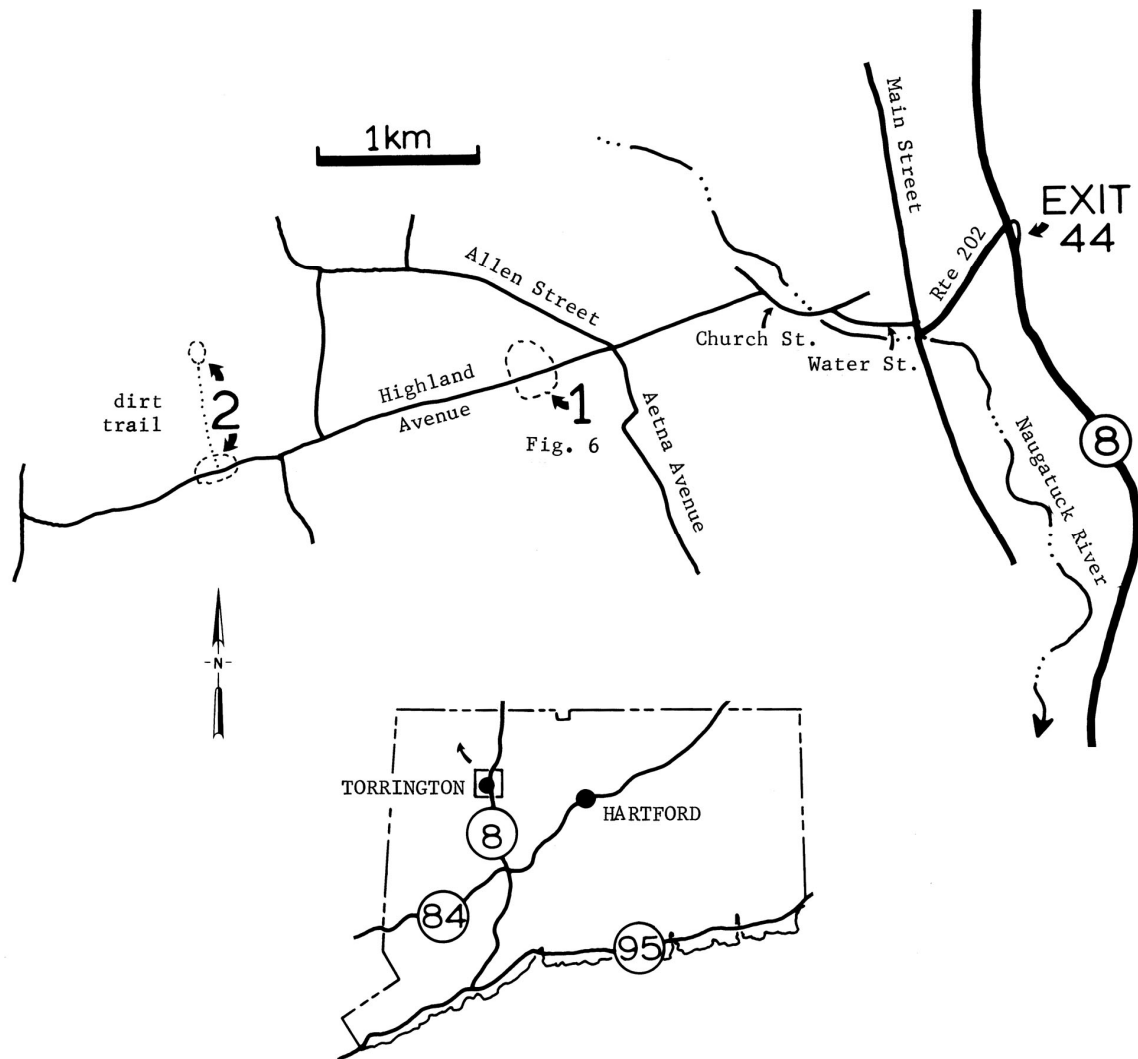


# **The Geology of Cameron's Line, West Torrington, Connecticut** *Charles Merguerian, Geology Department, Hofstra University, Hempstead, New York 11550.*



