxenite, hornblendite; Hg = gabbro; and Di = diorite. (See Figure 6.) The ultramafic rocks (Pp) are typically highly altered, medium-textured to pegmatitic, dense and deeply iron-stained, silver-green to dark-green to black hornblende orthopyroxenite, biotite-tremolite-orthopyroxenite, orthopyroxene hornblendite, hornblendite, and biotite hornblendite (Stops 06 and 07).

The main gabbroic mass of the Hodges Complex (Hg) is composed of medium- to very coarse-textured, dark-gray-weathering, hornblende-plagioclase-biotite-quartz gabbro (Stop 06). Labradorite (An50-55), generally clouded displaying oscillatory zoning, is about equal to the content of hornblende. The hornblende contains pyroxene ghosts defined by opaques suggesting that prior to metamorphism, pyroxene was an important mineral phase.

The dioritic rocks (Di) are by far the most variable in texture and mineralogic composition (Stops 05, 06, and 07). They are greenish to black and white, poor- to well-foliated, fine- to medium-textured, banded hornblende-plagioclase-biotite-quartz diorites. Alternating layers of subhedral hornblende together with euhedral- to subhedral laths of plagioclase together define an igneous flow layering. The diorites form the flow-layered chilled margin of the main gabbroic mass of the Hodges. Detailed petrographic descriptions of the various Hodges phases can be found in Merguerian (1977 ms).

Tyler Lake Granite

The Tyler Lake Granite (Stop 08) is an elongate pluton initially described by Gates and Christensen (1965) as the eastern mass of the Tyler Lake Granite. Intruded across Cameron's Line, it includes xenoliths of Hodges mafic-ultramafic rocks at the contact zone.

The S_1 + S_2 regional foliation exerted a strong control on the original geometric form of the Hodges and Tyler Lake intrusives. As a result, their shapes are sheetlike, rather than equidimensional. As discussed later, minerals of the Hodges contact aureole postdate the S_2 regional foliation in the Waramaug and Hartland wall rocks. Post-intrusive folding has deformed both Cameron's Line and the plutons; it brought about abundant metamorphic alteration of original igneous textures and phases (Table 01).

Structural Geology, Intrusive Relationships, and Metamorphism

The wall rocks of the Hodges Complex and the Tyler Lake Granite have experienced a complicated Phanerozoic structural history that began with two phases of isoclinal folding (F_1 and F_2) yielding two subparallel regional foliations (S_1 and S_2). F_1 folds (Figure 7) are rare and usually developed in amphibolites which were less ductile than the surrounding schistose rocks during subsequent deformation (Figure 8). In both the Waramaug and Hartland formations, F_2 folds have commonly deformed an S_1 foliation and parallel compositional layering. The orientations and styles of the D_1 and D_2 events were similar. So, also, is the grade of metamorphism (amphibolite facies) which is considered to be culminative with D_2. They mark the initial prograde metamorphic pulse (M_1 in Table 01) that culminated during the formation of Cameron's Line.

Cameron's Line is a zone, 15 to 90 m wide, of intense localized isoclinal F_2 folds, having limbs sheared parallel to S_2, with S_1 fabrics transposed, and that regionally truncate Hartland subunits. The synmetamorphic shear zone includes layers of mylonitic amphibolite intercalated with both Waramaug and Hartland rocks and, locally, deformed slivers of serpentinite (Stop 04). Away from Cameron's Line, D_2 created a penetrative regional foliation (S_2) in the Waramaug and Hartland Formations. Although it is not clear whether motion along Cameron's Line, initiated during D_1, has anything to do with the fact that S_2 axial surfaces and the trace of Cameron's Line in West Torrington are regionally parallel. However, this parallelism strongly suggests that Cameron's Line formed at essentially the same time as the S_2 in the wall rocks. A subsidiary D_2 shear zone, marked by mylonitic amphibolite (Stop 02) and a soapstone-chlorite-talc body (optional Stop 02a) are also present within the Hartland.

Figure 7 – Refolded F_1 isoclinal fold from the Patterson Pond exposure. S_2 shears the early S_1 composed of alternating hornblende and plagioclase rich layers. S_1 is traced within the axial region of the refolded F_1 fold. (Sample H-162).

A secondary regional metamorphic pulse (M_2 in Table 01) occurred after the Waramaug and Hartland formations had been juxtaposed. This is demonstrated by the fact that porphyroblasts of garnet, staurolite, and kyanite overgrow the S_2 foliation. Because the S_4 cleavage deforms the M_2 porphyroblasts, the peak of the M_2 metamorphic pulse was reached after D_2 but before D_4. The contact effects of the Hodges Complex also overprint the S_2 foliation. Therefore, it is likely that the Hodges was intruded synchronously with the regional M_2 event as shown in Table 01. Based on a Taconian U-Pb age on the Hodges, both the M_1 metamorphic pulse and the development of the Hodges contact aureole are of pre-middle Ordovician age. It is probable that the M_2 event is also of Ordovician vintage despite the fact that most workers in Western Connecticut attribute the growth of large post-regional foliation porphyroblasts to Acadian (middle Devonian) Barrovian metamorphism that has been documented in Massachusetts (Hatch, 1975; Stanley, 1975; Robinson and Hall, 1980).

Figure 8 – Isoclinal F_2 fold of the Hartland Formation amphibolite (Є -Oha) showing the development of S_2 in axial planar relationship to folded S_1. The S_1 foliation bears a lineation that is also folded by F_2. The S_1 foliation is traceable into the axial regions of F_1 isoclinal folds just outside the view of the photograph. The hammer handle is 18 inches in length. (From Merguerian, 1977 ms.)

Open- to tight, crenulate F_3 folds are present, but predominantly in the vicinity of the plutons (Figure 9). Their axial-surface cleavages commonly are parallel to the margins of the plutons; their regional effect on the map pattern of the plutons is trifling. These folds are interpreted as being syn-intrusive; their axial surfaces are not shown on Figure 4.

Near West Torrington the S_1 + S_2 foliations, Cameron's Line, and the Hodges and Tyler Lake plutons were strongly deformed by dextral F_4 folds (Figure 10) and cut by an associated axial-planar spaced schistosity. S_4 is characterized by the growth of idioblastic biotite and -hornblende and recrystallized quartz; by parting in M_2 garnet-, staurolite-, and kyanite porphyroblasts; and by brittle deformation of plagioclase twin lamellae. The S_4 schistosity crosscuts the large M_2 staurolite-kyanite-garnet porphyroblasts as well as the $S_1 + S_2 = M_1$ regional foliation (Table 01). Metamorphism (M_3) during the D_4 event fostered retrograde biotite and recrystallization of amphibole. In addition, the D_4 event caused widespread metamorphic recrystallization, serpentinization, and chloritization in the Hodges Complex and recrystallization and domainal shearing in the Tyler Lake Granite (Stops 05, 06, 07, and 08).

DEFORMATIONAL EVENT	LINEAR FEATURES	PLANAR FEATURES	IGNEOUS ACTIVITY	METAMORPHISM
D_1	F_1 isoclinal folds of compositional layering. L_1 quartz ribbing in gneisses and schists. Hornblende lineation in amphibolites.	S_1 gneissic layering in gneisses or hornblende-plagioclase foliation in amphibolites. Generally not recognized in schists.		? Amphibolite-grade M_1
D_2	F_2 penetrative isoclinal folds of early S_1 structures and compositional layering. L_2 mineral streaking in schists and gneisses.	S_2 regional foliation composed of oriented phyllosilicates+kyanite or sillimanite developed axial planar to F_2 folds.	? HODGES COMPLEX TYLER LAKE GRANITE *466±12 m.y.*	Amphibolite-grade M_2
D_3	F_3 shallow SW to NW plunging, open to tight, crenulate folds of the S_2 regional foliation. L_3 intersection lineation in massive rocks; crinkle axis in micaceous rocks.	S_3 crenulation or slip cleavage developed axial planar to F_3 folds. Oriented NW to WSW with shallow dips.	PEGMATITES	
D_4	F_4 steep SW plunging dextral synformal folds of the S_2 regional foliation	S_4 crenulation cleavage, slip cleavage, or spaced schistosity developed axial planar to F_4 folds. Orientation - N20°E, 75°NW.		? Biotite-grade M_3 (retrograde)
D_5	F_5 open folds and warps with variable hingelines. L_5 intersection lineation.	S_5 slip cleavage and rock cleavage axial planar to F_5 folds oriented NW to W with variable dip.	?	continued retrograde

Table 01 – Linear- and planar structural features and chronology of folding, igneous activity, and metamorphism in the vicinity of Torrington, Connecticut. (From Merguerian, 1985, Table 1, p. 420.)

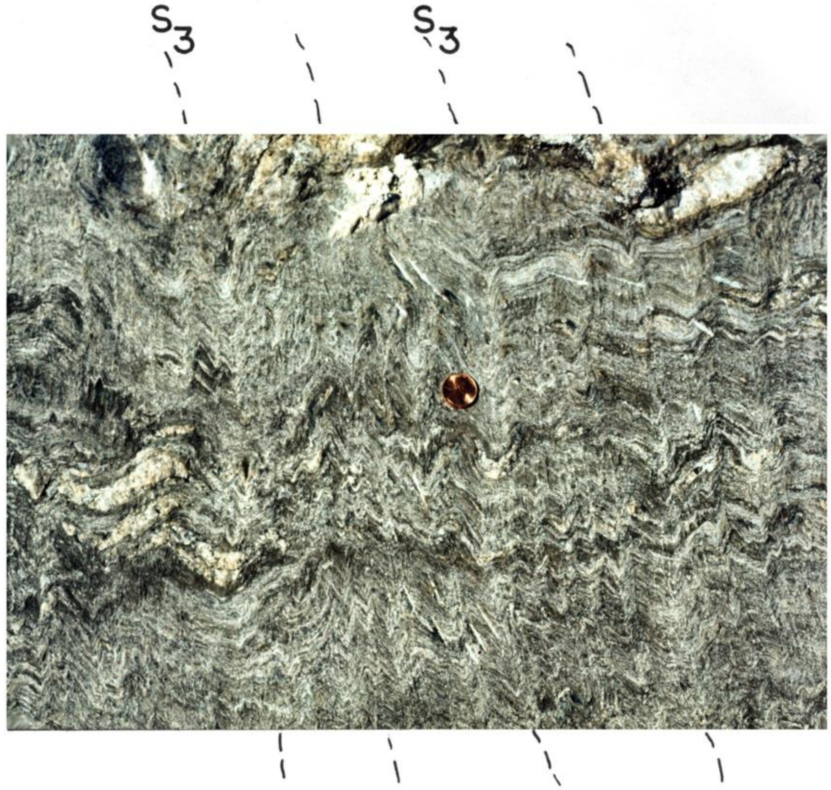

Figure 9 – Typical F_3 folds developed in the Hartland Formation (Ohgn) near the contact of the Tyler Lake Granite. Note the gentle warp of S_3. (From Merguerian, 1977 ms.)

Figure 10 – Southward view of typical SW-plunging F_4 folds in the Hartland Formation amphibolite from Klug Hull, immediately south of the Hodges Complex (Ꞓ- Oha). Scales: Hammer handle is 18 inches in length; coin is a U.S. dime. (From Merguerian, 1977 ms.)

A fifth-, and possibly sixth, deformation is suggested by the warping of the S_4 axial-surface trace (See Figure 4.) and by local open- to crenulate folds with variable plunges and shallow NE- and NW- to W-trending axial surfaces. This deformation is low grade and is marked by recrystallized quartz and chlorite +/- white mica. These crosscutting structural-, metamorphic-, and intrusive relationships are summarized in Table 01 and discussed in greater detail elsewhere (Merguerian 1977 ms, 1983, 1985, 1987).

Stereograms and Structure Sections

Stereograms of the major structural features described above are shown in Figure 11. Net #1 shows poles to S_2 in both the Waramaug and Hartland formations. The wide scatter of poles distributed about a NW-SE girdle indicates significant post-D_2 deformation. Poles to S_4 and F_4 fold axes and L_4 intersection lineations (Nets #2 and #3 in Figure 11) show a consistent trend for S_4 of about N19°E, 72° NW and F_4 about S50°W at 60°. Clearly, the girdle distribution of S_2 poles is largely the result of F_4 folding. Some scatter resulting from local F_3 and F_5+ folds may have also occurred.

Sections in Figure 12 have been drawn from map data and from axial-surface traces shown in Figure 4 but the exact configuration of F_1 closures in the subsurface is hypothetical. This has been caused by extensive D_2 transposition. In section A-A', the major obvious structure is a dextral F_4 synform with a steep western limb (vertical to locally overturned toward the east) and a shallow west-dipping eastern limb. The interference of F_1 and F_2 folds yields a complex interdigitating map pattern of Hartland subunits. The section shows that F_4 folds have been superimposed on the older structures, that Cameron's Line and the subsidiary D_2 shear zone have been folded, that Cameron's Line truncates Hartland subunit Ohgn, and that the Hodges and Tyler Lake Granite are discordant plutons.

Section B-B' shows a north-south view roughly parallel to the trace of S_4. Again, the complicated pattern of folds of the Hartland subunits, truncation of Hartland subunit Ohgn, and crosscutting relationships of the Hodges Complex with reespect to Cameron's Line are indicated.

