DUKE GEOLOGICAL LABORATORY

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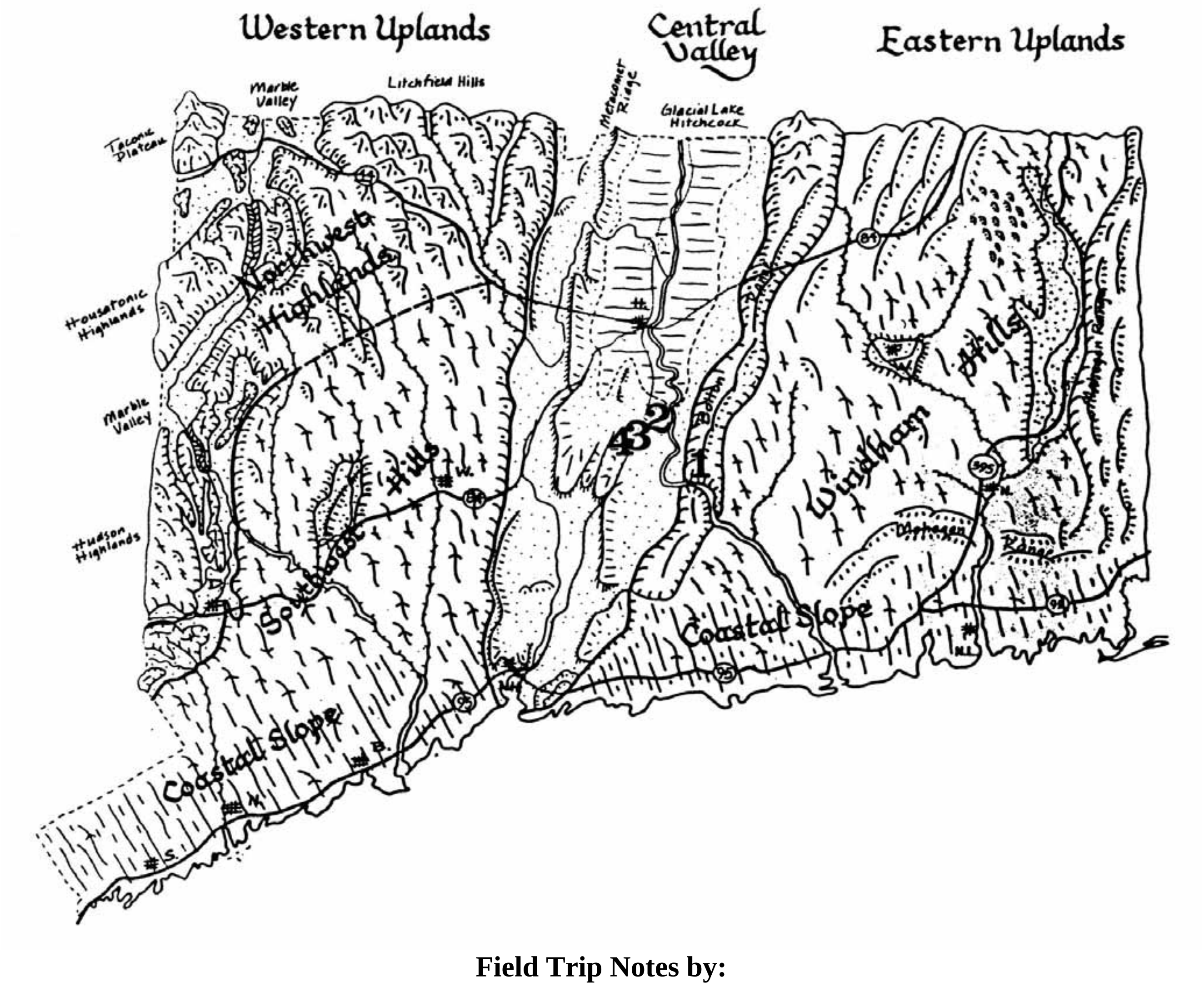
TRIPS ON THE ROCKS

Guide 25: Connecticut Mines II

Trip 43: 01/02 December 2001



Field Trip Notes by:

Charles Merguerian

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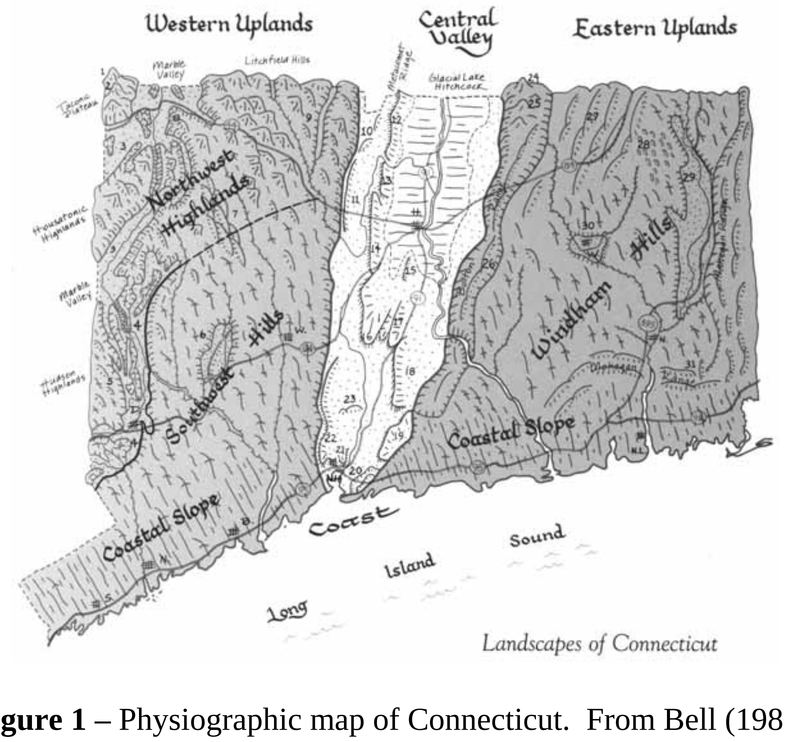
INTRODUCTION

Today's field trip to Connecticut is intended to introduce the participants to many of the region's former mines and unusual mineral prospects. We will visit, examine, and collect rocks and minerals from numerous sites in the crystalline highlands of western Connecticut (Day One) and poke around during Day Two in the crystalline rocks of eastern Connecticut (Figure 1). Table 1 (p. 33) 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 chronology of some important local geologic events. Table 2 (p. 35) summarizes the major local geologic units (stratigraphy) in terms of layers designated by Roman numerals.

GEOLOGIC BACKGROUND

Under this heading is discussed the bedrock units, the glacial deposits, and the drainage history of this weekend's field trip route. Driving directions and stop descriptions follow.



Landscapes of Connecticut

Figure 1 – Physiographic map of Connecticut. From Bell (1985).

BEDROCK UNITS

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

As we begin our geo-collecting journey from Hofstra University, a few thoughts about the crystalline rocks buried beneath our feet. The crystalline bedrock of southern New England marks the southern terminus of an important sequence of metamorphosed Proterozoic to Lower Paleozoic rocks of the Manhattan Prong (Figure 2) which widens northeastward into the New England Upland physiographic province of the Appalachian mountain belt. Originally, major parts of the Paleozoic strata of New England were deposited unconformably upon strongly deformed Proterozoic Y layered feldspathic and massive granitoid gneiss, amphibolite, and calc-silicate rocks of complex stratigraphy known as the Fordham and Yonkers Gneisses (Layer I). Proterozoic Z rift facies strata formerly separated the Layer I sequence from Layer IIA (Table 2).

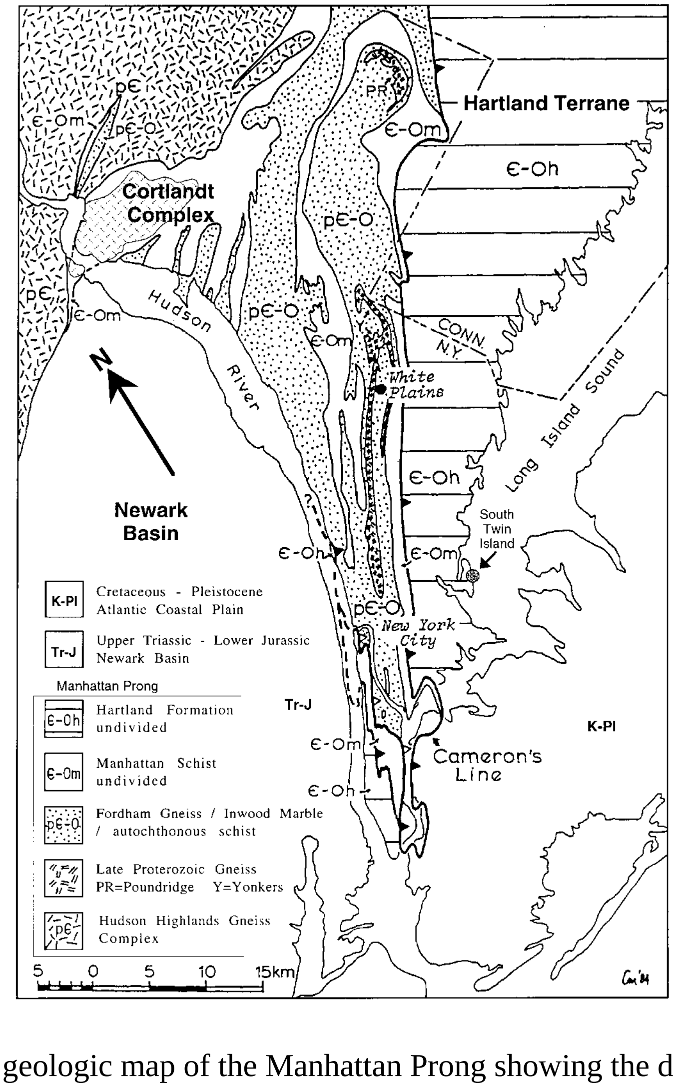


Figure 2 - Simplified geologic map of the Manhattan Prong showing the distribution of metamorphic rocks from Grenville cycle (Layer I; rocks of Proterozoic Y and Z age) and early phases of Appalachian cycle (Layer II; rocks of Early Paleozoic age). Most faults and intrusive rocks have been omitted. (Adapted from Mose and Merguerian, 1985, fig. 1, p. 21.)