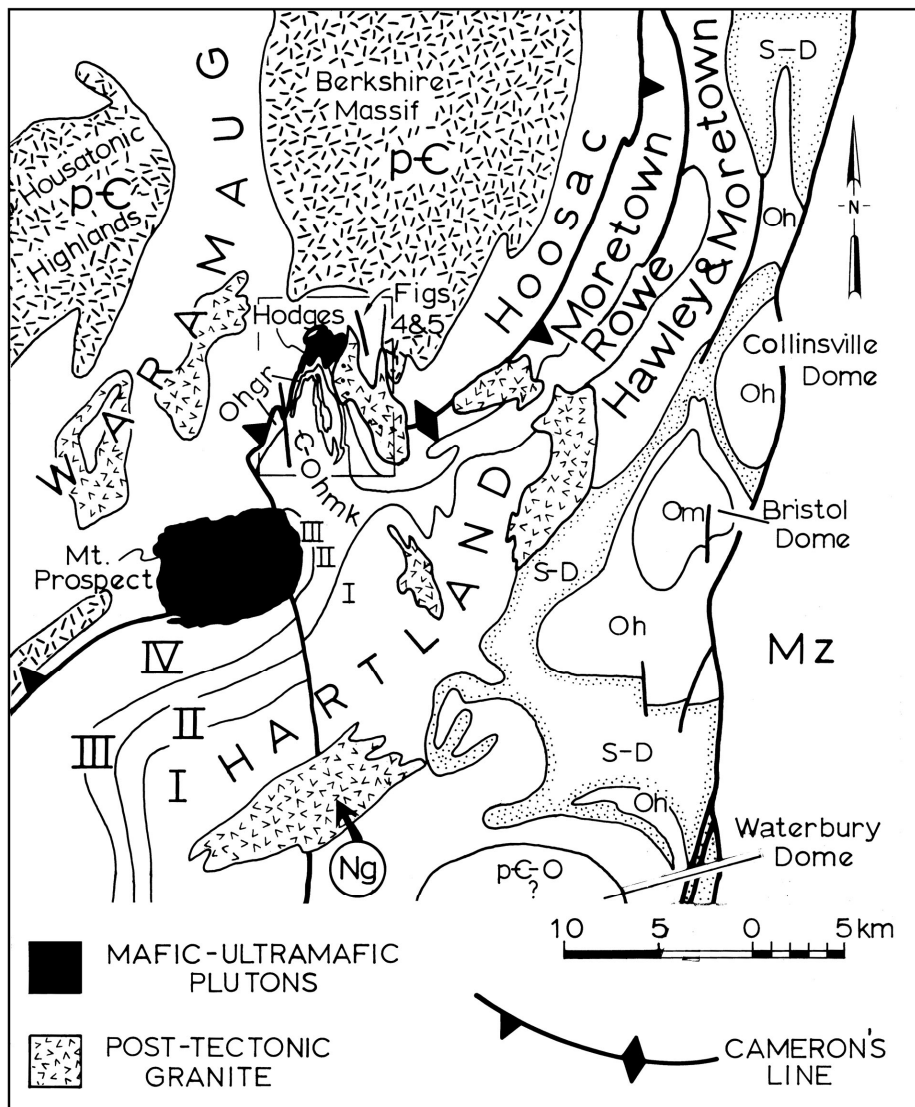
**Figure 1.** Sketch map of site.

## **LOCATION**

The site is situated in West Torrington, Connecticut, and consists of two stops in the West Torrington 7 ½-minute quadrangle (Fig. 1). They can be reached from Exit 44 of Connecticut 8 by traveling southwestward on Connecticut 202 (East Main Street). To reach Stop 1, travel westward from the center of Torrington on Connecticut 202 to Water Street then make a left onto Church Street which ultimately leads to Highland Avenue (Fig. 1) and park 2,000 ft (600 m) west of the intersection with Allen Street near Patterson Pond. Stop 2 is located on Highland Avenue 1.2 mi (1.9 km) west of Stop 1. Some outcrops in this site are readouts or outcrops in stream beds and no special permission is required. Others, however, are on private property and permission must be sought from landowners.

## SIGNIFICANCE

Modern interpretations (Robinson and Hall, 1980; Stanley and Ratcliffe, 1985) view the Middle Ordovician Taconic orogeny of the northern Appalachian mountain belt as the result of a collision between the lower Paleozoic continental margin of North America and a fringing volcanic arc. During the collision, the arc and intervening eugeosynclinal basin deposits were accreted to North America with imbrication of these disparate sequences at depth. The deformed strata now form a deeply-eroded tract of complexly-deformed high- to medium-grade metamorphic rocks. This site examines the geologic relationships exposed along Cameron's Line, a syn-metamorphic ductile shear zone separating metamorphosed continental slope and rise(?) deposits on the west from eugeosynclinal deposits on the east.