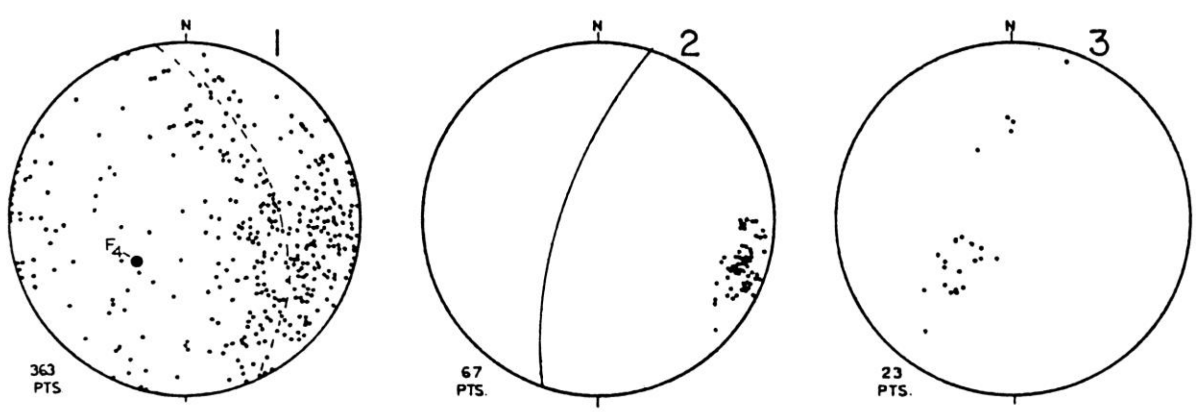

Figure 11 − Stereograms of structural elements showing (Net #1) a wide scatter of poles to the S_2 foliation about a NW to SE girdle (dashed line) whose pole is parallel to F_4 (Net #3). Poles to S_4 (Net #2) and F_4 fold axes and L_4 intersection lineations (Net #3) show a consistent trend for S_4 of about N19°E, 72° NW and F_4 about S50°W at 60°. (From Merguerian, 1985, fig. 7, p. 422.)

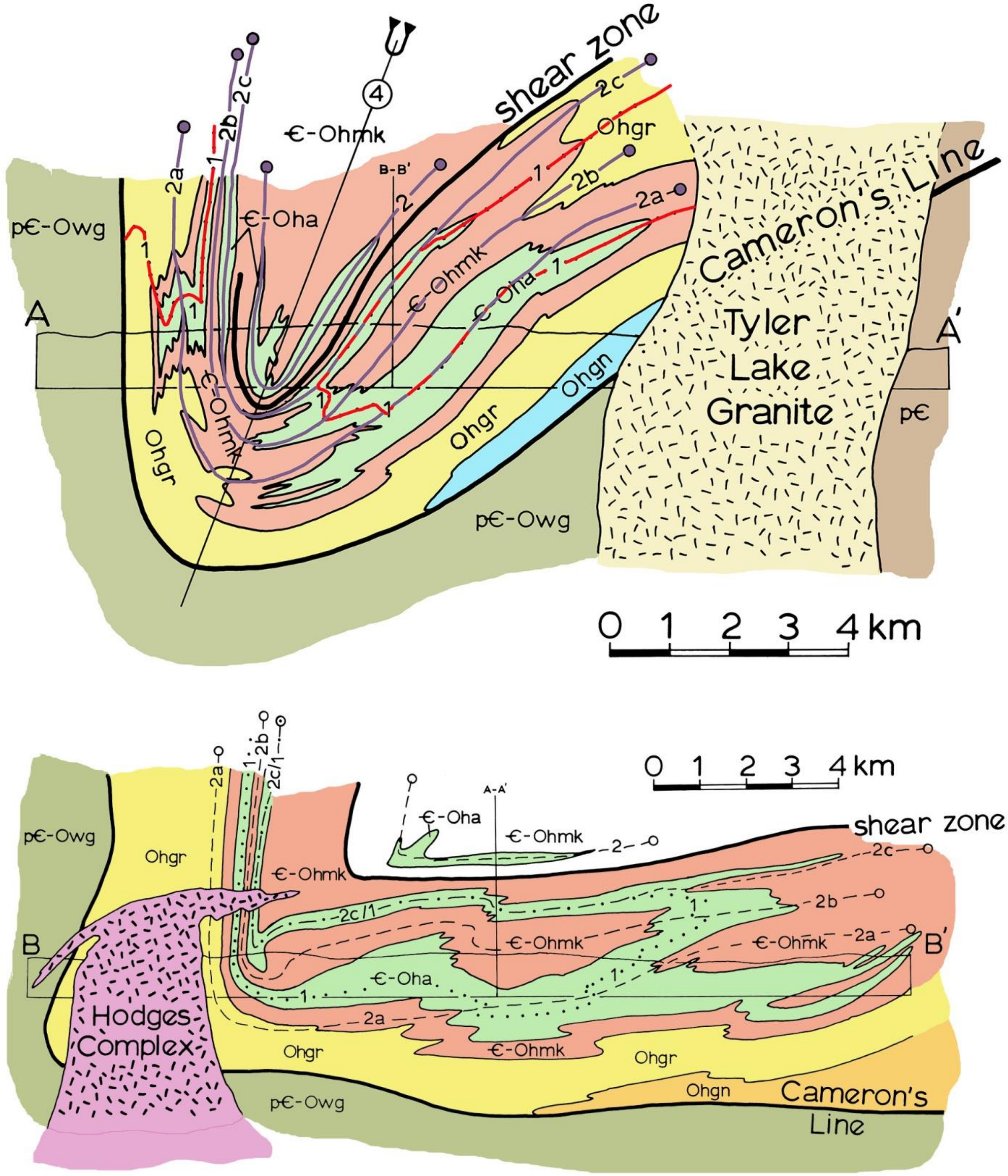

Figure 12 –Geologic structure sections. Section lines are shown in Figure 34. No vertical exaggeration. (Colorized from Merguerian, 1983, fig. 6, p. 358.)

Possible Temperature and Pressure (Depth) during Hodges intrusion

The mineral assemblage cordierite+garnet is unique to the contact aureole of the Hodges and is found nowhere else (Table 02). In addition, kyanite and cordierite co-exist with garnet-staurolite-quartz-plagioclase and biotite (H-169). There is a marked absence of muscovite and potassium feldspar in these contact rocks. Kyanite-cordierite coexistence is not commonly reported in the geological literature, although laboratory evidence indicates that there is significant overlap in the stability fields of kyanite and cordierite-garnet.

The disappearance of muscovite and absence of sillimanite and a K^+ feldspar phase is a problem since muscovite is stable at temperatures up to 700° C at pressures near the $A1_2SiO_5$ triple point. It is possible that muscovite was eliminated by reaction 3 in Figure 13 (curve plotted is for oligoclase composition of plagioclase). There is abundant evidence for the presence of kyanite and for the evolution of granitic liquids as pegmatites throughout the study area (removing K^+). The elimination of muscovite could also have taken place via reaction 2, although the presence of kyanite and absence of sillimanite (except for a singular, minor occurrence) would argue against such a paragenesis.

The equilibrium contact assemblages listed on Table 02 would suggest a P-T area of intrusion as shown between curves 3 and 4 in red and yellow on Figure 13 (however, equilibrium has not been proven between all minerals listed in a particular contact specimen!). If Althaus' estimate of the location of the aluminosilicate triple point is more nearly correct, then the P-T conditions of the Hodges intrusion would be defined by the "deeper" yellow ruled area only.

SAMPLE	UNIT	CONTACT ASSEMBLAGE	REGIONAL ASSEMBLAGE AWAY FROM CONTACT	REMARKS
H-169	Ohgr	cord-ky-st-gt-bi-plag-qtz-chl	bi-musc-qtz-plag±ky	Contact with gabbro on Klug Hill. Sample was 5 feet from contact.
H-31	Ohgk	cord-ky-st-bi-qtz	musc-bi-qtz-plag-ky±st	Contact of gabbroic and ultra-
H-68	Ohc	st-gt-qtz-bi-sill	qtz-musc-plag	mafic rocks with a screen of
H-69	Ohgk	cord-ky-gt-st-sill-bi-qtz-chl	musc-bi-qtz-plag-ky-±st	Hartland rocks. From the SW of the intersection of Weed Road and
H-30b	Ohau	hyp-hb-plag-bi-op	hb-plag-bi-op	Route 4.
H-43	p€-Owg	gt-plag-qtz-bi	gt-plag-qtz-bi	From contact of Waramaug and dio-
H-52A	p€-Owg	ky-bi-qtz-plag-gt	musc-gt-ky-qtz-plag	rite NNW of the Hodges Complex.
H-116	Ohc	grun-qtz	musc-bi-qtz-plag	From contact with diorite N of Route 4 and Klug Hill Road.
H-56	p€-Owga	hb-plag-bi-gt-op	hb-plag-bi-op	Direct from contact with diorite N of the Hodges Complex.
H-36	Ohau	hb-plag-bi-gt-op	hb-plag-bi-op	Direct from contact with ultra-mafic rocks N of the Hodges Nickel Prospect.

KEY:

cord = cordierite	plag = plagioclase	hyp = hypersthene
ky = kyanite	qtz = quartz	hb = hornblende
st = staurolite	chl = chlorite	op = opaques
gt = garnet	sill = sillimanite	grun = grunerite
bi = biotite		

Table 02 – Contact-metamorphic mineral assemblages in the country rocks near the Hodges Complex compared with the regional assemblage outside the contact aureole. (Merguerian, 1977 ms., Table 3, p. 77.)

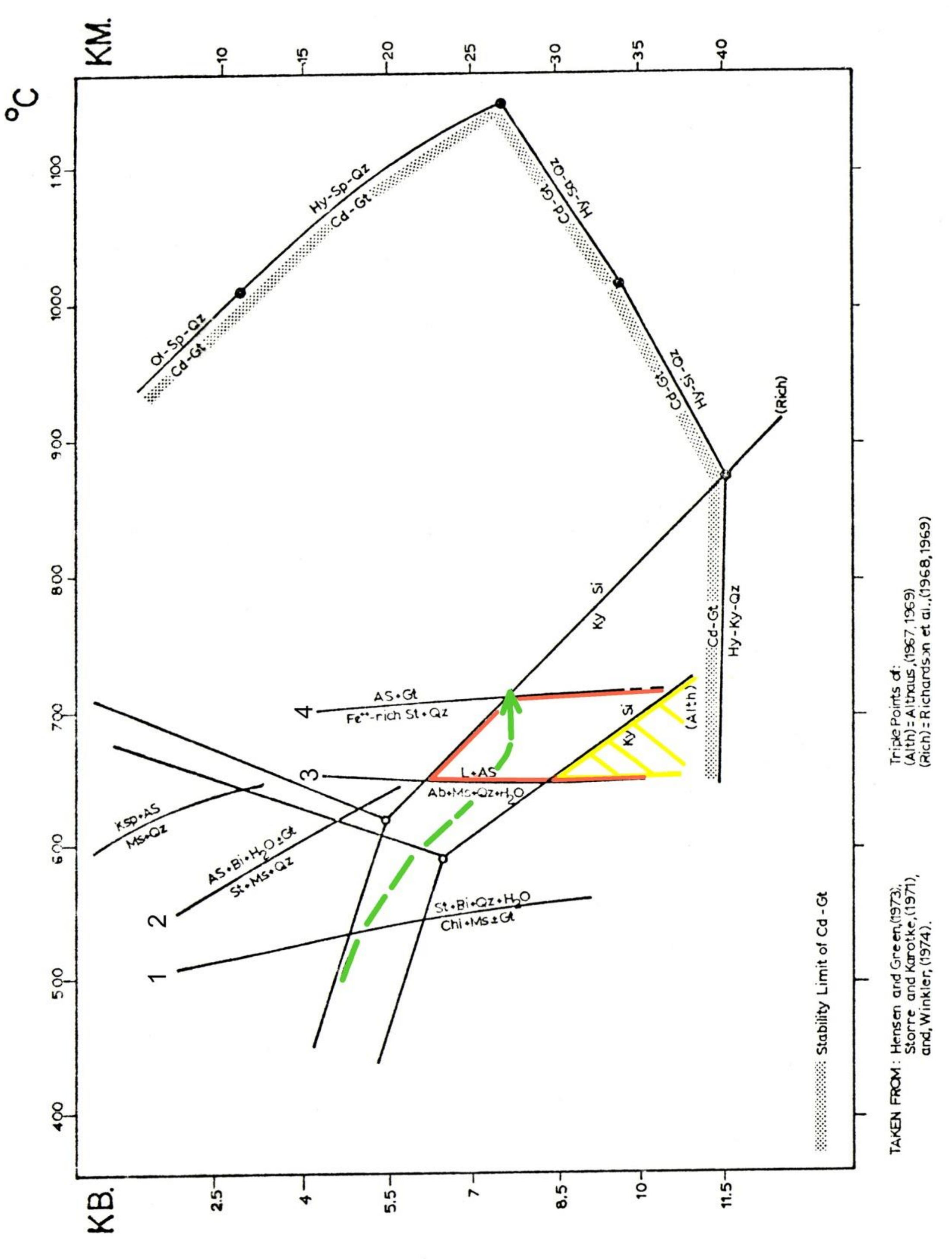

Figure 13 – The bold arrow is the suggested P-T trajectory experienced by rocks in the West Torrington quadrangle based on my analysis conducted in 1977. Abbreviations used are albite (Ab), aluminosilicate (AS), biotite (Bi), chlorite (Chl), cordierite (Cd), garnet (Gt), hypersthene (Hy), potassium feldspar (Ksp), kyanite (Ky), granitic liquid (L), muscovite (Ms), olivine (Ol), quartz (Qz), sapphirine (Sa), sillimanite (Si), spinel (Sp), and staurolite (St). (Adapted from Winkler (1974). Triple points of: (Alth) = Althaus (1967, 1969) and (Rich) = Richardson (1968) anf Richardson et al., (1969).)

