DUKE GEOLOGICAL LABORATORY

Web: www.dukelabs.com
E-Mail: CharlesM@dukelabs.com

TRIPS ON THE ROCKS

Guide 06: Western Connecticut Mines and Minerals I

Trip 06: 03 June 1989

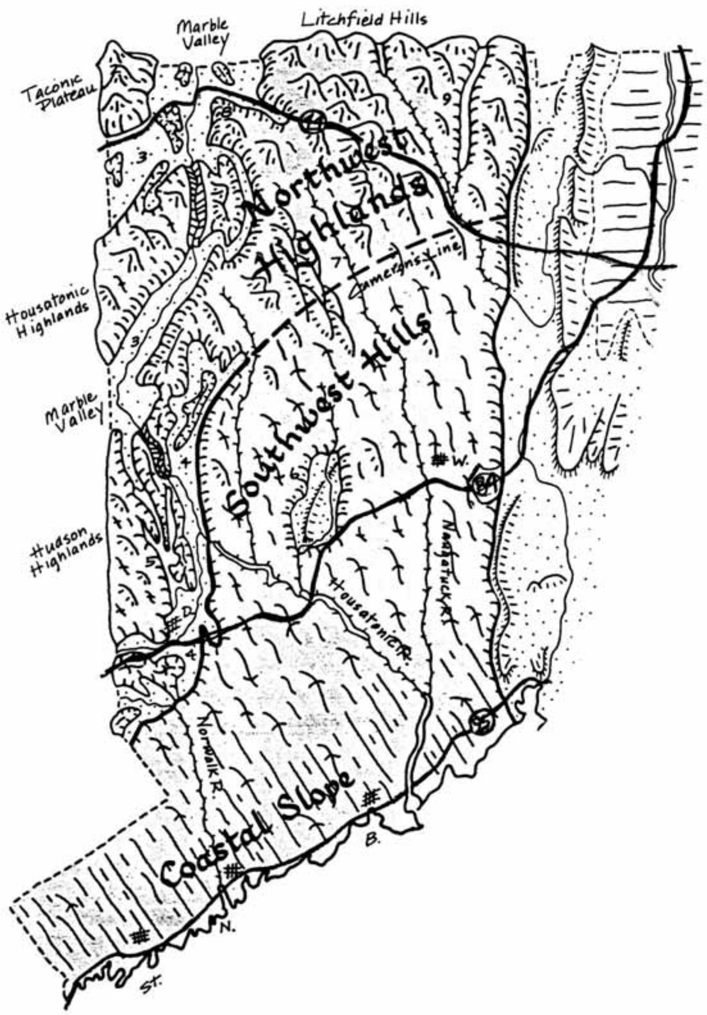


Figure 1 – Physiographic map of western Connecticut showing the various geological provinces. (From Bell 1985.)

Field Trip Notes by:

Charles Merguerian and John E. Sanders

CONTENTS

DUKE GEOLOGICAL LABORATORY

TRIPS ON THE ROCKS

Guide 06: Western Connecticut Mines and Minerals I
Trip 06: 03 June 1989

INTRODUCTION

Today's field trip to western Connecticut is intended to introduce the participants to many of the region's former mines and mineral prospects. We will visit, examine, and collect rocks and minerals from numerous sites in the crystalline highlands of western Connecticut (Figure 1, on cover). In addition, we will discuss the regional geology of the field-trip route placing particular emphasis on the plate-tectonic development of this part of the Appalachian mountain belt.

We will drive eastward from the Academy across to the East Side Highway and northward to the Major Deegan Expressway. From here, we will travel north to the Saw Mill River Parkway to Route 684 (North). Driving northward on 684 (across deeply eroded and highly folded and metamorphosed rocks of the Manhattan Prong) we will eventually drive across Cameron's Line, a major structural-stratigraphic dislocation within the Manhattan Prong. Near Brewster, New York, we will drive eastward on Route 84(E) to Exit 8 (Route 6) for a brief rest stop, then continue east on 84 to CT Route 8. Route 8, a beautiful transect through the crystalline highlands of western Connecticut, will take us to our first stop of the day near the towns of Litchfield and Harwinton, Connecticut.

Our trip will begin at an outcrop in Harwinton to examine the highly aluminous schist and interlayered gneiss that are characteristic of the Hartland Formation of western Connecticut, the host rock for most of the mineral deposits we will encounter today! Table 1 should be consulted for the following discussion. It is a time chart showing geologic time subdivisions shown on the bedrock maps herein, with estimates of numbers of years for their boundaries and a list of some important local geologic events. Table 2 summarizes the major local geologic units (stratigraphy) in terms of layers designated by Roman numerals.

GEOLOGIC BACKGROUND

Under this heading, we discuss the bedrock units, the glacial deposits, and the drainage history of our field-trip route.

BEDROCK UNITS

Layers I and II: Crystalline Complex of Paleozoic and older rocks

As we begin our geo-collecting journey from the New York Academy of Sciences, a few thoughts about the rocks beneath our feet. The crystalline bedrock of New York City marks the southern terminus of an important sequence of metamorphosed Precambrian to Lower Paleozoic rocks of the Manhattan Prong (Figures 2 and 3) which widens northward into the New England Upland physiographic province of the Appalachian mountain belt. Originally, the New York City strata were, in part, deposited on the complexly deformed sequence of layered feldspathic and massive granitoid gneiss, amphibolite, and calc-silicate rocks of uncertain stratigraphy known as the Fordham and Yonkers Gneiss (Layer I). As such, the complexly deformed, Proterozoic Y and Z basement sequence (Layer I) represents the ancient continental crust of proto-North America that became a trailing edge, passive continental margin throughout the early Paleozoic Era. Interestingly, the current geologic setting of eastern North America, with deformed Paleozoic and older basement covered by Mesozoic and younger sediments, is analogous to the past (except for differences in age, paleolatitude, geothermal regime, and paleotectonics).

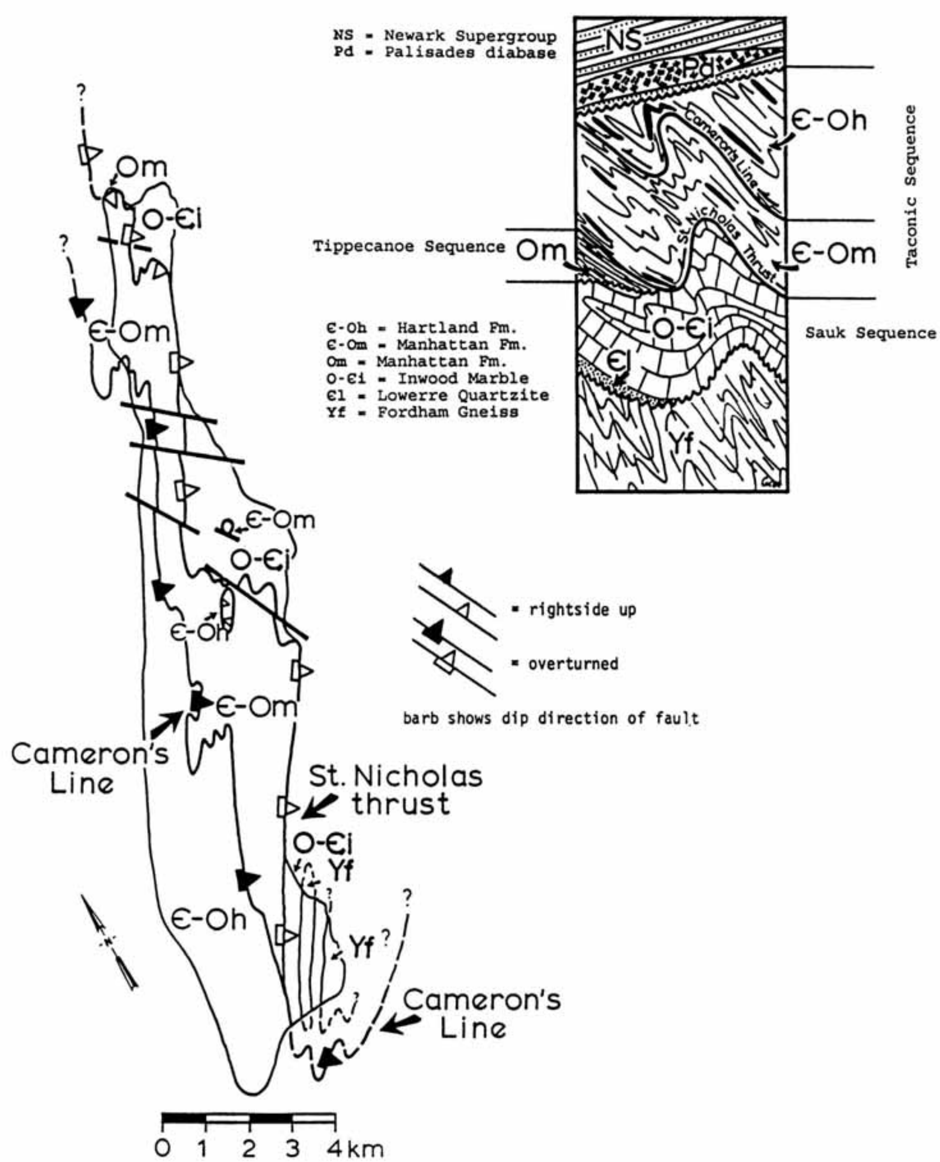


Figure 2 - Geologic map and section of Manhattan. (Mapped by CM, with layer labels from Table 2.)

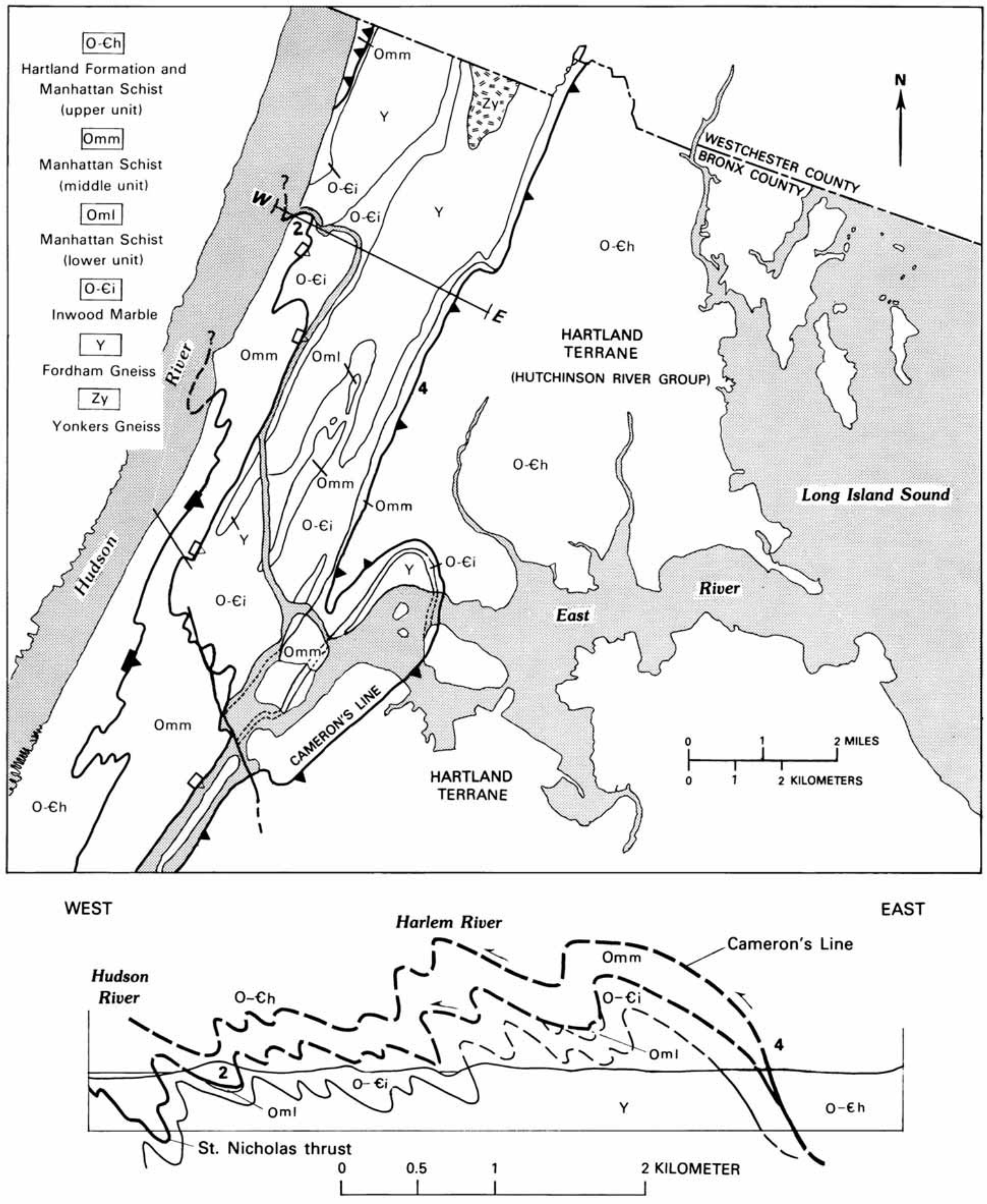


Figure 3 - Geologic map of the southern end of the Manhattan Prong (from Merguerian and Baskerville, 1987).

The Cambrian to Ordovician bedrock units in western Connecticut and New York City (Layer II) now form a deeply eroded sequence of highly metamorphosed, folded and faulted sedimentaryand igneous rocks (Figure 4) which began life roughly 550-450 million years ago as thick accumulations of both shallow- and deep-water sediments adjacent to the Early Paleozoic shores of proto-North America (Figure 5). Layer II can be divided into two sub-layers, IIA and IIB.

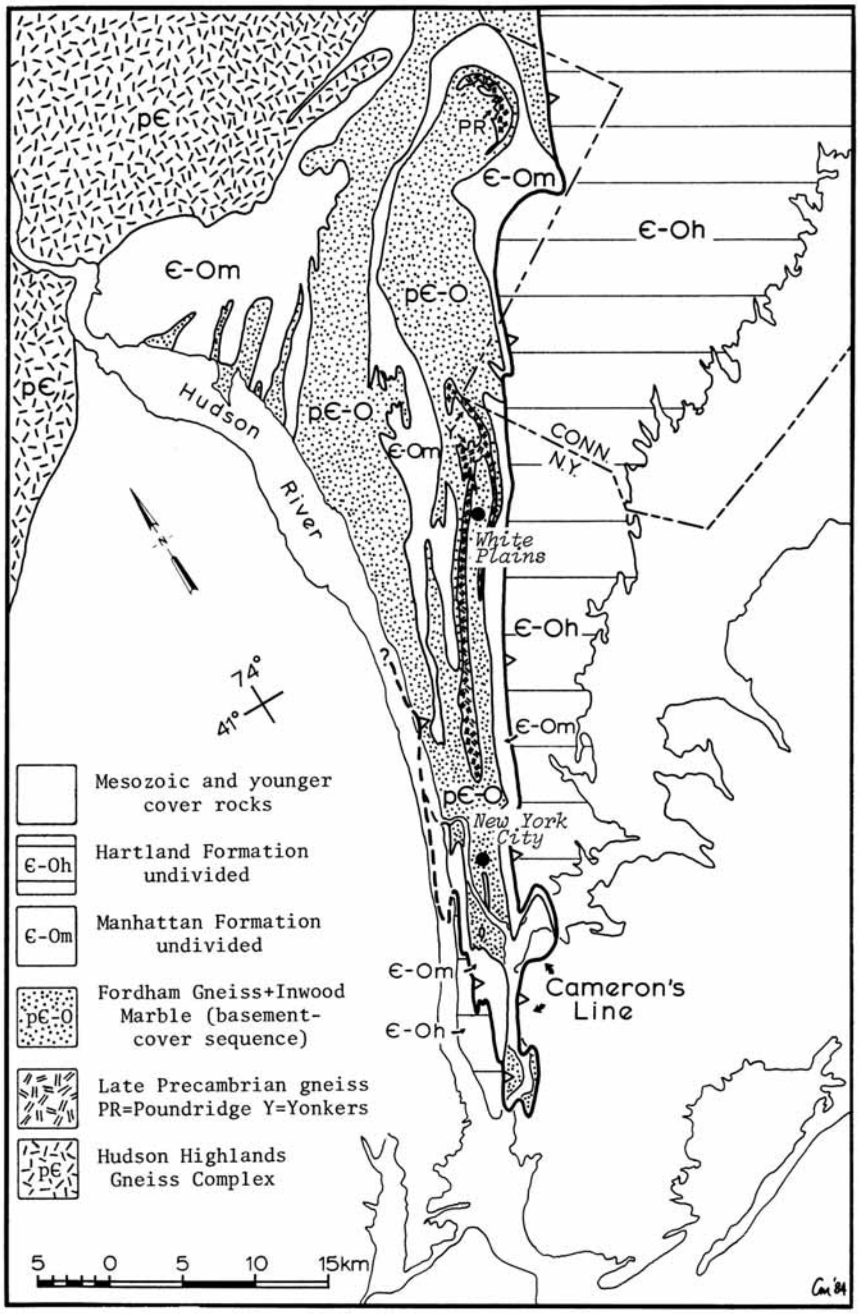


Figure 4 - Simplified geologic map of the Manhattan Prong showing the distribution of metamorphic rocks ranging in age from Precambrian to Early Paleozoic. Most intrusive rocks have been omitted. (Mose and Merguerian, 1985, fig. 1, p. 21.)

