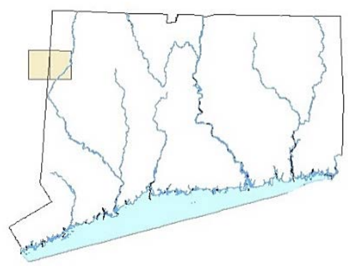
CONNECTICUT GEOLOGICAL AND NATURAL HISTORY SURVEY
DEPARTMENT OF ENERGY & ENVIRONMENTAL PROTECTION

Bedrock Geology of the Ellsworth and Eastern Part of the Amenia Quadrangles, Connecticut and New York

WITH MAP

JONATHAN L. BURR



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Thesis Report [155p.]
Plate 1: Bedrock Geologic Map
Plate 2: Outcrop Map
Plate 3: Planar Structural Features
Plate 4: Linear Structural Features
Plate 5: Structural Cross Sections and Aeromagnetic profiles

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GIS data available as GeMS format geodatabase

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BEDROCK GEOLOGY OF THE ELLSWORTH AND EASTERN PART OF THE AMENIA QUADRANGLES, CONNECTICUT AND NEW YORK

A Thesis Presented

by

Jonathan L. Burr

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Bedrock Geology of the Ellsworth and Eastern Part
of the Amenia Quadrangles, Connecticut and New York

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Approved as to style and content by:

Peter Robinson

Dr. Peter Robinson, Chairperson of the Committee

R. W. Bromery

Dr. Randolf W. Bromery, Member

Donald U. Wise

Dr. Donald U. Wise, Member

Donald U. Wise

Dr. Donald U. Wise, Department Head
Department of Geology and Geography

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ABSTRACT

The Ellsworth and Amenia quadrangles in northwestern Connecticut and eastern New York are underlain by a sequence of Precambrian (Grenvillian) gneisses, unconformably overlain by autochthonous Cambrian-Ordovician quartzites, marbles and schists, and allochthonous thrust sheets of Cambrian schists and amphibolite.

Stratified Precambrian rocks consist of various gneisses of sedimentary and volcanic origin which constitute six stratigraphic units. Four sheet-like igneous plutons that range from granitic to tonalitic as well as a small ultramafic body are present in the basement terrane. Outcrop observations indicate that granitic intrusions occurred in at least two phases, one which preceded and the other which followed an intervening penetrative deformation.

The Precambrian gneisses are unconformably overlain by the autochthonous Cambrian Lowerre Quartzite which is succeeded by the Cambrian-Ordovician Inwood Marble. The Middle Ordovician Manhattan A, consisting of a basal Marble Member and overlying Schist Member, unconformably overlies the older autochthonous rocks. Cambrian schist of the Everett Formation makes up a thrust sheet that overlies the Manhattan A in the northwest corner of the area. Cambrian schistose granulite, schistose gneiss and amphibolite of the Manhattan C constitute two thrust sheets which overlie the Manhattan A southeast of the basement gneisses. The schistose gneiss and granulite are eastern facies equivalents of the Lowerre Quartzite.

Five major phases of deformation are identified as follows:

1) Grenvillian isoclinal folding; 2) Taconian thrusting of the Everett Formation, Manhattan C and basement rocks over the autochthonous cover; 3) Taconian isoclinal folding during and after emplacement of thrusts and development of the predominant foliation; 4) Acadian northeast-trending, tight to open folds with upright axial plane cleavage; 5) late-stage folding with northwest-trending slip-cleavage.

Basement gneisses locally exhibit relict mineral assemblages of granulite facies metamorphism which have been retrograded to upper amphibolite facies during Paleozoic metamorphisms. Metamorphic grade in the cover rocks increases from staurolite zone in the northwest corner to sillimanite zone in the southeast part of the area. Peak metamorphism in the cover rocks probably coincided with Taconian isoclinal folding during the third phase of deformation.

Correlation of the aeromagnetic map for the Ellsworth quadrangle with the bedrock geology is based on field measurements of magnetic susceptibility. Low magnetic intensity for most of the area corresponds to the low susceptibility of most of the rocks. Magnetic anomalies are interpreted as caused by near-surface magnetite-bearing granitic gneisses in the basement or locally magnetite-rich schists of the Manhattan C. The low intensity expression over granitic gneiss with high measured susceptibilities along the western edge of the basement gneisses probably reflects thin, thrusted basement rocks above the non-magnetic marbles of the autochthonous cover.

INTRODUCTION

Location

The Ellsworth and Amenia quadrangles (Figure 1) are located in the Housatonic Highlands of northwestern Connecticut and adjacent New York. The study area covers approximately 69 square miles which includes the entire Ellsworth and the eastern quarter of the Amenia 7.5 minute quadrangles.

Topography and Drainage

The topography of the area (Plate 1) is dominated by the northeast-trending Housatonic Highlands which form an elevated terrain approximately 4 to 5 miles (6.5 to 8.1 km) wide that is underlain by Precambrian gneisses. Northeast-trending ridges and hills locally rise 200' (62 m) to 500' (154 m) above swampy low areas in the highlands. The Housatonic River flows north to south through the eastern part of the study area. It is incised into the Precambrian gneisses north of Bread Loaf Mountain but flows over Cambrian marbles south of that point. Steep slopes rise up to 800 feet (246 m) from the west bank of the Housatonic River and over 1000 feet (308 m) from the east bank to the eastern hills underlain by Cambrian schists and amphibolites. The northwest side of the Housatonic Highlands rises 600 to 720 feet (185 to 222 m) above the valley of Webatuck Creek which also flows over Cambrian-Ordovician marbles.

Relief over the study area exceeds 1131 feet (348 m) with a maximum elevation of 1551 feet (477 m) at Ellsworth Hill (Plate 1) and a minimum

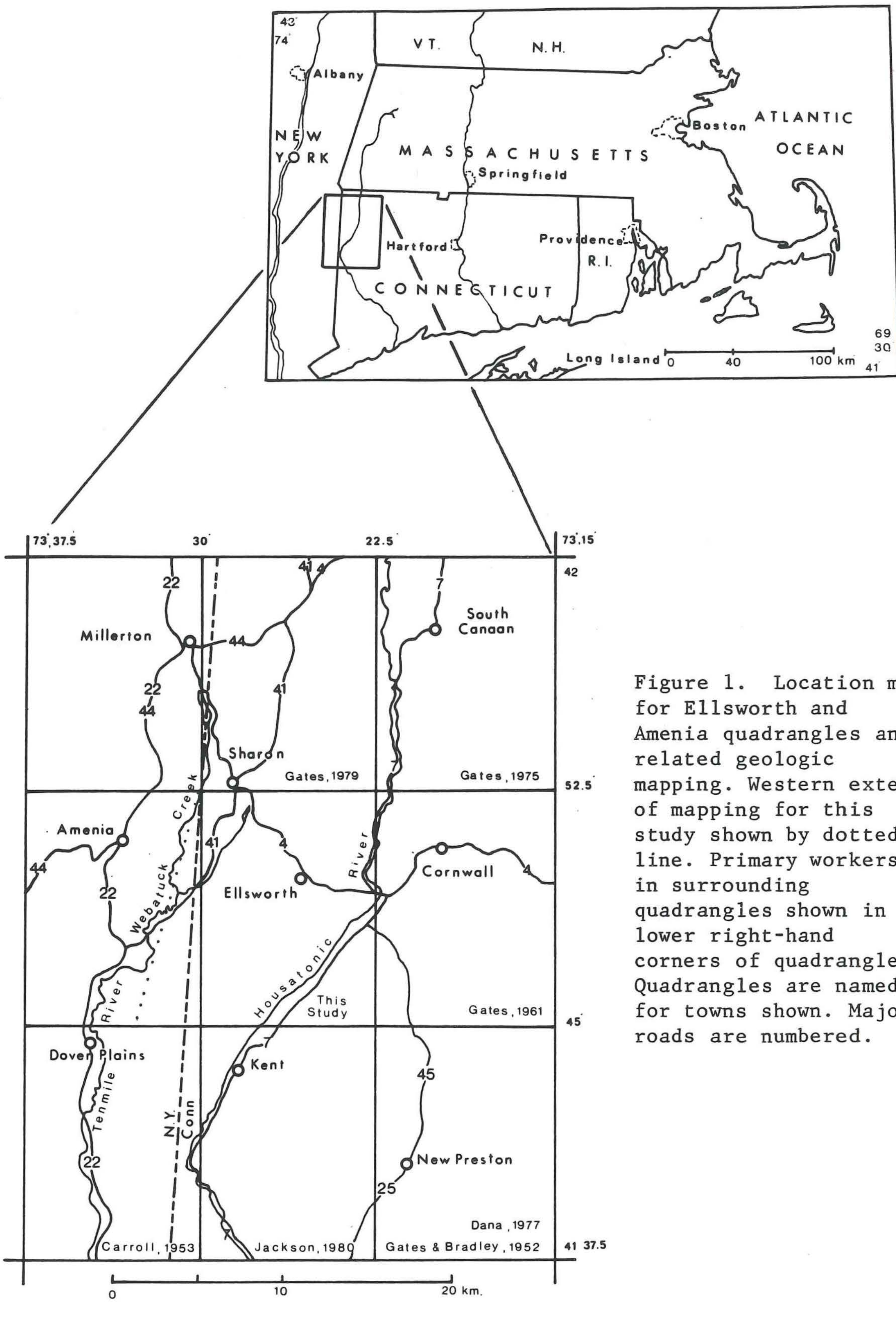


Figure 1. Location map for Ellsworth and Amenia quadrangles and related geologic mapping. Western extent of mapping for this study shown by dotted line. Primary workers in surrounding quadrangles shown in lower right-hand corners of quadrangles. Quadrangles are named for towns shown. Major roads are numbered.

elevation below 420 feet (129 m) where Webatuck Creek leaves the map area. Cross sections A-A' and B-B' (Plate 5) show west to east topographic profiles that illustrate the general influence of rock types on the landforms of the area.

The area is drained by the Housatonic River which is fed by brooks from the Housatonic Highlands and the eastern hills of Flanders Mountain and Whitcomb Hill (Plate 1). Streams also drain westward off of the Housatonic Highlands into Mill Creek which joins Webatuck Creek at Amenia Union.