Therefore the range of possibilities for prevailing P-T conditions during intrusion of the Hodges Complex vary from about 23 to 40 km of depth (6 to 11 Kb pressure) and temperatures ranging from 675° C to 700° C. Certainly the extremely high pressures are unreasonable since there is no evidence of eclogite in the ultramafic and mafic areas, nor of pyroxene or hornblende granulite facies mineralogy in the schistose country rocks. In actuality hornfelsic rocks do not differ markedly in mineralogy or texture from "normal" schists, gneisses, and amphibolites.

In the country rocks, post-S_2 staurolite-kyanite-garnet-biotite assemblages have been noted, and sillimanite grade rocks appear to the north and northwest of the study area. Because the contact aureole and regionally metamorphosed rocks outside the aureole contain staurolite, kyanite, garnet, and biotite porphyroblasts that include the regional schistosity (S_2), intrusion and post - S_2 regional metamorphism may have occurred at the same crustal levels. Because there is no clear overprinting of contact minerals by the late, post-S_2 regional metamorphism, the simplest interpretation is that the contact metamorphism and intrusion, and peak of regional metamorphism were coeval. If this is true, prograde metamorphism probably followed a trajectory as shown on Figure 13 as a green arrow. The flattening of the metamorphic trajectory arrow just below the triple point records local temperature increase at the walls of the Hodges Complex. Yet, the diagram is dated as it is from 1977 and the Al_2SiO_4 triple point has been moved to somewhat lower temperatures and pressures. As such, modern studies will better define these parameters.

Field Trip Localities

Driving Directions

Take Route 8 and get off at Exit 42 (CT Routes 118 and 8). Turn east on Route 118 at the end of the exit ramp and park in the commuter parking lot at the SE corner of the interchange. Outcrops of the Hartland upper member occur across (N) from the parking lot on the north side of Route 118. **This our meeting place for today's field trip.**

Stop 01 - Hartland Formation (upper member) granofels, schist, amphibolite, and coticule rocks [UTM Coordinates: 656.80E / 4624.88N, Torrington quadrangle.]

A convenient place to initiate today's field trip, the rocks exposed in the roadcut across from the commuter lot were originally described by Martin (1970). Here, 2- to 15-cm-scale very well-layered muscovite-biotite-plagioclase-quartz-(hornblende)-(garnet) granofels are interlayered with schist having similar mineral assemblages. The major minerals are listed in order of decreasing abundance, those in parentheses are not found in all exposures. The abundance of muscovite in the granofels and schist creates a lustrous sheen from foliation surfaces that reflects sunlight. A layer of hornblende-plagioclase-biotite-epidote-quartz-(garnet) amphibolite 2 m thick and some thin (cm-scale) coticule rocks are exposed on the south-facing portion of the exposure - see if you can spot them. The pervasive interlayering of granofels and schist, high content of muscovite and plagioclase, and presence of amphibolite and coticule suggest that the protoliths of these rocks were volcaniclastic graywackes and interlayered shale with subordinate basalt flows and possible hot spring hydrothermal mineralization. The Hartland upper member is similar to and correlative with the Moretown Formation and Ratlum Mountain Schist of western Connecticut and Massachusetts (Figure 14).

The dominant layering is parallel to the composite S_1 + S_2 regional foliation, all striking roughly N65°E and dipping 60°NW. The S_1 + S_2 foliation has been deformed by crenulate F_3 folds with axial surfaces oriented N30°E, 26°SE. The F_3 hinge lines are expressed as L_3 crinkle-axis lineations in highly micaceous layers and as L_3 intersection lineations in more-massive granofels. The F_3 and L_3 elements trend N55°E and plunge 9°. Note the upright warping of S_3 axial surface traces and the decrease in wavelength of F_3 folds in mica-rich interlayers. A pegmatite 2 m thick intrudes across the S_3 axial surfaces, locally rotating F_3 folds and older fabrics. Note the F_4 "z" folds with N20°E, 84°NW axial-planar slip cleavage.

Near the eastern end of the roadcut, L_2 lineations are deformed by subhorizonal F_3 folds and overprinted by L_3 lineations. The associated S_3 axial surfaces (N40°E, 20°SE) are warped by late F_4 crenulations with axial surfaces oriented roughly N25°E, 70°NW. Broad arching by later F_5+ is also evident.

On the west-facing portion of the roadcut adjacent to the northbound entrance ramp for Route 8, F_2 intrafolial folds are present in thinly layered granofels. The S_2 axial surface strikes N55°E and dips 56°NW and F_2 hingelines are subhorizontal, trending N55°E-S55°W. The F_2 folds deform a pre-existing S_1 mica foliation. To the north along the roadcut, many amphibolite layers are exposed.

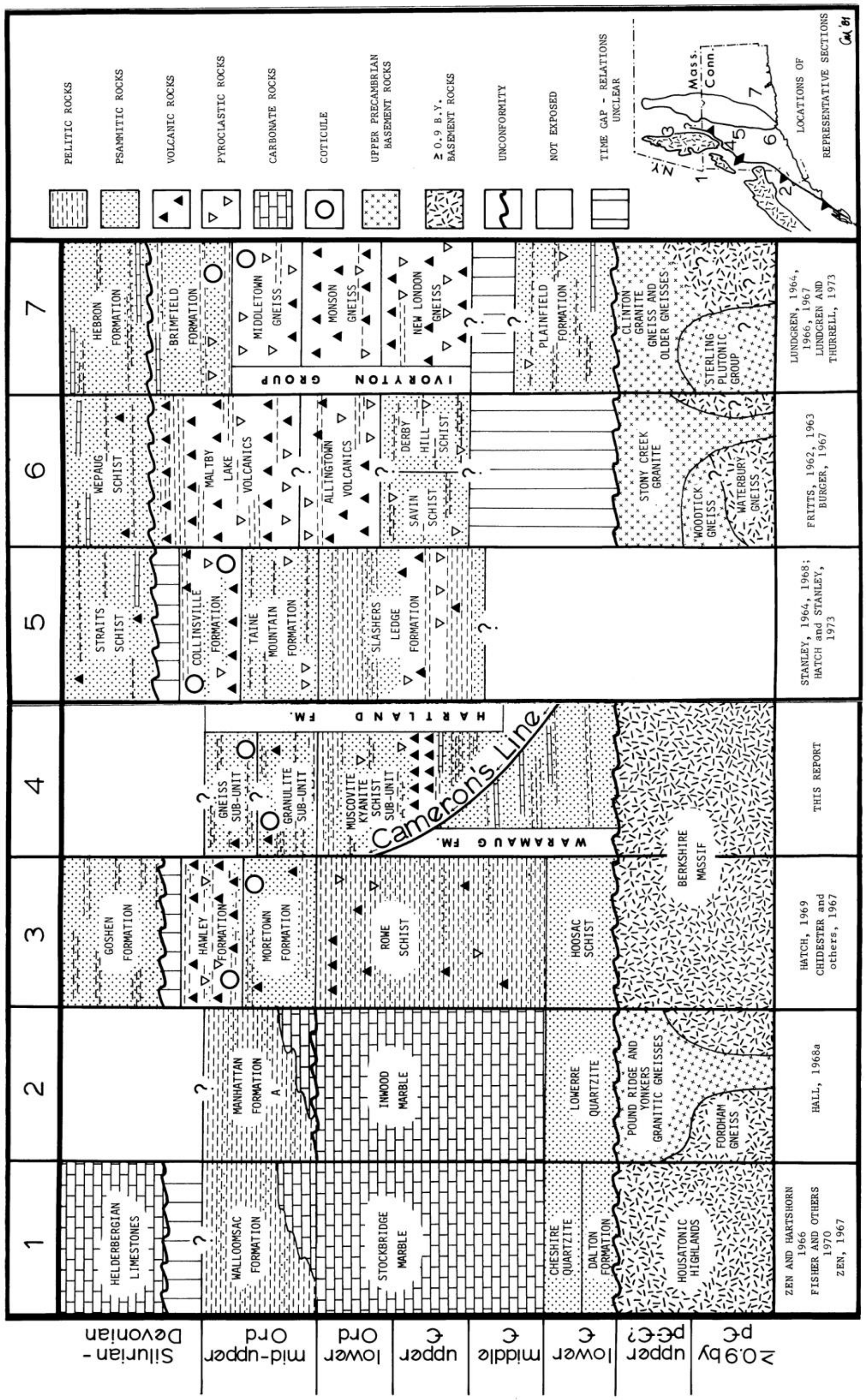

Figure 14 – Stratigraphic correlation chart for southern New England showing the interpreted protoliths of the lithologies depicted. Mixed symbols indicate relative, non-quantitative abundances of various pre-metamorphic lithologies. (From Merguerian, 1985, fig. 3, p. 414.)

MILEAGE **TOTAL INTERVAL**

0.0 0.0 Exit the commuter lot and take the northbound ramp for Route 8 toward Torrington. In the exposure 0.6 miles from the starting point, note the upright F_2 folds. At exit 44 (Routes 4 and 202, Downtown Torrington) follow the exit ramp to the traffic signal.

3.3 3.3 Make a left traveling westward on Route 202 (East Main Street) past three traffic lights.

3.9 0.6 At the fourth traffic light, bear right (across Main Street) up the hill onto Water Street. Follow Water Street past the railroad tracks to the traffic light.

4.3 0.4 Turn left onto Church Street. Drive over the Naugatuck River that separates Proterozoic Y gneiss of the Berkshire massif on the east from the Tyler Lake Granite on the west. Follow Church Street to the small traffic triangle.

4.6 0.3 Turn left (west) driving uphill onto Highland Avenue. For the next 0.9 miles, the Tyler Lake Granite crops out in wooded areas away from the road. Pass Allen Road on the right (5.2 mi.) and Stop 04 near Patterson Pond (5.6 mi.). Continue west, now driving on Ohgr and pass the radio towers to the right (6.3 mi.), which essentially mark the contact between the upper- and lower members of the Hartland.

6.4 1.8 Pass Westside Road on the right and Rossi Road on the left and continue uphill to the massive outcrops on either side of the road (here known as Soapstone Hill Road!).

6.8 0.4 Park in the bend of the road just past the exposures.

Stop 02 - Hartland Formation (lower member) amphibolite and subsidiary D_2 shear zone
[UTM Coordinates: 651.75E / 4629.13N, West Torrington quadrangle.]

The roadside exposures consist of fine- to medium-textured, dark-green hornblende-plagioclase-biotite-(quartz)-(epidote)-(chlorite)-(garnet) amphibolite with lineated prismatic hornblende. Elliptical quartz segregations up to 4 cm thick lie within the S_2 foliation. Elsewhere, felsic granofels, +/- hornblende, +/- biotite, +/- chlorite in layers 1 to 2 m thick, are interlayered with the amphibolite and the muscovitic schist.

The S_2 foliation strikes N15°W and dips 67°SW and a prominent L_2 hornblende lineation trends N80°W and plunges 65°. Because of intense transposition and overprinting during D_2, S_1 is essentially coplanar with S_2. S_2 and L_2 parallel the axial surfaces and hingelines of rootless F_2 isoclinal folds exposed on gently northeast-dipping joint faces. The S_1 foliation, composed of hornblende and plagioclase, is locally preserved in F_2 hinges. Because of the coplanar $S_1 + S_2$ foliation and a sub-parallel S_4 spaced cleavage striking N-S and dipping 75°W, the amphibolite tends to break into wedge-shaped pieces. Oriented samples show that S_4 is defined by idioblastic biotite, the product of M_3 metamorphism.

Walk 110 m west on Soapstone Hill Road where amphibolite exposures exhibit S_2 mylonitic layering (N14°W, 82°SW). Between these exposures, the muscovite schist is phyllonitic and thin. (See Figure 4.). The mylonitic textures mark a subsidiary D_2 shear zone that imbricates the Hartland amphibolite. Alternatively, shearing could simply have been the result of ductility contrasts developed across the amphibolite-schist contact.

STOP 02a (Optional) - Soapstone Quarry [UTM Coordinates: 653.63E / 4629.55N, West Torrington quadrangle.]

Walk north on a dirt trail immediately west of the parking area for Stop 02. Along the way, ridges are composed of amphibolite and the intervening valleys are underlain by muscovitic schist. Roughly 700 m north, the trail ends at a pit, of a former soapstone quarry, that is 90 m long by 20 m wide. (They don't call it Soapstone Hill Road for nothing, you know!). The excavation, which is oriented parallel to S_2 in the bounding muscovite-chlorite schist, produced commercial quantities of soapstone. Blocks from the tailings pile include talc-tremolite schist, chlorite schist, and very coarse amphibolite rich in opaque minerals. The quarry is on strike with mylonitic amphibolite to the south. The elongate shape parallel to S_2 and foliated nature of the altered serpentinite body suggests that the soapstone-talc body represents ultramafic rock deformed during D_2 and possibly D_1. It may mark a syntectonic ultramafic intrusive (Gates and Christensen, 1965) or a small sliver of ophiolite (Merguerian, 1979).

MILEAGE	TOTAL INTERVAL	
6.8	0.0	Continue west on Soapstone Hill Road and pull into a large clearing to the left.
7.3	0.5	Exposures for Stop 03 are in the woods north of the road.

Stop 03 - Hartland Formation (lower member) muscovite-kyanite-staurolite schist [UTM Coordinates: 651.10E / 4629.12N, West Torrington quadrangle.]