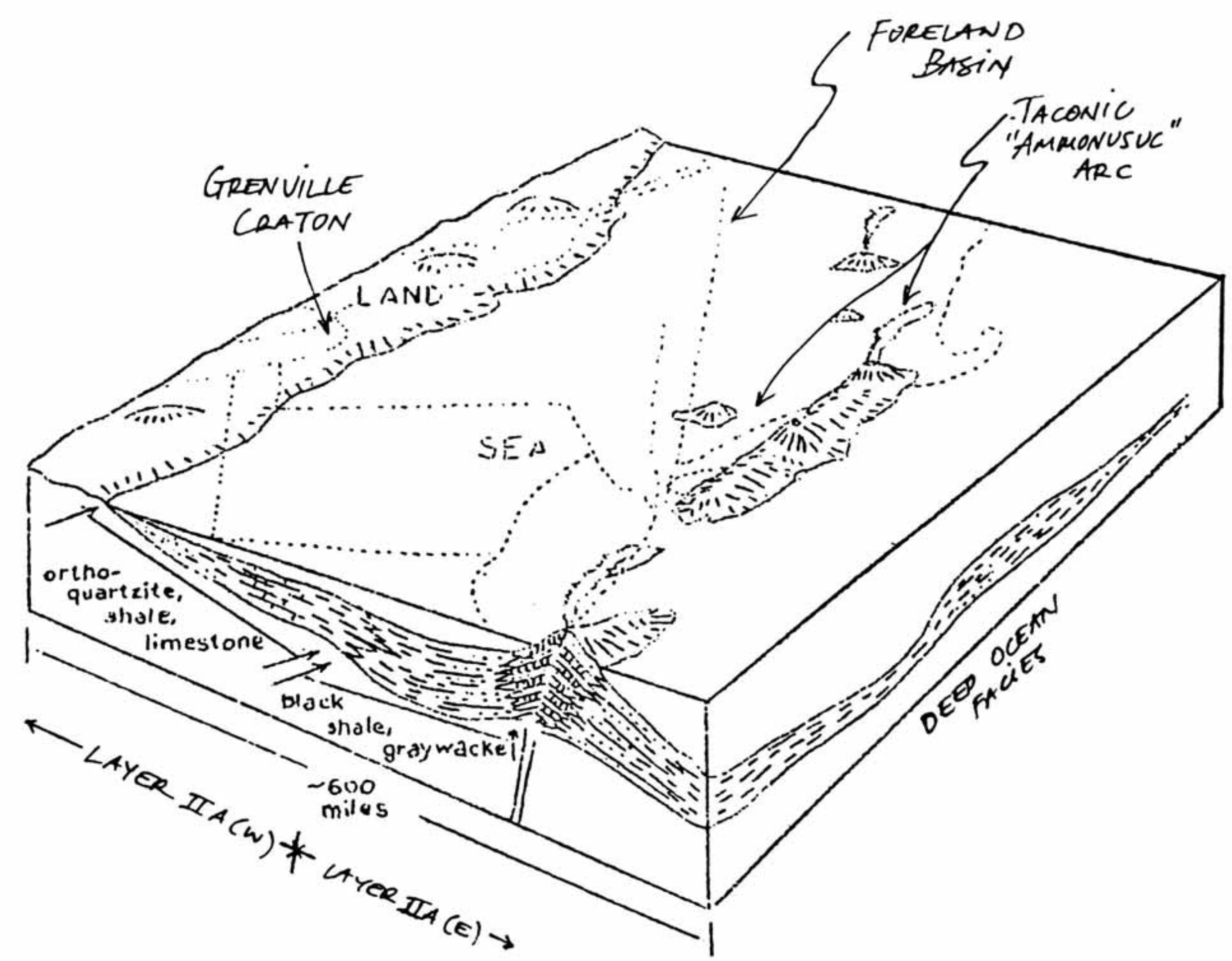


Figure 5 - Paleographic block diagram illustrating the passive continental margin of eastern North America during early Paleozoic times.

The older of these, IIA, represents the ancient passive-margin sequence of the proto-Atlantic (Iapetus) ocean. These rocks can be subdivided into two facies that differ in their original geographic positions with respect to the shoreline and shelf. A near-shore facies [Layer IIA(W)] was deposited in shallow water and is now represented by the Cambrian Lowerre Quartzite and Cambro-Ordovician Inwood Marble in New York City and as the Cheshire Quartzite and Stockbridge Marble in western Connecticut and Massachusetts. These strata began life as sandy and limey sediments in an environment not significantly different from the present-day Bahama Banks.

Farther offshore, fine-grained terrigenous time-stratigraphic equivalents of the shallow water strata (shelf sequence) were evidently deposited under deep water on oceanic crust [Layer IIA(E)]. This sequence is also of Cambrian to Ordovician age and is known as the Taconic sequence in upstate New York, as units C-Ot and C-Oh of the Manhattan Schist(s) (Figure 2), and is described below as the Waramaug and Hartland formations, respectively, of western Connecticut.

Layer IIB is younger strata that rests depositionally above the western shallow water platform [Layer IIA(W)]. In eastern New York State, these rocks are mapped as the Waloomsac Schist, and Manhattan Formation. In New York City, it is the Manhattan Schist unit Om which, according to CM, is demonstrably interlayered with the Inwood Marble and contains thin layers of calcite marble (Balmville equivalent) at its base at Inwood Hill Park in Manhattan (NYAS On-The-Rocks Trip #3). This field evidence is used to indicate that unit Om of the Manhattan Schist is in place where found and is therefore younger, or the same age, as Manhattan units Ꞓ -Ot and Ꞓ-Oh.

THE GEOLOGY OF CONNECTICUT

The crystalline terrane 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 (Layer IIA(E)) northward into the Connecticut Valley-Gaspe synclinorium (a large-scale downfold or "syncline" that effects a broad portion of the Earth's crust) (Figure 6). In addition, rocks of Layer IIA(W) crop out in westernmost Connecticut and are continuous with lower Paleozoic rocks of southeastern New York. Separated by Cameron's Line, a major ductile shear zone in the New England Appalachians, these two major geological terranes [Layers IIA(W) and IIA(E)] dominate the geologic framework of western Connecticut (Figure 7).

J. G. Percival (Figure 8) was a melancholy naturalist, poet, U. S. Army surgeon, botanist, and cunning linguist who collaborated with Webster on the first American dictionary. Clearly a character worthy of further discussion, the interested reader should consult Bell (1985) for more details. Of interest here, however, was the production of the first state geologic map of Connecticut in 1842 (Figure 9) by Percival who spent nearly seven years traversing Connecticut in a one-horse wagon, then by foot. Initially in 1835, Percival was accompanied by Shepard. By 1837, Shepard had published his comprehensive report on the economic mineral deposits of the state. Percival continued his work alone and eventually traversed the entire state along parallel East-West lines two miles apart. Percival's map (1842) is an excellent and thorough document with a long written report (now a collector's item!) that has proven more correct than modern mapping in certain areas.

The Hartland Formation (Cameron, 1951; Gates, 1951, 1952; Merguerian, 1977) 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) (Figure 10). The Hartland Formation (Layer IIA(E)) constitutes the bulk of the highlands of western Connecticut (Figure 7) and is a metamorphosed sequence of eugeosynclinal rocks (formerly deposited in deep water on oceanic crust). Occurring to the west of Cameron's Line is a sequence of massive gneissic rocks known as the Waramaug Formation (Cambrian and ?Ordovician) which is correlative to the north with the Cambrian Hoosac Schist and to the south with unit C-Ot of New York City (Merguerian, 1983). This sequence is interpreted as a continental slope/rise deposit that was situated between the depositional sites of Layers IIA (W) and (E). 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).

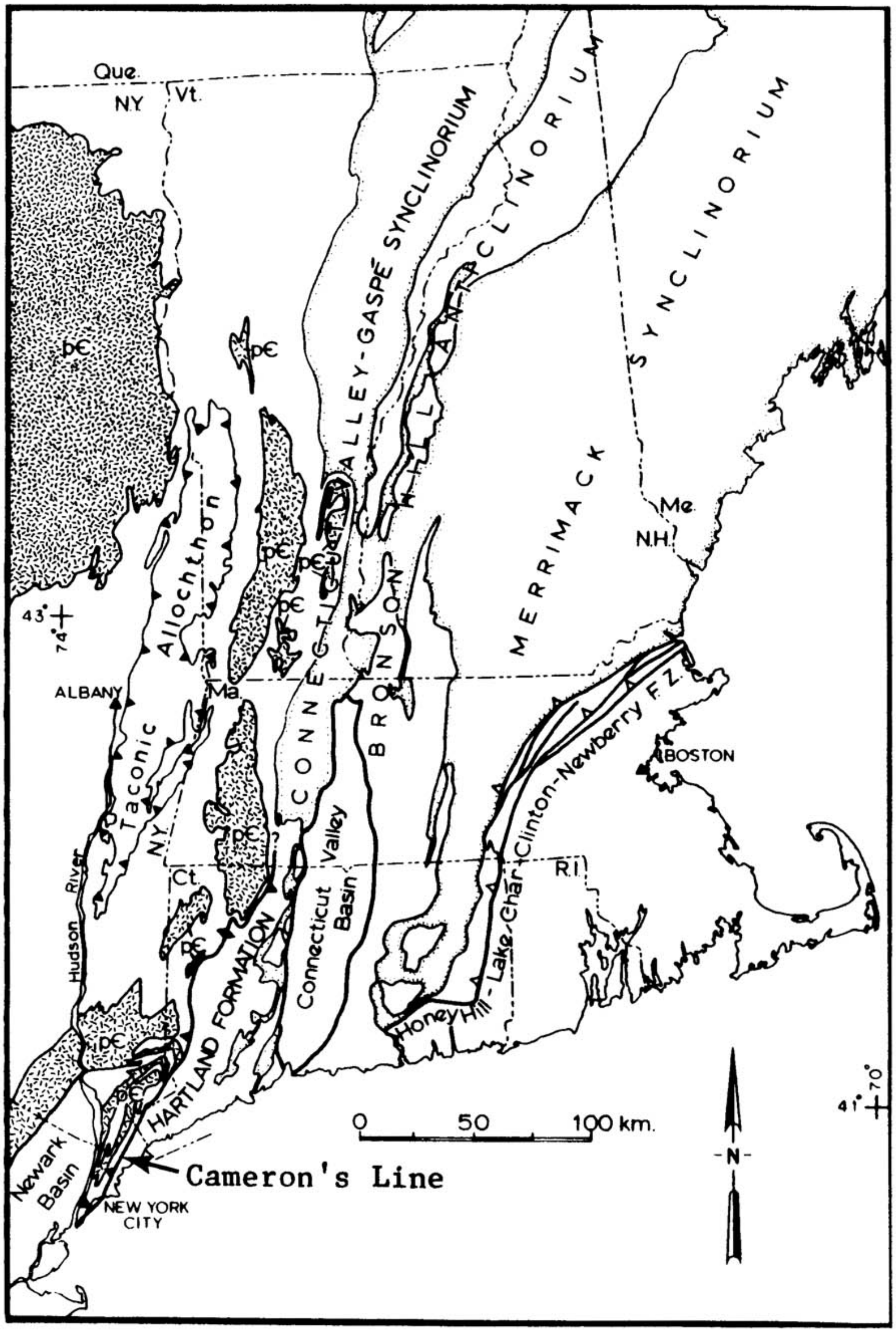


Figure 6 - Tectonic sketchmap of southern New England showing the major geotectonic provinces. (Merguerian, 1983, fig. 1, p. 343.)

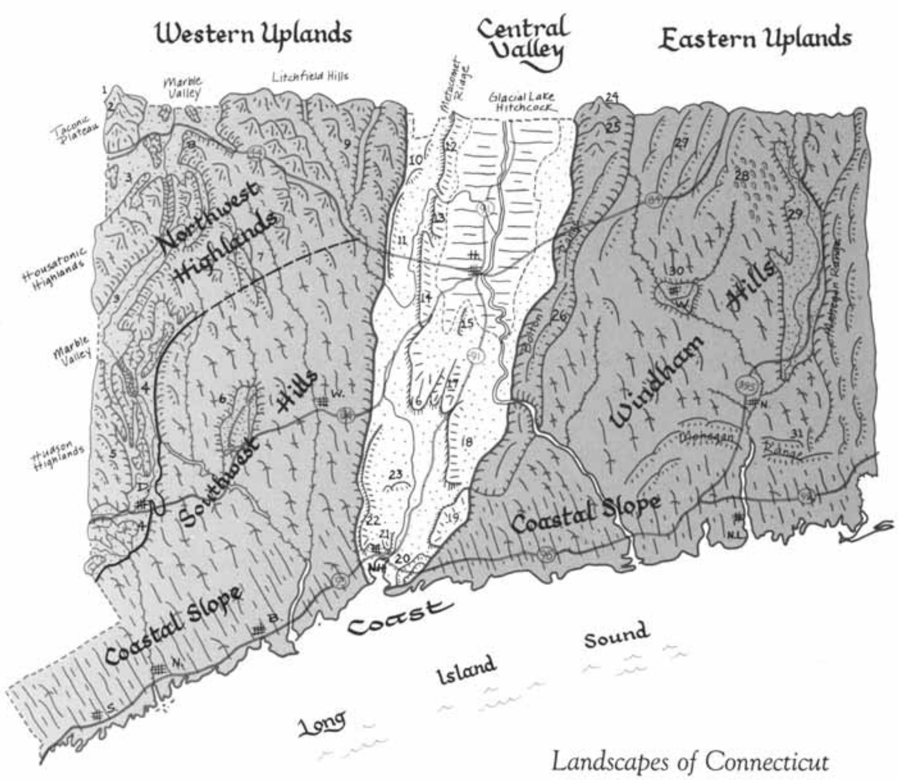


Figure 7 - Physiographic map of Connecticut showing the various geological provinces (from Bell, 1985).

Figure 8 - Drawing of cunning linguist James Gates Percival (from Bell, 1985).