Regional Geologic Setting

The study area occupies a region of high-grade metamorphic rocks which forms a province of the Applachian Orogen characterized by exposures of Precambrian Grenville basement rocks (Figure 2). The region underwent a complex tectonic history involving effects of the Grenville, Taconian and Acadian orogenies. The Ellsworth and Amenia quadrangles straddle the central portion of the Housatonic Highlands which consist of various Precambrian feldspathic, schistose and mafic gneisses with lesser amounts of amphibolites and calc-silicate rocks. These rocks represent metamorphosed sedimentary, volcanic and intrusive rocks (Hall, 1980). Other basement areas composed of similar rock types in the region are the Berkshire allochthon to the northeast, the Hudson Highlands to the southwest, and the Fordham Terrane which is located south-southeast of the Housatonic Highlands (Figure 2). All of these basement rocks represent "North American" continental crust (Hall and Robinson, 1982).

An autochthonous sequence of Cambrian quartzite unconformably

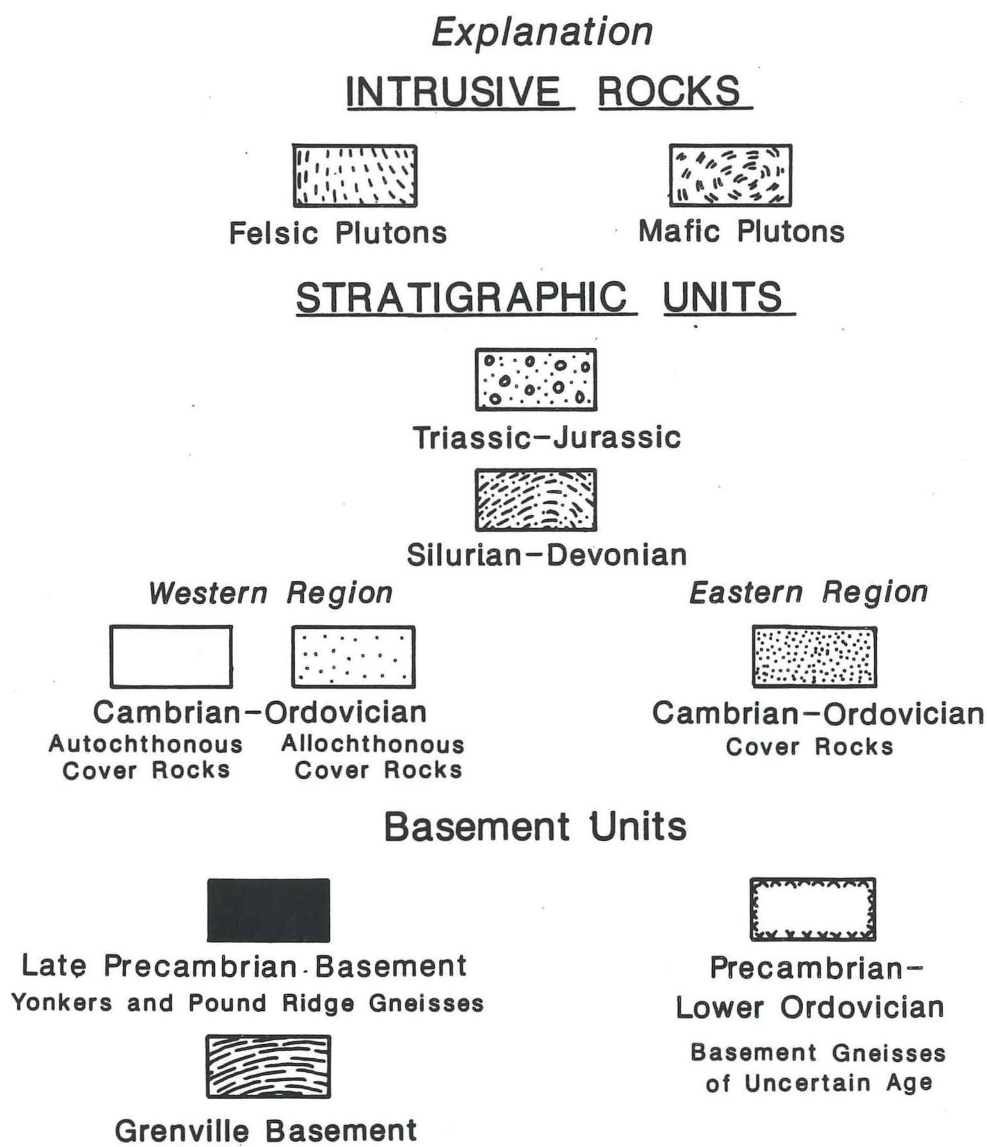
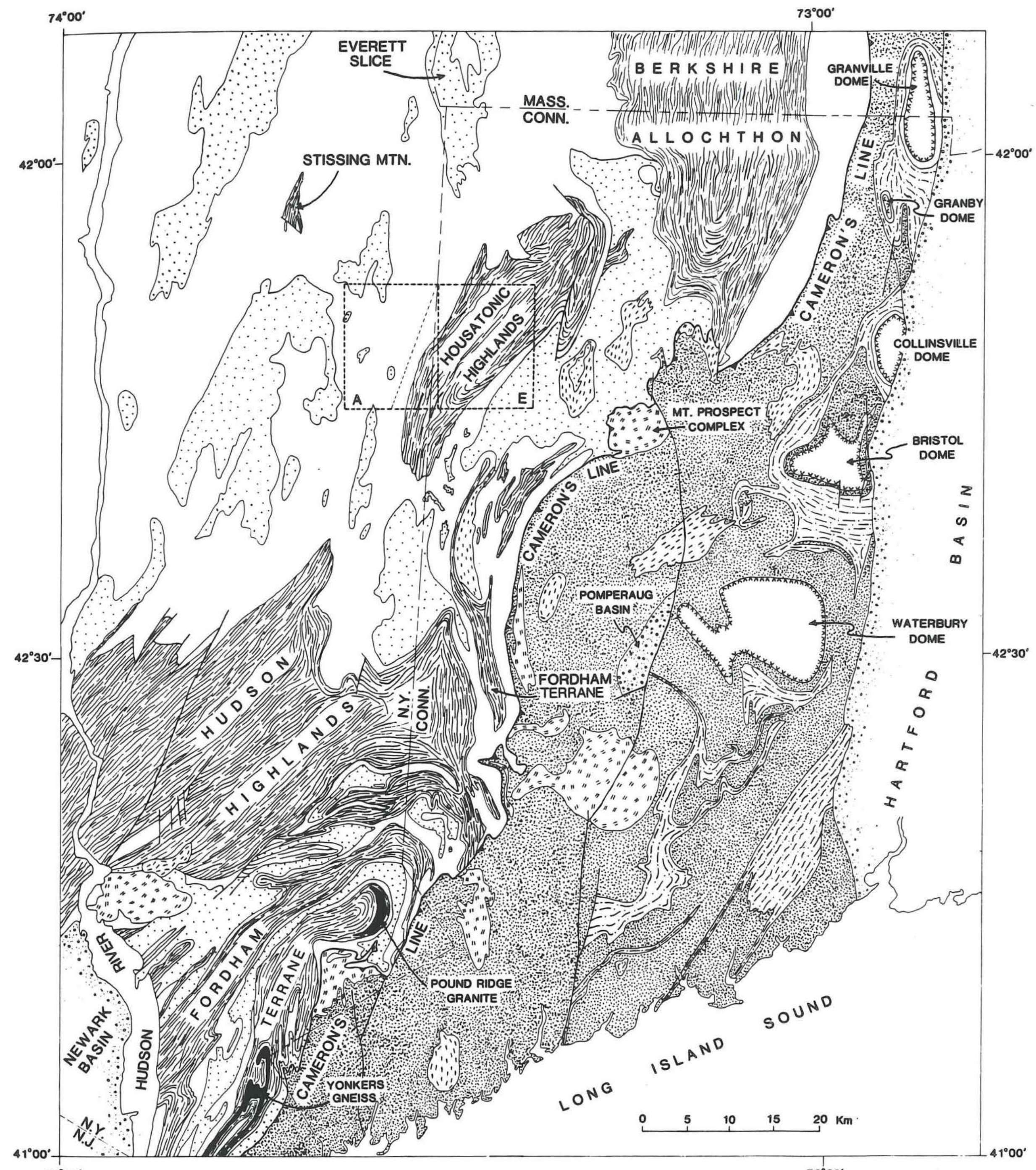


Figure 2. Generalized bedrock geologic map of western Connecticut and eastern New York (from Hall, 1980). A and E denote the Amenia and Ellsworth quadrangles, respectively.


74°00'
73°00'
42°00'
42°30'
41°00'
EVERETT SLICE
BERKSHIRE
ALLOCHTHON
MASS.
CONN.
GRANVILLE DOME
STISSING MTN.
GRANBY DOME
CAMERON'S LINE
HOUSATONIC HIGHLANDS
A
E
COLLINSVILLE DOME
MT. PROSPECT COMPLEX
BRISTOL DOME
HARTFORD BASIN
POMPERAUG BASIN
WATERBURY DOME
HUDSON HIGHLANDS
N.Y.
CONN.
FORDHAM TERRANE
LINE
POUND RIDGE GRANITE
RIVER
NEWARK BASIN
HUDSON
YONKERS GNEISS
LONG ISLAND SOUND
0 5 10 15 20 Km
N.Y.
N.J.

overlies the basement and is succeeded by Cambrian-Lower Ordovician Marbles which represent basal clastics and carbonate bank deposits, respectively. These rocks are truncated beneath a regional unconformity that is overlain by Middle Ordovician marble and sulfidic schist that represent limestones deposited on horsts and grabens and black shales derived from an emergent eastern source area at the onset of the Taconian orogeny (Zen, 1968).

The autochthonous cover rocks are exposed both on the west and east sides of the Housatonic Highlands marking the most northern occurrence of the carbonate bank deposits on the east flank of the Grenville basement massifs in New England. North of the Highlands extensive exposures of the shelf sequence are west of the basement uplifts. Southeast of the Housatonic Highlands the shelf sequence extends southward through the Fordham terrane to southeastern New York. The eastward extent of the bank sequence is truncated along Cameron's Line (Figure 2), a major regional thrust fault.