**Figure 2.** Regional geologic sketch map showing the regional geology around the West Torrington area (outlined). Same notation as in Figures 3 and 4 except: pC, Proterozoic Y rocks; O, Ordovician rocks; S-D, Silurian and Devonian rocks; Mz, Mesozoic rocks of the Hartford Basin; Oh, Hawley Formation; Ng, Nonewaug Granite; and Roman numerals refer to Hartland stratigraphic units proposed by Gates (1967). Heavy lines are faults.

The tectonic significance of Cameron's Line, long recognized as an important tectonic boundary in western Connecticut (Agar, 1927; Cameron, 1951; Rodgers and others, 1959; Gates and Christensen, 1965; Rodgers, 1985) and mapped as the Whitcomb Summit thrust in western Massachusetts (Stanley and Ratcliffe, 1985), can now be interpreted in the light of plate tectonics. The results of detailed mapping presented elsewhere (Merguerian, 1977, 1983, 1985a) suggest that in western Connecticut it marks a major deep-seated ductile fault related to the medial Ordovician Taconian imbrication of parts of the lower Paleozoic North American passive margin.

## **SITE INFORMATION**

The lower Paleozoic metamorphic rocks of the New England Appalachians form a continuous northeast-trending crystal-line belt across New England (Cady, 1969; Williams, 1978; Rodgers, 1985). They outcrop to the east of 900-1,100 Ma Proterozoic gneisses comprising, from south to north, the Hudson and Housatonic Highlands and the Berkshire and Green Mountains massifs (Fig. 2). The crystalline terrane of western Connecticut is bounded on the east by Mesozoic rocks of the Hartford Basin. To the west they decrease in metamorphic grade and are partly age and lithically correlative with weakly metamorphosed allochthonous strata forming the Taconic Mountains.

In northwestern Connecticut, Cameron's Line delimits the easternmost exposures of cratonal Proterozoic gneiss, massive Paleozoic carbonate shelf, and continental slope and rise (?) deposits. It separates a lower Paleozoic eugeosynclinal assemblage to the east (Hartland Formation) from partly coeval lower Paleozoic gneiss and schist with lithologic characteristics transitional between mio- and eugeosynclinal rocks (Figs. 2, 3). This western assemblage is known as the Waramaug or Hoosac Formation in Connecticut, as the Hoosac in Massachusetts, and as part of the Manhattan Formation in southeastern New York (Clarke, 1958; Gates, 1952; Hall, 1968a, 1968b; Hatch and Stanley, 1973; Merguerian, 1983; Merguerian and Baskerville, this volume). To the east, pre-Silurian rocks in the cores of the Bristol and Collinsville domes (Fig. 2) are unconformably mantled by Siluro-Devonian metamorphic rocks (the Straits Schist of Stanley, 1968; and Hatch and Stanley, 1973), which are correlative with rocks of the Connecticut Valley-Gaspe Synclinorium to the north (Goshen Formation in Fig. 3).

In West Torrington, there is a dramatic difference between the metamorphic rocks on either side of Cameron's Line (Figs. 2, 3). The Waramaug (p€-OWg) consists of massive quartzofeldspathic gneiss and schist with subordinate amphibolite and calc-silicate marble layers and lenses. The Hartland consists of dominantly well-layered micaceous schist, gneiss, and granofels (€-Ohmk, Ohgr, Ohgn) together with thick layers of complexly folded amphibolite (€-Oha, Ohau), and subordinate discontinuous layers and lenses of serpentinite and cotecule (garnetiferous quartzite; Figs. 3, 4). Due to this profound difference in lithology and the lack of massive carbonate rocks and Proterozoic crust east of Cameron's Line, it seems probable that the Hartland protoliths were deposited on oceanic crust. The massive character and presence of calc-silicate and amphibolite in the Waramaug Formation suggests that their protoliths probably represent continental slope and rise (?) deposits. Thus, Cameron's Line separates sequences originally deposited adjacent to the lower Paleozoic shelf-edge of North America.