Recent, new discoveries by Drs. Pamela and Patrick Brock indicate that a Proterozoic Z rift facies sequence correlative with the Yonkers Gneiss (the Ned Mountain Formation of Brock, 1989, 1993) locally rests unconformably above Layer I. As such, the complexly deformed, Proterozoic Y basement sequence (Layer I) constitutes 1.0 Ga and older continental crust only. The rift facies strata of proto-North America eventually was buried and laid the foundation for a trailing edge, passive continental margin by the early Paleozoic Era. Interestingly, the current geologic setting of eastern North America, with deformed Paleozoic and older basement covered by Mesozoic rift strata and a younger blanket of transgressive sediments, is analogous to the past (except for the obvious differences in age, paleolatitude, geothermal regime, and paleotectonics).

The Cambrian to Ordovician bedrock units in western Connecticut and New York City (Layer II) now constitute a deeply eroded sequence of highly metamorphosed, folded and faulted sedimentary and igneous rocks which began life roughly 550-450 million years ago as thick accumulations of both shallow- and deep-water sediment adjacent to the Early Paleozoic shores of proto-North America. Layer II can be divided into two sub-layers, IIA and IIB (Figure 3; see Tables 1 and 2).

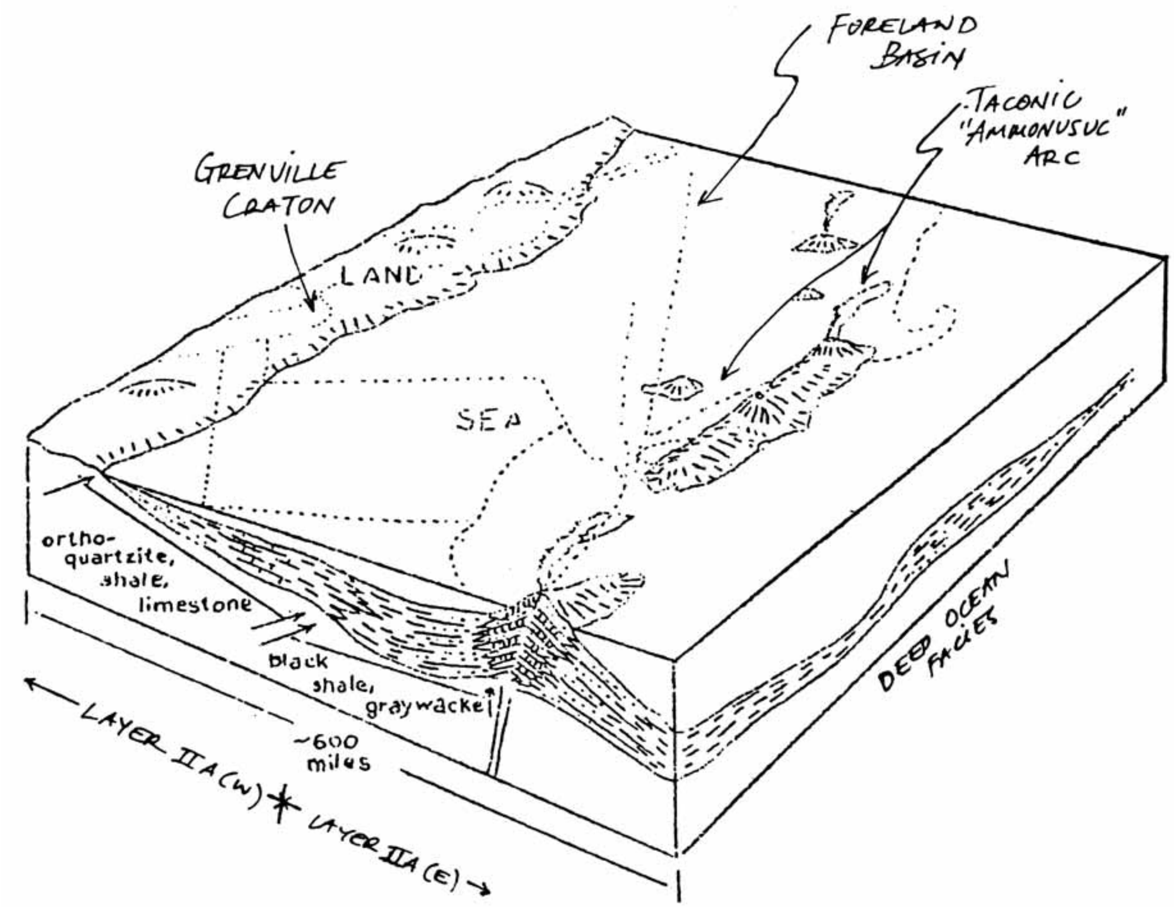


Figure 3 – Block diagram showing the lower Paleozoic continental shelf edge of embryonic North America immediately before deposition of Layer IIB. Current state outlines are dotted for reference. The depositional areas for Layers IIA(W) and IIA(E), and the position of the Taconic arc and foreland basin are indicated. Modified from a 1960s CCNY field trip guide.

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 first sandy and then 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 deeper water conditions 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 and as units Ꞓ-Om and Ꞓ -Oh of the Manhattan and Hartland Schist(s), respectively, in western Connecticut and New York City. (See Figure 3.)

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 Walloomsac Schist, and Manhattan Formation. In New York City, it is the Manhattan Schist unit Om that is demonstrably interlayered with the Inwood Marble (Ꞓ-Oi) and contains thin layers of calcite marble (Balmville equivalent) at its base at Inwood Hill Park in Manhattan. This field evidence is used to indicate that unit Om of the Manhattan Schist is in place where found. The overlying, structurally higher schist units (Ꞓ-Om and Ꞓ-Oh of the Manhattan and Hartland Formations, respectively) are allochthonous (Merguerian, 1996).

The Geology of Connecticut

The mineral-rich Paleozoic crystalline terrane of western Connecticut consists of a diverse assemblage of Proterozoic to lower Paleozoic metasedimentary and metaigneous rocks of the Hartland Formation (Layer IIA(E)) which can be traced from New York City northward into the Connecticut Valley-Gaspe synclinorium (Figure 4). 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.

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). The Hartland Formation (Layer IIA(E)) 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). The mineral localities of Day One of our field trip nestled in the Hartland Formation of the western uplands of Connecticut. (See Figure 1.)

Occurring to the west of Cameron's Line is a sequence of massive gneissic rocks known as the Waramaug Formation (Cambrian ? to Ordovician) which is correlative to the north with the Cambrian Hoosac Schist and to the south with Manhattan Schist unit Є-Om 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).

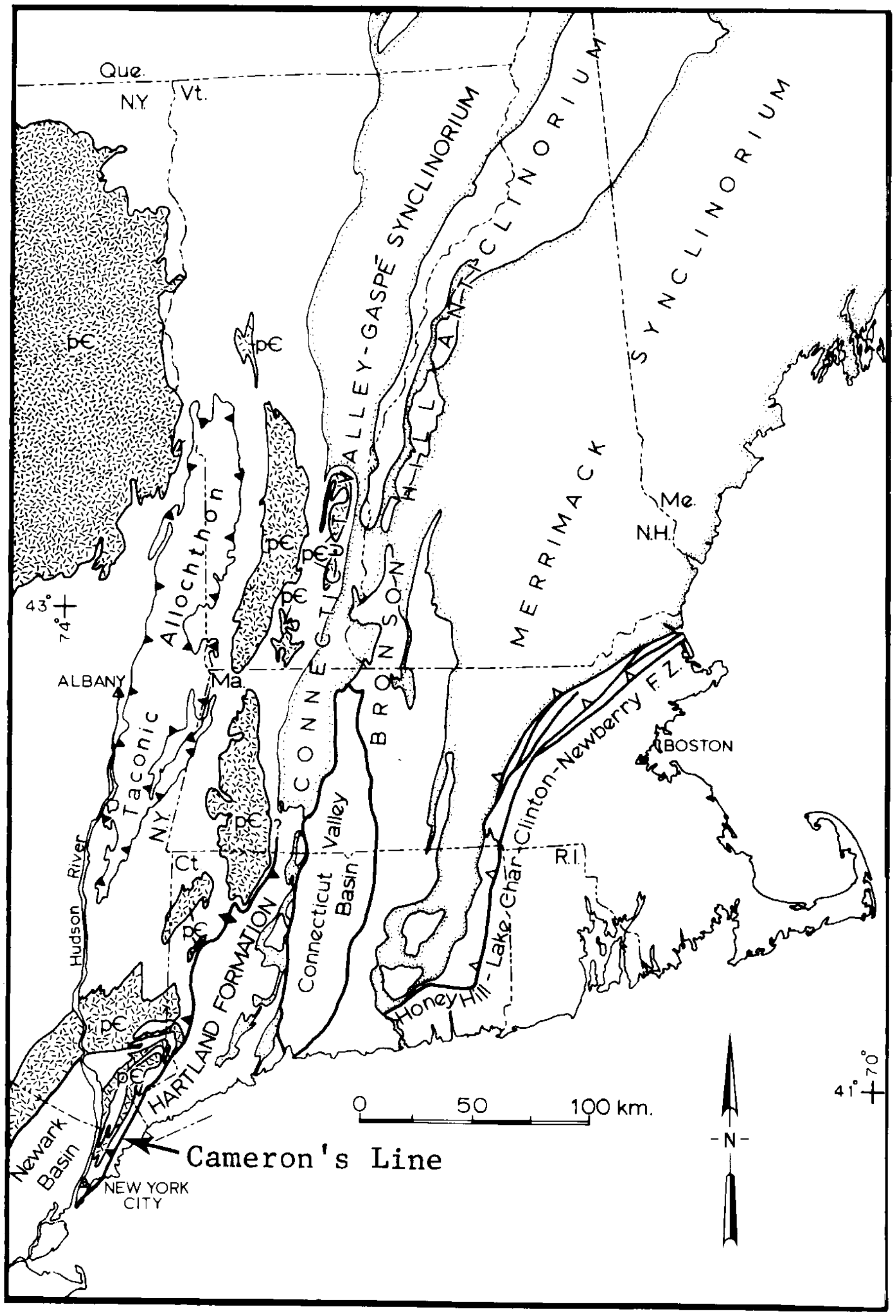


Figure 4 – Tectonic sketch map of southern New England showing the major geotectonic provinces (from Merguerian, 1983).