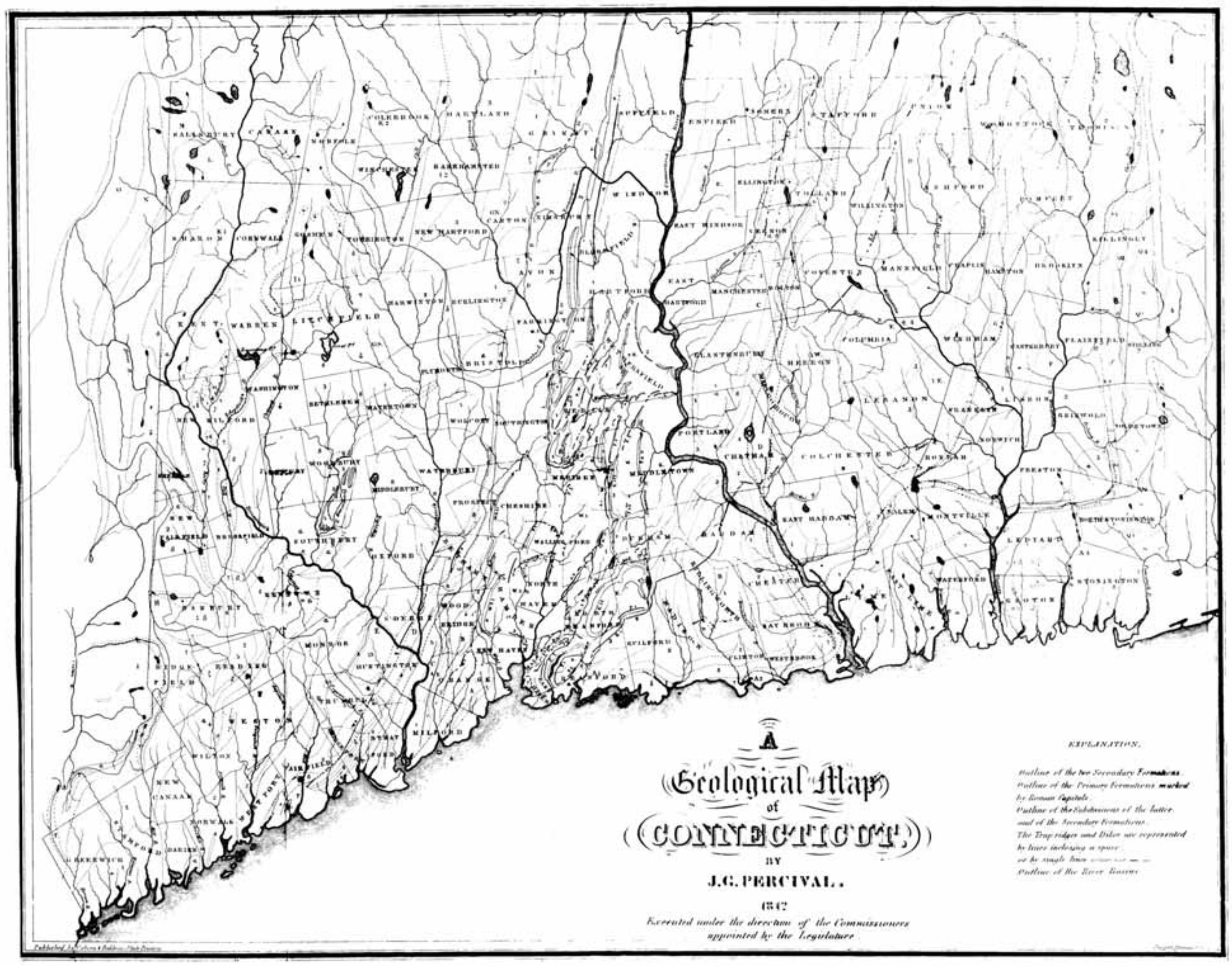


Figure 9 - J. G. Percival's geological map of Connecticut (1842).

Cameron's Line

According to Eugene Cameron (of Cameron's Line fame) in a confidential personal communication with CM, the geologic relationship of Cameron's Line was first noted by William Agar who shared same with E. Cameron. According to EC - "I don't know why they called it Cameron's Line, 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 quartzite and marble (shallow-water sedimentary strata [Layer IIA(W)] formed originally on continental crust of proto-North America. Together, Layers I and IIA(W) represent deformed North American craton and overlying shelf deposits.

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. 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 along strike in New England (Figure 11). Note the northwest (eastern New York state) to southeast (central Connecticut) stratigraphic variation from shallow-water shelf to deep-water volcanogenic interpreted protoliths in Figure 12.

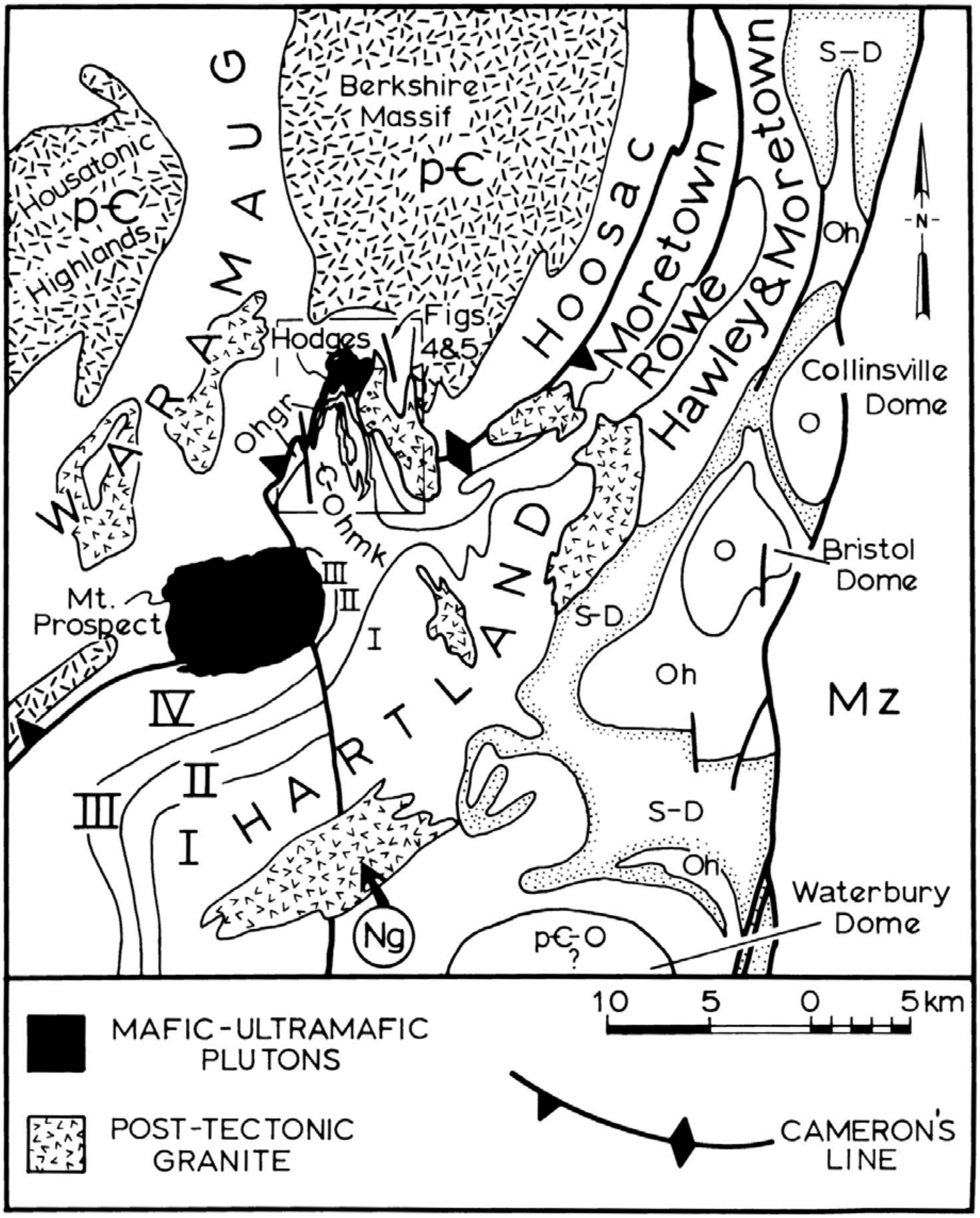


Figure 10 - Geologic map of northwestern Connecticut and vicinity. (Merguerian, 1983, fig. 2, p. 346.)

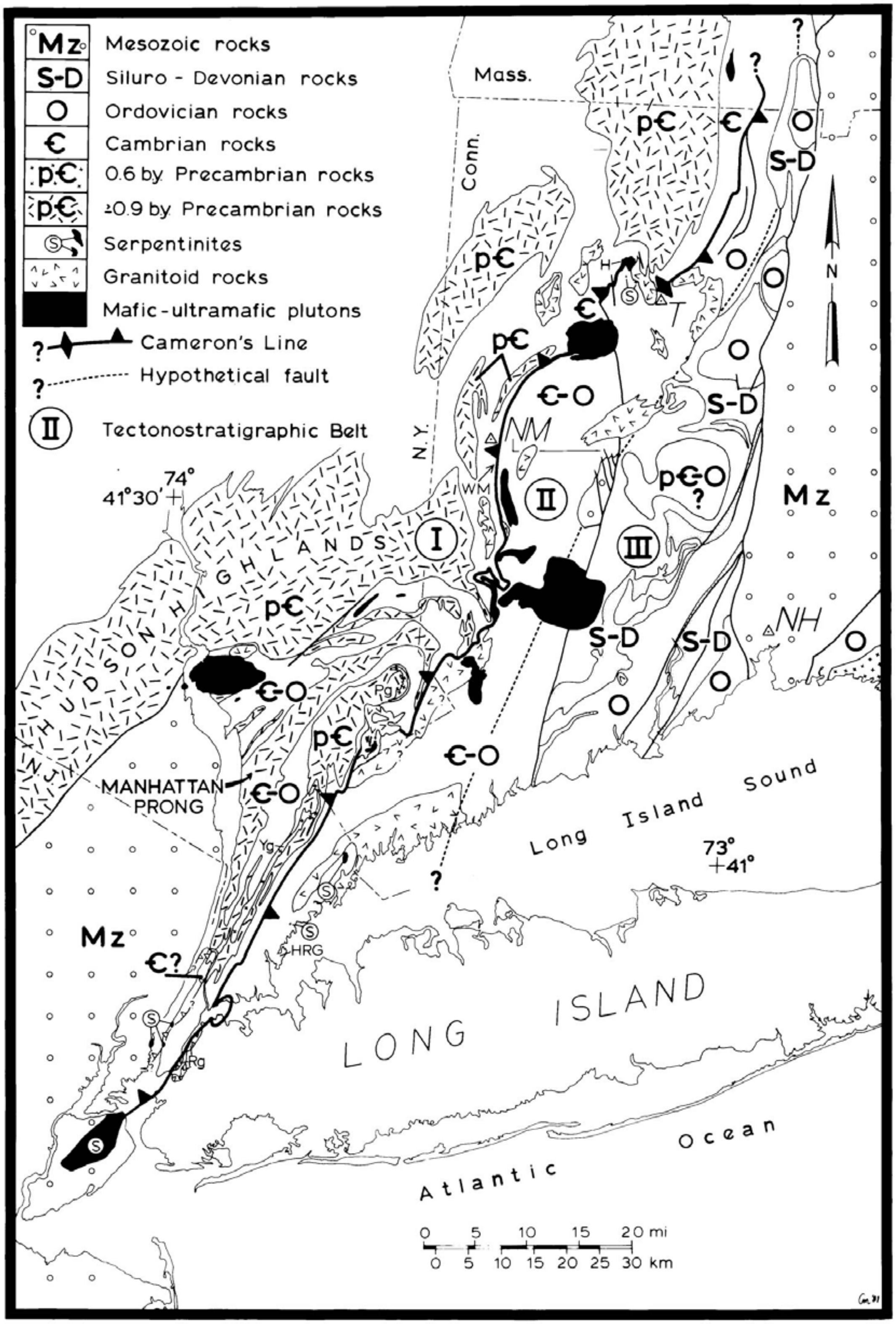


Figure 11 - Geotectonic map of western Connecticut and southeastern New York. (Merguerian, 1983, fig. 1, p. 343.)

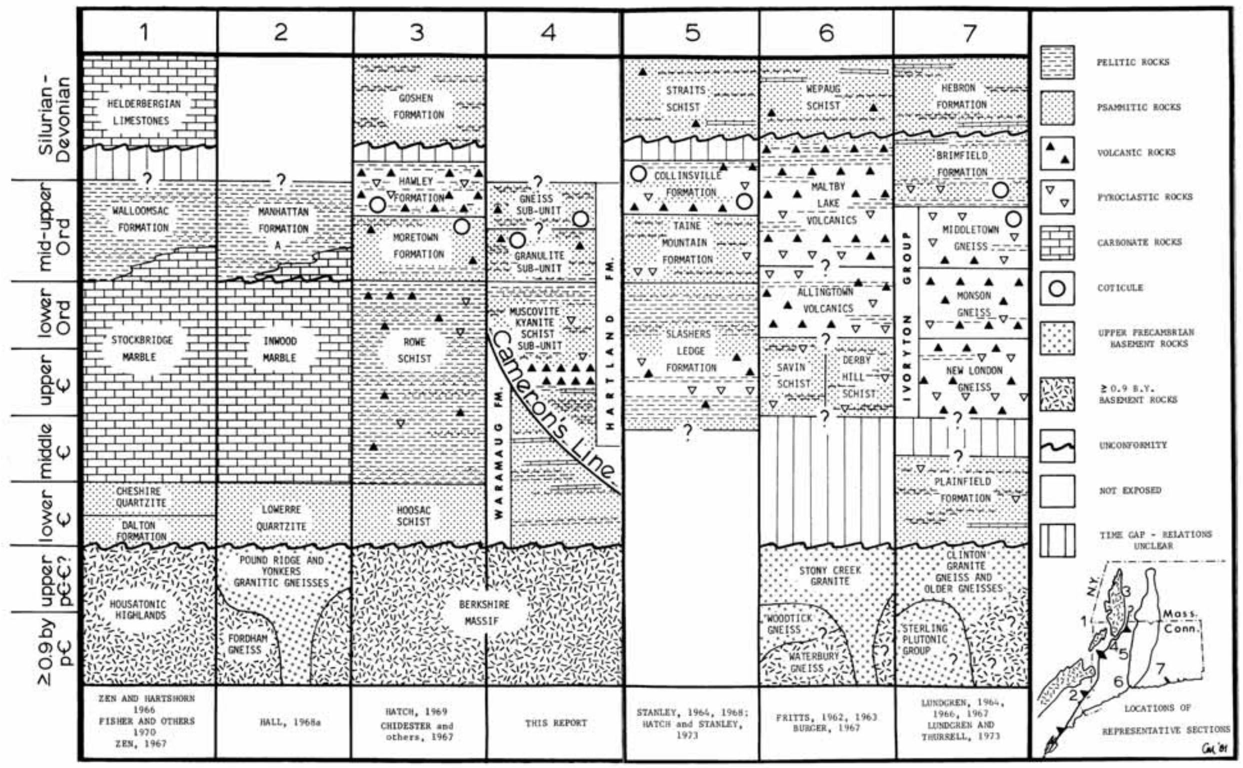


Figure 12 - Stratigraphic correlation chart showing interpreted protoliths of metamorphic rock units in southern New England. (Merguerian, 1985, fig. 3, p. 414.)

Numerous lower Paleozoic calc-alkaline plutons occur in western Connecticut. Near West Torrington, Connecticut, the Hodges mafic-ultramafic complex and the Tyler Lake Granite were sequentially intruded across Cameron's Line (Merguerian, 1977). Because of their formerly elongate shapes 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, these plutons are interpreted as syn-orogenic . The recognition of significant medial Ordovician plutonism across Cameron's Line (Mose, 1982; Mose and Nagel, 1982; Merguerian and others, 1984; Amenta and Mose, 1985) establishes a Taconian or possibly older age for the formation of Cameron's Line and the syntectonic development of regional metamorphic fabrics in western Connecticut (Merguerian, 1985). Judging by metamorphic minerals in the regional fabric, Layers IIA(W) and IIA(E) were juxtaposed at depths of roughly 20 km along Cameron's Line during early Paleozoic times. The force behind such deep-seated deformation presumably resulted from a collision between a volcanic-arc terrane and the passive continental margin of North America (Figure 13). At present, the arc terrane is exposed in the Bronson Hill Anticlinorium and its extension southward into cental Connecticut (Figures 6 and 11).

In summary, during a series of Paleozoic mountain-building episodes (the Taconic, Acadian, and Alleghanian orogenies), the sedimentary protoliths [Layers IIA(W and E) and IIB] of the New England Appalachians were sheared, folded, and metamorphosed during a collision between an exotic volcanic-island chain and the passive continental margin of proto North

America. 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 [Layer IIA(W)] and oceanic realms [Layer IIA(E)] and marks the root zone for much of the Taconic sequence in eastern New York state. The Hartland Formation (Complex) marks the deeply eroded roots of an uplifted accretionary complex marking the former trench into which the raw edge of North America was subducted. Merguerian's mapping in New York City and New England indicates that the allochthonous Manhattan Schist(s) are directly correlative with rocks of western Connecticut and Massachusetts along the east flank of the Berkshire and Green Mountains massifs and that various through-going geotectonic elements can be identified (Figure 11).