## ***Structural Geology***

Bedrock in the West Torrington Quadrangle provides evidence of at least five deformations that can be distinguished in the field by tracing axial surfaces of folds. The first two of these ( $D_1 + D_2$ ) are probably continuous, developing two phases of isoclinal folds ( $F_1 + F_2$ ) that culminate in the penetrative regional metamorphic fabric ( $S_1 + S_2$ ) developed in both the Waramaug and Hartland formations.  $F_1$  folds are rare but a local pre-existing  $S_1$  foliation is folded by  $F_2$  folds and  $S_1$  is regionally truncated along with sub-units of the Hartland Formation along Cameron's Line. The  $D_2$  structures are intensely developed in the vicinity of Cameron's Line. Furthermore, the regional parallelism and closer spacing of  $S_2$  axial surfaces near Cameron's Line and the development of mylonite support the conclusion that Cameron's Line marks a synmetamorphic  $D_2$  ductile fault between the Waramaug and Hartland formations.

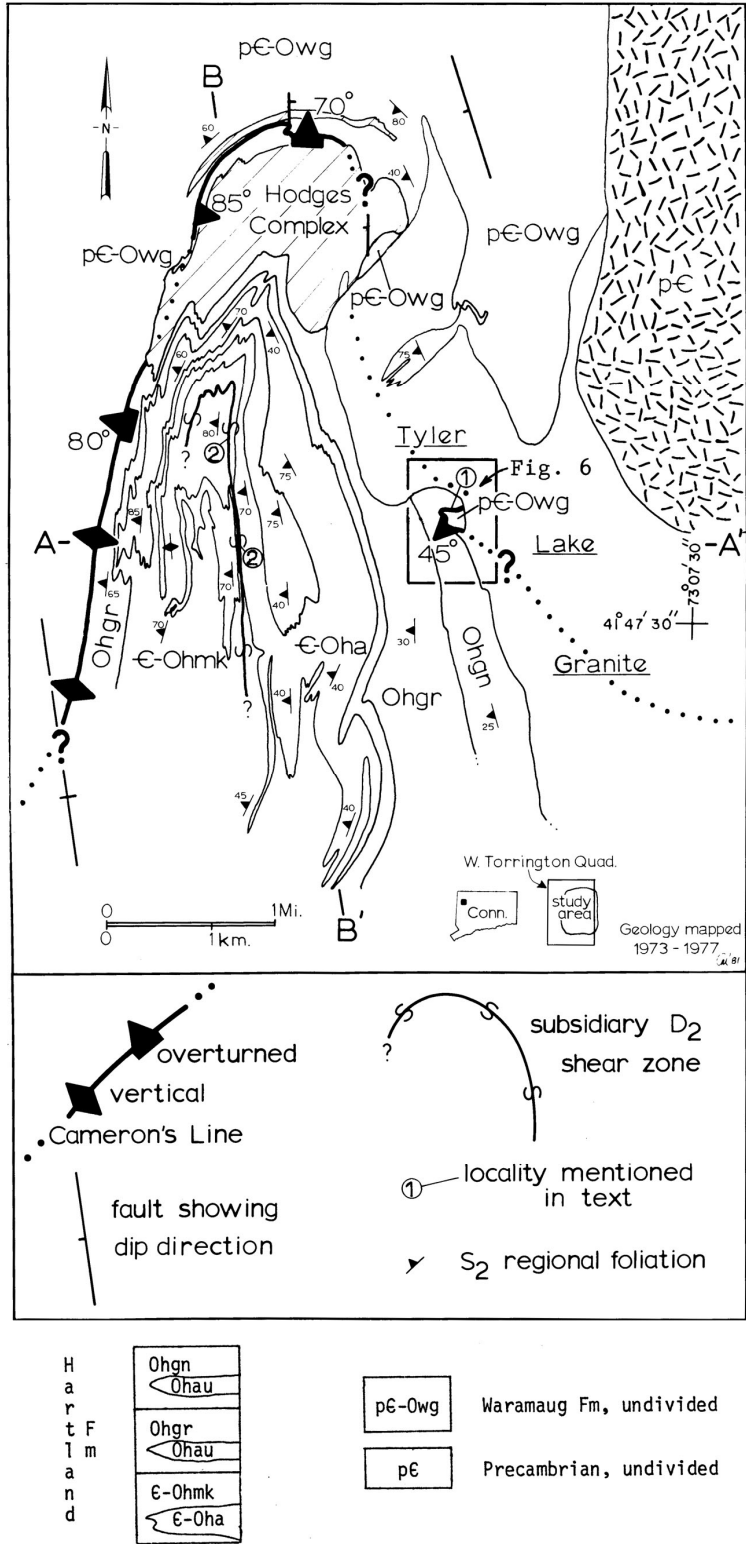
The  $S_1 + S_2$  regional foliation is locally warped by open  $F_3$  folds that formed during intrusion of the Hodges Complex and the Tyler Lake Granite, but they have little effect on map patterns (Fig. 4). The  $S_1 + S_2$  foliation and Cameron's Line is folded by dextral  $F_4$  folds with steep southwest-plunging axes and northwest-dipping axial surfaces. A spaced biotite schistosity or crenulation cleavage ( $S_4$ ) cuts all pre-existing structures as well as intrusive rocks of the Hodges Complex and Tyler Lake Granite. Finally, a weakly developed fifth deformation forms west- to northwest-trending spaced cleavage that cuts all previous structures and lithologic units, but has little effect on the map patterns. The superposition of these events has resulted in the complex map patterns shown in Figure 4 and in the interpretive cross sections of Figure 5.