An allochthonous sequence consisting of Cambrian schists and amphibolites structurally overlies the Middle Ordovician rocks. These rocks represent shales, siltstones and some volcanic rocks (Hall, 1968) that were transported to their present position by thrusting during the Taconian deformation. These rocks are an eastern facies of the clastic-carbonate bank sequence that were deposited on North American Grenville basement in a probable outer shelf or slope environment. Cameron's Line separates these rocks from eastern cover rocks (Figure 2) interpreted to have been deposited on oceanic crust.

Purpose of Study

This thesis is an outgrowth of reconnaissance bedrock mapping of the Ellsworth quadrangle for the Connecticut State Geologic and Natural History Survey. The primary goal of this study is the mapping and description of the Precambrian and Paleozoic stratigraphy of the area which includes the eastern portion of the Amenia quadrangle. Other goals of this study are as follows: 1) To understand the structural geometry and deformation history, 2) To document the metamorphic assemblages and understand the metamorphic history, and 3) To examine the correspondence of the aeromagnetic map with the bedrock geology.

Previous Work

Percival (1842) first described the rocks of the study area during a reconnaissance study of the geology of Connecticut. The work of W. H. Hobbs provided most of the information on the western highlands for Rice and Gregory's (1906) description of the geology of Connecticut and Gregory and Robinson's (1907) preliminary geologic map of Connecticut. Agar (1923, 1934) published reconnaissance maps of the region and described some of the plutonic rocks of the Housatonic Highlands. Balk (1936) mapped and studied the structure of Dutchess County which included the southwest end of the Housatonic Highlands. Carroll (1953) and Waldbaum (1960) mapped in the Dover Plains quadrangle and subdivided the carbonate stratigraphy (Figure 1). Mapping by Gates (1961, 1975, 1979) in the Cornwall, South Canaan and Sharon quadrangles (Figure 1) identified some of the contacts between Precambrian units described in this study. Jackson (1980) mapped the Kent quadrangle and provided detailed information on the basement-cover relations and deformation history in that area. Dana (1977) mapped in detail a portion of the New Preston quadrangle (Figure 1) and described the stratigraphy and deformations to the east of the Kent area.

Method of Study

Bedrock mapping was conducted during the summers of 1979 and 1980. Location of outcrops and contacts were plotted on a 1:24,000 USGS topographic base and descriptions of rocks and structural measurements were recorded in the field. Representative samples of the 24 rock units were collected and 101 specimens were selected for petrographic study (Tables 1-12). Planar structural features measured in the field were analyzed after compilation on computer cards and generation of contoured plots on equal area nets using programs written by Phelps Freeborn. Magnetic susceptibility measurements were made in the field using the Bison Model 3101 Magnetic Susceptibility System with an external coil.

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I would like to thank Sidney Quarrier of the Connecticut Geological and Natural History Survey for the support of my field work during the summer of 1979, thin section preparation and base maps. Shirley Scardino typed the manuscript. Farinaz Boudreau provided references and ideas about aeromagnetic interpretation. Robert Mollar of the National Audubon Society in Sharon, Connecticut, provided economical housing during the summer of 1980. Their help is appreciated.

I am especially thankful to my wife, Virginia L. Peterson, for her helpful ideas, her help with drafting of figures, and her encouragement, love and patience during the completion of this project. This thesis is dedicated to my parents, Francis and Marion, for their love and enthusiastic support of my academic interests.

STRATIGRAPHY

Stratified rocks of the Ellsworth and eastern part of the Amenia quadrangles consist of six Precambrian gneissic units unconformably overlain by basal Cambrian Lowerre quartzite succeeded by carbonate bank deposits of the Cambrian to Ordovician Inwood Marble (Figure 3). These rocks are in turn unconformably overlain by the Middle Ordovician Manhattan A schists with interbedded calcite marble. This sequence constitutes an autochthonous stratigraphy which occurs on the east and west flanks of the Housatonic Highlands in the study area (Plate 1).

Two major unconformities are present within the autochthonous sequence. One is the basal unconformity above the basement gneisses upon which the Lowerre Quartzite was deposited. The other is the Middle Ordovician unconformity which is marked by the contact of Manhattan A marble or schist with different members of the Inwood Marble.

Three allochthonous masses of Late Precambrian to Cambrian pelitic schists, schistose gneiss and amphibolites make up thrust sheets that are physically above the Middle Ordovician rocks. One thrust sheet is made up of Late Precambrian to Cambrian schists of the Everett Formation and occurs northwest of the Housatonic Highlands. The other thrust sheets consist of the Cambrian Manhattan C which is divided into four members that occur southeast of the Housatonic River (Plate 1). These rocks are interpreted as eastern facies equivalents of the autochthonous Cambrian quartzites.

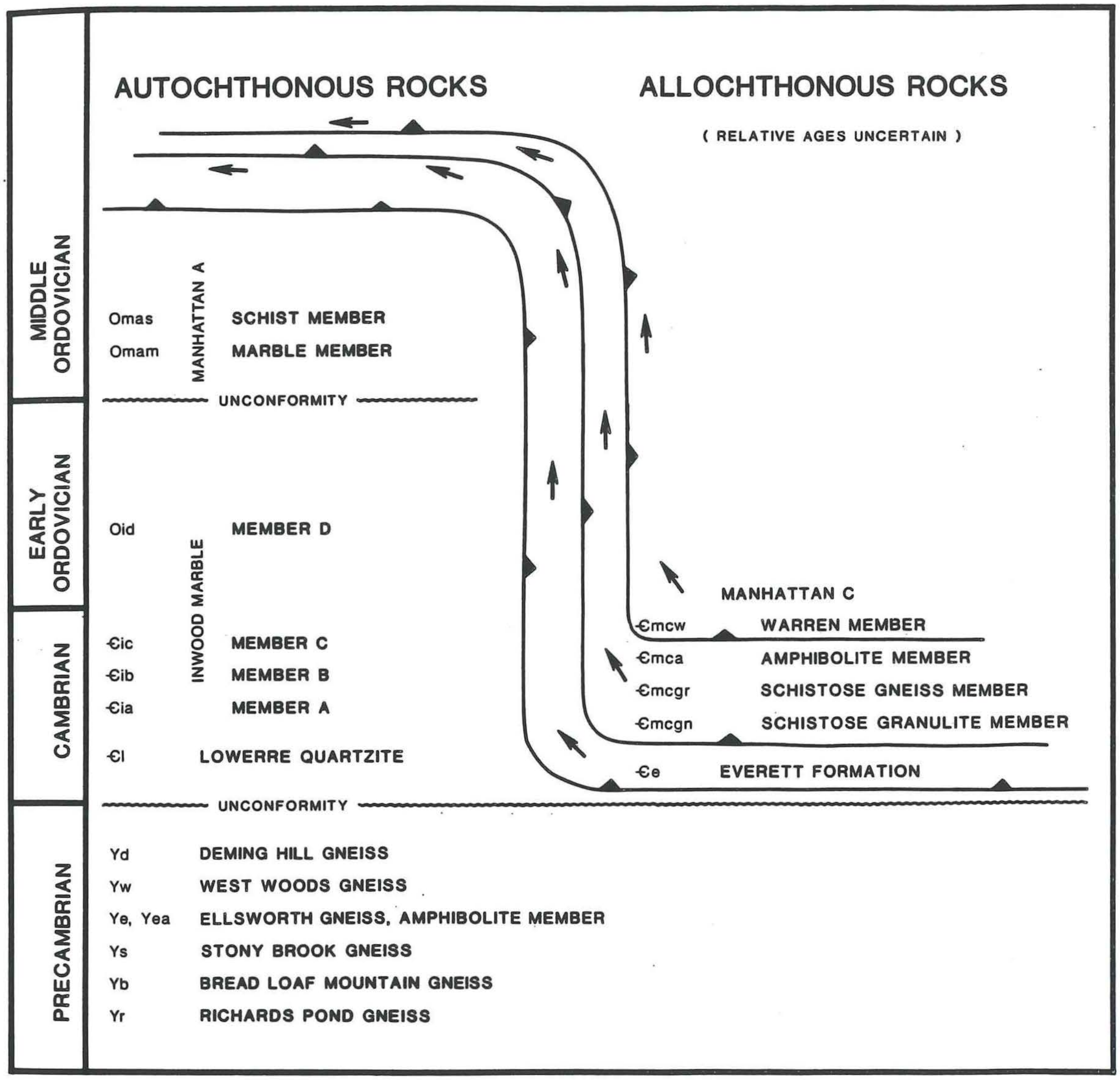


Figure 3. Stratigraphic column of the rocks in the study area showing the Precambrian and Paleozoic stratigraphic units. The Paleozoic units are divided into the autochthonous and allochthonous sequences. Diagramatic thrust faults indicate the present structural position of the allochthonous sequence above the autochthonous sequence.

PRECAMBRIAN ROCKS

Gneisses of the Housatonic Highlands are divided into six units that are named for areas in proximity to typical exposures (Figure 3). Four units, the Richards Pond Gneiss, Bread Loaf Mountain Gneiss, Stony Brook Gneiss and Ellsworth Gneiss, were mapped by Gates (1961) in the Cornwall quadrangle and they are traced into the Ellsworth quadrangle along its eastern border (Plate 1). These units generally consist of light-gray feldspathic gneisses and rusty-weathering, bedded quartz-feldspar gneisses with minor amounts of calc-silicates, mafic gneisses and amphibolites. The other two units, the West Woods Gneiss and Deming Hill Gneiss, occur in the western portion of the Precambrian area. The West Woods Gneiss consists of biotite-hornblende-plagioclase gneiss and the Deming Hill Gneiss mainly consists of amphibolite and biotite-quartz-plagioclase gneiss.

The relative ages of the rock units are not known because indicators of stratigraphic tops were not found. However, the Richards Pond Gneiss occupies the core of an isoclinal anticline in the basement and it is assumed to be the oldest unit with successively younger units on the limbs of the fold (Plate 1). Thus, the youngest exposed rocks occur to the west and the Deming Hill Gneiss is the youngest unit in the sequence.

Richards Pond Gneiss - Yr

Rocks of the Richards Pond Gneiss are exposed in a northeast trending zone from the region of Richards Pond to the east flank of Silver Hill and Bread Loaf Mountain (Plate 1). The type locality for the Richards Pond Gneiss occurs about 300 m southwest of Richards Pond.

Numerous exposures also occur on the hills and ridges to the northeast and southeast of the pond (Plates 1 and 2).