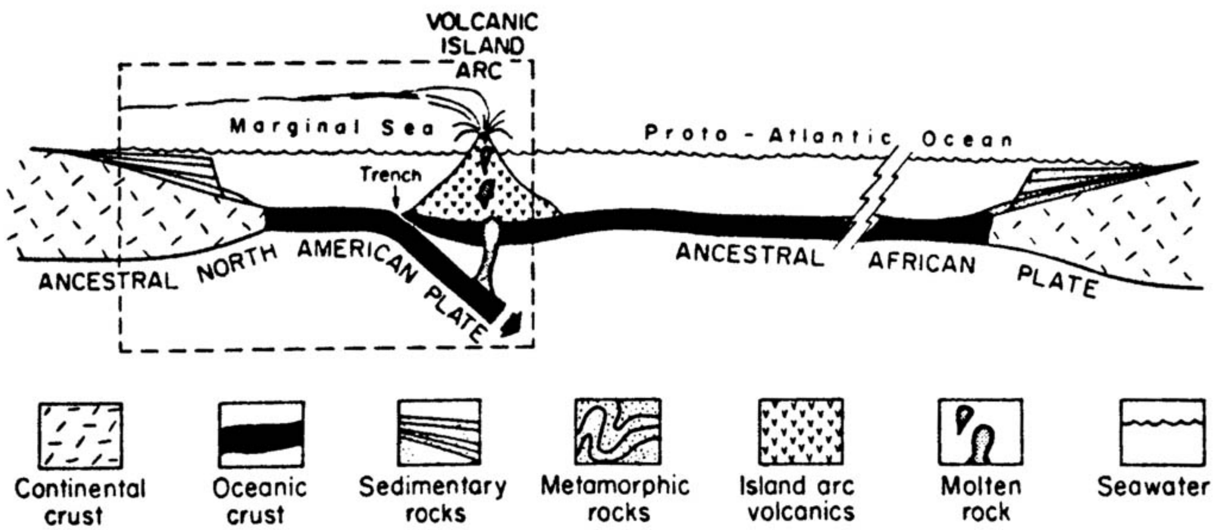


Figure 13 - Reconstructed cross-section for the beginning of Middle Ordovician time, showing North America and an offshore volcanic chain on a collision course (from Isachsen, 1980).

Layer V: Hartford Basin-Filling Strata

Although we shall not be making any stops at localities to examine the Newark Supergroup strata of Connecticut, we mention them for two reasons: (1) some mineral deposits in the pre-Newark rocks may have resulted from the Newark igneous activity and associated hot waters; and (2) the drainage history of western Connecticut includes activities that date back as far as the Late Triassic and Early Jurassic Periods when the Newark Supergroup was being deposited.

In Connecticut, the Newark-age strata are exposed in three areas: (a) the Hartford basin (forms the main region of central Connecticut, extending northward from New Haven Harbor into central Massachusetts); and two smaller areas underlain by strata thought to have been continuous formerly with those of the Hartford basin: (b) the Pomperaug Valley belt; and (c) the Cherry Brook valley belt, Canton Center. In all of these three areas, the regional dip of the strata is toward the east. Because all the strata were initially deposited in horizontal positions, their modern-day dips must be ascribed to the effects of tectonic uplift, with the axis of this feature located to the west of South Britain, Connecticut, where east-dipping Newark-age strata are exposed in the Pomperaug River.

GLACIAL DEPOSITS

The glacial deposits of Connecticut include the work of at least two ice sheets that flowed from contrasting directions: (i) from the NNE to the SSW, and (ii) from the NW to the SE, the same two directions discussed in the New York City region (Manhattan trip and Staten Island trip). These two directions were noticed under the heading of "Diluvial Scratches" by the great genius of Connecticut geology, J. G. Percival (1842). Two tills having these contrasting directions of flow have been described from central Connecticut: the older, Lake Chamberlain till with flow NW-SE; and the younger, Hamden till, with flow NNE-SSW (Flint, 1961). In addition, evidence for significant end moraines has been described along the Long Island Sound coast of Connecticut (Flint and Gebert, 1974 and 1976). JES thinks these end moraines are the terminal moraines for the glacier that deposited the Hamden till.

Drumlins having long axes oriented NW-SE are abundant in the Newtown-Roxbury area. In this same area, one can also find drumlins having long axes oriented NNE-SSW. Study of the U. S. Geological Survey topographic maps of the Roxbury and Newtown quadrangles will provide numerous examples of each. The co- existence of such drumlins inferred to have been the work of two different ice sheets is hard for some glacial geologists to accept. They argue that the younger glacier should have wiped out all traces of any older glacier, especially one having a contrasting flow direction (Flint, 1943, 1951). JES has no simple explanation for how this can have happened; he merely cites the topographic maps as proof that it did happen.

DRAINAGE HISTORY

The drainage history of Connecticut has resulted from several complex episodes of uplift and valley erosion, some of which antedated the arrival of the first Pleistocene continental glacier and some of which were related to periods of drainage re-arrangement that accompanied the melting of the glaciers.

As in the New York City region, the oldest surviving evidence for ancient drainage is contained in the Newark Supergroup. The provenance data (Krynine, 1950) and the cross strata in the Newark strata of the Southbury outlier show that the Late Triassic-Early Jurassic drainage flowed from E to W, from E of the basin-marginal fault along the E side of the Hartford basin all the way to South Britain.

The next possible time for drainage change was in the medial Jurassic Period in connection with the uplift and breakup of the Newark-Hartford basin complex. During this time, the regional arch formed with its axis lying W of the east-dipping strata at South Britain and E of the W-dipping strata of the Newark basin. This period of erosion culminated in the Cretaceous-age Fall Zone peneplain, whose traces in Connecticut have been studied by Flint (1963). A valley that may have formed at this time lies buried beneath New Haven harbor (Sanders, 1965, 1988 ms.; Haeni and Sanders, 1974). The age of this valley is not known, but one possible interpretation is that it extends to the WSW from New Haven harbor and disappears by going underneath the Upper Cretaceous strata underlying western Long Island. If so, it would be the same age as the strike valley at the base of the Newark Supergroup that passes beneath the Upper Cretaceous on western Staten Island.

Because the Upper Cretaceous coastal-plain strata probably covered parts of all of Connecticut and Massachusetts (at least all of the Hartford-Deerfield basin-filling strata to keep them out of circulation), we can infer that no drainage systems formed during the Late Cretaceous to the end of the Miocene. During this period western Connecticut was subsiding and receiving sediment during its passive-margin phase. After this phase, the first time when erosion could have started again is late in the Miocene Epoch (or early in the Pliocene Epoch), when New England was regionally elevated, all traces of any former up-dip extension of the coastal-plain strata were removed, and the depression now occupied by Long Island Sound was eroded. This depression was in existence when the Pleistocene glaciers arrived. This Pliocene time of elevation and erosion is probably as far back as it is possible to trace the history of most modern valleys.

Geophysical studies of the sub-bottom sediments in western Long Island Sound have shown that a U-shaped valley, trending more or less E-W, and with its thalweg extending down to about 600 feet below modern sea level has been cut into the coastal-plain strata (Grim, Drake, and Heirtzler, 1970). JES thinks this U-shaped valley was carved by one of the glaciers that flowed from the NW to the SE and was diverted to nearly W-E flow by the escarpment facing the inner cuesta lowland at the eroded edge of the coastal-plain strata.

The relationships between Pleistocene glaciers and drainage were complex; just how complex one is prepared to accept depends on how many glacial episodes may have affected the region and how much rearranging accompanied each glacial advance and retreat. This statement may seem self evident, but it is included because most of the students of the drainage history of Connecticut have thought in terms of a single Pleistocene glaciation and some of them have been persuaded that the effects of this glacier on the landscape and drainage were minimal.

A continental glacier would tend to deepen any valleys trending parallel to the glacier's flow direction and to fill any valleys trending at a high angle to this direction. Each glacial advance would terminate all previous drainage and each glacial retreat would enable new drainage networks to form. JES thinks that some of the new drainage may have been initiated on the top of the ice itself, so that anomalous cross-axial drainage routes, such as that of the Housatonic River across the Housatonic Highlands in northwestern Connecticut, for example, conceivably could have been established by superposition from the glacier. This is a concept that has not been considered by previous students of drainage history. Many such students have visualized the possibility that modern rivers may have attained their present locations as a result of superposition, but they supposed that the only way this could happen would be from the now-eroded former landward extensions of the coastal-plain strata.

The uniformity of flow directions associated with the glaciers that came from the NW and traveled SE, a rectilinear pattern found on even the highest ridges in today's landscape, suggests to JES that these features were eroded by a thick glacier whose flow direction was determined by the slope on the top of a thick ice sheet. Any rivers that began on the top surface of such an ice sheet would have been afforded numerous possibilities for superposition. How many times such thick glaciers overspread southern New England is not known, but JES thinks the minimum number is 2.

During the melting and retreat of the latest glacier, large lakes formed in the important lowlands--Long Island Sound and the central lowlands in Connecticut and Massachusetts (Ashley, 19XX). In these lakes were deposited varved sediments that Antevs (19XX) used to assemble a chronology of glacial retreat.

So much for the geologic background. We now turn to the specifics of today's trip, starting with the objectives.

OBJECTIVES

1) To examine the Hartland Formation of western Connecticut.

2) To locate and discuss glacial features.

3) To discuss the history of mining in western Connecticut.

4) To collect minerals and rocks from famous localities in western Connecticut.

5) Not to get bitten by ticks or mosquitos.

LIST OF LOCALITIES TO BE VISITED

(Stops 1 through 6, in western Connecticut are shown on the road map, Figure 14).

Stop 1: CT Route 8 outcrop of Hartland granofels, schist, and amphibolite.
Stop 2: Harwinton pegmatite (beryl and tourmaline).
Stop 3: New railway cut, near Thomaston Dam.
Stop 4: Roxbury Iron Mine.
Stop 5: Roxbury Garnet Mine.
Stop 6: Trumbull Tungsten Mine.

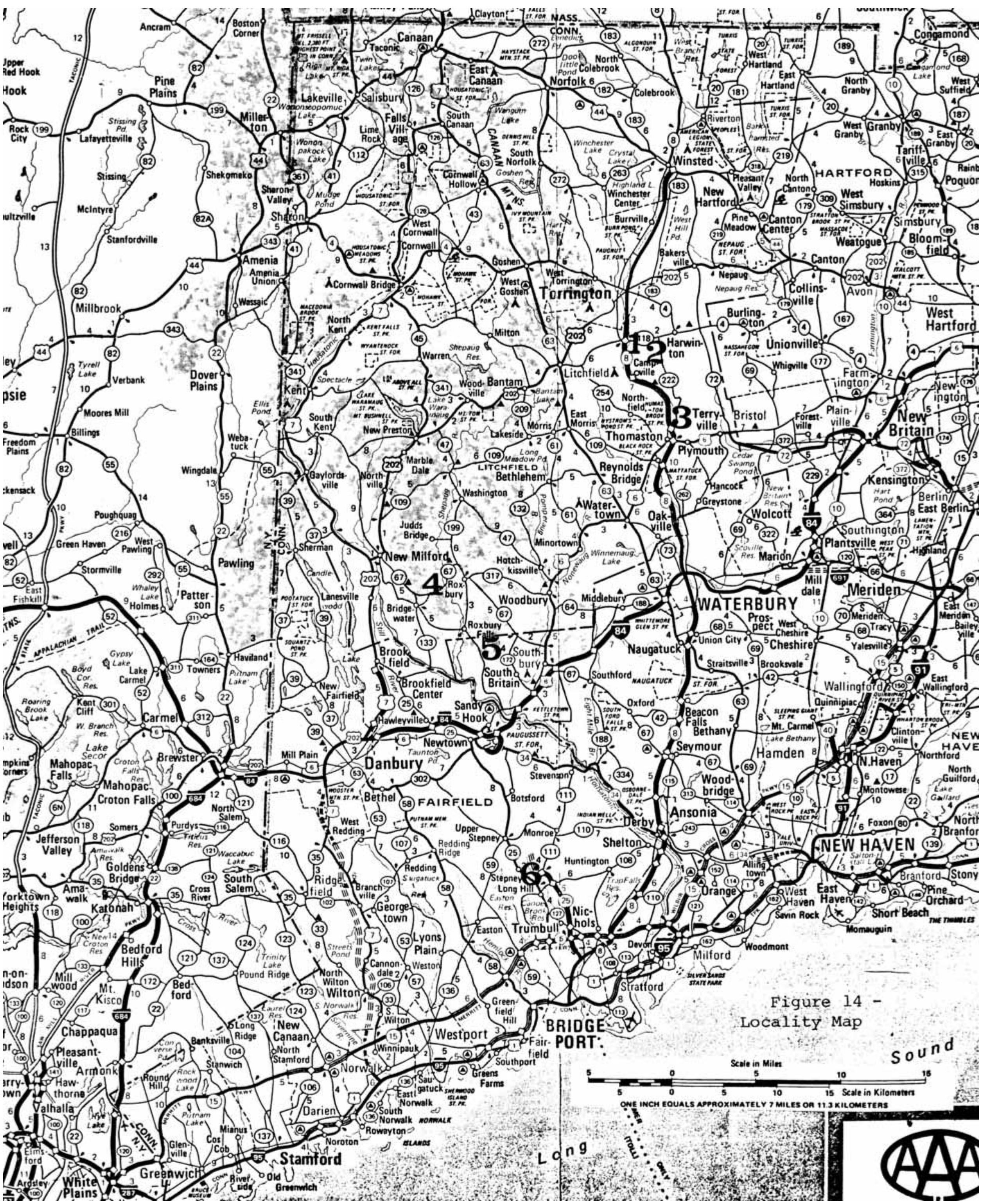


Figure 14 - Field Stop/Locality Map.

DRIVING DIRECTIONS

(NYAS to the western Connecticut via the Major Deegan Expressway, Routes 684, 84, and 8).

Turn L on 5th Ave. and drive south to 62nd Street. Turn L toward the East Side Drive and take the Drive north to the Third Avenue Bridge over to the Major Deegan Expressway (87N). Past Ardsley, New York, take the Saw Mill River Parkway northward toward Bedford Hills, New York. Just past Bedford Hills, switch to I-684(N) toward Brewster, New York and then switch to I-84(E) to Connecticut. Travel east to Exit 8 (Route 6) and at the end of the exit ramp turn R to shopping center entrance on R. This will be a brief rest stop (Friendly's); those of you who forgot to bring lunch can pick some up here (Pathmark).

To Stop 1: Turn L out of shopping center and follow signs to I-84(E). Continue east on I-84 until intersection with Connecticut Route 8. Take Route 8 northward toward Torrington, Connecticut, through the heart of the crystalline bedrock of western Connecticut. Note the interesting roadcuts on both sides of the road. Continue north to Exit 42 (Routes 118 and 8). Bear R (east) on Route 118 at the end of the exit ramp and park in the commuter parking lot. Outcrops of the Hartland occur across from the parking lot on the north side of Route 118.

To Stop 2: Turn R out of commuter lot driving eastward on Route 118 for about 1.5 miles. Turn right (before Connecticut Route 222) under powerline with vans safely away from side of road. Mineral collecting site is just a short walk southward along powerline right-of-way.

To Stop 3: Continue east on Route 118 to the intersection with Route 222. Turn R (south) on 222 for a pleasant drive for about 7.5 miles. Turn R into the entrance for the Thomaston Dam site and drive along the crest of the dry dam (flood control) to the parking area. Park close to the fence but do not block gates. The collecting area is to the west in a large railroad cut. Trains are rare but they DO RUN! PLEASE BE CAREFUL WHILE ON TRACKS!

To Stop 4: Turn R onto 222 and follow around to T intersection. Turn L (still on 222) and pass under Route 8 continuing southward into Thomaston (now on Routes 6 and 202). Go through Thomaston and turn R (west) following Routes 6 and 202 toward Watertown. Continue southwestward on 6 and 202 past intersectionms with Routes 63 and 61 into Minortown. Continue on 6 and 202 past Route 47 into Woodbury and turn R (west) onto Route 317 just past the center of Woodbury. Follow Route 317 (Good Hill Road) past Route 67 into the center of Roxbury. Drive west from the center of town on the extension of 317 (Wellers Bridge Road) westward for 1.3 miles over the Shepaug River. (The US Geological Survey gaging station for the Shepaug River is located on Wellers Bridge). After crossing the bridge, turn R on CT Route 67 toward Roxbury Station. In 0.6 mi, turn L into Mine Hill Road (sign for Roxbury Land Trust). Drive uphill 0.3 mi to parking lot. Walk to Stop 4, old Roxbury Iron Mine.