Cameron's Line was a locus for lower Paleozoic plutonic activity. It acted as a weak zone in the crust enabling late synorogenic mafic-ultramafic magmas of the Hodges Complex and the younger Tyler Lake Granite to intrude along it (Merguerian, 1977). The Hodges Complex, engulfing Cameron's Line in West Torrington (Fig. 4), is a small composite mass of pyroxenite, hornblendite, gabbro, and diorite that is not sheared or offset by the fault. Rather, a narrow contact aureole that developed in the bounding Waramaug and Hartland formations overgrows the  $S_2$  fold-fault fabric formed during the development of Cameron's Line.

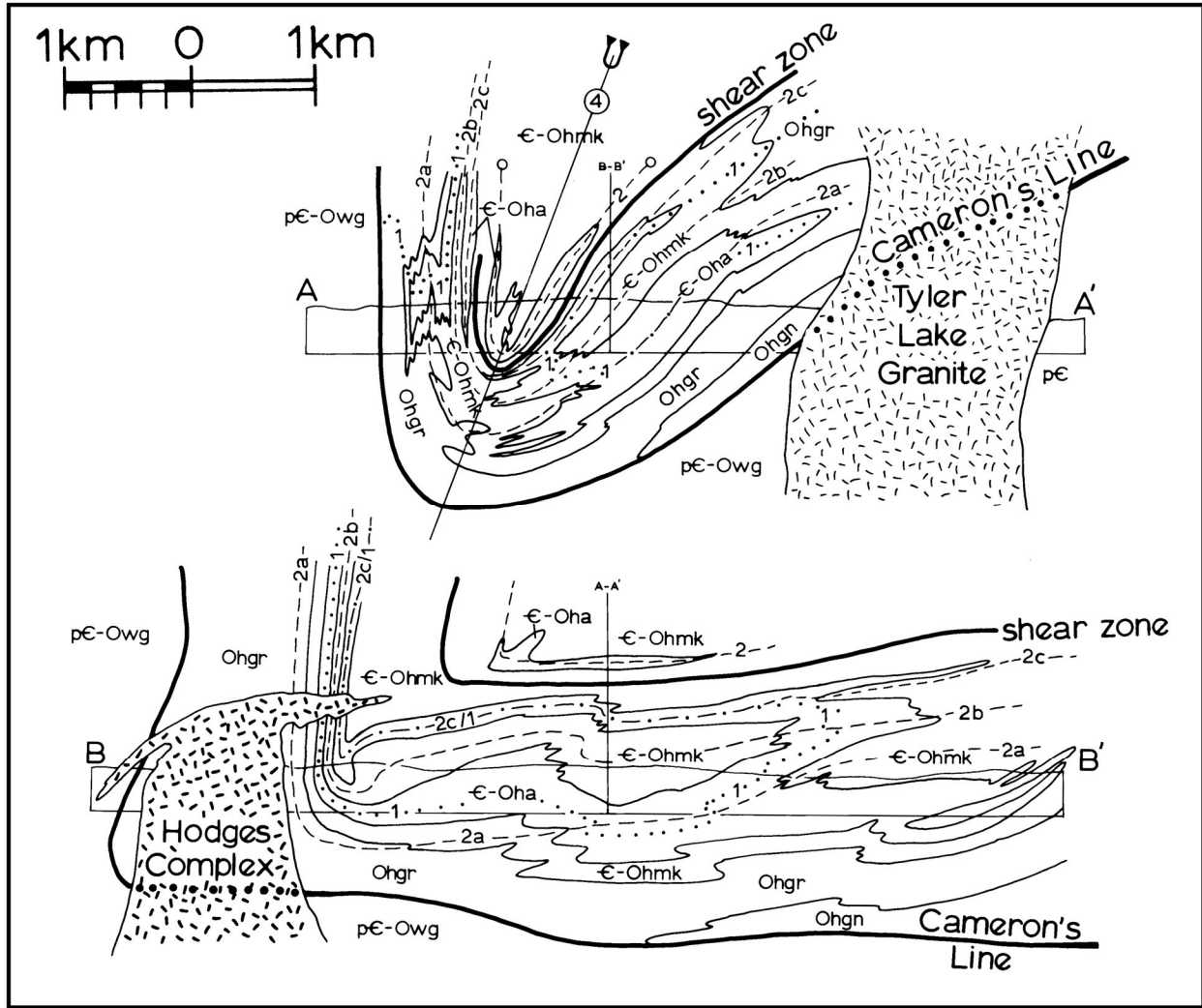
The Hodges Complex is cut on the east by the Tyler Lake Granite (Fig. 4). The Tyler Lake yielded a middle Ordovician Rb/Sr age (Merguerian and others, 1984), which thus establishes a minimum age for the faulting on Cameron's Line. Therefore, the two stops described below offer a view of an ancient deep-seated collisional boundary that probably formed during or diachronously before the medial Ordovician Taconic orogeny (Merguerian, 1985b).