The Richards Pond Gneiss (Table 1) consists of light-gray and white, layered, fine- to medium-grained, biotite-microcline-plagioclase-quartz gneiss. Garnet, hornblende and rare graphite occur locally while epidote, magnetite, ilmenite, sphene, apatite, zircon and secondary muscovite are commonly present in minor amounts. Compositional layering defined by discontinuous, white felsic layers ranging from 3 millimeters to 10 centimeters and typically 0.3-5 centimeters are characteristic. Outcrops may appear gray and white layered, streaked with thin felsic segregations, or uniform light-gray to gray due to irregular spacing of the layers.

The gray zones are finer-grained, contain more biotite and less microcline, and are more equigranular than the felsic layers. Biotite occurs as fine-grained disseminated flakes defining the foliation and locally forms thin concentrated zones several millimeters thick.

Local, fine-grained black biotite amphibolite occurs in thin (2-10 cm) discontinuous layers. On the knob south of Route 4 at Cornwall Bridge these layers contain pods of green diopside rimmed by hornblende. Dark-gray, biotite-quartz-plagioclase gneiss with flattened ellipsoidal masses of coarse biotite also occur at this location.

The unit occupies the core of an isoclinal anticline which, from limb to limb, has a thickness averaging 672 m with a maximum of 900 m. An approximate minimum thickness for the unit, since the base is not exposed, averages 336 m. These thicknesses are approximate because of

Table 1

Estimated Modes of Specimens from the Richards Pond Gneiss

Specimen	1-10	11-1	567	655	648
Quartz	41	47	45	51	39
Plagioclase	41	24[2]	17	25	46
(An%)[1]	(24)	(28)	(28)[3]	(31)	(28)
Microcline	9	17	25	8	tr
Myrmekite	-	tr	tr	tr	-
Biotite[4]	7	8	12	14	13
Muscovite[5]	tr	3	1	1	1
Chlorite[6]	tr	-	-	-	tr
Sericite	tr	tr	tr	tr	tr
Epidote[7]	2	1	tr	1	tr
Hornblende	tr	-	-	-	-
Garnet	tr	-	-	-	-
Allanite[8]	tr	-	tr	tr	-
Sphene	tr	tr	tr	tr	1
Apatite	tr	tr	tr	tr	tr
Zircon	tr	tr	tr	tr	tr
Magnetite	tr	-	tr	tr	-
Ilmenite[9]	-	tr	tr	-	-
Hematite	tr	-	-	-	-
100 Plag/Plag+Ksp	82	59	40	76	99
100 Qtz/Qtz+Fspar	45	53	52	61	45

[1]Approximate mol. % anorthite in plagioclase determined by Michel-Levy extinction angle method using determinative graph of Shelly (1975).

[2]Antiperthite.

[3]An% based on few measurements due to scarcity of twinned plagioclase.

[4]Biotite pleochroic formula: 1-10, pale-yellow (X), olive green to greenish-brown (Y&Z); 11-1, 567, 655, 648, pale-yellow (X), yellowish-brown to reddish-brown (Y&Z).

[5]Includes muscovite interpreted as secondary with ragged and embayed grain boundaries and associated with sericite alteration.

Table 1 (continued)

[6]Fe-rich chlorite occurs as alteration of biotite.

[7]Pistacite; biaxial negative, colorless (X) to pale yellow-green (Z).

[8]Allanite commonly rimmed by pistacite.

[9]Ilmenite commonly rimmed by sphene.

Description and location of rock specimens. Locations indicated on Plate 2.

1-10. Fine-grained, well foliated, light-gray biotite-microcline-quartz-plagioclase gneiss with rare garnet and hornblende. Specimen collected on the south side of Route 4 about 70 meters from the intersection with Route 7 (east-central area of map).

11-1. Fine-grained, well foliated, light-gray, muscovite-biotite-microcline-plagioclase-quartz gneiss. Specimen collected at an elevation of 930 feet, about 265 meters southeast from the top of Silver Hill (east-central area of map).

567. Fine-grained, well foliated, light-gray biotite-plagioclase-microcline-quartz gneiss. Specimen collected at an elevation of 1000 feet near the top of the knob overlooking the Housatonic River between Stewart Hollow Brook and Stony Brook (south-central area of map).

655. Light-gray- to gray-weathering, fine- to medium-grained, well foliated, light-gray biotite-microcline-plagioclase-quartz gneiss. Specimen collected at an elevation of 1170 feet, about 170 meters south from the east end of Richards Pond (southwest area of map).

648. Fine- to medium-grained, well foliated, light-gray biotite-quartz-plagioclase gneiss. Megacrysts of plagioclase up to 4 millimeters long are common. Specimen collected at an elevation of 1220 feet, about 410 meters east of the hill north of Richards Pond (south-central area of map).

the effects of minor folding and local intrusion of igneous rocks common to the region.

The Richards Pond Gneiss may have been derived from an intrusive granite sill, a feldspathic sandstone of appropriate composition or felsic volcanic material. The absence of intrusive contacts or well developed bedding, and the overall uniformity of rock type except for minor amphibolite interbeds, suggest that the unit is a metamorphosed felsic volcanic. The modes plot in the rhyodacite, dacite and quartz-andesite fields (Figure 4).

<u>Bread Loaf Mountain Gneiss - Yb</u>

The Bread Loaf Mountain Gneiss is exposed from the vicinity of Fuller Mountain northeast to Mine Mountain on the northwest side of the Richards Pond Gneiss and to the Housatonic River on the southeast side of the Richards Pond (Plate 1). The contact with the Richards Pond Gneiss defines an isoclinal anticline with the Bread Loaf Mountain Gneiss exposed on the limbs and in the hinge region of the fold. Rocks exposed on the northwest limb are in contact with the Stony Brook Gneiss which gives way to the Ellsworth Gneiss to the southwest. Rocks on the southeast limb are exposed along St. John's Ledges northeast to Stony Brook and are unconformably overlain by the Cambrian Lowerre Quartzite (Plate 1).

The Bread Loaf Mountain Gneiss (Table 2) is an undivided sequence of rocks consisting of interbedded graphitic quartzofeldspathic gneiss and schistose gneiss; amphibolites; hornblende-quartz-feldspar gneiss; gray, fine-grained, garnet-hornblende-biotite-quartz-plagioclase gneiss; and

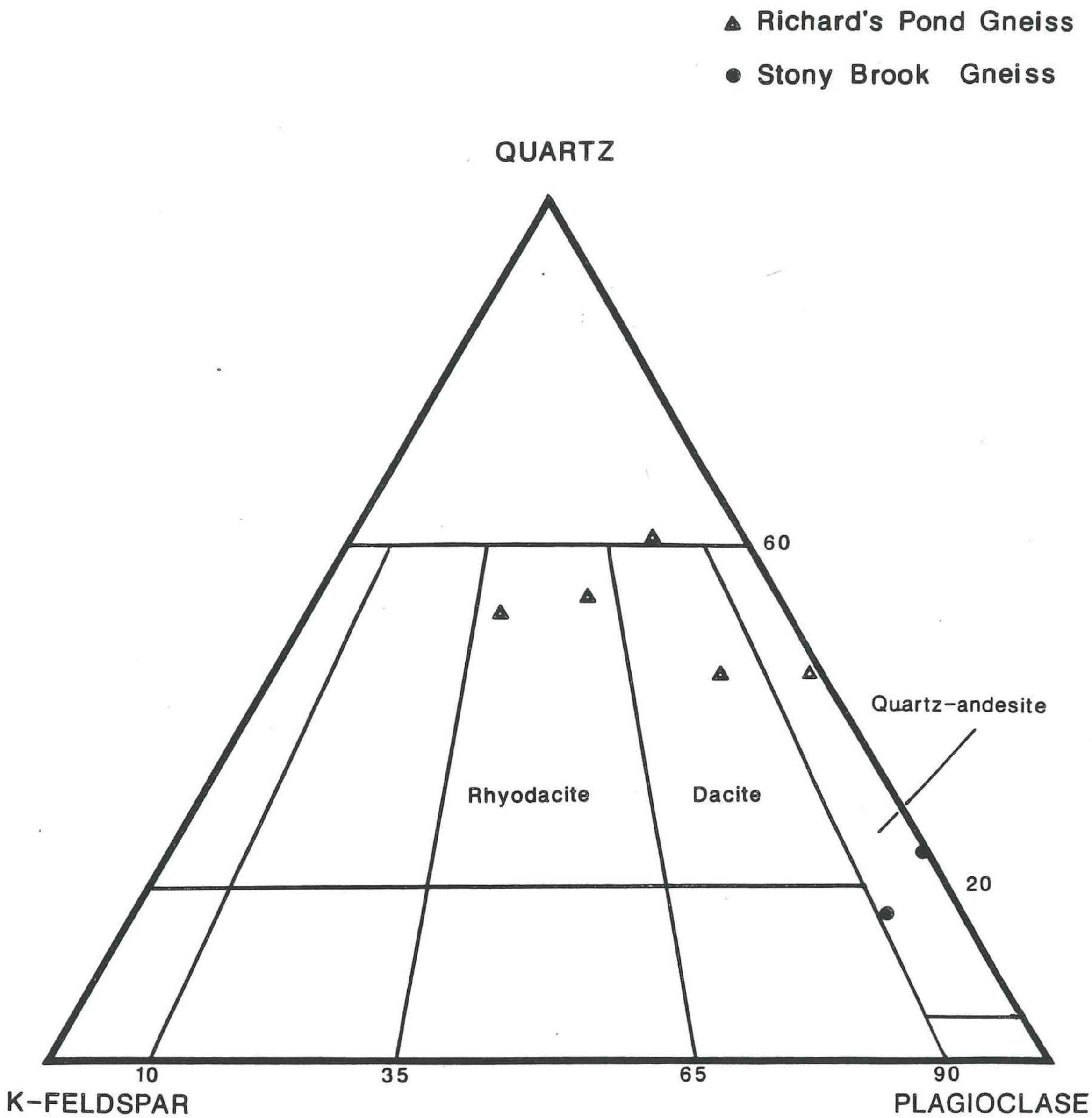


Figure 4. Plot of estimated modal quartz, plagioclase, and K-feldspar (normalized to 100%) from samples of Richards Pond Gneiss and Stony Brook Gneiss. Plot is adapted from Streckeisen (1973).