The lower-member Hartland schist crops out less than 50 m north of the road. The rocks are highly lustrous, gray-weathering, medium- to coarse quartz-muscovite-plagioclase-biotite-opaque-(garnet)-(chlorite)-(apatite) schists often containing 1-to 10-cm porphyroblasts of kyanite, staurolite, and garnet, and more rarely, plagioclase and biotite. The proportions of quartz and muscovite are roughly equal. Together, these two minerals constitute more than half the rock. The appearance of deeply eroded exposures is knotted. This results from differential weathering of porphyroblasts. Granular, clear- to smoky-gray quartz pods are conspicuous and have been flattened into S_2. Near contacts with amphibolite, the content of hornblende, chlorite, and/or biotite in the lower member increases markedly.

The muscovite schist, amphibolite, and rare felsic granofels of the lower member are probably derived from metamorphosed pelitic sediments within which units of basalt and rare volcaniclastic layers (ash-fall tuffs?) were interbedded. The rocks are lithically correlative with the Rowe Schist of western Connecticut and Massachusetts. (See Figure 14.) The large, non-oriented porphyroblasts of kyanite, staurolite, and garnet overgrow the S_2 foliation and represent the M_2 metamorphism (Table 01). Kyanite tends to occur mimetically within S_2. Staurolite forms porphyroblasts (sometimes twinned) protruding at random from the schist (Figure 15).

Figure 15 – Staurolite-kyanite schist of the lower unit of the Hartland Formation (Ꞓ-Ohmk), West Torrington, CT. Handlens is roughly 1 cm in diameter. (CM digital image of Dukelabs specimen 0830.)

MILEAGE TOTAL INTERVAL

7.3 0.0 Backtrack east on Soapstone Hill Road.
9.0 1.7 Make a sharp right onto a partly hidden dirt road just past Patterson Pond. Pull up as far as possible.

Stop 04 - Cameron's Line and dismembered ophiolite [UTM Coordinates: 653.70E / 4629.30N, West Torrington quadrangle.]

The mylonitic amphibolite (Ohau) exposure on the dirt road occurs within Cameron's Line, a zone 90 m thick consisting of highly sheared, tectonically intercalated units of the Hartland (upper member) and the Waramaug formations (Figure 16).

In the amphibolite, an S_2 mylonitic foliation (N85°W, 70°NE) is parallel to the axial surfaces of F_2 folds with sheared-out limbs plunging 40° into N75°W (Figure 17). In the hinge areas of F_2 folds, one finds an S_1 foliation composed of aligned hornblende. A specimen collected from this exposure after blasting in 1973 shows an F_1 isocline refolded by F_2 with significant shearing and recrystallization parallel to S_2. (See Figure 7.) F_3 folds with subhorizontal axial surfaces warp S_2. The mylonitic amphibolite is interlayered with lustrous muscovitic gneiss (Ohgn).

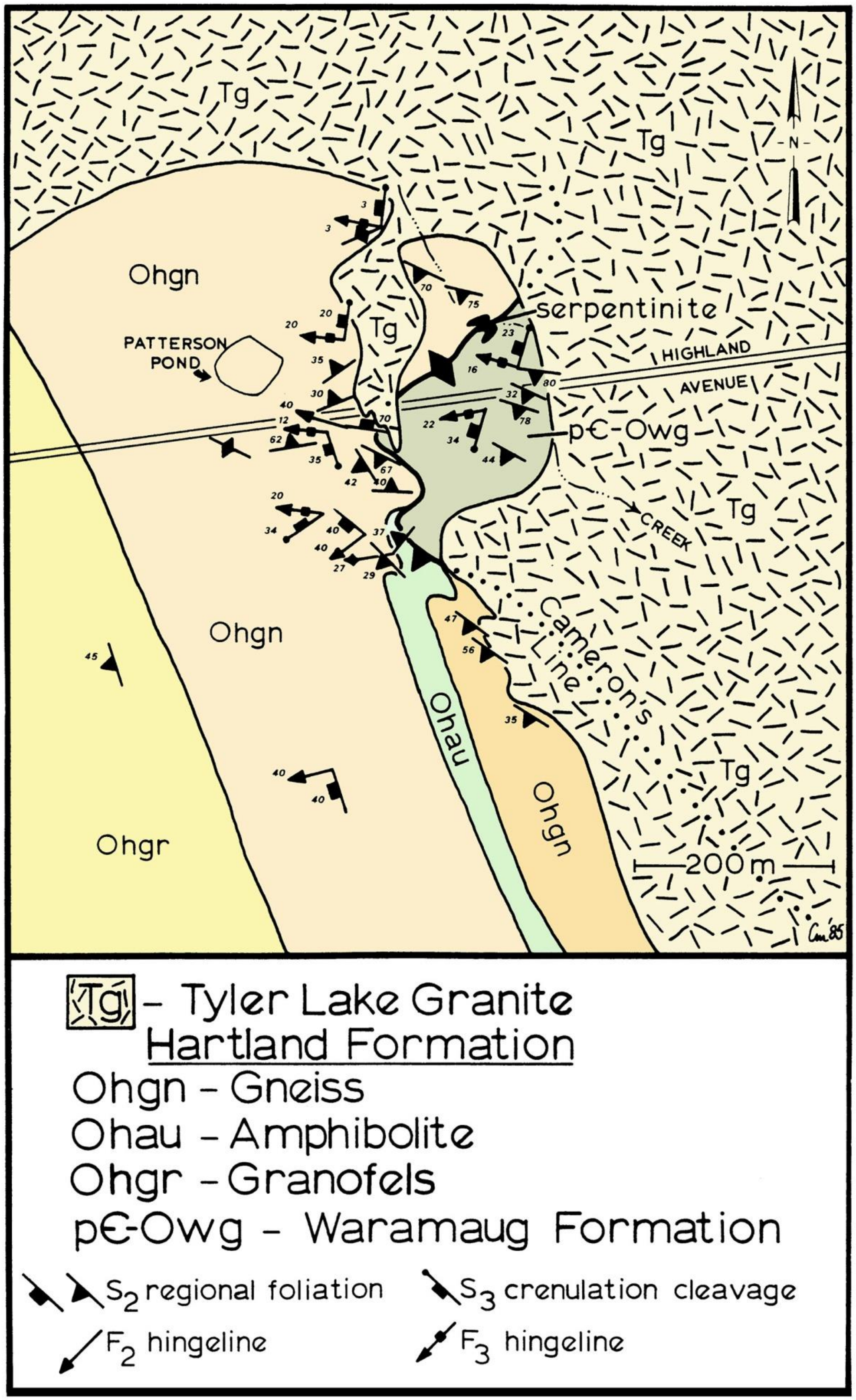

Figure 16 – Geological sketch map in the vicinity of Stop 04. (Colorized from Merguerian, 1987, fig. 6, p. 163.)

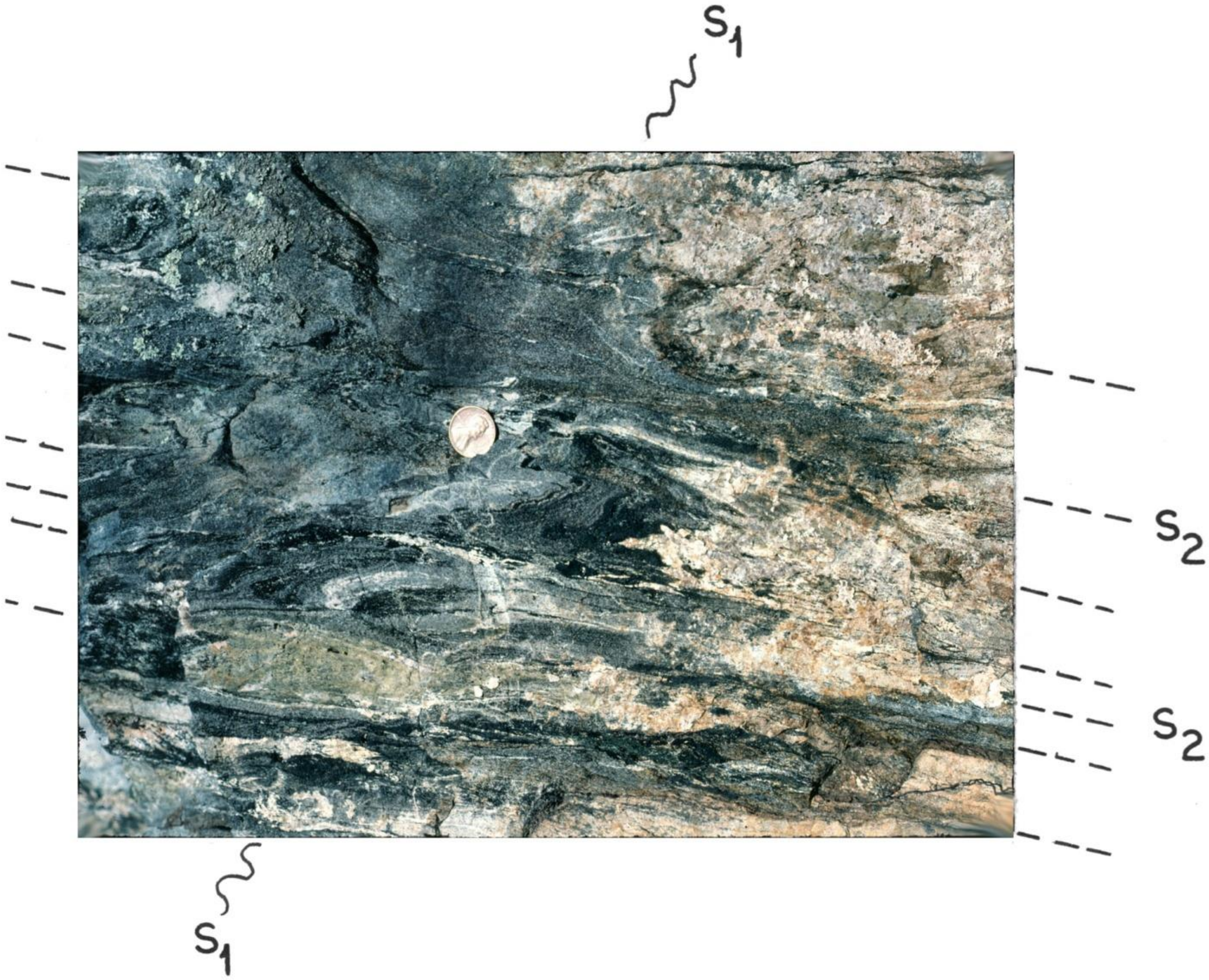

Figure 17 – Sheared amphibolite (Ohau) at the Hartland-Waramaug Formation contact (Cameron's Line) near Patterson Pond. The early gneissosity (S_1) is transposed along S_2 shear zones near the base of the photograph. (From Merguerian, 1977 ms.)

The Hartland crops out to the north, west, and south. (See Figure 16.) Follow the dirt road south, stopping first to examine the Hartland gneiss exposures on the subdued knob to the east. Here, because of F_3 folding, S_2 dips gently toward the west. About 120 m to the south, note mylonitic amphibolite in the woods to the east. S_2 strikes N40°E and dips 37°NW; L_2 trends S80°W and plunges 27°. Farther south and east, the Tyler Lake Granite crops out. Walk back to Highland Avenue and walk east roughly 100 m. The first exposure on the right (before the creek) consists of massive, rusty-weathering quartz-plagioclase-biotite-sillimanite-muscovite-garnet-chlorite-tourmaline gneiss of the Waramaug Formation. The laminated S_2 mylonitic foliation strikes N65°W and dips 32°SW. The Waramaug crops out to the south and north. As such, Cameron's Line is situated between these exposures and the cars.

As we walk north, adjacent to the small creek, note the overturned F_3 fold with pegmatite intruded along S_3. The small hill to the west is underlain by southwest-dipping Waramaug gneiss. Trace the creek to where a 10-m isoclinally folded serpentinite body is folded by F_2 folds

(Figure 18) and separates Waramaug rocks to the southeast from Hartland rocks to the west and northwest. The serpentinite is zoned and highly altered and contains relict olivine and orthopyroxene. The zoning (compositional? or tectonic?) has resulted from relative enrichment of greenish, intergrown cummingtonite and tremolite in the upper part of the body compared to the dense, black serpentine- and anthophyllite-enriched lower part.

In mineral composition and texture, this body differs from ultramafic rocks of the Hodges Complex. The overall eugeoclinal nature of the Hartland and the features resulting from D_2 (and possibly D_1) deformation in the serpentinite suggest that the body represents dismembered ophiolite (Merguerian, 1979). **Note:** As of March 2000, because of construction of homes immediately west of this classic exposure (Merguerian 1987), fill has been used to cover some of the original outcrop shown below as figure 18.

Figure 18 – Photograph (facing east) of an isoclinally folded serpentinite occurring at Cameron's Line with a steep S_2 axial surface trace (dashed line). The serpentinite is zoned and highly altered containing relict olivine and orthopyroxene with intergrown amphiboles. The compositional zoning (thin white line folded by F_2) is due to relative enrichment of matted cummingtonite and tremolite with minor serpentine in the upper part of the body in comparison to the dense black serpentine- and anthophyllite-enriched lower part. (Photograph taken ~ 1976.)

MILEAGE TOTAL INTERVAL

9.0 0.0 Drive east on Highland Avenue back to the turnoff from Church Street.
10.0 1.0 At the stop sign, turn left onto Riverside Avenue. At the entrance to Charlene Susan Besse Park (10.9 mi.), note the exposures of Waramaug amphibolite (p€-Owga). On the

hilltop roughly 500 m due south, Waramaug rocks are exposed. Continue north on Riverside Avenue to the intersection with State Route 4.