To Stop 5: Drive downhill from parking lot on Mine Hill Road. Turn R on CT Route 67. After 0.6 mi, turn L on Wellers Bridge Road and cross Shepaug River. After 0.9 mi, stop sign at crest of drumlin. After 0.5 mi, opposite Christ Church, Roxbury, turn R into South Street (also South Christian Street). Turn R on South Street; road follows the crest of a low drumlin trending NW-SE. In 0.6 mi, pass intersection with Apple Lane. Continue past Squire Rd. on L, River Road on R, and at Roxbury Falls, Lower River Road on R. Proceed uphill on Brown Brook Road (follows valley of Turrill Brook). After entering New Haven County and Newtown quadrangle, and after a 90-degree curve to L at the top of the hill, turn L into Perkins Rd. Drive to end of paved road and park. Walk in woods to Stop 5.

To Stop 6: Retrace route on Perkins Rd. to Brown Brook Road. After 0.9 mi., pass intersection of West Purchase Road on R. After another 0.6 mi, Stop Sign. Bear R on Purchase Road.; Stillson Road on L. (Powerline overhead at end of woods; George C. Waldo State Park.) After 2.2 mi, pass low wooden sheds on R. In another 0.2 mi, make Stop for River Road. Turn L onto River Road. In 1.2 mi. Stop; turn R onto Bridge over Housatonic River. In 1.6 mi, traffic light; turn R on US 6A and continue over I-84 into Newtown. In about 1 mi., intersection of CT 25. Turn L and follow to Jct with CT Route 111 at Long Hill (at NW end of expressway sector of CT Route 23). Turn L on Route 111 and take immediate R into Old Mine Park on Old Mine Road. Park in parking lot and walk to various parts of Stop 6.

Back to NYAS: Return to new Route 25 expressway, southbound ramp and follow to Merritt Parkway (westbound) toward New York. Follow Merritt Parkway to intersection with Hutchinson River Parkway. Take Hutchinson Parkway south to Cross Bronx Expressway westward into Manhattan.

DESCRIPTIONS OF INDIVIDUAL LOCALITIES ("STOPS")

STOP 1 - Hartland Formation (upper member) granofels, schist, and amphibolite. [UTM Coordinates: 656.80E / 4624.88N, Torrington quadrangle.]

The outcrops forming the cliffs across from the commuter lot were originally described by Martin (1970) and subsequently detailed by Merguerian (1985). Here, 2-15 cm-scale very well-layered muscovite-biotite-plagioclase-quartz-(hornblende)-garnet) granofels occurs with interlayered schist of similar mineral composition. 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 rocks creates a lustrous sheen from foliation surfaces reflecting sunlight, a hallmark of aluminous Hartland lithologies. A 2-m thick layer of hornblende-plagioclase-biotite-epidote-quartz-(garnet) amphibolite is exposed on the south-facing wall of the outcrop. The pervasive interlayering of granofels and schist, high muscovite and plagioclase content, and presence of amphibolite suggests that protoliths of these rocks were volcaniclastic graywackes and interlayered shale with subordinate basalt flows. The upper member of the Hartland Formation is similar to and correlative with the Moretown Formation of western Massachusetts and the unit Ꞓ-Oh in the New York City area (Figures 2, 10, and 12).

The dominant layering is parallel to a composite (S_1+S_2) regional foliation, all striking roughly N65°E with dips of 60°NW. The foliation is deformed by crenulate F_3 folds with axial surfaces oriented N30°E, 26°SE. The F_3 hingelines are expressed as L_3 crinkle lineations in the more massive granofels and trend N55°E with a 9° plunge. Note the upright warping of the S_3 axial surface traces and the decrease in wavelength of F_3 folds in mica-rich interlayers. Locally, a 2-m thick pegmatite intrudes across S_3 axial surfaces, rotating F_3 folds and older fabrics. Also note the F_4 "Z" folds with N20°E, 84° NW axial-planar slip cleavage. The complex sequence of folds and related structural features for this part of Connecticut are summarized in Table 3.

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

STOP 2 - Harwinton Pegmatite, Harwinton, Connecticut. [UTM Coordinates: 659.1E / 4625.2N, Torrington quadrangle.]

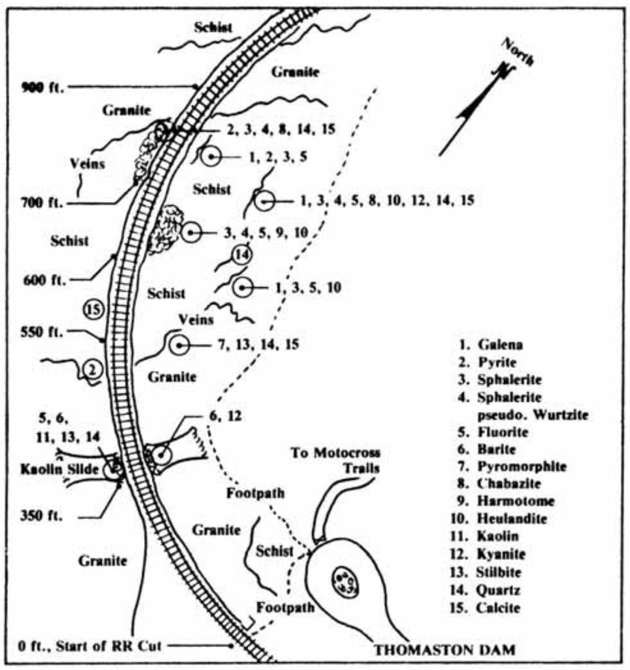
Back from the road a quarry was opened in a pegmatite in order to mine for feldspar. An important constituent in ceramics, paint, cleansing agents, and as a placebo or filler in drugs, feldspar was mined throughout New England in the 1900s. Luckily for mineral collectors, the quarry operators selected pure specimens of feldspar and left behind minerals that would interfere with the processing of feldspar. Here, these minerals include whitish to greenish beryl forming six-sided prismatic crystals and groupings up to 20 cm long and 30 cm long black tourmaline (schorl). Happy hunting!

STOP 3 - Thomaston Dam Site, Thomaston, Connecticut. [UTM Coordinates: 660.4E / 4617.4N, Thomaston quadrangle.]

The Thomaston dam, a dry dam to hold back flood waters, was built by the U.S. Army Corps of Engineers in 1957 in the aftermath of disastrous flooding of the Naugatuck River valley in 1955. Nearly 1.5 million cubic yards of fill were required to build the dry dam that stands 142 feet high and stretches for more than 2,000 feet across the Naugatuck valley. A new railroad cut was blasted to the west of the river valley that provided the rock that would ultimately build the dry dam. The railway was then diverted from the east to the west of the river with the eastern cut (still visible) employed as a spillway. The dam was completed in 1960 and cost more than $14 million and is now used as a picnic area, motocross trail, and, of course, mineral-collecting site.

Along the railroad cut a magnificent transect through the country rocks is visible. Here, dikes and sills of the Thomaston granite are clearly intrusive across the regional foliation of the Ratlum Mountain Schist of probable Ordovician age (equivalent to the Moretown Member of the Hartland Formation). Hartland metamorphic rocks are light to silvery gray schist and gneiss, rich in muscovite with subordinate biotite, plagioclase, quartz, and locally impressive concentrations of graphite. Were these originally kerogen-bearing rocks now reduced to graphitic schist? The metamorphic rocks locally contain laminae of coticule (garnet-quartz granofels) and are intruded by veins, sills, and dikes of granite.

A map of the collecting site is shown in Figure 15 from Segeler and Molon (1985). Mineral collectors try to identify veins peripheral to the granite that cut, commonly along joints or faults, across the foliation of the Hartland. During the late stages of magmatic crystallization, large, typically incompatible elements complex with the fluoride and chloride ions and, driven by high vapor pressure, purge through the surrounding country rock leaving well-crystallized mineral samples as vug- and fracture fillings. The common minerals found at Thomaston include fluorite (in various colors), quartz, kyanite, galena, pyromorphite, wulfenite, pyrite, wurtzite (a polymorph of sphalerite), and a host of zeolite minerals including stilbite, harmotone, heulandite, and chabazite. A complete listing of minerals found at Thomaston is reproduced in Table 4.



Minerals species reported at the Thomaston Dam, 1984.

Native Elements
Graphite
Sulfur

Sulfides
Chalcopyrite
Galena
Greenockite
Pyrite
Pyrrhotite
Sphalerite
Wurtzite

Oxides
Anatase**
Brookite**
Ilmenite
Magnetite
Pyrolusite
Rutile

Halides
Fluorite

Carbonates
Aragonite
Calcite
Cerussite
Hydrozincite
Malachite
Smithsonite

Sulfates
Anglesite
Barite
Copiapite
Jarosite
Melanterite

Phosphates, Vanadates
Autunite
Fluorapatite
Pyromorphite
Vanadinite

Tungstates
Wulfenite

Silicates
Actinolite
Albite
Apophyllite
Axinite
Beryl
Biotite
Chabazite
Chlorite
Clinozoisite
Datolite*
Diopside
Epidote
Almandine
Grossular
Harmotome
Hemimorphite
Heulandite
Hornblende
Hyalite
Kaolinite
Kyanite
Laumontite*
Microcline
Montmorillonite
Mordenite***
Muscovite
Natrolite*
Oligoclase
Phillipsite***
Phlogopite
Prehnite*
Quartz
Schorl
Sillimanite
Staurolite
Stilpnomelane
Stilbite
Titanite

* *Found in basalt of railway ballast.*
** *Found at other end of dam in minor cut.*
*** *Not confirmed.*

Figure 15 - Mineral map of the Thomaston Dam site, Thomaston, Connecticut (from Segeler and Molon, 1985).

STOP 4 - Roxbury Iron Mine, Roxbury, Connecticut. [UTM Coordinates: 638.71E / 4601.90N, Roxbury quadrangle.]

Originally opened as a silver mine in roughly 1750, iron ore was ultimately discovered (probably much to the surprise and chagrin of investors!) and, later (by 1800), mined for iron ore. Forming an important deposit of "spathic" or "sparry" ore, to use the old vernacular, the iron ore occurs as siderite, an iron carbonate. The siderite occurs with quartz, pyrite, black sphalerite, chalcopyrite, galena, limonite, and arsenopyrite (rare). The ore formed in a 2-3 m wide subvertical vein cutting the Hartland strata at a high angle. Here, the mine occurs along a fault? at the contact of the Mine Hill granite gneiss and mica quartzite, schist, and feldspathic mica quartzite and schist (Gates, 1959). Mineralization may have occurred here due to hydrothermal activity peripheral to the Mine Hill granite gneiss, a buried pluton, or be due to metamorphic melting at depth of carbonate-rich strata. Interesting reading on this mine can be found in Shepard (1837), Schairer (1931), and Januzzi (1972, especially pp. 194-203).

STOP 5 - Roxbury Garnet Mine, Roxbury Falls, Connecticut. [UTM Coordinates: 641.62E / 4595.95N, Roxbury quadrangle.]

The Roxbury garnet mines were operated as small prospect pits in the 1800s(?) and were a major source of garnet abrasive material until the huge discoveries in the Adirondacks near North Creek, New York. The garnets occur as perfect 1-3 cm dodecahedral (twelve-sided) crystals embedded in a crumbly, muscovite-quartz schist and granofels of the Hartland Formation. In some rocks, 1-2 cm tabular brown staurolite crystals coexist with garnet. Mapping by Gates (1959) indicates that the mines occur along the west edge of 1.5-mile lense of similar porphyritic rocks within more typical Hartland occurring on Mine Hill (Stop 4).

STOP 6 - Tungsten Mines, Old Mine Park, Trumbull, Connecticut. [UTM Coordinates: 648.48E / 4572.08N, Long Hill quadrangle.] ***Note:*** *Non-residents must obtain permission to park from the Trumbull Police Department.*

The following information has been provided by Mr. Earle C. Sullivan, a chemist by profession and now a historian and collector of minerals in his home state of Connecticut. Originally inhabited by Indians, the present site of Old Mine Park in Trumbull, Connecticut, is an area of historic and mineralogic interest (Figure 16). A map of the mine area is shown in Figure 17. Initially, the Indians mined quartz from the Champion Lode just west of the upper pit (Figure 17). The Indian name Saganawamps (meaning "on the side of the hill") was derived from accounts of early English-speaking settlers in the area. Clearly, the Indian interest in the mine area was in the manufacture of arrow points from the pure quartz vein (currently fenced in).

The first reference in town records dates back to 1725 when a deed was filed for a place named "Saganawamps". Mineral deeds were filed as early as 1757 by Howkins Nichols of Stratford for a 200-year lease on the property. After Nichols' death in 1758, it wasn't until 1803 that Elnathan Sherman of Trumbull leased Saganawamps to Philo and George Sherman to extract and bin burn lime as a thick layer of marble occurs at the mine site. By 1810, the Lane family of Monroe had found metallic minerals such as galena and bismuth in Monroe (currently Lane's and Booth's Bismuth Mines about 4 miles north of Saganawamps). By the early 1800s, Ephraim Lane was selling mineral specimens of tungsten, tellurium, topaz, and fluorite from Saganawamps.

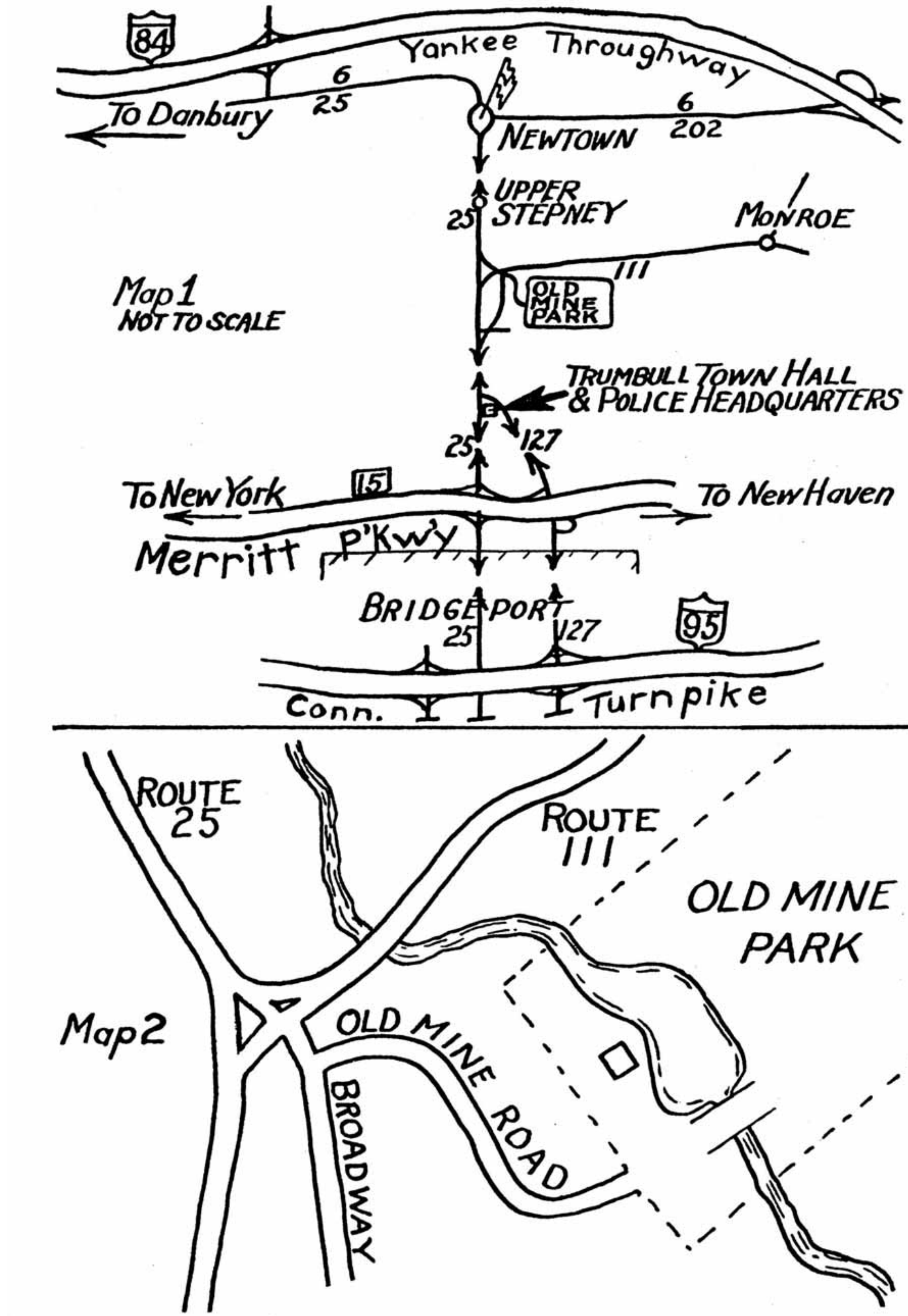


Figure 16 - Location map for Stop 6, Old Mine Park, Trumbull, Connecticut (from Sullivan, 1985).