Table 2

Estimated Modes of Specimens from the Bread Loaf Mountain Gneiss

	Quartz - Feldspar Gneiss				Calc-Silicate
Specimen	911	2-1	2-4	7-4	698
Quartz	54	61	55	79	tr
Plagioclase	11	27	22	2	17
(An%)[1]	(26)	(36)	(31)	(28)[3]	(31)
Microcline	17	5	15	1[4]	-
Myrmekite	tr	tr	tr	tr	-
Biotite[5]	17	3	6	5	tr
Muscovite[6]	1	4	2	1	-
Chlorite[7]	tr	-	-	-	-
Sericite	tr	tr	tr	tr	tr
Garnet	-	-	-	-	-
Hornblende[8]	-	-	-	-	10
Diopside	-	-	-	-	70
Epidote	-	tr[9]	tr	-	tr
Allanite	tr	tr	tr	-	tr
Sphene	tr	tr	tr	-	3
Apatite	tr	tr	tr	tr	tr
Zircon	tr[10]	tr[9]	tr[9]	tr	tr[9]
Graphite	tr	-	tr	12[11]	-
Magnetite	-	-	-	tr	tr
Ilmenite	tr	tr	-	-	-
Pyrite	tr	-	-	tr	-
Chalcopyrite	-	-	-	-	-
Hematite	tr	tr	-	-	tr

[1]Approximate mol. % anorthite in plagioclase determined by Michel-Levy extinction angle method using determinative graph of Shelly (1975).

[2]Antiperthite.

[3]An% based on few measurements due to scarcity of twinned plagioclase.

[4]Perthite.

Table 2 (continued)

Specimen	Mafic Gneiss 617	609	562		Amphibolite 2-2	10-1
Quartz	11	9	6	2		2
Plagioclase	70	16	68	65		55[2]
(An%)[1]	(24)	(25)	(37)	(25)[3]		(27)
Microcline	tr	-	-	-		12[4]
Myrmekite	-	-	-	-		-
Biotite[5]	15	1	12	10		4
Muscovite[6]	-	-	-	tr		-
Chlorite[7]	-	-	-	-		-
Sericite	tr	-	-	tr		-
Garnet	3	-	-	-		-
Hornblende[8]	tr	66	14	20		27
Diopside	-	7	-	-		-
Epidote	1[9]	tr[9]	-	tr[9]		tr
Allanite	tr	tr	tr	tr		tr
Sphene	tr	1	tr	1		tr
Apatite	tr	tr	tr	1		tr
Zircon	tr	tr	tr	tr		tr
Graphite	-	-	-	-		-
Magnetite	tr	-	tr	tr		tr
Ilmenite	-	-	tr	1		tr
Pyrite	-	-	-	-		-
Chalcopyrite	-	-	-	tr		-
Hematite	tr	tr	tr	tr		tr

[5]Biotite pleochroic formula: all specimens pale-yellow (X); 911, 2-1, 2-4, reddish-brown (Y&Z); 2-5, 617, 2-2, 10-1, olive-green, green to dark-brown (Y&Z); 7-4, 609, 698, 562, tan to light reddish-brown (Y&Z).

[6]Includes muscovite interpreted as secondary with ragged and embayed grain boundaries and associated with sericite alteration.

[7]Fe-rich chlorite occurs as alteration of biotite.

[8]Hornblende pleochroic formula: pale-yellow to pale-green (X), light-green (Y), green to bluish-green (Z). $2V_x$ around 50 degrees.

Table 2 (continued)

[9]Pistacite: biaxial negative, colorless (X) to pale-yellow-green (Z), birefringence up to second order red.

[10]Zircons noticeably rounded suggestive of detrital origin.

[11]Graphite in 7-4 occurs in swirled masses locally surrounded by thin "shells" of pyrite.

Description and location of rock specimens. Locations indicated on Plate 2.

911. Thin-layered, light-gray- to brown-weathering, very fine-grained graphite-muscovite-biotite-plagioclase-microcline-quartz gneiss. Specimen collected at an elevation of 1130 feet, 50 meters east of the trail near the end of Moray Road (east-central area of map).

2-1. Light-gray- to light-tan-weathering, fine-grained, light-gray muscovite-biotite-microcline-plagioclase-quartz gneiss. Sparse garnet present in outcrop. Specimen collected on south side of Route 4 approximately 170 meters west of Guinea Road (east-central area of map).

2-4. Rusty-brown-weathering, fine-grained, light-gray graphite-muscovite-biotite-microcline-plagioclase-quartz gneiss. Graphite flakes are unevenly distributed. Specimen collected at an elevation of 980 feet at the northeast end of Silver Hill (east-central area of map).

7-4. Rusty-yellow-weathering, poorly foliated, fine- to medium-grained, gray biotite-graphite-quartz granulite. Graphite flakes are up to .5 centimeters across. Specimen collected at the curve in the Penn Central railroad, southwest of Mine Mountain (east-central area of map).

698. Green, fine- to medium-grained sphene-hornblende-plagioclase-diopside calc-silicate gneiss. It occurs as 5-10 centimeter thick beds in well-layered hornblende-biotite-plagioclase gneiss. Specimen collected at an elevation of 1120 feet, approximately 430 meters north of Caleb's Peak, along the Appalachian Trail (south-central area of map).

617. Dark-gray, fine-grained, hornblende-garnet-biotite-plagioclase gneiss. Specimen collected at an elevation of 780 feet approximately 170 meters northwest of the confluence of North Kent Brook and its lowest tributary (south-central area of map).

Table 2 (continued)

609. Dark-gray-weathering, fine-grained biotite-hornblende-quartz-plagioclase gneiss with lenses of green, medium-grained diopside rimmed by hornblende. Specimen collected at an elevation of 900 feet on the steep slope approximately 900 meters west of the mouth of Stewart Hollow Brook (south-central area of map).

562. Gray-weathering, well foliated, fine- to medium-grained biotite-hornblende-plagioclase gneiss. Specimen collected at an elevation of 1100 feet near the top of a steep slope on the ridge between Stony Brook and Stewart Hollow Brook (south-central area of map).

2-2. Dark-gray, moderately foliated, fine- to medium-grained biotite-hornblende-plagioclase amphibolite. Specimen collected at same location as 2-1 (east-central area of map).

10-1. Medium-grained, black and white biotite-hornblende-plagioclase amphibolite. Sparse garnet present in outcrop. Compositional layering defined by irregular, thin (5-2 cm) quartz-microcline-plagioclase zones that are light-tan to light-pink-weathering. Specimen collected at an elevation of 800 feet, 215 meters north of the saddle in the ridge forming Bread Loaf Mountain (east-central area of map).

minor amounts of green, diopside calc-silicate rock. The type locality of these rocks occurs in roadcuts along Route 4 which parallels Guinea Brook on the south flank of Bread Loaf Mountain (Plates 1 and 2).

The graphitic quartzofeldspathic gneiss is variously light-gray-, light-brown- to rusty-weathering, fine- to medium-grained gneiss. The dominant minerals are quartz, plagioclase, microcline and biotite with disseminated graphite flakes up to 2 cm across and local scattered garnet. Accessory minerals include epidote, allanite, sphene, apatite, zircon, magnetite, ilmenite, pyrite and secondary muscovite (911, 2-1, 2-4, Table 2). The biotite content is extremely varied so that rocks range from poorly-foliated, white quartz-feldspar gneiss to schistose, light- to dark-gray biotite gneiss. Sugary granular textures are characteristic of the quartz-rich gneiss.

Fine- to medium-grained, dark-gray to black amphibolites are common throughout the unit (2-2, 10-1, 562, Table 2). They consist of plagioclase, hornblende and biotite with minor amounts of quartz, microcline, epidote, allanite, magnetite, ilmenite, apatite, sphene, zircon and chalcopyrite. Bedding thickness ranges from about 10 cm for thin discrete beds to greater than 20 m for massive, uniform exposures of amphibolite.

Gray-weathering, garnet-hornblende-biotite-quartz-plagioclase gneiss is well layered with interbeds of thin amphibolite and lenses or discontinuous layers of green diopside calc-silicate rock (617, 698, 609, Table 2). Compositional layering is defined by alternation of felsic- and mafic-rich layers typically 0.5 cm to 5 cm thick. Calc-silicate beds are 5 cm to 10 cm thick and at several locations there are 8-12 cm, light-gray quartzite beds. Locally there is uniform, fine-grained, garnet-biotite-plagioclase gneiss.

Subordinate rock types include fine- to medium-grained, sulfidic graphite-quartz granulites (7-4, Table 2), medium- to very coarse-grained, green, garnet-biotite-actinolite-hornblende-diopside calc-silicate rock and biotite schist. Thicknesses of these rocks range from centimeters to ten meters. The diopside calc-silicate rock commonly occurs in very coarse-grained pods within the graphitic quartz-feldspar gneiss.

The approximate thickness of the Bread Loaf Mountain Gneiss ranges from 835 m to 1050 m with an average of 930 m. The basal contact with the Richards Pond Gneiss is sharp and along strike different rock types of the Bread Loaf Mountain Gneiss occur at the contact. This relationship suggests that the Richards Pond Gneiss may rest unconformably above the Bread Loaf Mountain Gneiss or a thrust fault may be present between the two units. The contact is exposed on Mine Mountain, along Route 4 and very nearly exposed on the hinge of the isoclinal anticline. The Bread Loaf Mountain Gneiss consists of rocks that were deposited as feldspathic and calcareous sands, calcareous silts with carbonate-rich beds and felsic volcanics with minor mafic horizons.

Stony Brook Gneiss - Ys

The Stony Brook Gneiss crops out in a narrow zone between the Bread Loaf Mountain Gneiss on the east and the Ellsworth Gneiss on the west. Prominent exposures occur in Housatonic State Forest, east of East Street near Route 4 and in Stony Brook (Plates 1 and 2). The type locality for the Stony Brook Gneiss occurs in exposures on the slope east of East Street about 300 m. north of Guinea Brook. It is inferred that the unit pinches out on the east side of Skiff Mountain where exposure is poor.

Rocks of the Stony Brook Gneiss consist of uniform, light-gray, fine- to medium-grained, biotite-quartz-plagioclase gneiss with subhedral plagioclase augen up to 5 mm across. The augen stand out in relief on typically rounded, light-gray-weathering outcrop surfaces. Thin sections show an inequigranular texture dominated by plagioclase grains, locally granulated, surrounded by fine-grained quartz, microcline, myrmekite and biotite (Table 3). Biotite is disseminated and also forms small lenses which define the foliation. Secondary muscovite is locally visible in hand specimen, but epidote, allanite, sphene, apatite and zircon were identified only in thin section. Sample 199 contains trace amounts of scapolite and chlorite (Table 3). Quartz-feldspar veins 1-6 cm thick with several directions are common.