11.3 1.3 Turn right onto Route 4 and drive 0.25 miles east to Scarpelli's Drive-In. Those without lunch can pick something up here but we'll lunch at a nearby picturesque spot. With supplies in hand, drive west on Route 4 to the traffic light.

11.8 0.5 Turn right onto Route 272 toward Wrightville.

12.6 0.8 Turn right onto Brass Mill Dam Road.

12.9 0.3 **LUNCH STOP**. Park near the wide area south of the dam. There are nice places to lunch to the slopes to the north.

Post Lunch Stop

In the woods to the west, the Waramaug crops out. In the spillway north of the cars, are other excellent exposures although development in the area may preclude our studying them for too long. Here, the Waramaug and interlayered amphibolite have been deformed into 15-m amplitude F_2 folds with N42°E, 57°NW axial surfaces and hingelines trending S40°W at 15°. F_5 crenulate "z" folds trend W at 37°; the attitude of the S_5 axial-surface cleavage is N15°W, 52°SW. Because abundant closely spaced fractures oriented N20°W, 75°SW cut the exposed Waramaug rocks hereabouts as Stillwater Pond is fault controlled.

MILEAGE	TOTAL INTERVAL	
12.9	0.0	Backtrack on Brass Mill Dam Road.
13.2	0.3	Drive across Route 272 uphill onto Hodges Hill Road.
13.7	0.5	At the stop sign, turn right onto University Drive (Town Farm Road).
14.1	0.4	Turn left onto John Brown Road and continue to private driveway turnoff to the left.
14.3	0.2	Pull in as close as possible; we're at Stop 05.

Stop 05 - Waramaug Formation and contact relationships with Hodges diorite sills [UTM Coordinates: 652.38E / 4633.12N, West Torrington quadrangle.]

Walk roughly 60 m south on the dirt trail to an exposure of massive but internally laminated, gray-weathering quartz-plagioclase-biotite-sillimanite-muscovite-garnet gneiss. The rocks at this exposure are similar to those of the Waramaug at Stop 04. Because of differential erosion of quartz and sillimanite, the weathered surface is nubby. A 30-cm layer of garnet amphibolite has been isoclinally folded by F_2. Here, S_2 strikes N80°W and dips 83°SW. L_2 lineations trend N85°W at 26°. A spaced S_4 slip cleavage oriented N26°E, 84°NW deforms S_2.

To the northeast and southwest, the Waramaug crops out. The exposures on the northeast show S_1 metamorphic layering trending N20°E, 17°NW that has been folded by upright antiformal F_2 "m" folds having vertical axial surfaces oriented N75°W, and hingelines trending N75°W at 17°. To the southwest, the exposures illustrate the typical massive, nubby-weathered appearance of the Waramaug Formation. S_2 strikes N80°W and dips 83°NE; a prominent L_2 lineation trends N70°W at 36°. L_2 has been produced by intersection with S_1 that is locally preserved at a small angle to S_2. Commonly, S_1 has been transposed into parallelism with S_2 but here, because of F_2 isoclinal folding, S_1 dips 70° to 75° NE. The axial surface traces of F_2 isoclines are indicated in Figure 19.

At the southern margin of the gneiss, note the abundance of garnet. The enrichment marks the contact effects of adjacent flow-layered diorite of the Hodges Complex. The diorite forms a small sill intruded parallel to S_2 in the Waramaug. (See Figure 19.) The microscope shows that in the Waramaug wall rocks, the contact garnets (up to 1 cm) have grown across S_2. Garnet has also been enriched in the diorite. This enrichment suggests that limited alumina metasomatism from the wallrocks has taken place.

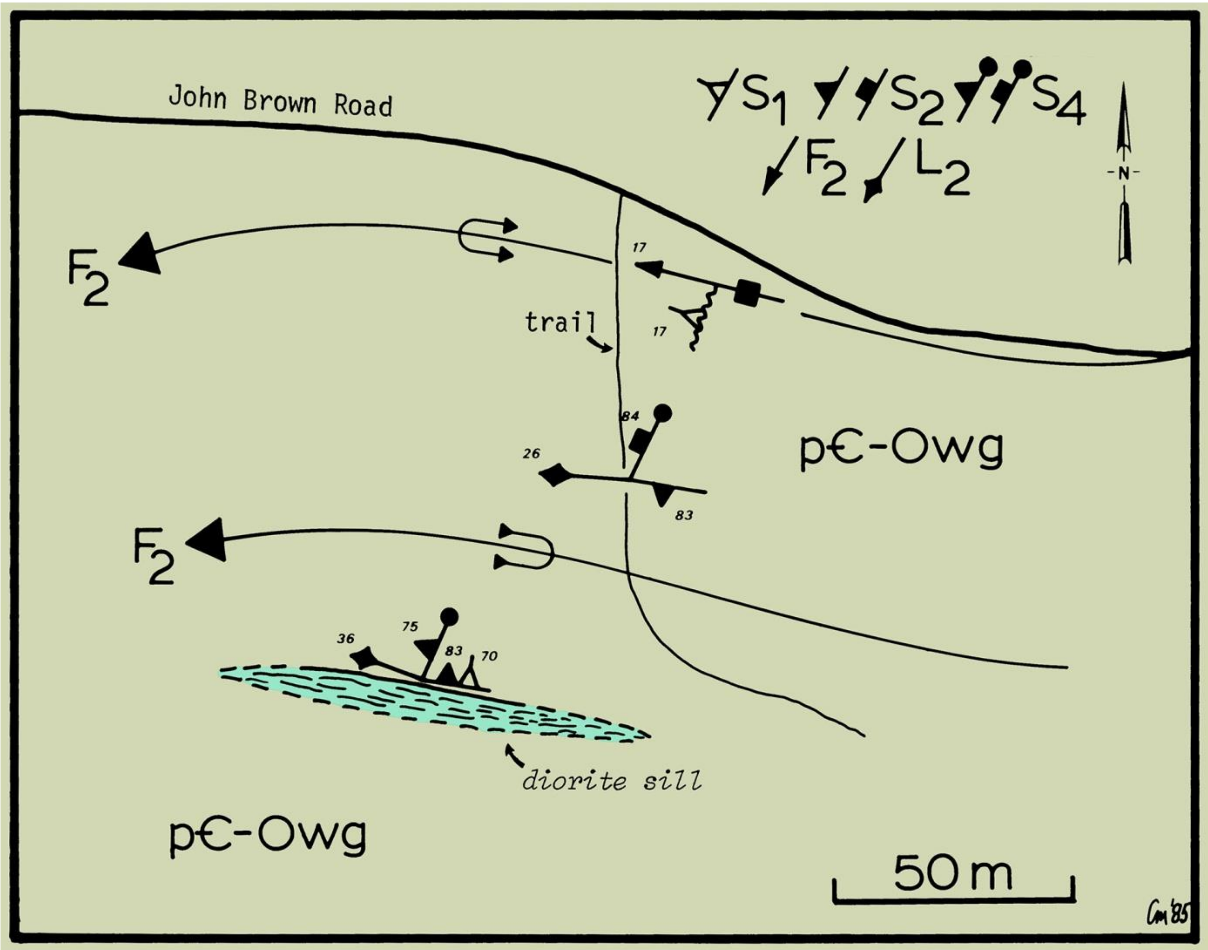

Figure 19 – Geological sketch map of Stop 05 showing outcrops described in text and trace of major subvertical S_2 axial surfaces. (Merguerian, 1985, fig. 11, p. 433.)

In the woods to the east and west, Hodges diorites were intruded as sills and lit-par-lit injection bodies (typically less than 10 m thick) along S_2 in the Waramaug. Flow layering, defined by oriented hornblende and biotite set in a matrix composed of plagioclase, is regionally parallel to S_2. In addition, garnetiferous diorite sills to the east are folded by SW-plunging F_4 folds and cut by a spaced S_4 biotite schistosity (developed during M_3) oriented N25°E, 75°NW.

The near east-west trend of S_2 in this area has resulted from the effects of the major dextral F_4 fold. (See Figure 4.) On the flanks of the F_4 fold (Stops 02, 03, 04, and 09), S_2 trends approximately NNE, but in the F_4 hinge areas (Stops 01 and 05), the trends are nearly east-west.

The post-S_2 field- and textural evidence on the contact relationships of the diorites fixes the time of intrusion as being late syn- to post-D_2. Crosscutting by features made during D_4 deformation and the overprinting effects of M_3 place an upper relative age limit on the Hodges intrusive episode.

MILEAGE TOTAL INTERVAL

14.3 0.0 Backtrack east on John Brown Road and turn right (south) on University Drive toward Route 4.
15.4 1.1 Turn right (west) on Route 4 and continue past Klug Hill Road and Wright Road to Weed Road.
16.4 1.0 Turn left (south) onto Weed Road and park about 0.1 miles south along the side of the road.
16.5 0.1 The 1320' hill to the west is Stop 06.

Stop 06 - Mafic and ultramafic rocks of the Hodges Complex [UTM Coordinates: 652.15E / 4632.64N, West Torrington quadrangle.]

As we walk up the overgrown trail westward from Weed Road, notice that the hill to the west is primarily composed of hornblende gabbro. Locally, this rock is melanocratic and its texture, porphyritic. Concentrations of mafic minerals and oriented hornblendes define a west-dipping flow layering. Near the top of the hill and in a small pod to the south, coarse pyroxenite and hornblendite crop out. Here, the Hodges intrusives mask Cameron's Line. But based on detailed tracing of screens and xenoliths Cameron's Line crosses the top of the hill in a S20°W direction. The Hodges rocks are in contact with both the Waramaug and Hartland to the west and east, respectively.

To the east, many xenoliths and screens of the Hartland (upper member) display the effects of contact metamorphism. New minerals include cordierite, kyanite, sillimanite, staurolite, and garnet. Muscovite has been eliminated. In the Hartland amphibolite, garnets up to 3 cm across have overgrow the S_2 foliation (Figure 20). Float blocks draping the slopes to the east of Weed Road include pieces showing hornblende porphyroblasts overgrown on S_2 in Hartland amphibolite. Contact-metamorphic assemblages are fully discussed at the next stop (Stop 07).

To the west, near exposures of the Waramaug, flow-layered diorite trends N25°E; the dips are vertical to steep easterly. The Waramaug consists of a dense hornfels peppered with garnet. Despite these contact-mineral changes, the characteristic nubby weathering is still preserved. Along the western slope of the 1320' hill, the Waramaug contains white tremolitic calc-silicate layers.

Figure 20 – Large (up to 3 cm) garnet porphyroblasts over grow the S_2 regional foliation in Hartland amphibolite near the intersection of Weed Road and Route 4. This area is NOT open to collecting - private property!

MILEAGE TOTAL INTERVAL

16.5 0.0 Return to Route 4 and turn right. Drive slow and prepare to turn left at Wright Road.
17.1 0.6 Follow Wright Road north and park near the first red barn on the left.
17.2 0.1 The ridge to the northwest is Stop 07.

Stop 07 - Mafic and ultramafic rocks of the Hodges Complex and the Hodges Nickel Mine and Prospects [UTM Coordinates: 651.80E / 4632.11N, West Torrington quadrangle.]

Walk from the red barns northwestward onto a ridge with the cell tower where flow-layered diorite grade westward into coarse-textured gabbroic rocks. The diorites were multiply intruded as thin sill-like masses parallel to S_2 in the Hartland Formation. In the contact zone, both the Hartland and the diorites have been strongly enriched in garnet. Flow layering in the diorites is oriented N65°E, 70°NW. Near the top of the ridge, massive gabbroic rocks are present; they extend toward the northeast. Chemistry indicates slightly alkalic compositions according to Nick Ratcliffe (pers. comm. 2015). His two gabbro analyses from this spot show:

SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	LOI	TOTAL
46.15	17.00	14.32		0.192	5.54	9.27	3.36	1.35	2.216	0.4	0.7	100.5
46.96	14.31	11.5		0.17	9.38	9.17	2.53	1.82	1.94	0.52	1.45	99.74

To the west, beyond the ridgecrest, a large NE-trending mass of pyroxenite and hornblendite crops out. The ultramafic mass, which crosscuts the diorite-gabbro contact and truncates flow layering in the diorite, is interpreted as the youngest intrusive in the Hodges Complex. Locally, the ultramafic rocks have been strongly sheared, chloritized and transformed into laminated serpentinite. The shear zone, oriented N36°E, 75°NW, cuts across the central part of the Hodges. It has resulted from shearing along the axial surface of the major regional F_4 synformal fold which warps Cameron's Line, the Hodges Complex, and the Tyler Lake Granite into a broad dextral flexure. In fact, the plutons may have acted as immobile plugs localizing the F_4 hinge area. To the southwest, the S_4 shear zone is also marked by zones of serpentinization and chloritization. In between these zones, relatively nonaltered pyroxenite and hornblendite are preserved.

Contact metamorphism of the Hodges wall rocks

The contact minerals of the Hodges overprint S_2 in both the Waramaug and Hartland formations. In the contact aureole, typical foliated textures in the wallrocks have been replaced by dense, finer-textured, garnet-rich hornfels (Figure 21A). In the contact aureole, amphibolite contains post-S_2 garnet and hornblende as discussed at Stop 06 (Figure 21B). Where gabbroic rocks have been intruded into the Hartland Ohc subunit, a randomly oriented colorless amphibole of the cummingtonite-grunerite series forms. To the northeast of Klug Hill, gabbroic rocks intrude the Hartland granofels (Ohgr). They have produced a unique cordierite-kyanite-staurolite-garnet-biotite-plagioclase (An23) assemblage (Figure 21C). In the contact aureole exposed at Stop 06, staurolite is abundant and the garnet contains microlites of sillimanite.