## **SITE DESCRIPTION**

***Stop 1. Cameron's Line Exposure.*** Biotite gneiss and schist of the Waramaug Formation crop out in the woods on both sides of Highland Avenue immediately to the west of the stream (Fig. 6). The rocks strike northwest and dip southwest. They are locally folded by  $F_3$  folds with sub-horizontal axial surfaces and are locally injected by granitoid of the Tyler Lake Granite.



**Figure 4.** Simplified geologic map of part of the West Torrington Quadrangle, Connecticut. The complex map pattern of Hartland amphibolite (ε-Oha) is due to superposition of F<sub>1</sub> and F<sub>2</sub> isoclinal folds produced during the formation of Cameron's Line and major dextral folding by southwest-plunging folds with northwest-dipping axial surfaces (F<sub>4</sub>). The approximate trace of Cameron's Line is dotted through intrusive rocks.

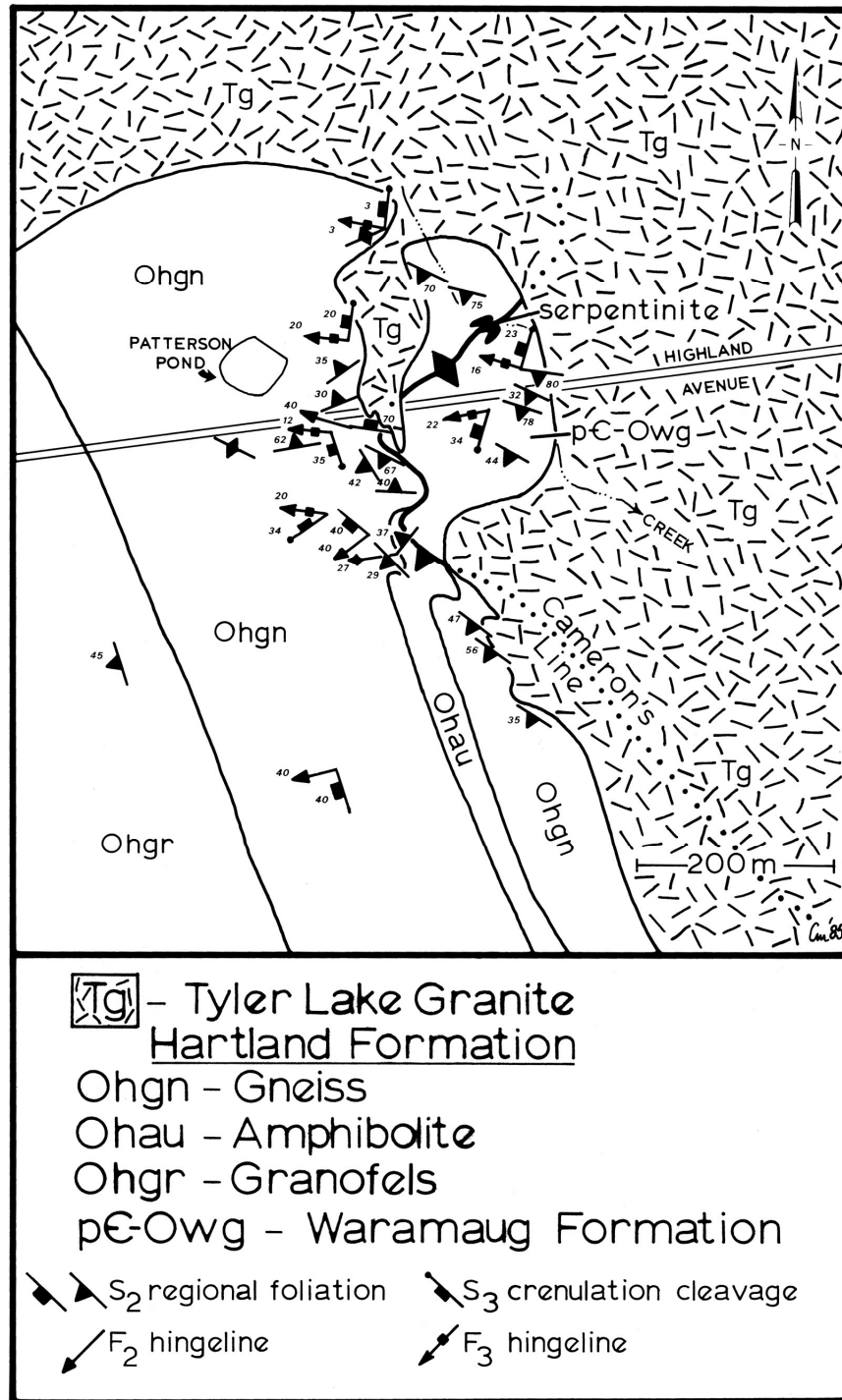


**Figure 5.** Geologic structure sections. Section lines shown in Figure 4. Numbered lines (1, 2a, 2b, 2c, 4) mark the projected axial surface traces of various fold generations. Note the regional parallelism of  $S_2$  axial surface traces with Cameron's Line and the effects of  $F_4$ , which in section A-A' plunges toward the reader. Also note the discordant contact relationship of both the Hodges Complex and the Tyler Lake Granite and truncation of Hartland gneiss sub-unit (Ohgn) against Cameron's Line. No vertical exaggeration.