The lower contact with the Bread Loaf Mountain Gneiss is not perfectly exposed but outcrops near the contact exhibit a sharp change in rock type from fine-grained, gray- to rusty-weathering graphitic quartzofeldspathic gneiss to light-gray, uniform biotite-quartz-plagioclase gneiss. A similar change in rock types occurs across the upper contact with the Ellsworth Gneiss which consists predominantly of well layered, gray- to rusty-weathering quartzofeldspathic gneiss, locally graphitic, and thin-bedded quartzites. Thickness of the Stony Brook Gneiss is quite varied, ranging up to a maximum of 360 meters in

Table 3

Estimated Modes of Specimens from the Stony Brook Gneiss

Specimen	5-3	199
Quartz	22	16
Plagioclase	68	71
(An%)[1]	(37)	(34)
Microcline	-	7
Myrmekite	-	tr
Biotite[2]	10	6
Muscovite[3]	tr	tr
Chlorite[4]	-	tr
Sericite	tr	tr
Epidote	tr	tr
Allanite	tr	tr
Scapolite[5]	-	tr
Apatite	tr	tr
Sphene	tr	tr
Zircon	tr	tr
Hematite	tr	tr

[1]Approximate mol. % anorthite in plagioclase determined by Michel-Levy extinction angle method using determinative graph of Shelly (1975).
[2]Biotite pleochroic formula: pale-yellow (X), yellow-brown to reddish-brown (Y&Z).
[3]Includes muscovite interpreted as secondary.
[4]Mg- or Fe-rich chlorite occurs as alteration of biotite.
[5]Marialite. Uniaxial negative, maximum birefringence first order yellow.
Description and location of rock specimens. Locations indicated on Plate 2.

5-3. Light-gray-weathering, well foliated, fine- to medium-grained biotite-quartz-plagioclase gneiss. Plagioclase megacrysts up to 5 mm. long stand out on weathered surfaces. Specimen collected at an elevation of 560 feet in Hatch Brook (northeast area of map).

199. Light-gray, well foliated, fine- to medium-grained biotite-quartz-plagioclase gneiss. Small plagioclase megacrysts are present. Specimen collected at an elevation of 940 feet in Stony Brook (central area of map).

the vicinity of East Street.

The Stony Brook Gneiss probably originated as a felsic volcanic rock or intruded conformably as a sill into the surrounding rocks. Modes (Figure 4) plot in the quartz-andesite field for volcanic rocks.

Ellsworth Gneiss - Ye

The Ellsworth Gneiss is the most extensive rock unit in the map area. It occupies the central region of the Housatonic Highlands from the ridge east of East Mountain, in the Amenia quadrangle, northeast to Macedonia Brook State Park, Ellsworth Hill, Sharon Mountain and Housatonic State Forest in the northeast corner of the Ellsworth quadrangle (Plate 1). It is bordered on the east by the Stony Brook Gneiss which gives way to the Bread Loaf Mountain Gneiss to the southwest. It physically overlies the West Woods Gneiss on the west.

Thickness calculations for the Ellsworth Gneiss are complicated in areas of the Ellsworth Granite Gneiss and the Sharon Mountain Granodiorite Gneiss which intrude the unit. However, the unit appears to taper from northeast to southwest with a range of 2499 m to 1595 m. The average thickness is 2104 m.

Rocks of the Ellsworth Gneiss are dominated by thick- and thin-bedded, gray- to rusty-weathering, fine- to medium-grained, muscovite-biotite-quartz-feldspar gneisses. Locally they contain minor amounts of graphite, garnet and sillimanite or hornblende. Subordinate thin-layered, gray quartzites, sillimanite-quartz granulites, amphibolites and calc-silicate rocks are interbedded with these gneisses. The type locality for the Ellsworth Gneiss occurs around and over the knob in

Housatonic State Forest where the predominant muscovite-biotite-quartz feldspar gneiss (specimens 1683 and 1683a, Plate 2) is well exposed. Nearby, Hatch Brook also provides excellent exposures of these rocks and includes one outcrop of a diopside-calcite marble.

Beds of light-gray to gray, muscovite-biotite-quartz-feldspar gneiss differ in composition from micaceous, schistose gneiss (879, 1683, 524, 527, 796, Table 4) to uniform feldspathic gneiss and gray quartzite (17-2, 1683a, 791, 16-2, 901 and 523, Table 4). Plagioclase (An% 24-39) is the predominant mineral with lesser amounts of quartz, microcline, biotite and secondary muscovite. Garnet, graphite, sillimanite or hornblende are locally present and accessory minerals include scapolite, calcite, sphene, apatite, zircon, ilmenite, magnetite, pyrite, chalcopyrite, pyrrhotite and secondary chlorite.

Areas of uniform rock type with bedding thicknesses of 3 m or greater are prevalent, but thicknesses are on the order of 5 cm to 1.5 m where it is well bedded. The micaceous gneisses and quartzites tend to be thinner bedded than the more feldspathic gneisses. Thin compositional layering (2-10 mm) forms the gneissic foliation and is defined by discontinuous quartz-feldspar segregations and muscovite-biotite folia. This foliation is common everywhere, though more pronounced in the micaceous gneiss.

The rocks are gray- to rusty-weathering and feldspathic segregations are commonly yellow-stained. In general the more micaceous gneiss exhibits the most rusty-weathering which is attributed to the presence of sulphides. Quartz-feldspar layers stand out in relief on weathered

Table 4

Estimated Modes of Specimens from the Ellsworth Gneiss

	Biotite - Quartz - Plagioclase Gneiss								
Specimen	879	17-2	1683a	1683	791	16-2	523	524	527
Quartz	8	29	14	10	12	10	58	14	26
Plagioclase	49	61	62	42	74[2]	81[2]	17	48	51
(An%)[1]	(37)	(31)	(24)	(24)	(30)	(29)	(25)	(26)	(28)
Microcline	-	1	16	24	tr	1	21	tr	-
Myremekite	-	tr	tr	tr	-	-	tr	-	-
Biotite[4]	15	7	6	18	14	8	3	38	20
Muscovite[5]	28	2	2	6	-	tr	1	tr	tr
Chlorite[6]	-	-	-	-	-	tr	-	-	-
Sericite	tr	tr	tr	tr	tr	tr	tr	tr	tr
Garnet	-	tr	-	-	-	-	-	-	1
Epidote[10]	tr	tr	tr	tr	tr	tr	-	-	-
Allanite	tr	tr	tr	tr	tr	tr	tr	-	tr
Sphene	tr	tr	tr	tr	tr	tr	tr	tr	tr
Apatite	tr	tr	tr	tr	tr	tr	tr	tr	1
Zircon[12]	tr	tr	tr	tr	tr	tr	tr	tr	tr
Graphite	-	-	-	tr	-	-	-	-	-
Magnetite	-	-	-	tr	-	-	-	-	tr
Ilmenite[13]	tr	tr	tr	tr	-	tr	tr	tr	1
Pyrrhotite	-	-	-	tr	-	-	-	-	-
Rutile	-	-	-	-	-	-	-	-	-
Hematite	-	tr	-	tr	-	-	tr	-	tr

*Specimens 287 and 803 are probably metamorphosed intrusive rocks.

[1]Approximate mol. % anorthite in plagioclase was determined by the Michel-Levy extinction angle method using the determinative graph of Shelly (1975).

[2]Antiperthite.

[3]Perthite.

Table 4 (continued)

	Mylonitic Gneiss		Granulite			
Specimen	796	901	6-1	922	922a	803*
Quartz	28	9	56	83	5	23
Plagioclase	38[2]	75	28	-	-	56[2]
(An%)[1]	(34)	(39)	(41)	-	-	(26)
Microcline	1	1	tr	-	-	11[3]
Myremekite	tr	tr	-	-	-	tr
Biotite[4]	22	11	16	11	8	9
Muscovite[5]	11	4	-	2	2	1
Chlorite[6]	-	-	-	-	-	tr
Sericite	tr	tr	tr	-	-	tr
Sillimanite	-	-	-	3	85	-
Epidote[10]	tr	-	tr	-	-	tr
Allanite	tr	tr	tr	-	-	tr
Sphene	tr	tr	tr	-	tr	tr
Apatite	tr	tr	tr	-	-	tr
Zircon[12]	tr	tr	tr	tr	tr	tr
Magnetite	-	-	-	-	-	tr
Ilmenite[13]	tr	tr	tr	-	-	-
Chalcopyrite	-	-	-	1	-	-
Pyrite	-	-	-	tr	-	-
Rutile	-	-	tr	-	-	-
Hematite	-	-	-	-	tr	tr

[4]Biotite pleochroic formula: All specimens pale-yellow (X); 7-9, 237b, 238, 853, 6-3, yellow-brown to light-brown (Y&Z); 879, 791, 626, 527, 287, 803, olive-green to brown (Y&Z); other specimens reddish-brown to brown-red (Y&Z).

[5]Includes muscovite interpreted as secondary.

[6]16-2, 526, 803, Fe-rich chlorite; 290 and 238, Mg/Fe approx. 1.

[7]Hornblende pleochroic formula: pale-yellow to pale-green (X), light-green to light-brown-green (Y), light-green, green, brownish-green to bluish-green (Z); $2V_x$ = 45-70 degrees.

[8]Actinolite: colorless (X), pale-green (Y), pale- to light-green (Z).