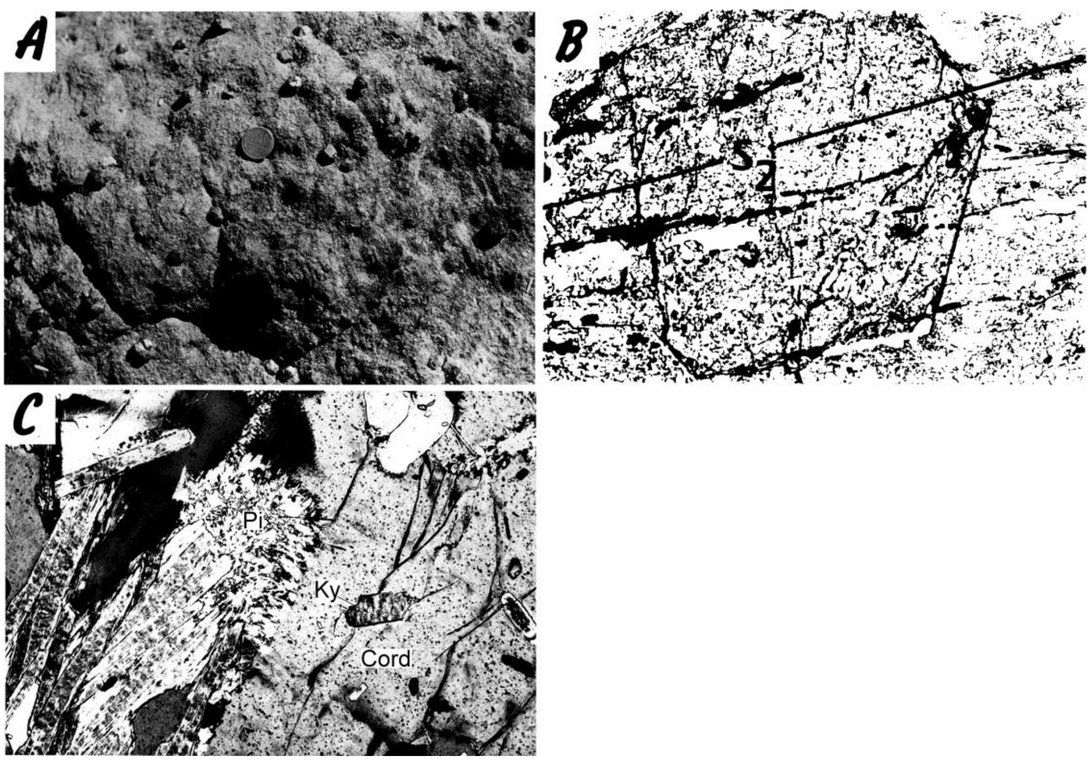

Figure 21 – Contact-metamorphic effects in wallrocks of the Hodges Complex. A) Contact-induced garnet enrichment in Hartland granofels xenolith from Stop 07. B) Garnet porphyroblast overprinting the penetrative S_2 foliation in Hartland amphibolite (Ohau) from contact aureole of the Hodges Complex at Stop 06. C) Cordierite (Cord) with typical pinnite (Pi) alteration coexisting with kyanite (Ky). Sample from contact of Hodges Gabbro with Hartland Granofels (Ohgr) on the northeast slope of Klug Hill. (From Merguerian, 1985, fig. 12, p. 436.)

No clear overprinting of contact minerals by M_2 kyanite, staurolite, or garnet porphyroblasts were detected. Rather, identical minerals formed in the contact aureole suggesting that intrusion of the Hodges and regional M_2 metamorphism were coeval (Table 01). Local temperature increases adjacent to the Hodges Complex produced cordierite +/- sillimanite and fostered the breakdown of muscovite. The 446 Ma Hodges Complex was emplaced during the late stages of the Taconic orogeny when oversteepened subduction beneath a thick orogenic welt tapped mafic- and ultramafic magmas that ascended along Cameron's Line (Merguerian 1983). Minimal contact effects are noted in the periphery of the Tyler Lake Granite presumably becuase the wallrocks were already at elevated regional metamorphic temperatures after the Hodges intrusives.

The Hodges Nickel Prospect

In addition to the deposits at Mt. Prospect, nickel from Torrington has been referenced in all of the literature that bear on the subject. Thus, Percival (1842), Shepard (1837) and Howe (1915) all discuss the Torrington locality whose mining may date back to the 1700s. Work by Agar (1930), Cameron (1951) and Gates and Christensen (1965), and Merguerian (1977 ms) have helped us understand the geology of the prospects of which I have found three extending in an east-west fashion from the main flooded shaft and mine dump (Figure 22). At the mine dump surrounding the main shaft ultramafic rock showing disseminated and podiform sulfides including pyrrhotite, chalcopyrite, and pentlandite, present in decreasing relative amounts. Earlier images of the same spot (Figure 23) show a stark landscape.

Figure 22 – View of the flooded main shaft of the Hodges Nickel mine taken in 1975 by the author. The pit, which measures about 40’ x 15’, is surrounded by a huge mine dump of ultramafic rock showing sulfides.

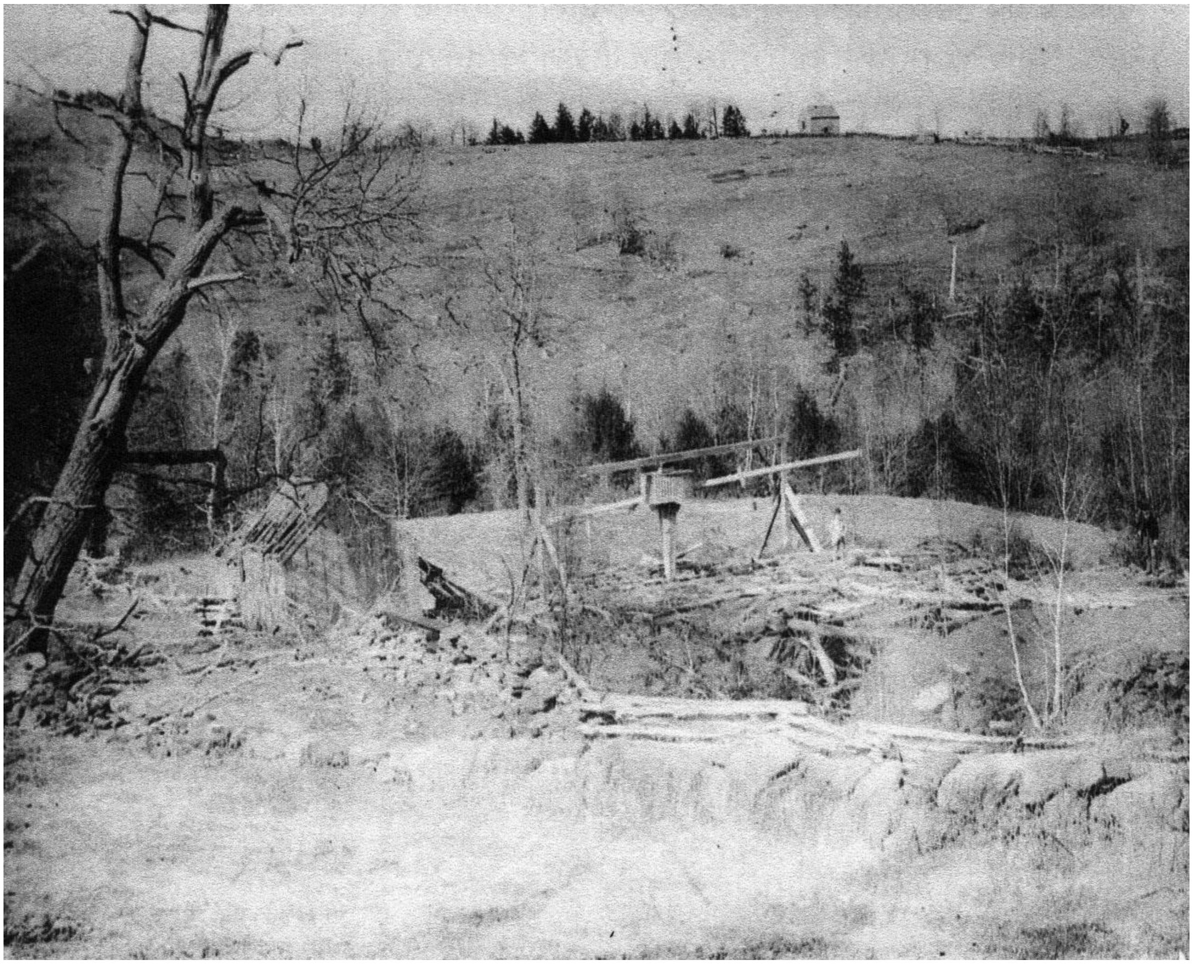

Figure 23 – Photograph taken circa late 1800s of old nickel mine (Hodges mine) in West Torrington. (From Cooper 2005, p. 26.)

Most workers describe the Hodges nickel mines as lacking any meaningful economic value yet Blake (1883) reports that nickel ore was mined "on a considerable scale". Most of the ore was sent to England for processing but alas the adventure was unprofitable and ceased operating shortly after a flurry of activity. Again, we suspect that stock holders were left holding the bag, a common theme in Connecticut mining endeavors (Moritz and Merguerian 2015). Mineral collectors have added fluorapatite, chlorite, amphibole, and violarite to the discovery menu according to www.Mindat.org.

MILEAGE TOTAL INTERVAL

17.2 0.0 Drive back to Route 4 and turn left. Follow Route 4 east to Lovers Lane.
18.2 1.0 Turn right onto Lovers Lane and make another immediate right into Bicron Electronics Co. parking lot. (Alt. PDF Co., before Bicron.)
18.3 0.1 The Tyler Lake granite crops out in the creek bed along the south edge of the lot.

Stop 08 - Tyler Lake Granite. [UTM Coordinates: 653.00E / 4631.34N, West Torrington quadrangle.]

Near the creek bed is exposed tan-weathering, medium-grained, foliated quartz-microcline-plagioclase-muscovite-biotite-garnet-(chlorite)-(apatite) granite (Figure 24). An X-ray fluorescence analysis by Dr. D. Radcliffe of Hofstra University produced the following % result: SiO_2 = 73.0, Al_2O3 = 14.2, Fe_2O3 = 1.4, MgO = 0.6, CaO = 0.8, K_2O = 5.5, Na_2O = 3.1, TiO_2 = 0.2, MnO = 0.1, loss on ignition = 0.7 (total = 99.6). The granite has been foliated by cm-spaced micaceous layering (S_4) oriented N36°E, 60°NW. The S_4 foliation is cut by a faint slip cleavage (S_6?) oriented N10°E, 42°SW.

The Tyler Lake Granite contains xenoliths of the Hodges rocks and is in direct contact with all major metamorphic units in the area (except Ꞓ-Ohmk and Ꞓ-Oha). Widely separated sample suites from the granite yield a well defined 466 +/- 12 Ma Rb-Sr isochron with initial Sr 87/86 = 0.7082 +/- 0.0011 (Merguerian and others, 1984). The 446+/- 7Ma U-Pb age on the Hodges is more reliable than the Rb-Sr age on the Tyler Lake calculated over 30 years ago. Since the Tyler Lake includes Hodges xenoliths, it must be younger than 446 Ma and younger than the S_2 regional foliation and Cameron's Line. The Sr 87/86 data imply that the Tyler Lake Granite was derived either from anatectic melting of the continental crust or materials derived from the crust (i.e., Waramaug and Hartland sequences). As such, partial melting and assimilation of subducted Hartland and Waramaug strata may have been an important process.

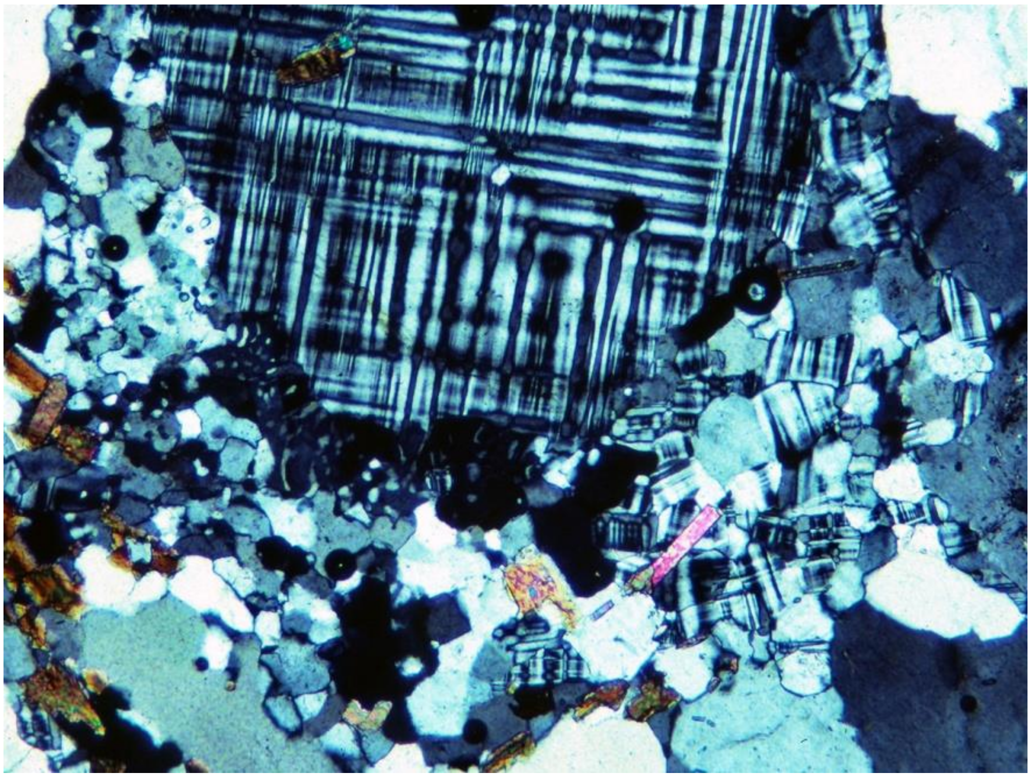

Figure 24 – Polarized light photomicrograph of the Tyler Lake Granite showing deformed large porphyroclast of microcline in a fine-textured recrystallized matrix of alkali feldspar, plagioclase, quartz. biotite, muscovite, and garnet. (Field of view ~ 2 mm.)