J. G. Percival was a melancholy naturalist, poet, U. S. Army surgeon, botanist, geologist, 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 mapping of the first state geologic map of Connecticut in 1842 by Percival who spent nearly seven years traversing Connecticut in a one-horse wagon, then by foot. Initially in 1835, Percival was accompanied by C. U. 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 research effort with a thick written report (now a collector's item!) that has proven to be more correct than modern mapping in certain areas (Figure 5).

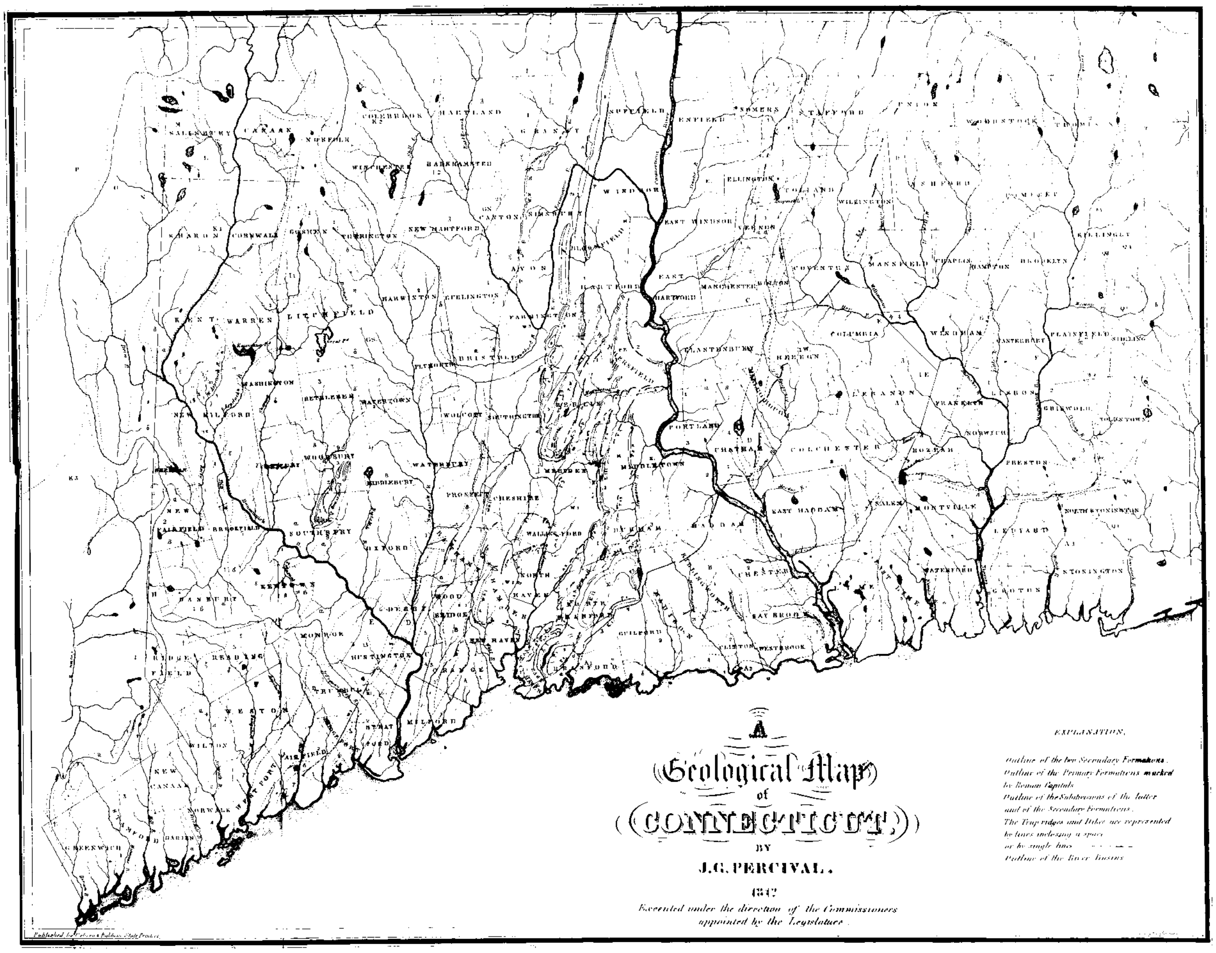


Figure 5 – Geologic map of Connecticut by Percival (1842).

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. (See Figure 4.) 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 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 time.

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. At present, the arc terrane is exposed in the Bronson Hill Anticlinorium and its extension southward into central Connecticut. (See Figures 2 and 4.) Thus, during a series of Paleozoic mountain-building episodes (the Taconic, Acadian, and Alleghenian 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. 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.

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 may mark the root zone for much of the Taconic sequence in eastern New York State.

Layer V: Hartford Basin-Filling Strata

Although we shall not be collecting stops at localities in the Hartford basin-filling strata of Connecticut (Figure 6), we will stop to see some of these fascinating rocks on Day Two. We mention them here 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.

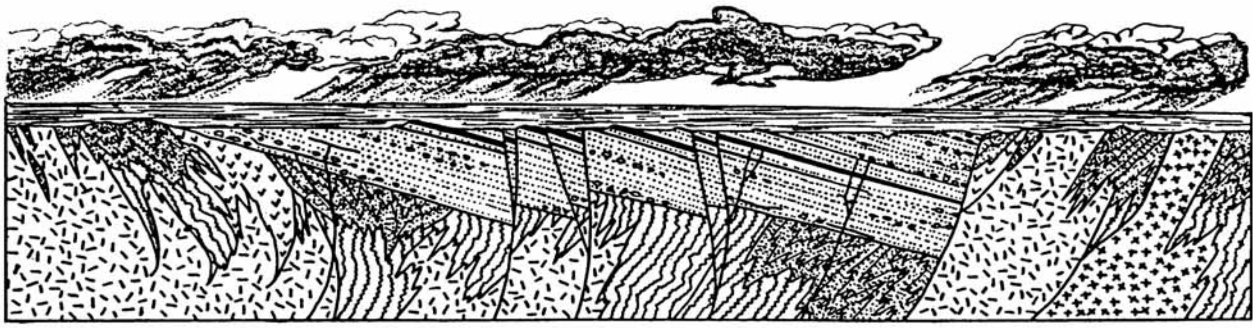


Figure 6 – Geologic section across the Hartford basin showing the unconformable relationship of the Newark strata atop the western uplands and steep normal fault contact with the eastern uplands. (From Barrell, 1915.)

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 an enclave of 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). J. E. Sanders has suggested that “the 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 coexistence 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). No simple explanation exists for how this could have happened; the topographic maps provide 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 time (Late

Cretaceous to the end of the Miocene) while 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.

OBJECTIVES

1) To examine the Hartland Formation and related rocks of western Connecticut.
2) To discuss the history of mining in Connecticut.
3) To collect amazing minerals and rocks from famous localities in Connecticut.
4) Not to get bitten by ticks or mosquitos.

LIST OF LOCALITIES TO BE VISITED

(Stops 1 through 10, in Connecticut are shown on the road map below, Figure 7).
Detailed driving directions are provided below.

STOP 1 - West Redding Garnet Locality, Bethel quadrangle.

STOP 2 - Dravite (Tourmaline) Locality and Bierman Pegmatite Quarry, Botsford quadrangle.

STOP 3 - Roxbury Garnet Mine, Roxbury quadrangle.

STOP 4 - Roxbury Iron Mine, Roxbury quadrangle.

STOP 5 - Thomaston Dam Site, Thomaston quadrangle.

STOP 6 - Harwinton Pegmatite, Torrington quadrangle.

STOP 7 - Simpson Quarry, Glastonbury quadrangle.

STOP 8 - Arsenopyrite and “Gold” Mine, Middle Haddam quadrangle.

STOP 9 – Swanson’s Pegmatite Quarry, Middle Haddam quadrangle.

STOP 10 - Arkose “Brownstone” Quarries, Middletown quadrangle.

OPTIONAL STOP – Dinosaur Museum and Trackway, Rocky Hill, Hartford South quadrangle.

Figure 7 – Index map showing all of the intended stops for this weekend's trip.