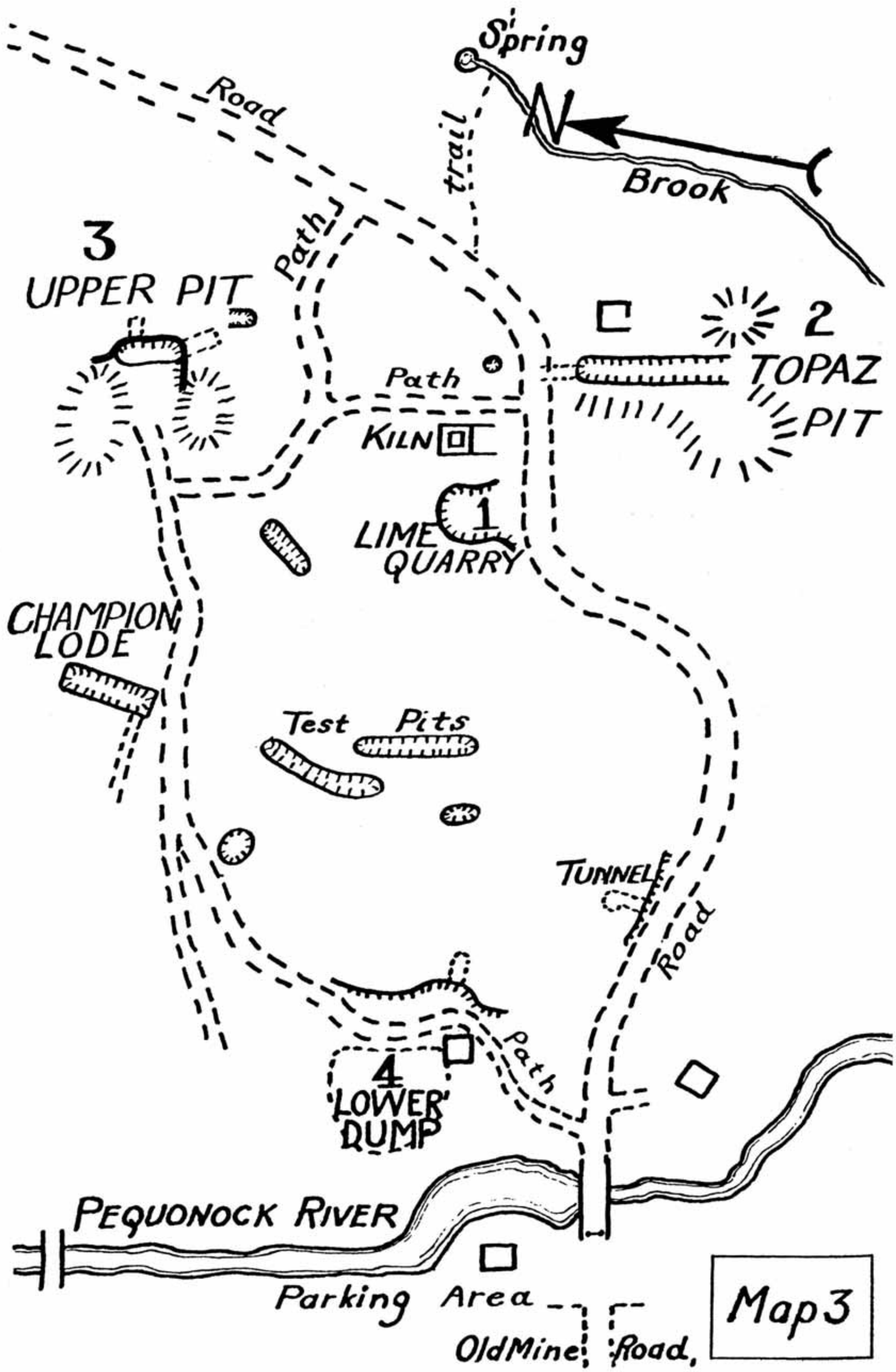
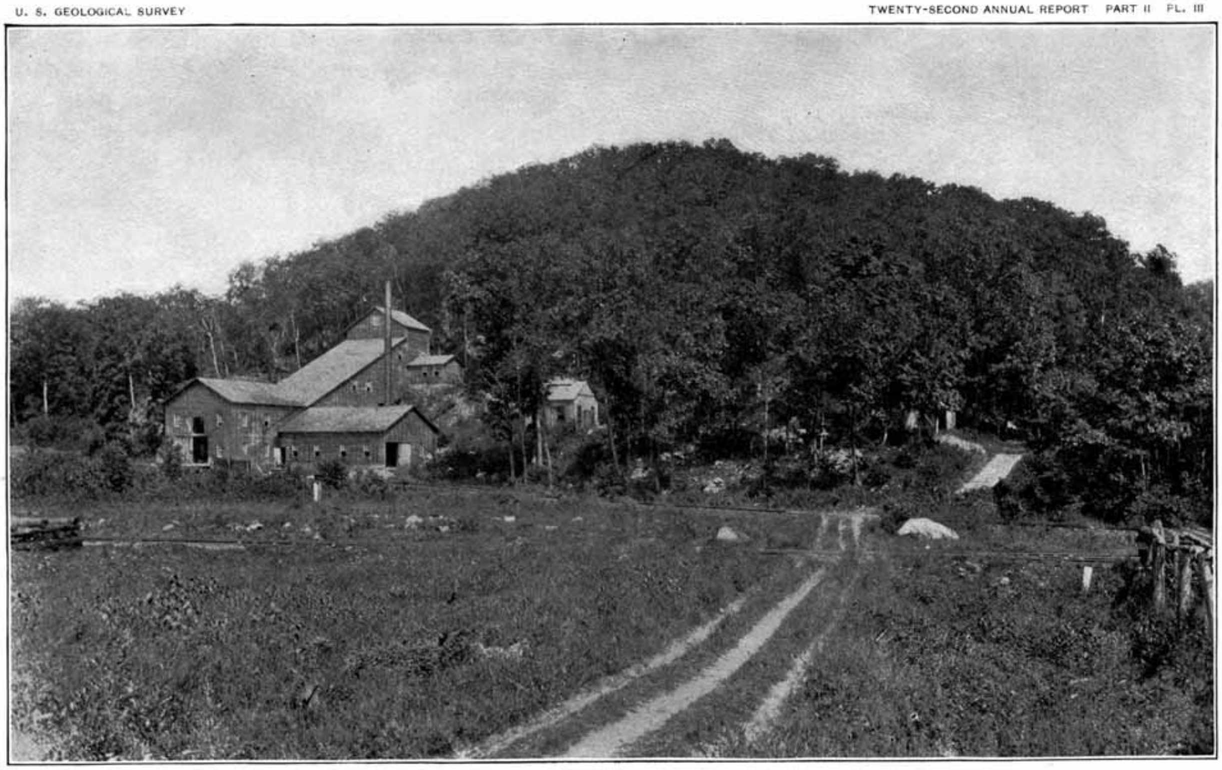


Figure 17 - Sketch map showing location of mineral pits at the tungsten mine, Old Mine Park (Sullivan, 1985).

Up to the mid 1800s, tungsten ores and minerals were of interest to mineral collectors only as no commercial uses for these minerals were known. By 1855, however, the strength of tungsten-steel had been discovered and the search for tungsten ores became a priority. The Lane family kept deed to Saganawamps, then in 1871 a hopeful investor, Thomas A. Hubbard, of Brooklyn, New York, bought up all of the available land in the vicinity of Saganawamps except for the region known as Pheobe Meadows (Figure 17). By the latest 1800s, a Dr. Adolph Gurlt, from the University of Bonn, Germany, performed a detailed survey of the tungsten deposit at Trumbull and recommended, in 1893, its further development.

Mining rights were purchased by the American Tungsten Mining and Milling Company of West Virginia by 1899 and construction of mine buildings began with the issue of $100,000 in bonds. A photo of the early mine works (circa 1900) is shown in Figure 18 from Hobbs (1901). The plant was shut down due to separation problems between pyrite and tungsten ore (wolframite) and by 1906, the American Tungsten Mining and Milling Company was declared bankrupt!

U. S. GEOLOGICAL SURVEY TWENTY-SECOND ANNUAL REPORT PART II PL. III



VIEW OF TUNGSTEN MINES, LONG HILL, CONNECTICUT.

In the foreground is seen the mill of the American Tungsten Mining and Milling Company.

Figure 18 - View of tungsten mines, Long Hill, Connecticut. (circa 1900).

William H. Hobbs, from the U.S. Geological Survey, became interested in the mine in 1900 and he noted that the mine failure was partly due to the fact that they did not follow the recommendation of Dr. Gurlt who suggested digging upward from pit #1 along the vein which would allow gravity removal of ore and proper drainage (Figure 19). Instead, the American Tungsten miners began mining at pits #2 and #3 and ran into flooding and ore-removal problems.

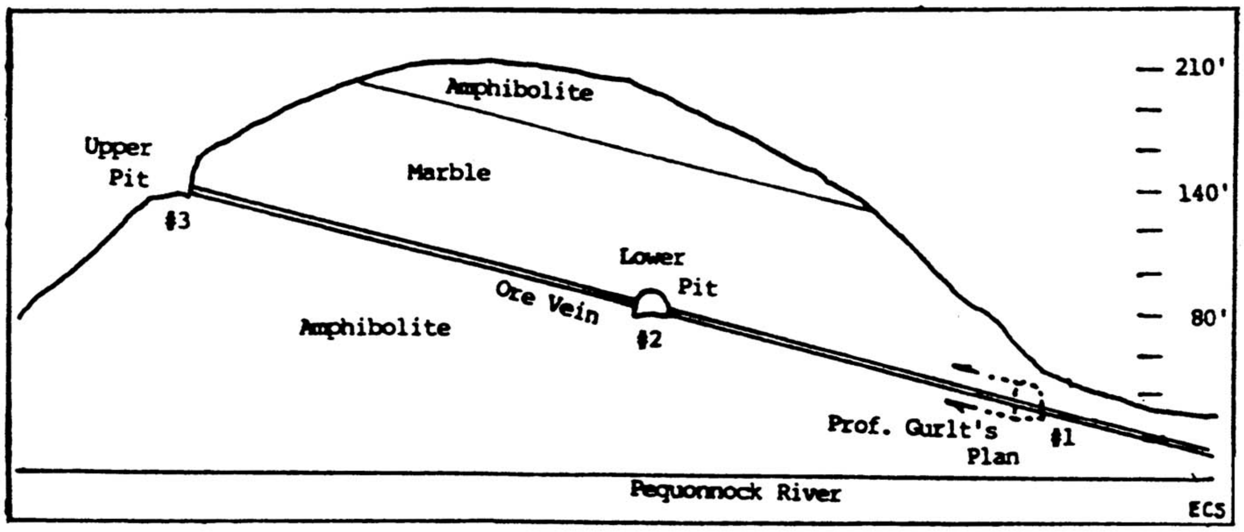


Figure 19 - Diagram-section of Saganawamps looking east from the river (vertical height exaggerated 2:1).

Restarts, fires (some of suspicious origin), and closings dominated the Trumbull mine in the early 1900s and by 1937, as a result of tax default, the Town of Trumbull took ownership of the property and by 1940, named it Old Mine Park for use by residents. Minor interest in the mine was initiated by the Japanese bombing of Pearl Harbor as a source of strategic minerals, but this never amounted to much.

Crowley (1968) mapped the Long Hill quadrangle and shows the Trumbull Tungsten mine located in the Hartland Formation in a thin marble layer sandwiched between two layers of amphibolite. The presence of marble to the east of Cameron's Line is rare but according to CM, can easily be explained as a slide block (olistolith) formed within the trench sequence. Mineralization occurs at the contact between the amphibolite and marble in a typical contact-metamorphic environment (Figure 20) with epidote, scheelite, and pyrite occurring as replacement minerals. Locally, the scheelite has been replaced by wolframite (pseudomorph) which retains the crystal shape of scheelite.

The minerals of Old Mine Park are numerous and listed on pages 38-41 along with a guide to where the minerals are found (keyed to Figure 17). Of particular interest here is the mineral fluorite which occurs in its reddish-brown variety exhibiting fluorescence, phosphorescence, and thermoluminescence. Try this experiment at home. Boil some water on the stove then turn out the flame, turn out the lights, and drop the reddish-brown fluorite into the hot water. Voila -- thermoluminescence! Have fun collecting here and plan to return someday on your own. Remember to register your car with the Trumbull Police as Old Mine Park is intended for residents only.

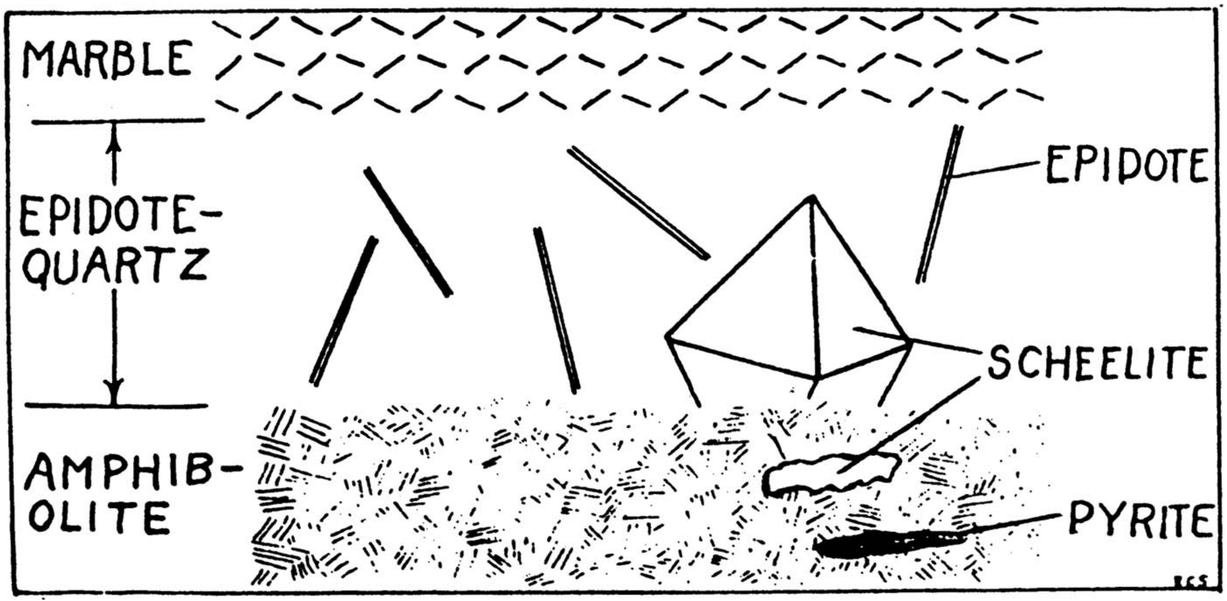


Figure 20 - Sketch of lower contact minerals (Sullivan, 1985).

To guide the mineral collector more easily toward a successful search, the various areas are located and described separately. In each of these areas, certain minerals have been found in relative abundance, but are not limited to the described locations. Most of the old and now barely visible test pits have produced some of the minerals reported elsewhere in the Park. As these test pits have been undisturbed for many years, a little hard work then should prove rewarding.

The principal and much worked locations are known to local collectors as:

1. The lime quarry
2. The topaz pit
3. The upper pit,and,
4. The lower dump

1. The lime quarry floor is overgrown with plants but digging around will turn up all blocks of marble. Some are almost black, some white, and some pink. The marble layers contain very small brown flakes of phlogopite, small green grains of pyroxene, and small brassy crystals of pyrite. Thin blackish veins in the marble consist of prochlorite.

2. Just beyond the lime quarry and the kiln ruins is the topaz pit. The north end of the long trench leads into the topaz+fluorite vein and the south end spreads out to form the waste dump. The best specimens of topaz have been found here with margarite, margarodite, purple fluorite, and sphalerite. Considerable quartz and some scapolite also occur here.