Stop 09 - Old Litchfield Mines. [UTM Coordinates: 652.944E / 4627.01N, West Torrington quadrangle.]

This stop was fully described late last year in an NEIGC guide (Moritz and Merguerian 2015) that focused on the unique mineral geoenvironment but I will include pertinent details in the stop description below. **The site is on private property and is only accessible during this GSC field trip by permission of the owners.**

Gigantic kyanite (to 40 cm) and ilmenite (to 20 cm) porphyroblasts were discovered in 2012 during some landscaping activity at this location. The locality is situated in NE Litchfield along U.S. Route 202 (Torrington Road) near the border with Torrington. The owners excavated, cleaned and set aside boulders exhibiting these crystals (Figure 25) and saved many smaller specimens. They also unearthed and preserved two shallow, vertical mine shafts. Despite the large size of abundant kyanite and ilmenite crystals, the mining apparently was for Cu and explains several brief, vague and mysterious 19th century reports of Cu prospecting in Litchfield during the late 18th to mid-19th centuries.

Figure 25 – Huge kyanite porphyroblasts in massive quartz. (From Moritz and Merguerian, 2015, fig. 36, p. C1-23.)

Geology and Mineralogy

Originally mapped by Gates and Christensen (1965) the region to the north of Route 202 was remapped by Merguerian (1977 ms) and similar rocks and minerals were found there. The area is underlain by metamorphic bedrock consisting of the Cambro-Ordovician Rowe Schist, originally pelitic siltstone/subgreywacke and shale; interbedded black or mottled, massive amphibolite and hornblende gneiss, representing ocean floor basalt; and lenses of calc-silicate rock, originally impure carbonates. The amphibolite is generally fine to medium-grained, well foliated and composed of hornblende and albite (An30) with minor accessory biotite, quartz, titanite, chlorite, clinozoisite, ilmenite and magnetite. Some of it is altered to epidote, typically forming a thinly banded, pistachio green and black rock, with fine-grained, specular hematite in joints. The minor calc-silicate lenses contain generally massive actinolite, grossular, albite, scapolite, epidote, titanite, quartz. These rocks underwent Barrovian prograde metamorphism to amphibolite facies (staurolite grade) during the Ordovician Taconian and Devonian Acadian orogenies.

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

Rowe Schist Porphyroblasts

The Rowe Schist is primarily (>50%) muscovite and quartz, with subordinate biotite and albite. Zones of emerald green muscovite variety fuchsite (with 0.56% chromium oxide) are abundant, these were noticed by the owner during excavations and are not mentioned in the literature. Within the schist are porphyroblasts of kyanite, ilmenite, staurolite, albite, biotite, and almandine. Merguerian (1977 ms, 1985) notes that the schist contains “large (up to 10 cm) porphyroblasts of garnet, biotite, staurolite, and kyanite”. Gates and Christensen (1965) noted the prevalence of kyanite in the site area, but make no mention of the large bull quartz masses, which here are up to a 2 meters thick and ~10 meters along strike.

A geological sketchmap of Stop 09 (Figure 26) shows 5 sub-stops that we will visit in order to examine the regional geology including the quartz veins, faults and mine workings of the area. The rocks consist of Rowe Schist with local amphibolite and are internally folded by isoclinal F_1 and F_2 folds and warped by late SW-plunging crenulate "s" folds of the foliation as shown by the warping of the S_2 foliation form lines. The schist is cut by two quartz veins (yellow in Figure 26) which vary in thickness from 3-4 m (northern vein) to ~2 m thick (southern vein). The northern vein is discordant to the S_2 regional foliation, trends N40°E, is steep to vertical and shows some slight variation in dip from NE to SW and an N65°E, 90° offshoot at sub-stop 3 (Shaft #2). This vein is cut along its NW margin by a major fault highlighted by a healed fault breccia which trend N40°E, 90° between sub-stops 2 and 3. The quartz vein has been exposed in both open pit shafts (sub-stops 3 and 5) in search of ore minerals.

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

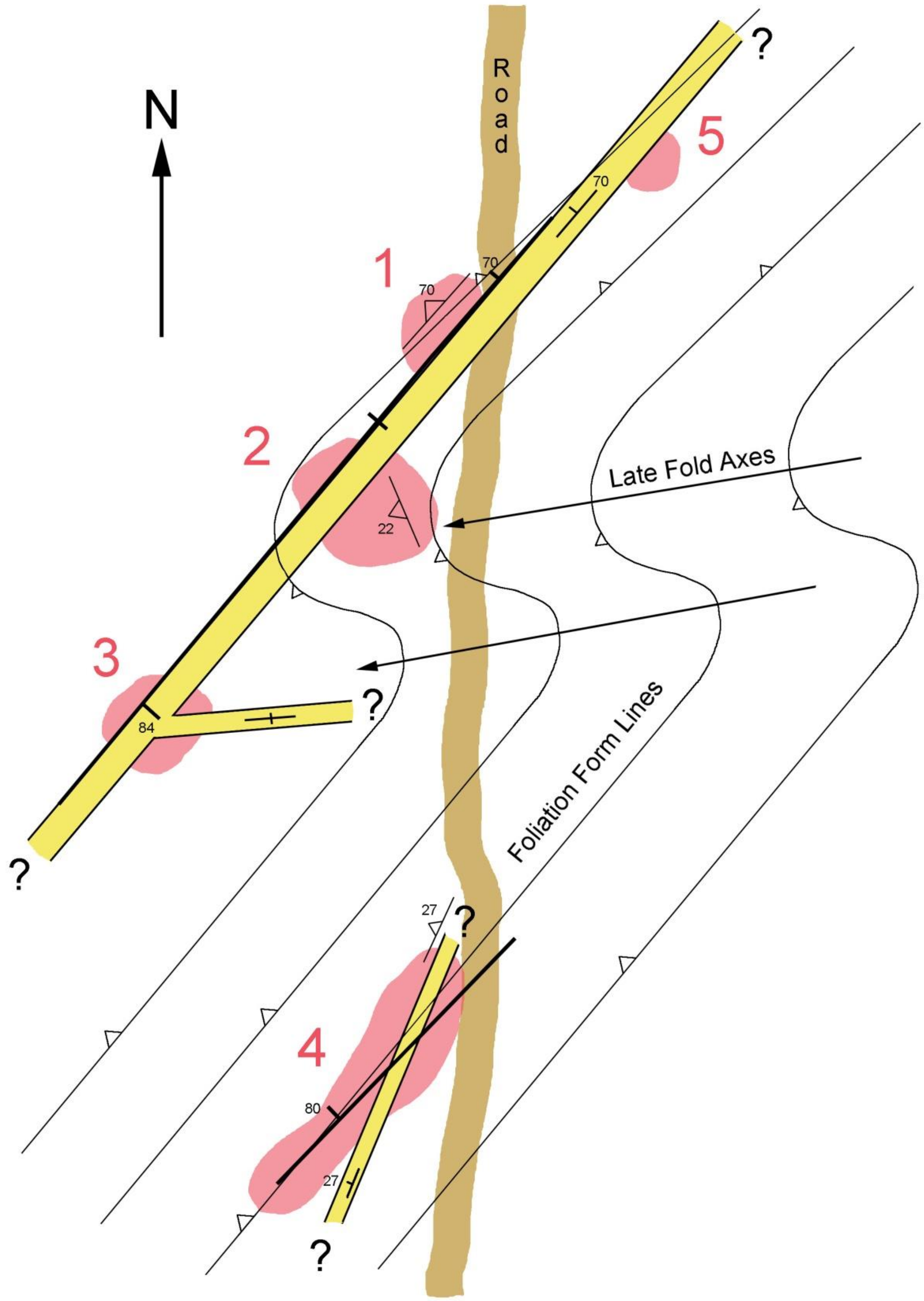

Figure 26 – Geological sketchmap of the area of Stop 09 showing the five sub-stops to be studied during our visit. Pink areas show the five numbered sub-stops. Note that Shaft #1 (as described in text) is sub-stop 5 and Shaft #2 is sub-stop 3. Also indicated are the quartz veins (yellow), the major faults (bold black lines with dip barbs showing dip direction), S_2 foliation form lines (fine black lines with foliation symbols, and the axes of late, crenulate folds of the S_2 regional foliation. The access road is shown in tan. Map is an initial draft, not to scale - for overview of site only.

The deformed kyanite and ilmenite crystallized within the schist and the conformable, associated quartz-rich boudins appear related to compressional metamorphism, given the temperatures and pressures required for their formation. Merguerian (1985) suggested they are Taconian, presumably related to regional thermal maxima produced during intrusion of the Hodges Complex which is ~446 Ma (Ratcliffe et al. 2012). But the much larger euhedral crystals found in the discordant quartz masses, although also deep-seated, require a different explanation. Exposures here provide clues to the origin of these discordant quartz masses.

One of the exposures is a vertical cut showing meter-scale quartz masses within the schist. The quartz appears to mostly cross-cut the host schist foliation, with the latter appearing to interfinger and fade into the quartz (Figure 27). A shear zone that extends into and cuts part of the schist as well is present along a portion of the quartz/schist contact. While the sense of motion along the shear is not obvious from this feature alone, the ragged portions of the contact give the impression that the schist was separated by ductile extension.

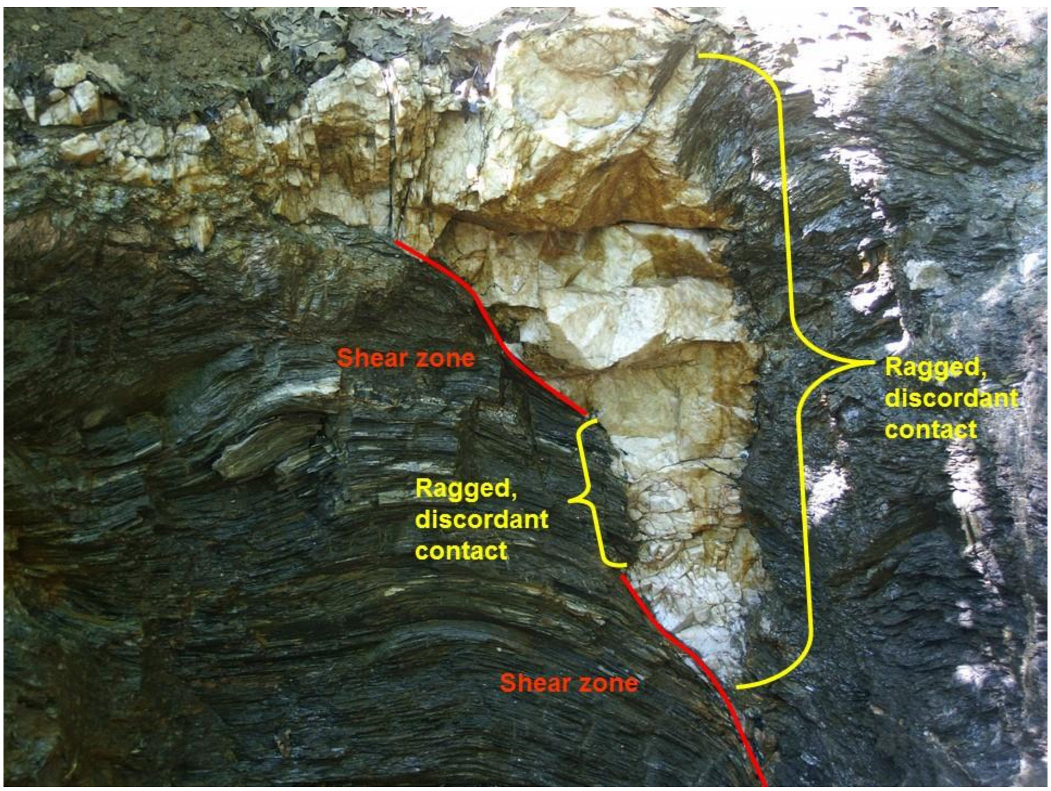

Figure 27 – Detail of the west wall of "Shaft #2" (sub-stop 3) exposing a cross-section of a discordant quartz vein in Rowe Schist. The contact at right is ragged with the schist foliation fading into the quartz. The contact at left truncates a late fold of foliation that exhibits normal shear sense that extends into and disrupts the foliation of the schist. These features suggest the schist was torn open by extension. View is about 2 m wide. (From Moritz and Merguerian 2015, fig. 40, p. C1-26.))