DRIVING DIRECTIONS

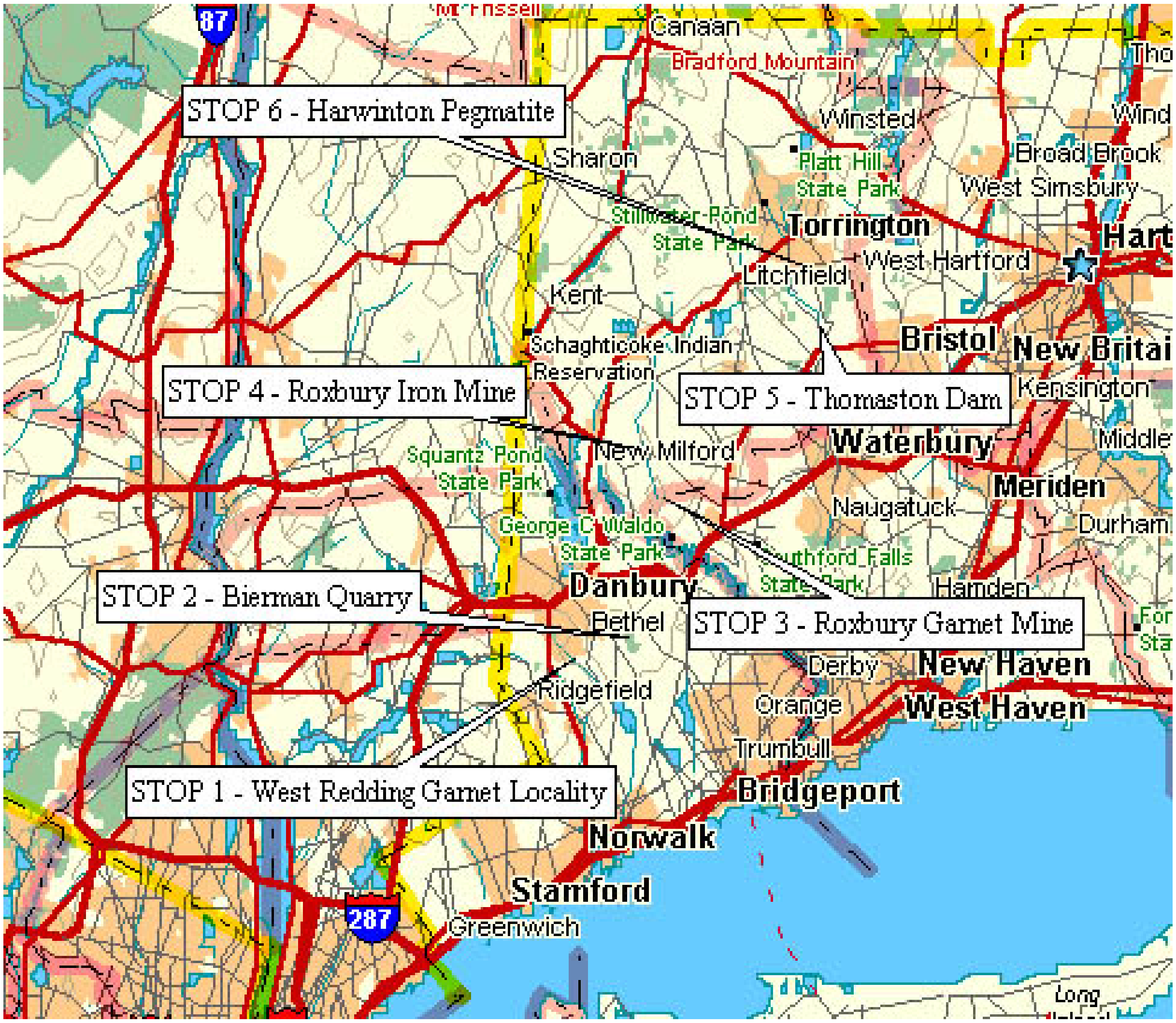
From Hofstra Campus (mileages from Hofstra campus are approximate): First take local roads from the University to the Meadowbrook Parkway N. Head W on the Northern State Parkway and get off at the appropriate exit to take the Clearview Expressway N to the Throgs Neck Bridge. Pay toll. From here take I-95 for a few miles and then switch to the Hutchinson River Parkway, continuing north to the split off with the Merritt Parkway (Route 15). The road log provided below, picks up from the beginning of the Merritt Parkway. The prime objective of Day One is to try to get to all six stops before we lose daylight or, our minds. A detailed locality map and road log for Day One is reproduced below. Details for Day Two follow, in turn.

DAY 1 - ROAD LOG

(Picks up from Merritt Parkway where it splits off from the Hutchinson River Parkway).

Mileage	**Comments**
37.9	Merritt Parkway (15) splits off to R.
57.8	Exit 39B for Route 7 N.
59.3	Bear R and follow Route 7 N.

59.4 Turn L to follow Route 7 N.
61.3 At T-intersection, turn L to follow Route 7 N toward Wilton, CT.
62.6 Wilton Train Station.
66.9 Follow signs to Route 7 N.
67.6 Enter Branchville, CT.
67.9 Route 102 (W) on R; Follow Route 7 N.
69.2 Florida Hill Road on L.
69.7 Turn R onto Simpaug Turnpike.
69.9 Pass over Rail Road (Do Not Pass Go, Do Not Collect $200). Crops of gently dipping Stockbridge Marble on L side before you approach RR bridge.
70.2 Bear L across RR at Topstone Road T-intersection.
70.25 Turn R parallel to RR tracks to follow Simpaug Turnpike N.
71.4 Turn R under RR tracks.
71.45 Turn L to continue on Simpaug Turnpike N at split off for Marchand Road.
72.1 STOP 1 exposure on R. Continue ahead 0.3 miles to park at West Redding RR Station. Walk back to exposure to collect massive and finely crystalline grossular (Ca^{++}-rich) garnet and clinopyroxene rock.



STOP 1 – Grossular Garnet Locality, West Redding, Connecticut. [UTM Coordinates: 630.71E / 4575.38N, Bethel quadrangle].

Covering roughly 60 acres of land, this enigmatic massive fine-grained grossularite garnet + diopside rock in West Redding has made many mineral collectors and geologists take notice. Walk up the steep slope east of Simpaug Turnpike to see highly fractured, massive cinnamon-colored grossular garnet rock, part of a 0.6-km wide heart-shaped mass found at the faulted contact between the Stockbridge Marble and injected muscovitic schist of the Rowe Schist member of the Hartland Formation (Figure 8). According to Rodgers et al (1985), we are directly on Cameron's Line at this locality.

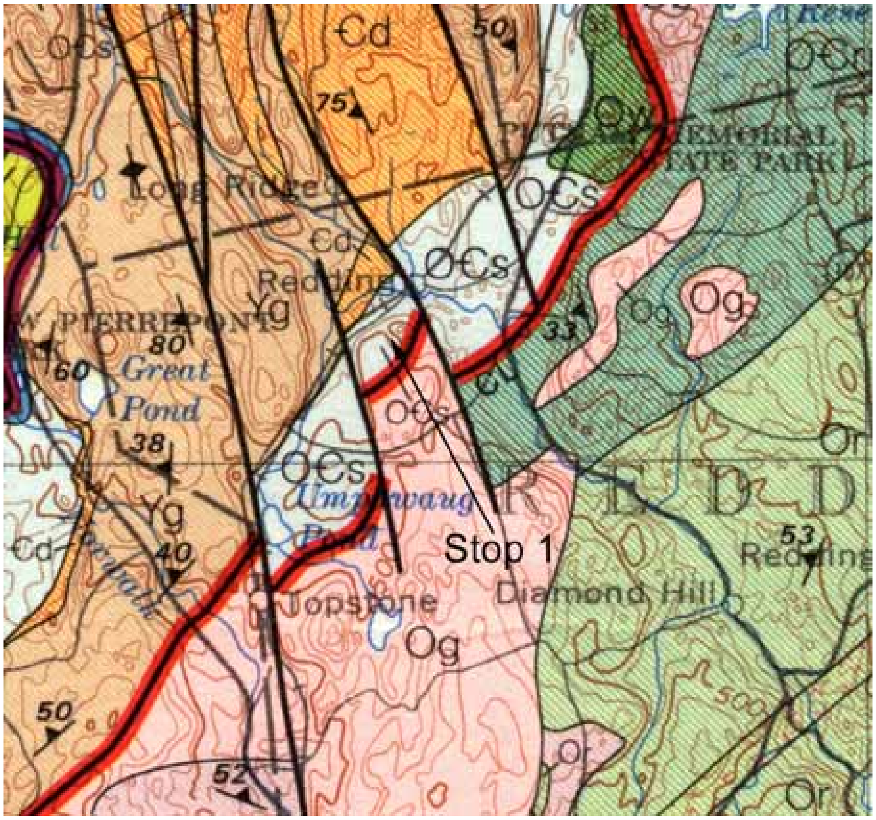


Figure 8 – Geologic map of the area surrounding Stop 1 showing the Proterozoic rocks to the west (Yg), the Stockbridge Marble belt (OꞒs), Cameron's Line (CL in red), the injected schistose rocks of the Rowe Formation (OꞒr), and Ordovician granitoids (Og) that may be responsible for this unusual Ca^{++}-enriched skarn deposit. Adapted from Rodgers et al., (1985).

Two knolls at this locality are almost entirely composed of grossularite garnet (var. essonite) and lesser clinopyroxene. Mostly the garnet occurs alone with minor quartz and localized quartz veining has been observed. Chemical analysis of the garnet (SiO_2 = 39.10%, CaO = 34.85%, Al_2O_3 = 19.61%, and total $FeO+Fe_2O_3$ = 5.44%), are quite similar to published analyses of grossular garnet, including the phenomenal grossular garnet crystals from Morelos, Mexico. The West Redding garnet is relatively soft (for garnet) at 6.5 to 7, or less than quartz.

In some areas, particularly the northeast end of the exposed mass and in a railroad cut to the southwest, mixtures of clinopyroxene and garnet produce a beautifully speckled green and cinnamon-colored rock. The clinopyroxene occurs as light green anhedral diopside whose mode varies from 30% to 60% in the pyroxene-rich zones. Rocks consisting of 90% fine-grained clinopyroxene have been found in pits to the east and in the railroad cut to the west. At the highest eastern knob, a unique fine-grained colorless rock was found to consist of quartz, diopside, garnet, andesine, zoisite, titanite, wernerite, and apatite (listed in order of abundance). Together with the grossular garnet that underlies most of the locality, the assemblage of minerals found here (calcium-iron silicates) mandates the introduction of silica in a skarn-type contact metamorphic setting.

According to Agar and Kreiger (1932), the unique mineralogy of the deposit suggests that it “originated by both igneous and metamorphic processes”, suggesting that contact metamorphism and silicification during syntectonic intrusive activity was important (Figure 9). The garnet formed during contact metamorphism and silicification at the marble-schist contact during the injection of granitoids and later pegmatite dikes.In addition to the obvious mineral to be found at the famous West Redding **garnet** locality, collectors have reported calcite, clinozoisite, diopside, quartz, wernerite, apatite, andalusite, coccolite, titanite, graphite, tremolite, and plagioclase.