3. Climbing above the kiln ruins, a faint trail leads to a better well-traveled trail which, when followed north, leads to the upper pit. Scheelite, wolframite, epidote, pyrite, tungstite, and the chlorophane variety of fluorite have all been found here. This

4. The lower dump has not produced much recently, but digging well below the surface should get results. One procedure that can help in finding scheelite or wolframite is to heft each rock picked up. Because of the high density of " tungsten ores, any rock containing them in quantity will have a heftier feel. If a likely specimen is found, use great caution if attempting to break it as tungsten minerals are very easily smashed by a careless blow. One could end up with useless chips instead of a museum specimen.

Any mineralized area, such as Old Mine Park, can have minerals that have not been previously reported, the Trumbull Historical Society will appreciate being told of any new find. If such is your good fortune, please inform the Society of its name, the location where found, its relative abundance, and if possible, give the Society a duplicate for its Mineral Display Case. One must remember that Saganawamps has intentionally been left in a semi-wild condition so use caution while in the Park.

According to Mr. Earle C. Sullivan in 1985, the following minerals have been recently found at Old Mine Park. Locality numbers refer to the locality map (Figure 17).

Amphibole, variety hornblende; greenish-black grains making up the rock amphibolite gneiss. Best locality #3.
Arsenopyrite; silver white to steel grey, usually found massive at #3 and #4.
Biotite; black mica, found in the pegmatite veins.
Calcite; in marble. The best collecting area is the Lime Quarry (#l) where it occurs as white, pink, and dark grey crystalline masses.
Chlorite, variety prochlorite; greenish-black flakes in thin veins in the marble (#l).
Epidote; grey-green to dark olive green in crystal masses and in fibrous inclusions in the quartz. Best locality is the Upper Pit, #3.
Feldpars; creamy-white with one perfect, one good, and one poor cleavage (#2).
Fluorite; purple to dark reddish brown, easily broken with excellent cleavage. Easily found at #2 and #3, the reddish brown specimens are usually fluorescent and phosphorescent in UV light and also exhibit thermoluminescence, a rare visual treat in boiling hot water.
Garnet; in dark reddish brown masses in the marble (#4).
Limonite; brown stains coating many of the rock surfaces, especially #4.
Marcasite; pale yellow to bronze metallic color in veins, especially #4.
Margarite; fibrous micaceous bands between the topaz and the country rock, best at #2.
Margarodite; pearly or silvery micaceous flakes in masses with topaz at #2.
Muscovite mica; found in the pegmatite veins.
Phlogopite; a bronze colored mica found in very small flakes in the marble at #1.
Pyroxrene, variety coccolite'; very small grass-green grains in the marble at #1.
Pyrrhotite; dull brown streaks in the amphibolite-gneiss at #3.
Quartz; clear to dark grey at #2, #3, and #4.
Scapolite; light creamy white radiating crystalline masses at #2 and #3.

Scheelite; high density, creamy white to light tall crystals or small masses in the epidote-quartz, amphibolite, or pegmatite. Fluoresces bright blue-white in short wave UV light. It occurs throughout Old Mine Park but the best place to look is at the Upper Pit, #3.
Topaz; colorless, grey or tan, usually as crystal sections. Distinguished from quartz by its higher density and hardness, and its perfect basal cleavage. Best spot is #2.
Tourmaline; found only in the pegmatites as longitudinally striated black crystal sprays or as single crystals.
Wolframite; dull black and high density. Found as octahedral pseudomorphs of scheelite or as small blobs wherever scheelite could occur.

Other minerals that have been reported as occurring at Old Mine Park are described below. Those most likely to be found are underlined.

Apatite; brown, green, grey, yellow, or white, six sided crystals softer than quartz.
Barite; usually white, two perfect cleavages, high density.
Beryl; vitreous luster, harder than quartz, color usually greenish to white and forms six sided crystals.
Bismuth; grey metallic luster with a pink tinge, easily scratched by a knife, high density, one perfect cleavage.
Bornite, an ore of copper; black metallic luster, tarnishes easily to show 'Peacock' colors.
Chalcopyrite, also an ore of copper; brassy yellow metallic luster,
Cronstedtite; vitreous luster, black to brownish black, one perfect cleavage. Occurs as tapering hexagonal pyramids.
Diaspore; vitreous luster, pearly on cleavage face, white to greenish grey, one perfect cleavage. First reported as euclase by Shepard (Ref. No. 24) that he later corrected (Ref. No. 1).
Galena, an ore of lead; color is lead grey metallic luster, usually in cubic crystals with a cubic cleavage.
Hematite; submetallic luster when compact, color red-brown with a red streak. When pulverized and mixed with a binder becomes 'rouge', a polishing material for glass and metal. Also used by primitive peoples as a body paint.
Hypersthene; a member of the pyroxene group; has a nonmetallic luster, pearly on cleavage surface with two distinct cleavages, color is dark greenish-black, streak is brownish-grey, brittle.
Ilmenite; iron black to brownish black with submetallic luster, black to brownish black streak.
Malachite, an ore of copper; green with light green streak, usually in small masses.
Kelanterite; usually as a powdery coating, very soft with a yellow green color.
Pickeringite; very soft colorless to pale yellow with a silky luster. Usually found under overhanging ledges or other protected places.
Rutile; was known as 'red oxide of titanium, color red to black with a metallic luster and white streak.
Siderite; tan to brown with light brown streak, three distinct cleavages resembling calcite.
Sphalerite, an ore of zinc; white, yellow, brown or jet black with a resinous luster and six directions of perfect cleavage.
Sphene; also known as 'titanite', yellow, green, brown, or black with a resinous to waxy luster, brittle.
Talc; pearly to greasy luster, very soft, white to grey, one perfect cleavage.

Tungstite; very rare, usually as a lemon-yellow powdery coating on or near tungsten minerals.
Zoisite; white, grey, brown, or red with a vitreous luster, one perfect cleavage, crystals usually deeply striated, brittle. Shannon (Ref. No. 125) reported that specimens resembling zoisite from Trumbull actually tested as epidote.

The following minerals have been reported as found in Trumbull outside of Old Mine Park.

Albite
Analcite
Apatite
Bertrandite
Beryl
Biotite
Brookite
Bornite
Calcite
Chalcanthite
Feldspars
Fluorite
Galena
Garnet
Greenockite
Hematite
Hornblende
Ilmenite
Limonite
Marcasite
Muscovite
Pyrite
Quartz
Rutile
Scapolite
Scheelite
Sphalerite
Tourmaline
Topaz

ACKNOWLEDGEMENTS

We would like to thank the US Army Corp of Engineers for allowing access to the Thomaston Dam collecting site, and to the Archibald family for access to the Roxbury garnet mine. We also thank Mr. Gilbert Standley of the Trumbull Park Commission for permission to collect at Old Mine Park and the staff of Duke Geological Laboratories for assistance with trip details. Mr. Earle C. Sullivan has provided CM with abundant information on Old Mine Park and has helped in many ways throughout the years with field trips in western Connecticut.

The field-trip leaders (CM and JES) wish to thank all of our field-trip participants, present and past, for their unbridled enthusiasm for our 1988-89 trips (especially those where the weather was bleak!). This field-trip guidebook is dedicated to the late Mr. Ray Wadhams formerly of Torrington, one of the "Good Old Boys" who introduced CM to western Connecticut humor as well as to many, many mineral collecting sites.

TABLES

Table 01 - GEOLOGIC TIME CHART

(with selected major geologic events from southeastern New York and vicinity)

ERA Periods (Epochs)	**Years (Ma)**	**Selected Major Events**
CENOZOIC		
(Holocene)	0.1	Rising sea forms Hudson Estuary, Long Island Sound, and other bays. Barrier islands form and migrate.
(Pleistocene)	1.6	Melting of last glaciers forms large lakes. Drainage from Great Lakes overflows into Hudson Valley. Dam at The Narrows suddenly breached and flood waters erode Hudson shelf valley. Repeated continental glaciation with five? glaciers flowing from NW and NE form moraine ridges on Long Island.
(Pliocene)	6.2	Regional uplift, tilting and erosion of coastal-plain strata; sea level drops. Depression eroded that later becomes Long Island Sound.
(Miocene)	26.2	Fans spread E and SE from Appalachians and push back sea. Last widespread marine unit in coastal-plain strata.
MESOZOIC	66.5	
(Cretaceous)		
	96	Passive eastern margin of North American plate subsides and sediments (the coastal-plain strata) accumulate.
	131	(**Begin Atlantic Passive-Margin Stage II**).
(Jurassic)		Baltimore Canyon Trough forms and fills with 8,000 feet of pre-Cretaceous sediments.
		Atlantic Ocean starts to open. Newark basins deformed, arched, eroded.
	190	Continued filling of subsiding Newark basins and mafic igneous activity both extrusive and intrusive.
(Triassic)		Newark basins form and fill with non-marine sediments.

PALEOZOIC	245	
(Permian)		Pre-Newark erosion surface formed.
	260	**Appalachian orogeny.** (Terminal stage.) Folding, overthrusting, and metamorphism of Rhode Island coal basins; granites intruded.
(Carboniferous)		Faulting, folding, and metamorphism in New York City area. Southeastern New York undergoes continued uplift and erosion.
(Devonian)	365	**Acadian orogeny.** Deep burial of sedimentary strata. Faulting, folding, and metamorphism in New York City area. Peekskill Granite and Acadian granites intruded.
(Silurian)		
	440 450	**Taconic orogeny.** Intense deformation and metamorphism. Cortlandt Complex and related rocks intrude Taconian suture zone. (Cameron's Line and St. Nicholas Thrusr Zone). Arc-continent collision. Great overthrusting from ocean toward continent. Taconic deep-water strata thrust above shallow-water strata.
(Ordovician)		Ultramafic rocks (oceanic lithosphere) sliced off and transported structurally above deposits of continental shelf.
(Cambrian)		Shallow-water clastics and carbonates accumulate in west of basin. (= **Sauk Sequence**; protoliths of the Lowerre Quartzite, Inwood Marble, Walloomsac Schist). Transitional slope/rise sequence (Manhattan Schist) and deep-water terrigenous strata (Hartland Formation) form to east. (= **Taconic Sequence**).
PROTEROZOIC		
	570	Period of uplift, rifting,and erosion followed by subsidence of margin and development of **Iapetan Passive-Margin Stage I**.
(Z)	600	Rifting with rift sediments, volcanism, and intrusive activity. (Ned Mountain, Pound Ridge, and Yonkers gneiss protoliths).
(Y)	1100	**Grenville orogeny.** Sediments and volcanics deposited, compressive deformation, intrusive activity, and granulite facies metamorphism. (Fordham Gneiss, Hudson Highlands and related rocks).
ARCHEOZOIC		
	2600	No record in New York.
	4600	Solar system (including Earth) forms.

Table 02
Generalized Descriptions of Major Geologic "Layers", SE New York State and Vicinity

This geologic table is a tangible result of the On-The-Rocks Field Trip Program conducted by Drs. John E. Sanders and Charles Merguerian between 1988 and 1998. In Stenoan and Huttonian delight, we here present the seven layer cake model that has proved so effective in simplifying the complex geology of the region. Under continual scrutiny and improvement, we provide this updated web-based information as a public service to all students and educators of geology. We encourage any comments, additions, or corrections. References cited can be sought by following this link.

LAYER VII - QUATERNARY SEDIMENTS

A blanket of irregular thickness [up to 50 m or more] overlying and more or less covering all older bedrock units. Includes four or five tills of several ages each of which was deposited by a continental glacier that flowed across the region from one of two contrasting directions: (1) from N10°E to S10°W (direction from Labrador center and down the Hudson Valley), or (2) from N20°W to S20°E (direction from Keewatin center in Hudson's Bay region of Canada and across the Hudson Valley). The inferred relationship of the five tills is as follows from youngest [I] to oldest [V]. [I] - Yellow-brown to gray till from NNE to SSW, [II] - red-brown till from NW to SE, [III] - red-brown till from NW to SE, and [IV] - yellow-brown to gray till from NNE to SSW, and [V] - red-brown till from NW to SE containing decayed stones (Sanders and Merguerian, 1991a,b, 1992, 1994a, b; Sanders, Merguerian, and Mills, 1993; Sanders and others, 1997; Merguerian and Sanders, 1996). Quaternary sediments consist chiefly of till and outwash. On Long Island, outwash (sand and gravel) and glacial lake sediment predominates and till is minor and local. By contrast, on Staten Island, tills and interstratified lake sediments predominate and sandy outwash appears only locally, near Great Kills beach.

[Pliocene episode of extensive and rapid epeirogenic uplift of New England and deep erosion of major river valleys, including the excavation of the prominent inner lowland alongside the coastal-plain cuesta; a part of the modern landscape in New Jersey, but submerged in part to form Long Island Sound].

~~~~~~~~~~~~~~~~~~~~Surface of unconformity~~~~~~~~~~~~~~~~~~~~

LAYER VI - COASTAL-PLAIN STRATA (L. Cretaceous to U. Miocene; products of Passive Continental Margin II - Atlantic).

Marine- and nonmarine sands and clays, present beneath the Quaternary sediments on Long Island (but exposed locally in NW Long Island and on SW Staten Island) and forming a wide outcrop belt in NE New Jersey. These strata underlie the submerged continental terrace. The basal unit (L. Cretaceous from Maryland southward, but U. Cretaceous in vicinity of New York City) overlaps deformed- and eroded Newark strata and older formations. Also includes thick (2000 m) L. Cretaceous sands and shales filling the offshore Baltimore Canyon Trough. At the top are Miocene marine- and coastal units that are coarser than lower strata and in many localities SW of New Jersey, overstep farther inland than older coastal-plain strata. Capping unit is a thin (<50 m) sheet of yellow gravel (U. Miocene or L. Pliocene?) that was prograded as SE-directed fans from the Appalachians pushed back the sea. Eroded Newark debris is present in L. Cretaceous sands, but in U. Cretaceous through Miocene units, Newark-age redbed debris is conspicuously absent. This relationship is considered to be proof that the coastal-plain formations previously buried the Newark basins so that no Newark-age debris was available until after the Pliocene period of great regional uplift and erosion. The presence of resistant heavy minerals derived from the Proterozoic highlands part of the Appalachians within all coastal-plain sands indicates that the coastal-plain strata did not cover the central highlands of the Appalachians.

[Mid-Jurassic to Late Jurassic episode of regional arching of Newark basin-filling strata and end of sediment accumulation in Newark basin; multiple episodes of deformation including oroclinal "bending" of entire Appalachian chain in NE Pennsylvania (Carey, 1955), and one or more episodes of intrusion of mafic igneous rocks, of folding, of normal faulting, and of strike-slip faulting (Merguerian and Sanders, 1994b). Great uplift and erosion, ending with formation of Fall-Zone planation surface].

~~~~~~~~~~~~~~~~~~~~Surface of unconformity~~~~~~~~~~~~~~~~~~~~

LAYER V - NEWARK BASIN-FILLING STRATA (Upper Triassic and Lower Jurassic)

Newark-age strata unconformably overlie folded- and metamorphosed Paleozoic strata of Layer II and some of the Proterozoic formations of Layer I; are in fault contact with other Proterozoic formations of the Highlands complex. Cobbles and boulders in basin-marginal rudites near Ramapo Fault include mostly rocks from Layers III, IIB, and IIA(W), which formerly blanketed the Proterozoic now at the surface on the much-elevated Ramapo Mountains block. The thick (possibly 8 or 9 km) strata filling the Newark basin are nonmarine.

In addition to the basin-marginal rudites, the sediments include fluvial- and varied deposits of large lakes whose levels shifted cyclically in response to climate cycles evidently related to astronomic forcing. A notable lake deposit includes the Lockatong Formation, with its analcime-rich black argillites, which attains a maximum thickness of about 450 m in the Delaware River valley area. Interbedded with the Jurassic part of the Newark strata are three extrusive complexes, each 100 to 300 m thick, whose resistant tilted edges now underlie the curvilinear ridges of the Watchung Mountains in north-central New Jersey. Boulders of vesicular basalt in basin-marginal rudites prove that locally, the lava flows extended northwestward across one or more of the basin-marginal faults and onto a block that was later elevated and eroded. The thick (ca. 300 m) Palisades intrusive sheet is concordant in its central parts, where it intrudes the Lockatong at a level about 400 m above the base of the Newark strata. To the NE and SW, however, the sheet is discordant and cuts higher strata (Merguerian and Sanders, 1995a). Contact relationships and the discovery of clastic dikes at the base of the Palisades in Fort Lee, New Jersey, suggest that the mafic magma responsible for the Palisades was originally intruded at relatively shallow depths (roughly 3 to 4 km) according to Merguerian and Sanders (1995b).