Supporting this interpretation is the presence of the large, euhedral ilmenite crystals along some of the contacts (Figure 28). These crystals are not rooted in the schist but must have grown out into an open (liquid-filled) space to have such perfect and undeformed shapes. Eventually the interstitial spaces solidified into massive quartz and remained undeformed. Consequently, in boulders where the quartz has broken away from the contact mostly ilmenite cross-sections are exposed. Removal of intact crystals is extremely difficult because of their good parting, brittleness, relative thinness, and the brittleness of the enclosing quartz.

Figure 28 – Tabular terminated 5 cm ilmenite crystal in milky quartz vein, West Torrington, CT. Note 1 cm handlens in background for scale. (CM digital image of Dukelabs specimen 0063 collected 1975.)

Although ilmenite is described as weakly magnetic, many of the crystals proved to be strongly magnetic or to internally vary from non-magnetic to strongly so. Closer inspection showed that many of the "ilmenite" porphyroblasts are actually partly or completely pseudomorphed by very fine-grained magnetite, hematite and/or rutile (Moritz and Merguerian 2015). This finding raises the question about the character of ilmenite from other state localities and whether there is any paragenetic relationship between these pseudomorphous minerals and their isolated counterparts in the schist.

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

Mining

The discovery of two long-abandoned vertical mine shafts on the property and other evidence of mining activity is interesting from both an historical and geological perspective because both the timing and the reasons for it were (apparently) undocumented and uncertain. As discussed further in Moritz and Merguerian (2015), this site is not as undocumented as initially believed, but the absence of any map with a mine name on it certainly contributed to its obscurity.

One shaft ("Shaft #1" = sub-stop 5 for reference) was discovered beneath a shallow, suspicious depression and was filled with debris, trash and water-soaked logs and timbers (Figure 29). Its upper part is a pit that passes through 3-4 meters or so of glacial overburden that leads to an approximately 1.25-meter-square vertical shaft about 4 meters deep cut into competent, but mineralogically unremarkable schist except for abundant fuchsite. At the base is a very short tunnel, barely more than a meter long, with part of the ceiling still held up by original timbering. Tool marks from drilling and picking are still evident on the walls, floor and ceiling. The owner has since preserved it by constructing a small shelter over the shaft and installing lights and pumps. Connecticut State Archaeologist Nick Belantoni has inspected it and believes the timbering is 200-300 years old.

Figure 29 – Shaft #1 (sub-stop 5) after excavation. Original mine timbering is visible at the top of the short tunnel lit up behind the site owner. The schist contains emerald-green muscovite variety fuchsite, likely mistaken for malachite. (From Moritz and Merguerian 2015, fig. 43, p. C1-C27.)

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

REFERENCES CITED

Agar, W. M., 1930, The Hodges Nickel prospect, Torrington, Connecticut: Am. Jour. Sci., 5th Ser., v.19, pp. 185-194.

Alavi, M., 1975, Geology of the Bedford Complex and surrounding rocks, southeastern New York: Amherst, Massachusetts, University of Massachusetts, Department of Geology, Contribution No. 24, 117 p.

Amenta, R. V., and Mose, D. G., 1985, Tectonic implications of Rb-Sr ages of granitic plutons near Cameron's Line in western Connecticut: Northeastern Geology, v. 7, no. 1, p. 11-19.

Althaus, E., 1967, The triple point andalusite-sillimanite-kyanite. An experimental and petrologic study: Contr. Mineralogy Petrol., v.16, pp. 29-44.

Althaus, E., 1969, Experimental evidence that the reaction of kyanite to form sillimanite is at least bivariant: Am. Jour. Sci., v.267, pp. 273-277.

Baskerville, C. A., 1982, Adoption of the name Hutchinson River Group and its subdivisions in Bronx and Westchester Counties, southeastern New York: United States Geological Survey Bulletin 1529-H, Stratigraphic Notes, 1980-1982, Contributions to Stratigraphy, p. Hl-HlO.

Bennington, J Bret, and Merguerian, Charles, 2007, Geology of New York and New Jersey: Physical Geology Textbook Supplement: Thomson Brooks/Cole Company, 24 p.

Blake, W., 1883, Nickel: Mineral resources for U.S., l882: United States Geological Survey, p. 401-402.

Cameron, E. N., 1951, Preliminary report on the geology of the Mount Prospect Complex: Connecticut Geological and Natural History Survey Bulletin 76, 44 p.

Clarke, J. W., 1958, The bedrock geology of the Danbury quadrangle: Connecticut Geological and Natural History Survey Quadrangle Report 7, 47 p.

Cooper, F. E., 2005, Thunder on the Mountain: The era of the Mt. Prospect nickel mines: Privately published by author, #2 Area Historical Series, Litchfield, CT, 26 p.

Gates, R. M., 1951, The bedrock geology of the Litchfield quadrangle, Connecticut: Connecticut Geological and Natural History Survey Miscellaneous Series 3 (Quadrangle Report 1), 13 p.

Gates, R. M., 1952, The geology of the New Preston quadrangle, Connecticut. The bedrock geology Part 1: Connecticut Geological and Natural History Survey Miscellaneous Series 5 (Quadrangle Report 2), p. 5-34.

Gates, R. M., and Christiansen, N. I., 1965, The bedrock geology of the West Torrington quadrangle: Connecticut Geological and Natural History Survey Quadrangle Report 17, 38 p.

Hall, L. M., 1968a, Geology in the Glenville area, southwesternmost Connecticut and southeastern New York, Section D-6, p. 1-12 in Orville, P. M., ed., Guidebook for field trips in Connecticut: New England Intercollegiate Geological Conference Annual Meeting, 60th, New Haven, CT, October 1968: Connecticut Geological and Natural History Survey Guidebook 2, not consecutively paginated.

Hall, L. M., 1968b, Times of origin and deformation of bedrock in the Manhattan Prong, p. 117-127 in Zen, E-an; White, W. S.; Hadley, J. B.; and Thompson, J. B., Jr., eds., Studies of Appalachian Geology: Northern and Maritime: New York, Wiley-Interscience, 475 p.

Hall, L. M., 1971, Preliminary correlation of rocks in southwestern Connecticut (abstract): Geological Society of America Abstracts with Programs, v. 3, no. 1, p. 34 (only).

Hall, L. M., 1976, Preliminary correlation of rocks in southwestern Connecticut, p. 337-349 in Page, L. R., ed., Contributions to the stratigraphy of New England: Boulder, CO, Geological Society of America Memoir 148, 445 p.

Hatch, N. L., Jr., 1975, Tectonic , metamorphic , and intrusive history of part of the east side of the Berkshire Massif, Massachusetts: United States Geological Survey Professional Paper 888-D, p. D51-D62.

Hatch, N. L., Jr.; and Stanley, R. S., 1973, Some suggested stratigraphic relations in part of southwestern New England: United States Geological Survey Bulletin 1380, 83 p.

Howe, E., 1915, Sulphide -bearing rocks from Litchfield, Connecticut: Economic Geology, v. 10, p. 330-347.

Jackson, R. A., 1980 ms., Autochthon and allochthon of the Kent quadrangle, western Connecticut: Amherst, MA, University of Massachusetts Department of Geology and Geography Ph. D. Dissertation, 147 p.

Jackson, R. A., and Hall, L. M., 1982, An investigation of the stratigraphy and tectonics of the Kent area, western Connecticut, p. 213-246 in Joesten, S; and Quarrier, S. S., eds., Guidebook for field trips in Connecticut and south central Massachusetts: New England Intercollegiate Geological Conference, Annual Meeting, 74th, 482 p.

Martin, C. W., 1970, The bedrock geology of the Torrington quadrangle, Connecticut: Connecticut Geological and Natural History Survey Quadrangle Report 25, 53 p.

Merguerian, Charles, 1977 ms., Contact metamorphism and intrusive relations of the Hodges Complex along Cameron's Line, West Torrington, Connecticut (M.A. thesis): The City College of New York, Geology Department, 89p. plus maps (scale 1:12,000).

Merguerian, Charles, 1979, Dismembered ophiolite along Cameron's Line West Torrington, Connecticut (abstract): Geological Society of America Abstracts with Programs, v. 11, no. 1, p. 45 (only).

Merguerian, Charles, 1981, Coticules in New England - ancient examples of metalliferous sediments (abs.): EOS, American Geophysical Union, Transactions, v. 62, p. 310.

Merguerian, Charles, 1983, Tectonic significance of Cameron's Line in the vicinity of the Hodges Complex - an imbricate thrust model for western Connecticut: American Journal of Science, v. 283, no. 4, p. 341-368.

Merguerian, Charles, 1985, Geology in the vicinity of the Hodges Complex and the Tyler Lake granite, West Torrington, Connecticut: in R.J. Tracy, editor, Guidebook for field trips, New England Intercollegiate Geological Conference, 77th Annual Meeting, New Haven, Connecticut, p. C2-1 - C2-32.

Merguerian, Charles, 1987, The geology of Cameron's Line, West Torrington, Connecticut, p. 159-164 in Roy, D. C., ed., Northeastern Section of the Geological Society of America, Centennial Fieldguide, Volume 5, 481 p.

Merguerian, Charles, 1995, The Taconic problem--alive and well in New York City (NYC) (abstract): Geological Society of America Abstracts with Programs, v. 27, no. 1, p. 68 (only).

Merguerian, Charles; and Baskerville, C. A., 1987, The geology of Manhattan Island and the Bronx, New York City, New York, p. 127-140 in Roy, D. C., ed., Northeastern Section of the Geological Society of America, Centennial Fieldguide, Volume 5, 481 p.

Merguerian, Charles; and Merguerian, Mickey, 2004, Geology of Central Park – From rocks to ice: *in* Hanson, G. N., *chm*., Eleventh Annual Conference on Geology of Long Island and Metropolitan New York, 17 April 2004, State University of New York at Stony Brook, NY, Long Island Geologists Program with Abstracts, 24 p.

Merguerian, Charles; and Ratcliffe, N. M., 1977, A reinterpretation of the Hodges Mafic Complex and its relation to deformation along Cameron's Line in West Torrington, Connecticut (abstract): Geological Society of America Abstracts with Programs, v. 9, p. 301-302.

Merguerian, Charles; Mose, D. G.; and Nagel, S., 1984, Late syn-orogenic Taconian plutonism along Cameron's Line, West Torrington, Connecticut (abstract): Geological Society of America, Abstracts with Programs, v. 16, no. 1, p. 50 (only).

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

Mose, D. G., 1982, Rb-Sr whole-rock studies: western Connecticut, p. 550-552 in Year Book 81: Washington, D. C., Carnegie Institution of Washington, 000 p.

Mose, D. G.; and Nagel, S., 1982, Chronology of metamorphism in western Connecticut: Rb-Sr ages, p. 247-262 in Joesten, R., and Quarrier, S. S., eds., New England Intercollegiate Geological Conference Annual Meeting, 74th, Guidebook for field trips in Connecticut and south central Massachusetts, 482 p.

Pelligrini, T., 1977, Bedrock geology of the Mamaroneck quadrangle, N. Y.: New York State Museum and Science Service Map and Chart Series No. 29.

Percival, J. G., 1842, Report on the geology of the State of Connecticut: New Haven, Connecticut, Osborn and Baldwin, 495 p.

Ratcliffe, N.M., Tucker, R.D., Aleinikoff, J.N., Amelin, Yuri; Merguerian, Charles; and Panish, P.T., 2012, U-Pb zircon and titanite ages of late- to post-tectonic intrusions of the Cortlandt-Beemerville magmatic belt, CT, NY, and NJ: relation to Iapetan closure in the Taconic orogeny: Geological Society of America Abstract # 200033, Abstracts with Programs, v. 44, no. 2, p. 73.

Richardson, S.W., 1968, Staurolite stability in a part of the system Fe-Al-Si-O-H: Jour. Petrology, v.9, pp. 476-488.

Richardson, S.W., Gilbert, M.C., and Bell, P.M., 1969, Experimental determination of kyanite-andalusite and andalusitesillimanite equilibria; the aluminum silicate triple point: Am. Jour. Sci., v.267, pp. 259-272.

Robinson, Peter; and Hall, L. M., 1980, Tectonic synthesis of southern New England, p. 73-82 in Wones, D. R., ed., International Geological Correlation Project, Proceedings, Project 27: The Caledonides in the U. S. A.: Blacksburg, VA, Virginia Polytechnic Institute and State University Department of Geological Sciences Memoir 2, 329 p.

Rodgers, John, 1985, Bedrock geological map of Connecticut: Hartford, Connecticut, Connecticut Geological and Natural History Survey, Connecticut Natural Resources Atlas Series (2 sheets, scale 1:125,000).

Sevigny, J. H., and Hanson, G. N., 1995, Late-Taconian and pre-Acadian history of the New England Appalachians of southwestern Connecticut: Geological Society of America, Bulletin, v. 107, 95, p. 487-498.

Seyfert, C. K., and Leveson, D. J., 1969, Speculations on the Hutchinson River Group and the New York City Group, p. 33-36 in Alexandrov, E. A., ed., Symposium on the New York City group of formations: New York State Geological Association Annual Meeting, 40th, Flushing, New York, Queens College: Flushing, NY, Queens College Department of Geology Geological Bulletin 3, Queens College Press, 83 p.

Shepard, C. U., 1837, Report on the geological survey of Connecticut: New Haven, 188p.

Stanley, R. S., 1975, Time and space relationships of structures associated with the domes of southwestern Massachusetts and western Connecticut: United States Geological Survey Professional Paper 888-F, p. F69-F96.

Winkler, H.G.F., 1974, Petrogenesis of metamorphic rocks: Third edition, Springer-Verlag, New York, 320p.