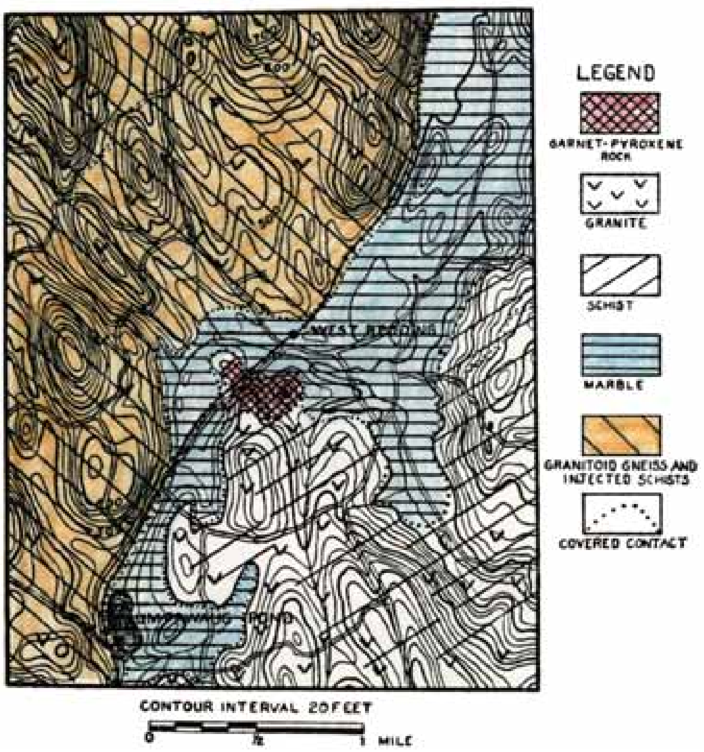
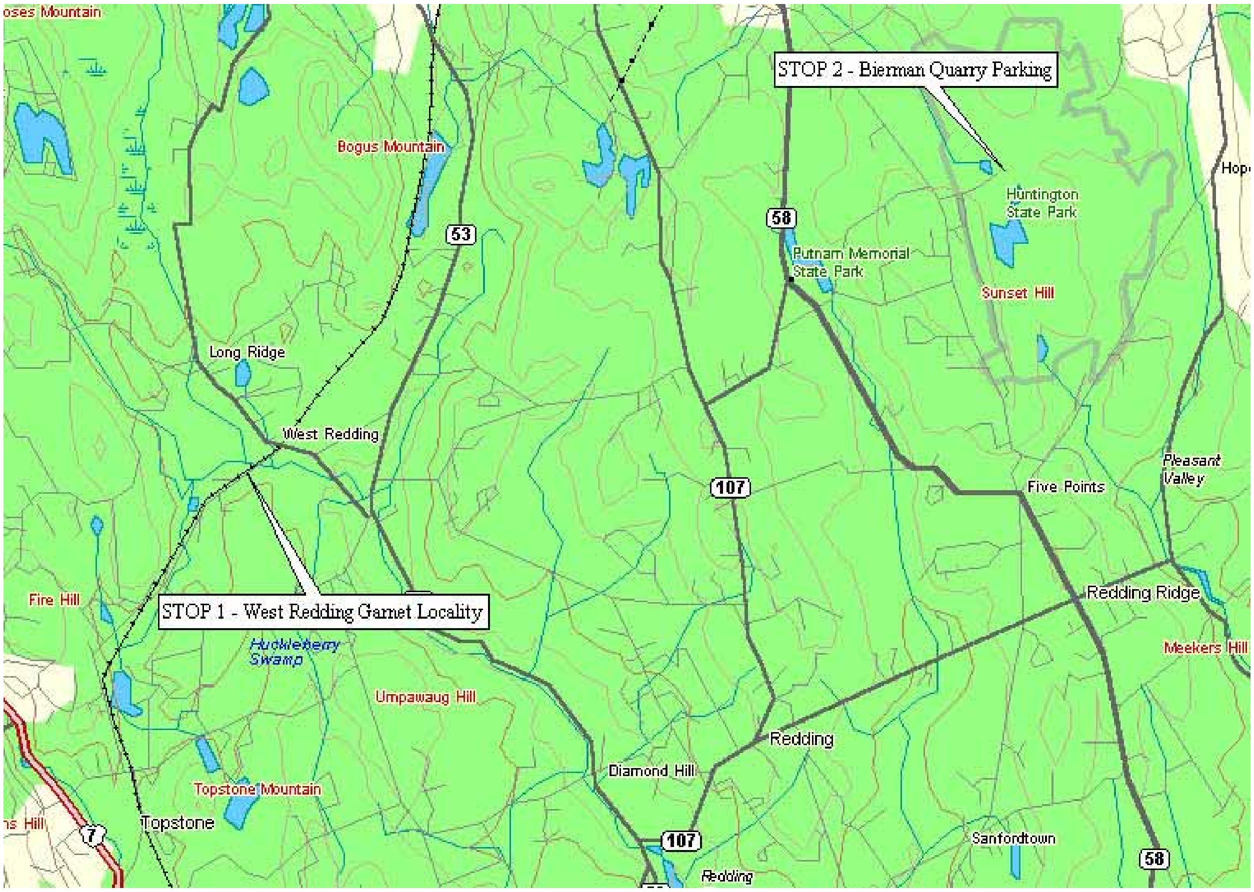


Figure 9 – Geologic map of the West Redding garnet locality demonstrating that the grossular garnet + diopside rock (red) is the contact with Stockbridge marble (blue) and injected (granitized) muscovitic Rowe schist (diagonal ruling). NW-trending brittle faults (See Figure 8) cut through the area and are likely responsible for the highly fractured nature of the garnet rock. Adapted from Agar and Kreiger (1932) using similar coloring as Figure 8.

73.1 Back into vans and continue N on Simpaug Turnpike for Stop 2.
73.4 Turn R (E) on Side Cut (Station) Road.
73.8 Bear L at fork in road.
73.85 Turn L onto CT Route 53.
74.1 Pass Gallows Hill Road on R.
74.7 Turn R onto Lime Kiln Road heading E.
74.9 Note marble outcrop on R before bend in road (They don't call it Lime Kiln Road for nothing you know!).
76.4 At T-intersection, turn R onto Chestnut Ridge Road.
76.6 T-intersection turn L onto Route 107.
77.4 At left branch of T-intersection, turn L (N) onto road leading to Route 58 N.
78.9 Turn R onto Sunset Hill Road.
80.2 Turn L onto Dodgingtown Road (Mevlans Road).
80.4 Go past parking area perched on R.
80.6 Parking area on L - site of an old house (only foundation remains). At this point we hike in about a mile past gated trail for STOP 2. Follow the sketch map for dravite locality (to the R of old building (only chimney left) and nearby Bierman Quarry (across creek and down to R).



STOP 2 - Dravite (Tourmaline) Locality and Bierman's Quarry, Bethel, Connecticut. [UTM Coordinates of Parking area: 637.25E / 4578.40N; UTM of Bierman Quarry 638.37E / 4578.35N, Botsford quadrangle.]

Walk into woods about 0.6 miles in a northeasterly direction and hope for the best. These two places are hard to find but Figure 10 should help. The pegmatite is noted for beryl, bertrandite, opalite, columbite, and uraninite.

According to John Betts of the New York Mineral Club, dravite tourmaline can be found as double terminated black crystals 10 cm long by 4 cm thick in the ledge and boulders west of the quarry. These crystals are quite lustrous when cleaned. The Bierman quarry is noted for beryl and unique bertrandite pseudomorphs after beryl. Bertrandite can also be found as crystals in between plates of cleavlandite. Many bertrandite crystals are twinned on the c-axis and vary in size from less than 1 mm to 6 mm.

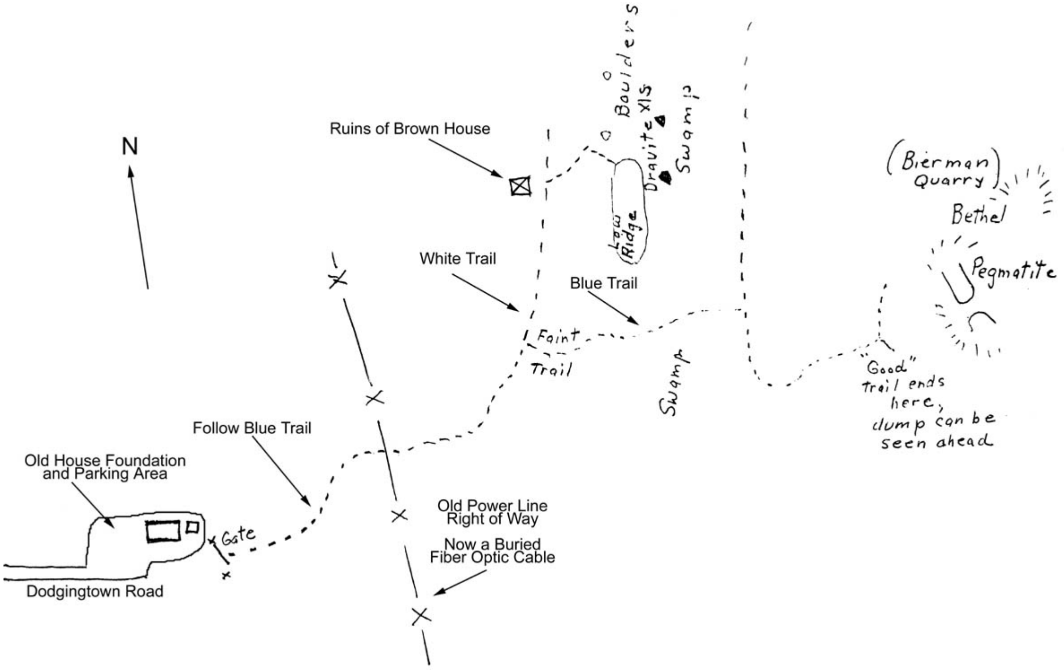


Figure 10 – Modified sketchmap by Mr. Earle C. Sullivan (not to scale) showing the locations of the dravite-rich pegmatite and the Bierman Quarry mine and dump, about a mile in from gate.