Xenoliths and screens of both Stockton Arkose and Lockatong Argillite are present near the base of the sill. Locally, marginal zones of some xenoliths were melted to form granitic rocks (examples: the trondhjemite formed from the Lockatong Argillite at the Graniteville quarry, Staten Island, described by Benimoff and Sclar, 1984; and a "re-composed" augite granite associated with pieces of Stockton Arkose at Weehawken and Jersey City, described by J. V. Lewis, 1908, p. 135-137).

[**Appalachian terminal orogeny**; large-scale overthrusts of strata over strata (as in the bedding thrusts of the "Little Mountains east of the Catskills" and in the strata underlying the NW side of the Appalachian Great Valley), of basement over strata (in the outliers NW of the Hudson Highlands, and possibly also in many parts of the Highlands themselves), and presumably also of basement over basement (localities not yet identified). High-grade metamorphism of Coal Measures and intrusion of granites in Rhode Island dated at 270 Ma. Extensive uplift and erosion, ending with the formation of the pre-Newark peneplain].

~~~~~~~~~~~~~~~~~~~Surface of unconformity~~~~~~~~~~~~~~~~~~~

LAYER IV - COAL MEASURES AND RELATED STRATA (Carboniferous)

Mostly nonmarine coarse strata, about 6 km thick, including thick coals altered to anthracite grade, now preserved only in tight synclines in the Anthracite district, near Scranton, NE Pennsylvania; inferred to have formerly extended NE far enough to have buried the Catskills and vicinity in eastern New York State (Friedman and Sanders, 1982, 1983).

[**Acadian orogeny**; great thermal activity and folding, including metamorphism on a regional scale, ductile deformation, and intrusion of granites; dated at ~360 Ma].

LAYER III - MOSTLY MARINE STRATA OF APPALACHIAN BASIN AND CATSKILLS (Carbonates and terrigenous strata of Devonian and Silurian age)

(Western Facies)	**(Eastern Facies)**
Catskill Plateau, Delaware Valley monocline, and "Little Mountains" NW of Hudson-Great Valley lowland.	SE of Hudson-Great Valley lowland in Schunnemunk-Bellvale graben.
Kaaterskill redbeds and cgls.	Schunnemunk Cgl.
Ashokan Flags (large cross strata)	Bellvale Fm., upper unit
Mount Marion Fm. (graded layers, marine)	Bellvale Fm., lower unit (graded layers, marine)
Bakoven Black Shale	Cornwall Black Shale

Onondaga Limestone	
Schoharie buff siltstone	Pine Hill Formation
Esopus Formation	Esopus Formation
Glenerie Chert	
Connelly Conglomerate	Connelly Conglomerate
Central Valley Sandstone	
Carbonates of Helderberg Group	Carbonates of Helderberg Group
Manlius Limestone	
Rondout Formation	Rondout Formation
Decker Formation	
Binnewater Sandstone	Poxono Island Formation
High Falls Shale	Longwood Red Shale
Shawangunk Formation	Green Pond Conglomerate

[**Taconic orogeny**; 480 Ma deep-seated folding, dynamothermal metamorphism and mafic- to ultramafic (alkalic) igneous intrusive activity (dated in the range of 470 to 430 Ma) across suture zone (Cameron's Line-St. Nicholas thrust zones). Underthrusting of shallow-water western carbonates of Sauk Sequence below supracrustal deep-water eastern Taconic strata and imbrication of former Sauk-Tippecanoe margin. Long-distance transport of strata over strata has been demonstrated; less certain locally is proof of basement thrust over strata and of basement shifted over basement. In Newfoundland, a full ophiolite sequence, 10 km thick, has been thrust over shelf-type sedimentary strata]. In NYC and throughout New England, dismembered ophiolite is common (Merguerian 1979; Merguerian and Moss 2005, 2007).

~~~~~~~~~~~~~~~~~~~~Surface of unconformity~~~~~~~~~~~~~~~~~~~~

LAYER II - CAMBRO-ORDOVICIAN CONTINENTAL-MARGIN COVER (Products of Passive Continental Margin I - Iapetus). Subdivided into two sub layers, IIB and IIA. Layer IIA is further subdivided into western- and eastern facies.

LAYER IIB - TIPPECANOE SEQUENCE - Middle Ordovician flysch with basal limestone (Balmville, Jacksonburg limestones).

Not metamorphosed / Metamorphosed
Martinsburg Fm. / Walloomsac Schist
Normanskill Fm. / Annsville Phyllite

Subaerial exposure; karst features form on Sauk (Layer IIA[W]) platform.

~~~~~~~~~~~~~~~~~~~~Surface of unconformity~~~~~~~~~~~~~~~~~~~~

LAYER IIA [W] - SAUK SEQUENCE

Western shallow-water platform
(L. Cambrian - M. Ordovician)

Copake Limestone (Stockbridge,
Rochdale Limestone (Inwood Marble)
Halcyon Lake Fm.
Briarcliff Dolostone
Pine Plains Fm.
Stissing Dolostone
Poughquag Quartzite
Lowerre Quartzite
Ned Mtn Fm.

LAYER IIA [E] - TACONIC SEQUENCE

Eastern deep-water zone
(L. Cambrian-M. Ordovician)

(Ꞓ-Oh) Hartland Fm.
(Ꞓ-Om) Manhattan Fm.

[**Pre-Iapetus Rifting Event**; extensional tectonics, volcanism, rift-facies sedimentation, and plutonic igneous activity precedes development of Iapetus ocean basin. Extensional interval yields protoliths of Pound Ridge Gneiss, Yonkers granitoid gneisses, and the Ned Mountain Formation (Brock, 1989, 1993). In New Jersey, metamorphosed rift facies rocks are mapped as the Chestnut Hill Formation of A. A. Drake, Jr. (1984)].

~~~~~~~~~~~~~~~~~~~~Surface of unconformity~~~~~~~~~~~~~~~~~~~~

LAYER I - PROTEROZOIC BASEMENT ROCKS

Many individual lithologic units including Proterozoic Z and Y ortho- and paragneiss, granitoid rocks, metavolcanic- and metasedimentary rocks identified, but only a few attempts have been made to decipher the stratigraphic relationships; hence, the three-dimensional structural relationships remain obscure. Followed by a period of uplift and erosion.

~~~~~~~~~~~~~~~~~~~~Surface of unconformity~~~~~~~~~~~~~~~~~~~~

[**Grenville orogeny**; deformation, metamorphism, and plutonism dated about 1,100 Ma. After the orogeny, an extensive period of uplift and erosion begins. Grenville-aged (Proterozoic Y) basement rocks include the Fordham Gneiss of Westchester County, the Bronx, and the subsurface of western Long Island (Queens and Brooklyn Sections, NYC Water Tunnel #3), the Hudson Highland-Reading Prong terrane, the Franklin Marble Belt and associated rocks, and the New Milford, Housatonic, Berkshire, and Green Mountain Massifs.]

~~~~~~~~~~~~~~~~~~~~Surface of unconformity~~~~~~~~~~~~~~~~~~~~

In New Jersey and Pennsylvania rocks older than the Franklin Marble Belt and associated rocks include the Losee Metamorphic Suite. Unconformably beneath the Losee, in Pennsylvania, Proterozoic X rocks of the Hexenkopf Complex crop out.

Table 3

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.		
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.	PEGMATITES	? 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

REFERENCES CITED

Barrell, Joseph, 1915, Central Connecticut in the geologic past: Connecticut Geological and Natural History Survey Bulletin 23, 44 p.

Barrell, Joseph, and Loughlin, G. F., 1910, The lithology of Connecticut: Connecticut Geological and Natural History Survey Bulletin 13, 207 p.

Bell, Michael, 1985, The face of Connecticut. People, geology, and the land: Hartford, Connecticut Geological and Natural History Survey, 196 p.

Brock, P. J. C., 1989, Stratigraphy of the northeastern Manhattan Prong, Peach Lake quadrangle, New York-Connecticut, p. 1-27 in Weiss, Dennis, ed., New York State Geological Association Annual Meeting, 61st, Field trip guidebook: Middletown, NY, Orange County Community College, Department of Science and Engineering, 302 p.

Brock, P. J. C., 1993 ms., Geology of parts of the Peach Lake and Brewster quadrangle, southeastern New York and adjacent Connecticut, and basement blocks of the north-central Appalachians: New York, NY, City University of New York Graduate Faculty in Earth and Environmental Sciences, Ph. D. Dissertation, 494 p., 6 plates.

Cameron, E., and Shaninin, V., 1947, Beryl resources of Connecticut: Economic Geology, v. 42, p. 353-367.

Cameron, E., Larrabee, D., & et al., 1954, Pegmatitie investigations 1942-1945, New England: United States Geological Survey Professional Paper 255, 352 p.

Crowley, W. P., 1968, The bedrock geology of the Long Hill and Bridgeport quadrangles, Connecticut: Connecticut Geological and Natural History Survey Quadrangle Report 24, 81 p. plus maps (scale 1:24,000).

Davis, W. M., 1891, The geological dates of origin of certain topographical forms on the Atlantic slope of the United States: Geological Society of America, Bulletin, v. 2, p. 545-584.

Day, D. T., 1885, Tungsten: in Mineral Resources of the United States 1883-1884, United States Government Printing Office, Washington, D. C., p. 574-575.

Denny, C. S., 1982, Geomorphology of New England: United States Geological Survey Professional Paper 1208, 18 p.

Flint, R. F., 1930, The glacial geology of Connecticut: Connecticut Geological and Natural History Survey Bulletin 47, 294 p.

Flint, R. F., 1961, Two tills in southern Connecticut: Geological Society of America Bulletin, v. 72, no. 11, p. 1687-1691.

Flint, R. F., 1963, Altitude, lithology, and the Fall Zone in Connecticut: Journal of Geology, v. 71, no. 6, p. 683-697.

Flint, R. F., and Gebert, J. A., 1974, End moraines on and off the Connecticut shore (abstract): Geological Society of America, Abstracts With Programs, v. 6, no. 7, p. 738-739.

Flint, R. F. and Gebert, J. A., 1976, Latest Laurentide ice sheet: new evidence from southern New England: Geological Society of America Bulletin, v. 87, p. 182-188.

Gates, R. M., 1959, Bedrock geology of the Roxbury quadrangle, Connecticut: United States Geological Survey, Geologic Quadrangle Map GQ-121 (scale 1:24,000).

Gregory, H. E., and Robinson, H. H., 1907, Preliminary geological map of Connecticut: Connecticut Geological and Natural History Survey Bulletin 7, 39p.

Grim, M. S., Drake, C. L., and Heirtzler, J. R., 1970, Sub-bottom study of Long Island Sound: Geological Society of America Bulletin, v. 81, no. 3, p. 649-665.

Haeni, F. D., and Sanders, J. E., 1974, Contour map of the bedrock surface, New Haven-Woodmont quadrangles, Connecticut: United States Geological Survey, Miscellaneous Field Investigations Map MF 557A.

Harte, C. R., 1944, Connecticut's iron and copper: Connecticut Society of Civil Engineers, 60th Annual Report, p. 131-166.

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

Hess, F. L., 1917, Tungsten minerals and deposits: United States Geological Survey Bulletin 652, 85p.

Hiller, J., Jr., 1971, Connecticut Mines and Minerals: Hiller's Crystal Shop Press, Shelton, Connecticut, 64p.

Hobbs, W. H., 1901a, The Newark System of the Pomperaug Valley, Connecticut: United States Geological Survey, Annual Report, 21st, Part 3, p. 7-160.

Hobbs, W. H., 1901, The old tungsten mine at Trumbull, Connecticut: United States Geological Survey, Annual Report, 22nd, Part 2, p. 7-22.

Hobbs, W. H., 1901b, The river system of Connecticut: Journal of Geology, v. 9, p. 469-485.

Hovey, E. O., 1890, The oil well at Southbury, Connecticut: Scientific American, v. 62, p. 275.

Januzzi, R. E., 1972, The mineral localities of Connecticut and southeastern New York: The Mineralogical Press, Danbury, Connecticut, 294p.

Johnson, D. W., 1931a, Stream sculpture on the Atlantic slope, a study in the evolution of Appalachian rivers: New York, New York, Columbia University Press, 142 p.

Johnson, D. W., 1931b, A theory of Appalachian geomorphic evolution: Journal of Geology, v. 39, no. 6, p. 497-508.

Keith, H. C., 1935, The early iron industry of Connecticut (Part I): Connecticut Society of Civil Engineers, 51st Annual Report, p. 148-175.

Krynine, P. D., 1950, Petrology, stratigraphy, and origin of the Triassic sedimentary rocks of Connecticut: Connecticut Geological and Natural History Survey Bulletin 73, 247 p.

Kummel, H. B., 1893, Some rivers of Connecticut: Journal of Geology, v. 1, p. 371-393.

Malde, H. M., 1967, Surficial geology of the Roxbury quadrangle, Connecticut: United States Geological Survey, Geologic Quadrangle Map GQ-611 (scale 1:24,000).

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

Merguerian, C., 1977, 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, C., 1981, Coticules in New England - ancient examples of metalliferous sediments (abs.): EOS, American Geophysical Union, Transactions, v. 62, p. 310.

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

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

Merguerian, C.; and Baskerville, C. A., 1987, The geology of Manhattan Island and the Bronx, New York City, New York: in D. C. Roy, editor, Northeastern Section of the Geological Society of America, Centennial Fieldguide, p. 137-140.

Myer, G. H., 1962, Hydrothermal wurtzite at Thomaston Dam, Connecticut: American Mineralogist, v. 47, p. 977-979.

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

Platt, J. N., Jr., 1957, Sedimentary rocks of the Newark group in the Cherry Brook valley, Canton Center, Connecticut: American Journal of Science, v. 255, p. 517-522.

Pynchon, W. H. C., 1899, Iron mining in Connecticut: Connecticut Magazine, v. 5, p. 20-26; 232-238; 277-285.

Rice, W. N., and Gregory, H. E., 1906, Manual of the geology of Connecticut: Connecticut Geological and Natural History Survey, Bulletin 3, 263 p.

Rogers, John, 1985, Bedrock geological map of Connecticut: Hartford, Connecticut, Connecticut Geological and Natural History Survey, Connecticut Natural Resources Atlas Series.

Rogers, John; Gates, R. M.; and Rosenfeld, J. L., 1959, Explanatory text for preliminary geologic map of Connecticut, 1956: Connecticut Geological and Natural History Survey Bulletin 84, 64 p.

Ryerson, K.H., 1968, Rockhound's guide to Connecticut (Pequot Handbook 3): Stonington, Connecticut, The Pequot Press, Inc., 60 p.

Sanders, J. E., 1965, Sediment-filled deep valleys underlying New Haven Harbor, Connecticut, revealed by continuous seismic profiling using sparker and pneumatic sources (abs.): American Geophysical Union, Transactions, v. 46, no. 1, p. 105.

Sanders, J. E., 1988 ms., Sediment-filled deep V-shaped, bedrock-walled valleys underlying New Haven Harbor, Connecticut, revealed by continuous seismic-reflection profiling using sparker- and compressed-air sound sources: 76 p.

Schairer, J. F., 1931, The minerals of Connecticut: Connecticut Geological and Natural History Survey Bulletin 51, 121 p.

Segeler, C. G., and Molon, J., 1985, The Thomaston Dam Site, Thomaston, Connecticut: Rocks and Minerals, May/June 1985, p. 119-124.

Shannon, E. V., 1921, Some minerals from the old tungsten mine at Long Hill, Connecticut: United States National Museum, Proceedings, v. 58, p. 469-482.

Shannon, E. V., 1921, The old tungsten mine in Trumbull, Connecticut: American Mineralogist, v. 6, p. 126-128.

Sharp, H. S., 1929, The physical history of the Connecticut shoreline: Connecticut Geological and Natural History Survey Bulletin 46, 97 p.

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

Sohon, J. A., 1951, Connecticut Minerals - their properties and occurrence: Connecticut Geological and Natural History Survey Bulletin 77, 128p.

Sullivan, E. C., 1985, History and minerals of Old Mine Park (Saganawamps): Trumbull, Connecticut, Trumbull Historical Society, 67 p.

Yedlin, L. N., 1947, Garnet at Roxbury and W. Redding, Connecticut: Rocks and Minerals, v. 22, no. 9, p. 824-826.

Filename: DL OTR06 Connecticut Mines I.doc