On the south side of Highland Avenue roughly 600 ft (200m) west of the stream, mylonitic Harland amphibolite separates the Waramaug rocks from muscovitic schist, gneiss, and granofels of the Hartland Formation (Figs. 4, 6). Sub-units of the Hartland (Ohgn and Ohau) are regionally truncated along Cameron's Line (Figs. 3-6).

The rarely exposed contact, Cameron's Line, between the Hartland and Waramaug formations typically contains tectonically interleaved rocks from both formations. The contact, which has been mapped through the Hodges Complex by examining xenoliths and screens and identified elsewhere in the West Torrington quadrangle, is actually a zone 50 to 300 ft (15 to 90 m) thick that typically incorporates mylonitic amphibolite layers up to 10 ft (3 m) thick. Here, the  $S_1$  metamorphic layering is locally preserved within  $F_2$  fold hinges, but strong shearing

parallel to  $S_2$  axial surfaces forms a penetrative  $D_2$  fold-fault fabric that marks Cameron's Line. Amphibolites away from Cameron's Line also show the effects of  $F_2$  folds, but the high degree of shearing and disarticulation of the pre- $D_2$  fabrics is unique to the fault zone.



**Figure 6.** Sketch map showing geologic relations of Stop 1 (details in text). The warping of Cameron's Line and the  $S_2$  regional foliation is due to shouldering near the Tyler Lake Granite and the effects of syn-intrusive  $F_3$  folds. Same notation as in Figure 4.