80.6 Back in vans. Next stop is Roxbury Falls for the Roxbury Garnet Mine. Take Dodgingtown (Mevlans) Road back out to Sunset Hill Road.
81.0 Turn R onto Sunset Hill Road back toward Route 58.
82.3 Turn R onto Route 58 N.
83.7 Turn R onto Route 302 toward Newtown.
85.9 Beautiful Downtown Dodgingtown.
86.6 Bear L to remain on Route 302 at intersection with Hattertown Road.
89.9 Turn L onto CT Route 25 and U.S. 6.

90.2 Turn R onto U.S. Route 6 (E) toward Exit 10 of I-84.
90.9 Pass under RR bridge.

91.2 Turn R into **Blue Colony Diner** for **PIT STOP** and revitalization of precious body fluids. After pitting, reboard van and continue ahead, over I-84 at Exit 10 interchange where U.S. Route 6 becomes magically transformed to U.S. Route 6A. We will follow CM at great risk along the back roads into Stop 3 and beyond.

91.8 Turn L onto Glen Road at 4-way intersection in the center of Sandy Hook. Follow along SE margin of the Pootatuck River, a tributary of the larger Housatonic River ahead.
93.5 Mid span on bridge over Housatonic River just south of side cut from Pootatuck River.
93.55 Turn L at end of bridge onto River Road.
95.3 Turn R onto Purchase Road.
97.5 At stop sign, turn L onto Purchase Brook Road.

98.7 At stop sign, jog L and then go straight onto Brown Brook Road. Intersection with Purchase Hill Road (R) and Gilbert Road (L).
99.0 Turn R onto Perkins (Garnett) Road (Leave Newtown quadrangle; enter Roxbury quadrangle) and follow it down and to the L.
99.5 After L turn, drive to end of paved road, follow ahead to dirt road and park up ahead in designated area.
99.7 After paying parking fee ($5/car) to Mrs. Archibald (203 264-3550), walk along trail into wooded area NW of the Archibald home to collect from Stop 3.

STOP 3 - 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 of massive almandine garnet in the Adirondacks near North Creek, New York. The Roxbury garnets occur as perfect 1-3 cm dodecahedral (twelve-sided) crystals embedded in a crumbly, muscovite-quartz schist and granofels of the Hartland Formation (Figure 11). 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 lens of similar porphyritic rocks within more typical Hartland occurring on Mine Hill (Stop 4).

Mineral collectors have also reported biotite, clinochlore, gypsum, magnetite, kyanite, hematite, limonite, loellingite, pyrite, and pyrrhotite.

Figure 11 – Porphyroblastic dodecahedral garnet up to 1 cm in size and tabular staurolite exposed in fine-grained muscovitic schist of the Hartland Formation. (CM digital image.)

99.7 Backtrack out of this area.

100.4 Turn R at intersection with Brown Brook Road traveling northward toward Roxbury.
100.6 Turn R, following a 90° turn up hill. Proceed northwards along valley of Turrill Brook.
101.4 Pass Roxbury Falls. Lower River Road on L.
101.8 Pass Minor Bridge (River) Road on L.
102.8 Follow L fork onto River Road.
104.7 Turn L onto Weller’s Bridge Road across Shepaug River. (The US Geological Survey gaging station for the Shepaug River is located on Wellers Bridge.)
104.8 Turn R onto CT Route 67 (Botsford Hill Road).
105.4 Turn L into Mine Hill (Quarry) Road (sign for Roxbury Land Trust).
105.7 Drive uphill to parking area on R. Walk eastward to Stop 4, the Roxbury Iron Mine.

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 the result of hydrothermal activity peripheral to the Mine Hill granite gneiss, a different 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).

Backtrack across Shepaug River back into Roxbury on Wellers Bridge Road.
Continue eastward on the extension of Wellers Bridge Road (Route 317).
Follow Route 317 (Good Hill Road) into Woodbury and pick up U.S. Routes 6 and 202 northeastward past Minortown toward Thomaston.
Turn L and continue northward through Thomaston on U.S. Routes 6 and 202.
Turn R onto 222 after passing under Route 8.
Drive northward and turn L across the top of the dry dam and park at the end of the road for Stop 5.

STOP 5 - 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.

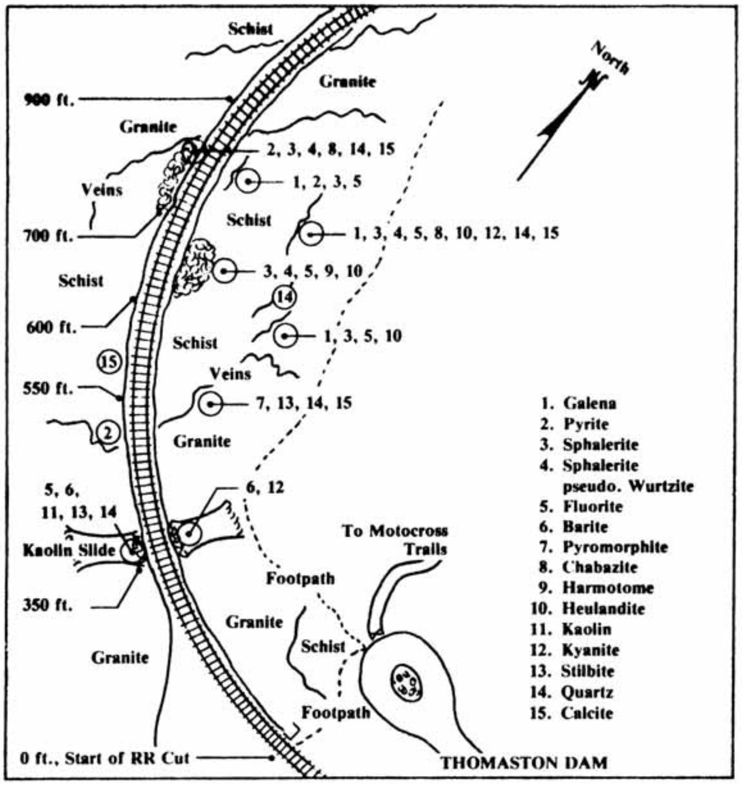
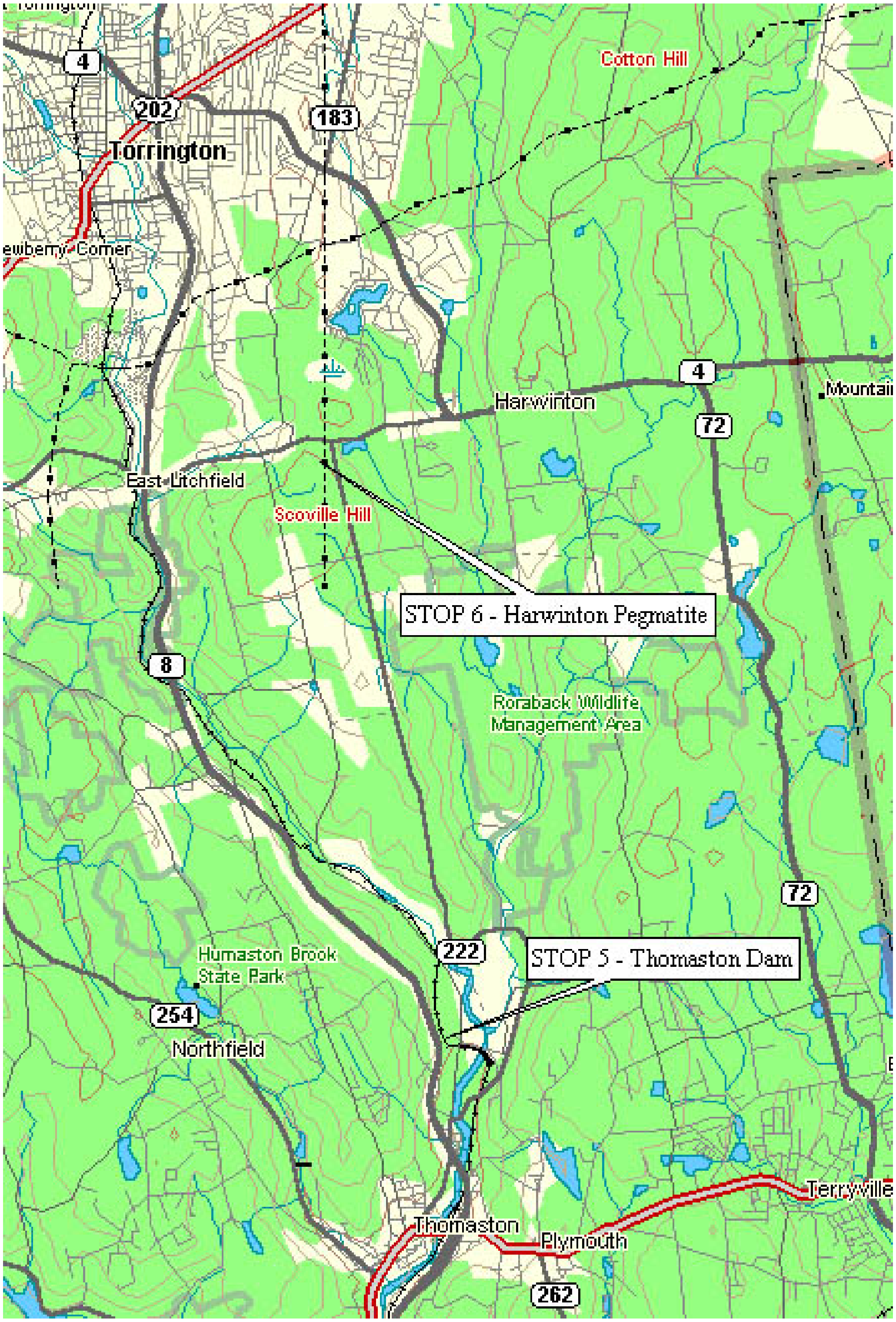


Figure 12 – Map of the collecting area at the railroad cut at Thomaston Dam, Connecticut. From Segeler and Molon (1985).