Table 4 (continued)

	Mafic Gneiss						Calc-Silicate
Specimen	626	290	237a	237b	7-9	238	853
Quartz	6	8	24	63	56	27	72
Plagioclase	78	70	21	17	4	9	15
(An%)[1]	(31)	(28)	(66)	(45)	(Olig)	(Byt)	(65)
Microcline	-	-	-	tr	2	-	-
Myrmekite	-	-	-	-	-	tr	-
Biotite[4]	11	21	-	12	23	3	9
Muscovite[5]	-	tr	-	-	-	-	-
Chlorite[6]	-	tr	-	-	-	tr	-
Sericite	tr	tr	-	-	-	-	-
Garnet	-	-	10	6	12	-	1
Hornblende[7]	3	tr	7	tr	2	59	tr
Cummingtonite	-	-	35	-	-	-	-
Calcite	-	1	-	-	-	-	-
Epidote[10]	-	-	-	-	-	-	2
Allanite	-	tr	-	tr	-	tr	-
Scapolite[11]	2	-	-	-	-	-	-
Sphene	tr	tr	-	tr	-	tr	1
Apatite	tr	tr	tr	tr	tr	tr	tr
Zircon[12]	tr	tr	tr	tr	tr	tr	tr
Magnetite	tr	-	-	-	-	-	tr
Ilmenite[13]	tr	tr	3	2	1	2	tr
Chalcopyrite	-	-	tr	tr	-	-	-
Rutile	-	-	-	-	-	-	-
Hematite	tr	tr	-	tr	tr	-	tr

[9]Ferroan calcite (stained).

[10]Pistacite: 17-2, 1683a, 1683, 791, biaxial neg., colorless (X) to pale-yellow-green (Z); Clinozoisite: 5-7 and 1682, biaxial pos., colorless.

[11]Marialite: uniaxial neg.

[12]Zircons commonly rounded suggestive of detrital origin.

Table 4 (continued)

Specimen	Amphibolite 526	1682	6-3	1437	809	844	287*
Quartz	10	5	tr	tr	4	4	22
Plagioclase	62	1	60	50	41	51	53
(An%)[1]	(40)	(?)	(67)	(49)	(29)	(45)	(37)
Microcline	-	-	-	-	tr	-	10
Myrmekite	-	-	-	-	-	-	tr
Biotite[4]	8	2	1	tr	tr	tr	11
Chlorite[6]	tr	-	-	-	-	-	-
Sericite	tr	-	-	tr	tr	tr	tr
Garnet	1	-	-	-	-	-	tr
Hornblende[7]	16	88	35	43	51	41	3
Augite	-	-	-	5	2	-	-
Cummingtonite	-	-	4	-	-	-	-
Epidote[10]	-	1	-	2	tr	tr	tr
Allanite	tr	-	-	tr	tr	tr	-
Sphene	tr	tr	tr	tr	2	3	tr
Apatite	1	tr	tr	tr	tr	tr	tr
Zircon[12]	tr	tr	tr	tr	tr	tr	tr
Magnetite	tr	-	tr	tr	-	-	tr
Ilmenite[13]	2	3	tr	-	tr	1	1
Chalcopyrite	-	tr	-	-	tr	tr	-
Pyrite	-	-	-	tr	tr	-	tr
Hematite	tr	tr	tr	tr	-	tr	tr

[13]Ilmenite commonly rimmed by sphene.

Description and location of rock specimens. Location indicated on Plate 2.

879. Light- and dark-gray, well foliated, fine-grained, muscovite-biotite-quartz-plagioclase gneiss. Compositional layering defined by thin (1-3 mm) segregations of micas and quartz-plagioclase. Specimen collected at an elevation of 540 feet at the gorge in Macedonia Brook (southwest area of map).

Table 4 (continued)

Specimen	Marble 5-7
Quartz	7
Microcline	tr
Diopside	9
Actinolite[8]	1
Calcite	81[9]
Epidote[10]	2
Allanite	tr
Sphene	tr

17-2. Gray-weathering, well foliated, fine-grained, light-gray, garnet-muscovite-biotite-quartz-plagioclase gneiss. Specimen collected at an elevation of 1110 feet, 190 m east of the 1054 foot spot elevation on East Street (east-central area of map).

1683a. Fine-grained, uniform, light-gray, biotite-quartz-microcline-plagioclase gneiss. Biotite is evenly disseminated in a bed 1 m thick. Specimen collected at an elevation of 1000 feet on the south side of Pine Knob in Housatonic State Forest (northeast area of map).

1683. Rusty-weathering, well foliated, fine-grained, light-gray, graphite-muscovite-biotite-quartz-feldspar gneiss. Compositional layering defined by thin (1-3 mm) micaceous segregations alternating with thin (2-8 mm) quartz-feldspar zones. Specimen collected from interbed with 1683 (northeast area of map).

791. Gray, fine- to medium-grained, biotite-quartz-plagioclase gneiss. Specimen collected at an elevation of 1280 feet, near the top of the small hill, 240 m north of the bend in Dolldorf Road (southwest area of map).

16-2. Light-gray, well foliated, fine- to medium-grained, biotite-quartz-plagioclase gneiss. Specimen collected about 50 m west of the highest point on East Street (northeast area of map).

523. Light-gray- to tan-yellow-weathering, light-gray, very fine-grained, biotite-feldspar-quartz gneiss. Specimen collected at an elevation of 1180 feet in the stream draining Peck Pond (west-central area of map).

Table 4 (continued)

524. Light-gray- to gray-weathering, fine-grained, quartz-biotite-plagioclase gneiss. Biotite is disseminated and forms distinct, thin (1-2 mm) pods parallel to foliation. Specimen collected at an elevation of 1240 feet in the same stream as 523 (west-central area of map).

527. Gray-weathering, medium- to coarse-grained, garnet-biotite- quartz-plagioclase gneiss. Specimen collected at an elevation of 1350 feet on the hill 620 m north of the inlet to Peck Pond (west-central area of map).

796. Light-gray, well foliated, fine-grained, muscovite-biotite-quartz-plagioclase gneiss. Thin (1-5 mm) protomylonitic shear zones truncate and are sub-parallel to the gneissic foliation. Specimen collected at an elevation of 1100 feet on the hillside west of the crossroads in Macedonia Brook State Park (southwest area of map).

901. Gray-weathering, fine-grained, muscovite-biotite-quartz-plagioclase gneiss. Thin (1-3 mm) micaceous segregations alternate with smeared out felsic zones (central area of map).

6-1. Dark-gray, fine-grained, biotite-plagioclase-quartz granulite, locally with sillimanite. Specimen collected from the west side of Route 7 at 46 degrees, 34 mins. latitude (northeast area of map).

922. Gray- to rusty-weathering, fine-grained, gray, sillimanite-biotite-quartz granulite. Specimen collected from the same location as 6-1, only on the east side of Route 7 (northeast area of map).

922a. Gray- to rusty-weathering, well foliated muscovite-biotite-quartz-sillimanite granulite interlayer in 922, 2 cm to 5 cm thick (northeast area of map).

803. Light-gray, uniform, fine-grained, biotite-quartz-feldspar gneiss (metamorphosed granodiorite). Specimen collected from the top of hill 1361 in Macedonia Brook State Park (southwest area of map).

626. Gray-weathering, fine-grained, uniform, gray, scapolite-hornblende-biotite-quartz-plagioclase gneiss. Specimen collected from pavement outcrop on the southwest side of Skiff Mountain Road, opposite the southeast end of Peck Pond (west-central area of map).

290. Gray-weathering, dark-gray, fine- to medium-grained, hornblende-biotite-quartz-plagioclase gneiss with rare calcite. Specimen collected from the small hill at the head of the stream feeding Peck Pond from the northeast (central area of map).

Table 4 (continued)

237a. Rusty-brown-weathering, dark-gray, very fine-grained, ilmenite-garnet-plagioclase-quartz-cummingtonite gneiss. Beds are 5 cm to 8 cm thick. Specimen collected about 100 m southwest of 901 along Northrop Road (central area of map).

237b. Dark-rusty-gray-weathering, very fine-grained, hornblende-garnet-biotite-plagioclase-quartz granulite. Specimen collected from bed 8 cm thick at same outcrop as 237a (central area of map).

7-9. Gray-weathering, fine-grained, gray, hornblende-garnet-biotite-quartz granulite with minor amounts of feldspar. Specimen collected at an elevation of 1140 feet on the west flank of Pine Knob in Housatonic State Forest (northeast area of map).

238. Brown-weathering, dark-gray, fine-grained, biotite-quartz-plagioclase-hornblende granulite. Specimen collected from bed 5 cm to 8 cm thick at an elevation of 1300 feet on the ridge northwest of Herb Road (central area of map).

853. Gray- to rusty-weathering, fine- to medium-grained, hornblende-garnet-epidote-biotite-plagioclase-quartz calc-silicate gneiss. Specimen collected from bed 10 cm to 15 cm thick at an elevation of 1080 feet on the ridge west of Macedonia Brook State Park headquarters (southwest area of map).

526. Gray-weathering, gray, fine- to medium-grained, well foliated garnet-biotite-hornblende-plagioclase amphibolite. Specimen collected at elevation of 1350 feet on the west flank of hill located 525 m north of the inlet stream to Peck Pond (west-central area of map).

1682. Dark red-brown-weathering, fine-grained, poorly foliated, dull greenish-gray, biotite-cummingtonite-hornblende-plagioclase amphibolite. Specimen collected at an elevation of 1290 feet on the east side of the hill between Hatch Brook and its tributary (northeast area of map).

6-3. Dark-gray-weathering, fine-grained, poorly foliated, dull greenish-gray, biotite-cummingtonite-hornblende-plagioclase amphibolite. Specimen collected about 75 m west of 6-1 (northeast area of map).

1437. Rusty-brown-weathering, fine- to medium-grained, augite-hornblende-plagioclase amphibolite. Compositional layering defined by mafic- or plagioclase-rich zones. Specimen collected at an elevation of 1080 feet on the hill east of Macedonia Brook approximately 750 m south of the intersection of West Woods Road and Keeler Road (west-central area of map).

Table 4 (continued)

809. Dark-gray- to rusty-weathering, fine- to medium-grained, dark-gray, augite-plagioclase-hornblende amphibolite with minor amounts of quartz, microcline and biotite. Specimen collected along the old road west of the crossroads in Macedonia Brook State Park (southwest area of map).

844. Dark-gray- to rusty-weathering, fine- to medium-grained, hornblende-plagioclase amphibolite. Specimen collected along the old road at the 832 spot elevation in Macedonia Brook State Park (southwest area of map).

287. Dark-gray-weathering, massive, medium- to coarse-grained, garnet-hornblende-biotite-quartz-feldspar gneiss (metamorphosed granodiorite). Feldspar augen up to 2 cm long are common. Specimen collected at an elevation of 1370 feet on the east flank of the hill southeast of the sharp bend in West Woods Road (central area of map).