Trace the streambed 300 ft (100 m) northwestward from where it crosses Highland Avenue to where a 30-ft-thick (10m) isoclinally folded serpentinite body occupies the contact zone between Waramaug rocks to the southeast and Hartland rocks to the west and northwest. Folded by  $F_2$  folds (Fig. 7), the serpentinite body is compositionally zoned and strongly altered. It contains relict olivine and orthopyroxene with recrystallized cummingtonite, anthophyllite, and tremolite. It is distinct in mineralogy and texture from ultramafic rocks of the Hodges Complex and other nearby mafic-ultramafic plutons that post-date Cameron's Line.



**Figure 7.** Photograph (facing east) of an isoclinally folded serpentinite occurring at Cameron's Line with a steep  $S_2$  axial surface trace (dashed line). The serpentinite is zoned and highly altered containing relict olivine and orthopyroxene with intergrown amphiboles. The compositional zoning (thin white line folded by  $F_2$ ) is due to relative enrichment of matted cummingtonite and tremolite with minor serpentinite in the upper part of the body in comparison to the dense black serpentinite- and anthophyllite-enriched lower part.

Hartland rocks to the southwest (immediately southeast of Patterson Pond) contain layers of amphibolite and pink-orange 1 mm laminae of garnetiferous quartzite (coticule; Merguerian, 1979). The coticule rock, the overall eugeosynclinal nature of the Hartland rocks, and the structural position of the serpentinite together suggest that the serpentinite body represents metamorphosed dismembered oceanic lithosphere (ophiolite).

**Stop 2. *Subsidiary Shear Zone.*** Massive Hartland amphibolite occurs 1.2 mi (1.9 km) west on Highland Avenue (known here as Soapstone Hill Road) in excellent roadside outcrops. Here, the typical foliated but non-mylonitic character of the amphibolite is obvious in contrast to mylonitic amphibolite of Stop 1.  $F_2$  isoclinal folds of the  $S_1$  metamorphic foliation are exposed on the roadcut north of Soapstone Hill Road. Steep northwest-dipping  $S_4$  slip cleavage related to southwest-plunging crenulations, cuts the  $S_1 + S_2$  composite foliation and forms wedge-like angular pieces of amphibolite due to the intersection of structural fabrics.

At the sharp bend in Soapstone Hill Road at the western end of the roadcut, phyllonitic muscovite schist of the Hartland (€-Ohmk) marks a subsidiary  $D_2$  shear zone that imbricates the schist and amphibolite in the area (Figs. 4, 5). The shear zone is marked by  $F_2$  isoclinal folds with sheared out limbs and a deeply-weathered zone to the south. About 2,300 ft (700 m) northward from Soapstone Hill Road along a dirt trail, it is marked by a soapstone-talc-chlorite schist quarry that may represent another ophiolite body. Away from the shear zone the Hartland schists and amphibolites are medium- to coarse-grained and do not show the abundant shearing parallel to  $F_2$  axial surfaces that characterizes the ductile faults.

## **SUMMARY**

Cameron's Line in West Torrington is a zone of ductile deformation that separates metamorphosed Upper Proterozoic(?) to lower Paleozoic continental slope and rise (?) rocks of the Waramaug Formation from dominantly eugeosynclinal rocks of the Hartland Formation. Subunits of the Hartland are truncated along strike against Cameron's Line where early metamorphic fabrics ( $S_1$ ) are obliterated by the intense fold-fault fabric ( $S_2$ ). The  $S_2$  fabric is the dominant regional foliation found on either side of the fault.

The  $S_2$  axial surface traces are regionally parallel to the mapped trace of Cameron's Line. The spatial coincidence of intense localized isoclinal  $F_2$  folds with sheared-out limbs and imbricated lithologies, including mylonitic amphibolite and rare serpentinite, suggests that Cameron's Line and its subsidiary shear zone mark deep-seated ductile faults. Indeed, many of the stratigraphic complications of the Hartland Formation in western Connecticut may result from other, as yet unrecognized ductile faults.

Available data suggest that Cameron's Line may be a thrust within the deep levels of a west-facing Taconian accretionary prism formed when the North American shelf and transitional sequence (Waramaug Formation) became juxtaposed with oceanic rocks of the Hartland Formation during closure of a fringing marginal basin. Today, the Hartland Formation represents a deeply-eroded portion of the accretionary complex of oceanic basin rocks formerly positioned between the lower Paleozoic passive margin of eastern North America and a volcanic archipelago to the east.

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