A map of the collecting site is shown in Figure 12, adapted 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, and a host of zeolite minerals including stilbite, harmotone, heulandite, and chabazite. Of particular interest to mineral collectors is the presence of wurtzite, a polymorph of sphalerite. It occurs as bronze, sub-metallic hexagonal crystals that look like small concertinas standing on end.



Drive out from west end of Thomaston dry dam and turn L to drive northward on Route 222. Turn L onto Route 118 and park to the L under the powerline. Walk in a bit southward under the powerline for the pegmatite dump.

STOP 6 - 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). CM has found parallel twins of beryl and beautiful 4 cm terminated smoky quartz crystals. Happy hunting!

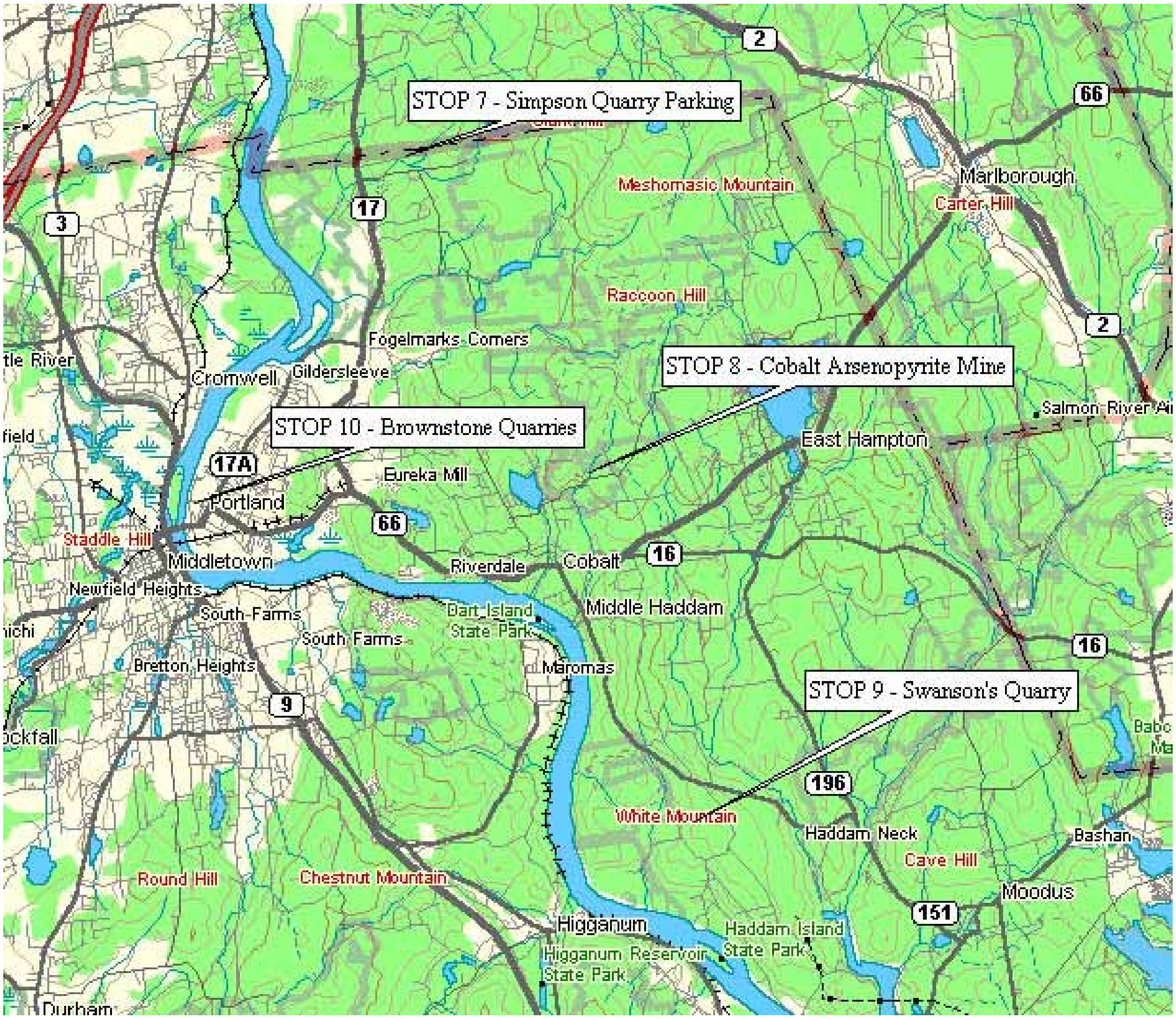
Drive westward toward Route 8 and take Route 8 north toward Torrington (Exit 44). At the end of Day One, stay over in Torrington, CT at their fabulous Super 8 motel.

DAY TWO - ROAD LOG

Take Route 8 back to I-84 and then eastward or take 202 to 44 to 372 to 9 to Middletown. Pass over James J. Arrigoni Bridge and enter Portland, CT. The road log below is tacked on but I came from a different direction on my pre-trip check so the mileages do not follow from Day One. A map of the area is shown below.

131.7 Bear L following signs for 66 E and 17 N onto Arrigoni Bridge.
132.2 Mid-span on Arrigoni Bridge over the meandering Connecticut River. Look L and R for spectacular views to the north and south along the river valley. On the north side of the eastern footing of the bridge, are large sandstone quarries, the type locality for the Portland Formation. Here, the hematite-stained arkose and quartzose sandstones have been quarried for use as building stones. Some of the older buildings in Portland (ahead) are constructed of these materials. New Yorkers know this appealing but easily friable building material as "brownstone". Just downstream from this bridge, the river curves to its L and leaves the Central Valley province to enter the Eastern Uplands province. The boundary between these two provinces is the basin-marginal fault at the east side of the Hartford basin.
132.7 At east end of bridge and stop lights (Brooks Pharmacy on SE corner), travel straight ahead for Route 17A through Portland. Road to R is CT Route 66 toward Route 17 and Cobalt.
133.0 Portland Post Office on L.
134.1 Pass road junction with Bartlett Street Extension. The famous Strickland quarry is located in Collins Hill at the east end of the Bartlett Street Extension. Currently owned by a golf course and closed and inaccessible for many years now, the Strickland quarry was one of the prized localities for cleavlandite (unique “platy” albite), beryl, tourmaline, spodumene, manganapatite, garnet, lepidolite and a host of other collectible specimens.
135.0 Pass over Carr Brook. Meander loop of Connecticut River on L.
135.7 Road junction of CT Routes 17 and 17A (Fogelmarks Corner). Turn L onto Route 17 N.
137.9 Pass Isinglass Hill Road on R.
138.0 Turn R onto Michelle Drive.

138.4 Exposed contact between pegmatite (E) and lineated biotite gneiss (W) on L.
138.7 Park at end of paved road and walk into the woods (N) to Simpson Quarry (Stop 7).



STOP 7 – Simpson's Quarry, Glastonbury, Connecticut. [UTM Coordinates: 700.50E / 4612.00N, Glastonbury quadrangle.]

The Simpson Quarry is another typical pegmatite with many gemmy stones found scattered throughout the dump. Look for beryl, spessartine garnet, schorl, torbernite, autunite, and other pegmatite minerals.

The best collecting is accomplished by digging down into the dump materials and selecting specimens for their mineral content (showing) or potential (vuggy, visible crystal faces, etc.). The potentially good specimens should be interrogated and broken down (with a hammer). Experience helps here as minor "shows" of minerals on the side of a rock specimen would entice the mature collector into breaking the rock open to see what's inside. Look especially for the hexagonal outline of beryl and other minerals of "color". A view of a fabulous collection of bluish-green beryl found at the Quarry is shown in Figure 13.

Figure 13 – View of beryl crystals found in 2001 by a local collector from Thomaston, CT. (CM digital image taken 02 December 2001.)

Drive out from Michelle Drive and turn L onto Route 17 southbound.
Turn L onto Route 66 E.
In Cobalt, turn L on Route 151 and follow road northward.
Turn R and find Gadpouch Road to visit Stop 8.

STOP 8 - Arsenopyrite and "Gold" Mine, Cobalt, Connecticut. [UTM Coordinates: 704.0E / 4605.6N; Middle Haddam quadrangle.]

This prospect, first mined in 1661, is one of the oldest prospects in western Connecticut and is described by Blake (1883), Shannon (1921), and Kirkland (1954). The mine was closed for a while but reopened in 1762 and worked until the 1850s. Remains of old stone walls, a kiln, and a deep vertical shaft (fenced in) can be found on the upland trail. Twenty tons of ore were shipped to China. The main mineral of interest here is arsenopyrite (Figure 14), occurring as bright silver-colored, wedge-shaped crystals in bull quartz. Scorodite, niccolite, sphalerite, galena, chloanthite, and smalltite have also been reported. Chomiak (1989) and Januzzi (1972) list a great number of minerals from this site.

Figure 14 – Photomacrograph of 4 mm wedge-shaped arsenopyrite crystal in milky quartz collected from Cobalt mine. (CM specimen and photo.)

A few years ago, gold was reported found from this area by our friend Professor Tony Philpotts of the University of Connecticut. This discovery generated a lot of interest by local collectors and, as Ernest P. Worrell would have said, "swindlers and entremanures". As such, the Parks Department sought to close off access to all. Student mapping projects at U. Conn. of the shafts and tunnels are in progress as of 1996. According to our dear friend Professor Dickson of Eastern Connecticut State University, there was an older couple who had lived near this property for probably 50 years or so. Back in 1996 samples of their hair were analyzed using XRF and traces of gold were detected. In 1999, twenty-five soil samples were collected at 5m spacing and analyzed around their house using XRF. Although no traces of gold were found, arsenic was detected.

Up to 6 ounces of gold per ton are reported here, much higher than typical gold mines. The adits, which are dug into the moderately dipping schist, are clearly visible in the ravine.

Walk down to the ravine and walk upstream. Look for quartz boulders and break them open to find the arsenopyrite. The blue-tagged hiking trails are maintained by the Connecticut Forest and Park Association (203 346-TREE). The phone number for Connecticut State Parks is (860 424-3200). The local park supervisor (Bruce Elliot) can be reached at (203 295-9523).

Drive out from Gadpouch Road and turn L onto Route 151 extension.
Continue past Route 66 on Route 151 toward Middle Haddam.
Pass Middle Haddam and take R onto Haddam Neck Road to, of all places, Haddam Neck.
Stop near powerlines about 0.5 miles down from Route 151 near Firehouse (but do not block Fire Department access). Walk along powerlines to workings of Swanson's Quarry for Stop 9.

STOP 9 – Swanson's Pegmatite Quarry, Haddam Neck, Connecticut. [UTM Coordinates: 706.65E / 4499.03N, Middle Haddam quadrangle.]

This is an old pegmatite quarry with very extensive workings. Several dumps exist as well as nearby prospects for hard rock collecting. Fine- to coarse-grained purple lepidolite, muscovite, green to yellow beryl, and green tourmaline (elbaite) are found here.

Drive back to Route 151 and turn L through Middle Haddam.
Turn L onto Route 66 (W) to intersection of CT Routes 17A and 66 at Brock's Pharmacy.
Turn L and follow signs to Industrial Area immediately before Arrigoni Bridge.
At base of hill, turn R then another quick R onto Brownstone Road.
Follow along to quarries (Stop 10) exposed on R.
Nice view of both quarries from crest of Silver Street.

STOP 10 - Arkose "Brownstone" Quarries at East End of Arrigoni Bridge. [UTM Coordinates: 696.24E / 4606.95N, Middletown quadrangle.]

Nothing much to say here, it's getting late. Two great quarry exposures of micaceous arkose, used for many years to build the fine Brownstones of New England, including those in Manhattan and Brooklyn.

Cross over James J. Arrigoni Bridge.

PLAN A - Turn L to get onto Route 9 N for Cromwell and Rocky Hill for Dinosaur museum (Optional Stop).

PLAN B - Alternatively, follow 9N past I-91 to view exposures of Newarkian strata on Route 9N - then backtrack to I-91 S to 15 S to return back to Hofstra University.

OPTIONAL STOP - Dinosaur State Park at Rocky Hill. [UTM Coordinates: 695.3E, 4613.6N, Hartford South quadrangle.]

The following account of the history of Dinosaur State Park is quoted from Rodgers and Skinner (1985, Trip C1, Stop 8, p. C1-10 and C1-11):

"In 1966, the State Highway Department chose this site for a central Highway Department Research Laboratory, close to but not on Interstate I-91 near the geographic center of the state. One Friday afternoon in August (according to Ostrom, 1968, p. C3-1, the date was 24 August 1966), one of the bull-dozer operators, Mr. Ed McCarthy, engaged in clearing the overburden to bedrock before construction, turned up flat slabs of sandstone on which he recognized some large dinosaur footprints (such prints have of course been well known in the Connecticut Valley for 150 years). After investigating, the project engineer, Mr. Tom Jeffreys, stopped excavation in the area and called the Yale Peabody Museum, the University of Connecticut, and the newspapers; later an announcement was broadcast on TV, and the Saturday Hartford Courant carried the story. As word of the find spread, many persons came down over the weekend to pick up samples for their patios, rock-gardens, etc. The news also reached Ms. Jane Cheney, Director of the Children's Museum in Hartford, who went directly to Governor John Dempsey (about to stand for re-election) and persuaded him that the find was exceptional and should be preserved. At a meeting of state officials on Monday morning, it was agreed that the Peabody Museum would direct the bulldozer operators while they determined the size and significance of the deposit; Prof. John Ostrom of the Museum and Prof. Joe Webb Peoples of Wesleyan University, then Director of the Connecticut Geological and Natural History Survey, were in general charge. Later the Governor declared the locality The Dinosaur State Park. A news item concerning the dinosaur trackway appeared on the front page of the Hartford Courant for twelve straight days. Clearing continued for several weeks, until a single surface of sandstone displayed over two thousand tracks. Testing elsewhere on the property showed that the layer with the tracks was even more extensive; moreover it is only one of five layers within about 2 meters of rock that display tracks.

"By this time, it was thought that enough had been uncovered to make a spectacular display, and the work was stopped; the main concern after that was to preserve the tracks against the approaching winter's freezes and thaws. The tracks were therefore covered up, and, except for one or two brief spells, the main discovery site has not been uncovered since. On the other hand, in 1967 a more modest area was uncovered west of the main site (in the same layers), which could be covered by a temporary structure (a plastic bubble kept up by excess air pressure), and this area became the main exhibit at the Park. Later the temporary structure was replaced by the present more permanent structure, but the original plan to build a larger museum over the main, original discovery has never been carried through. In any case, the Park was duly dedicated in 1967 by Governor Dempsey; honor was paid to Mr. McCarthy, the original finder of the tracks; and the Rocky Hill High School Band played a new piece of music called 'Dinosaur', written for the occasion by its director.

"As the Hampden flow forms the ridge immediately south of the trackway area, the stratigraphic position is known exactly; when the I-91 cuts about 2 1/2 miles to the southwest were opened, the trackway levels were pinpointed there. While the main trackway was still uncovered, a trench was dug down dip to the south, which showed that the trackway layers are cut downdip by a small thrust fault, dipping south more steeply than the beds, so that the trackways layers are brought back up closer to the land surface. If a museum is ever built over the original site, this trench could be reopened and the thrust fault displayed. Its westward extension is clearly responsible for the right offset of the Hampden ridge between the Park and I-91.

"The Highway Department, deprived of their original site, had to recommence operations about a mile farther east, and rumor has it that the bulldozer operators were given strict order to stop for nothing. *(**P. S.** - Ed McCarthy, the bulldozer operator-dinosaur-footprint-discoverer, became a local folk hero. He had been "educated" about dinosaur footprints by his daughter, then in grade school, who had become fascinated by what she had learned about dinosaurs at school. What he saw were counterparts of the original footprints, made as depressions in the underlying mud but now preserved as positive-relief features on the bottoms of the overlying sandstone layers. Few, if any, footprints are present on the tops of the sandstones. Subsequently, Mr. McCarthy was reassigned to "other duties;" his supervisors evidently figuring that his rate of bulldozing would drop dramatically because he probably would be studying every piece of sandstone his blade turned over.)*

During the Jurassic Period, roughly 185 Ma, mudflats extended over much of the flat floor of the Hartford basin. Fault-related uplifts along the eastern basin-marginal fault of this basin provided intermittent supplies of coarse clastic sediments eroded from the pre-Triassic crystalline rocks of the persistently elevated Eastern Highland block. Into the Hartford basin poured many sediments that we now see as interbedded red sandstones, shales, conglomerates and non-red-colored lacustrine deposits. Many dinosaurs traversed these muddy plains searching for food (not mineral specimens as had been commonly thought!) and left tracks in their wake. Fossil bones of these dinosaurs have never been found as the conditions that preserve tracks are not the best for preserving bone, but the search continues. The geodesic dome constructed here preserves a multitude of tracks for the public to see and admire. If we stop here and time permitting, we suggest a brief visit to the dinosaur footprint area where you may create a plaster cast of a Eubrontes footprint.

ACKNOWLEDGEMENTS

I would like to thank the U. S. Army Corp of Engineers for once allowing access to the Thomaston Dam collecting site, and to the Archibald family for access to the Roxbury garnet mine. Mr. John A. Carter and Earle C. Sullivan have provided CM with abundant information and have helped in many ways throughout the years with field trips to Connecticut. Mr. Steve Steiglitz and John Betts of the New York Mineralogical Club have also been helpful in providing information. Miss Karen Krajenke assisted in scanning and proofreading this manuscript. 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 and to Dr. John E. Sanders, dear friend and cohort in the decade-long On-The-Rocks Field Trip Series.

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	(Passive-margin sequence 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	**Taconic orogeny.** Intense deformation and metamorphism.
	450	Cortlandt Complex and related rocks intrude Taconian suture zone. (Cameron's Line). Arc-continent collision.
(Ordovician)		Great overthrusting from ocean toward continent. Taconic deep-water strata thrust above shallow-water strata. Ultramafic rocks (oceanic lithosphere) sliced off and transported 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, part of Manhattan Schist Fm.). Deep-water terrigenous silts form to east. (= Taconic Sequence; protoliths of Hartland Formation, parts of Manhattan Schist Fm.). (Passive-margin sequence I).

PROTEROZOIC

	570	Period of uplift and erosion followed by subsidence of margin.
(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,	Bellvale Fm., lower unit

marine)	(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].

~~~~~~~~~~~~~~~~~~~~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. / Manhattan Schist (Om - lower unit).
Normanskill Fm. / Annsville Phyllite

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

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

LAYER IIA[W] - SAUK SEQUENCE	**LAYER IIA[E] - TACONIC SEQUENCE**
Western shallow-water platform (L. Cambrian-M. Ordovician)	Eastern deep-water zone (L. Cambrian-M. Ordovician)
Copake Limestone	Stockbridge
Rochdale Limestone	or Inwood Marbles
Halcyon Lake Fm.	
Briarcliff Dolostone	(Ꞓ-Oh) Hartland Fm.
Pine Plains Fm.	(Ꞓ-Om) Manhattan Fm.
Stissing Dolostone	(in part).
Poughquag Quartzite	
Lowerre Quartzite [Base not known]	

[**Pre-Iapetus Rifting Event**; extensional tectonics, volcanism, rift-facies sedimentation, and plutonic igneous activity precedes development of Iapetus [Layer II = passive continental margin I] ocean basin. Extensional interval yields protoliths of Pound Ridge Gneiss, Yonkers granitoid gneisses, and the Ned Mountain Formation (Brock, 1989, 1993). Followed by a period of uplift and erosion. 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.

~~~~~~~~~~~~~~~~~~~~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.

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