5-7. Tan- and dark-gray-weathering, massive, medium- to coarse-grained, white and pale-green, diopside-calcite marble. Specimen collected at an elevation of 730 feet in Hatch Brook (northeast area of map).

surfaces and quartzite beds have a distinctive pitted or "lacey" surface where less resistant minerals have weathered out. Well bedded outcrops appear slabby.

Very fine- to fine-grained, typically thin bedded (5-25 cm) mafic gneisses and calc-silicate rocks are common throughout the unit (626, 290, 237a, 237b, 7-9, 238, 853, Table 4). They are dark-gray-, brown- to rusty-weathering and consist of garnet, hornblende, cummingtonite, epidote, biotite, plagioclase and quartz. Up to 3% ilmenite is present in some specimens. Outcrops within 50 meters of the contact with the Sharon Mountain Granodiorite Gneiss on the east end of Bound Road have thin beds of garnetiferous calc-silicate granulites.

Sillimanite-bearing gneiss is rare; however, there are gray- to rusty-weathering, fine- to medium-grained, biotite-sillimanite-quartz granulites that contain thin zones of up to 85% sillimanite (922, 922a, Table 4). These rocks are interlayered with biotite-plagioclase-quartz granulite that is locally garnetiferous (6-1, Table 4). These rock types occur near the contact with the Stony Brook Gneiss.

A tan- to gray-weathering, massive, medium-grained, dull-green and white diopside-calcite marble occurs at one locality in Hatch Brook (Plate 1; 5-7, Table 4). The bed is no more than 3 m thick and weathers with a nubby surface because silicate minerals stand out in relief.

The lower contact with the Stony Brook Gneiss is not exposed but it can be approached within several meters at a few locations. It appears to be a sharp contact based on the different rock types on either side of it. The contact with the Bread Loaf Mountain Gneiss and St. John's

Ledges Granite Gneiss is not exposed. Rocks of the Ellsworth Gneiss are probably derived from aluminous and feldspathic sandstone or siltstone with interbedded shale and minor amounts of limestone or dolomite.

Ellsworth Amphibolite - Yea. Dark-gray to black, fine- to medium-grained, biotite-hornblende-plagioclase amphibolites, locally with scattered garnet, are interlayered with the quartz-feldspar gneiss. They occur as thin beds up to 2 m thick, as lenticular bodies parallel to compositional layering and as mappable horizons (Plate 1; 526, 1682, 6-3, Table 4). Northeast of Hatch Brook on Sharon Mountain dark-gray to deep red-brown-weathering, fine- to medium-grained amphibolite with scattered garnet is mapped with associated biotite-hornblende-plagioclase gneiss, dull-green to black, diopside-hornblende calc-silicate beds and black biotite schistose gneiss. In the southeast corner of the Amenia quadrangle dark-gray-weathering, fine- to coarse-grained amphibolite with sparse garnet is mapped with subordinate thin layered (5-25 cm) hornblende-biotite-quartz-plagioclase gneiss. Thicknesses of uniform amphibolite in this area exceed 3 m.

A thin, amphibolite of limited extent is present along the upper contact with the West Woods Gneiss. The rocks are typically brown-weathering, locally gray- to brown-weathering, and consist of augite-hornblende-plagioclase amphibolite (1437, 809, 844, Table 4). Augite occurs in two specimens (1437, 809) where it is rimmed by hornblende and contains relict exsolution lamellae of pigeonite.

West Woods Gneiss - Yw

The West Woods Gneiss occurs in a northeast trending zone from Bog Hollow Brook, through Macedonia Brook State Park and West Woods to Hamlin Pond (Plate 1). It is a resistant rock that underlies the prominent ridge through the area. The unit is bordered to the east by the Ellsworth Gneiss and to the west by the Deming Hill Gneiss. The type locality for the West Woods Gneiss occurs in roadcuts along a bend in Route 4, east of Bog Meadow Pond (Plates 1 and 2).

The West Woods Gneiss is characterized by gray- to black-and-white-layered, fine- to medium-grained, biotite-hornblende-plagioclase gneiss. Other minerals seen in hand specimen include quartz, sparse garnet, epidote, magnetite and sulphides. In addition, thin section study showed microcline, allanite, calcite, sphene, apatite, zircon, ilmenite, chalcopyrite and secondary muscovite, chlorite and hematite (1-15, 9-2, Table 5). Compositional layering is defined by discontinuous alternations of mafic and felsic layers and lenses 2 mm to 10 cm thick. Layers up to 2 m thick of uniform, well foliated, gray, hornblende-biotite-plagioclase gneiss and layers of biotite plagioclase gneiss are common. Scattered megacrysts of black hornblende and white to dull-green plagioclase, typically 2 mm to 6 mm long, are common. Plagioclase megacrysts locally exceed 3 cm. Outcrops are gray-weathering and locally slabby as in the roadcuts along Route 4. The felsic layers are white- to light-tan-weathering. Minor interbeds consist of light-tan-weathering, medium-grained plagioclase and quartz with thin (1-2 cm), discontinuous mafic layers and calc-silicate pods consisting typically of green

Table 5

Estimated Modes of Specimens from the West Woods Gneiss

	Hornblende-Biotite Plagioclase Gneiss				Calc-Silicate	Intrusive	
Specimen	1-15	9-2	438	353	757	*17-4	*17-3
Quartz	5	10	25	19	1	28	10
Plagioclase	67[3]	68	47[3]	63	tr	22	69
(An%)[1]	(27)[2]	(25)	(27)	(26)	?	(27)	(36)
Microcline	2	3[4]	21[4]	tr	-	47[4]	-
Myrmekite	-	tr	1	-	-	tr	-
Biotite[5]	12	7	5	15	-	2	1
Muscovite[6]	tr	-	tr	-	-	1	-
Chlorite[7]	tr	-	tr	-	-	tr	-
Sericite	tr	tr	tr	tr	-	tr	tr
Hornblende[8]	12	9	-	tr	5	-	17
Augite[9]	-	-	-	-	-	-	2
Diopside	-	-	-	-	23	-	-
Garnet	-	-	-	-	-	-	1
Scapolite[10]	-	-	-	2	63	-	-
Calcite	tr	tr	-	-	-	-	tr
Epidote[11]	2	1	tr	tr	4	tr	tr
Allanite	-	tr	tr	tr	-	tr	tr
Sphene	tr	1	1	tr	4	tr	-
Apatite	1	1	tr	1	tr	tr	tr
Zircon	tr	tr	tr	tr	-	tr	tr
Magnetite	tr	tr	tr	-	-	tr	tr
Ilmenite[12]	tr	-	-	tr	-	-	tr
Pyrite	-	-	-	-	tr	-	tr
Chalcopyrite	tr	-	-	-	tr	-	-
Hematite	-	tr	tr	tr	tr	-	-

*Specimen 17-4 from pink granite gneiss sill; 17-3 collected from probable dike of metamorphosed quartz-diorite.

[1]Approximate mol, % anorthite in plagioclase determined by Michel-Levy extinction angle method.

[2]Antiperthite.

[3]An% based on few measurements due to scarcity of twinned plagioclase.

Table 5 (continued)

[4]Perthite.

[5]Biotite pleochroic formula: all specimens pale-yellow (X); Y&Z: 1-15, 9-2, 844, olive-green to green-brown; 438, 353, 1437, 809, 17-3, yellow-brown, reddish-brown to red-brown; 17-4, dark-brown.

[6]Includes muscovite interpreted as secondary.

[7]Fe-rich chlorite occurs as alteration of biotite specimen. Specimen 438 has chlorite with Fe/Mg ≅1.

[8]Hornblende pleochroic formula: 1-15, pale-yellow (X), light-green (Y), bluish-green (Z), $2V_x$ = 20 degrees, Hastingsite; 9-2, same as above only $2V_x$ = 30 degrees, Hastingsite; 17-3, 1437, 353, 809, 844, 757, pale-yellow (X), light-green (Y), brownish-green, green to bluish-green (Z).

[9]Augite contains relect pigeonite lamellae: 1437, "001" angle "100" = 115 degrees; 809, "001" angle "100" = 112 degrees; 17-3, "001" angle "100" = 112 degrees indicating approximate Fe/Mg ratios of 55% to 70% in the augite host (Jaffe, et al., 1975).

[10]Marialite. Uniaxial negative.

[11]Most specimens Pistacite. 757 Clinozoisite, biaxial pos.

[12]Ilmenite commonly rimmed by sphene.

Description and location of rock specimens. Locations indicated on Plate 2.

1-15. Black- and white-layered, medium- to coarse-grained biotite-hornblende-plagioclase gneiss. Compositional layering defined by felsic and mafic segregations .2 cm to 1 cm thick. Sparse garnet and sulphides in hand specimen. Specimen collected on the north side of Route 4 opposite Joray Road and benchmark 1341 (north-central area of map).

9-2. Gray- to black- and white-layered, fine- to coarse-grained, biotite-hornblende-plagioclase gneiss. Local dull-green plagioclase megacrysts up to 3 cm long. Specimen collected at an elevation of 1320 feet on the northwest flank of the hill west of Hamlin Road (north-central area of map).

438. Light-gray-weathering, fine- to medium-grained, biotite-quartz-microcline-plagioclase gneiss. Felsic nature of rock may be due to proximity to granitic gneiss. Specimen collected at an elevation of

1300 feet on the southwest end of the hill 1050 m N30E of the intersection of West Woods Road and Skiff Mountain Road (west-central area of map).

353. Gray-weathering, fine- to coarse-grained, biotite-quartz-plagioclase gneiss. Locally contains scapolite. Specimen collected at an elevation of 1340 feet at the southwest end of the small hill, 600 m southwest of the intersection of Route 4 and Joray Road (north-central area of map).

757. Rusty-weathering, fine-grained, dull-greenish-gray, hornblende-diopside-scapolite calc-silicate rock. Specimen collected at an elevation of 1000 feet west of Macedonia Brook and about 600 m north of the crossroads in the park (southwest area of map).

17-4. Medium- to coarse-grained, light-pink granite gneiss with sparse hornblende. Specimen collected from a sill approximately 10 m thick at the same location as sample 1-15 (north-central area of map).

17-3. Dark-gray, fine- to medium-grained, homogeneous, garnet-biotite-hornblende-quartz-plagioclase gneiss. Rock is probably a dike of quartz-diorite intruded into the unit, but contacts are not exposed. Specimen collected on the south side of Route 4, 170 m west of Joray Road (north-central area of map).

diopside, hornblende and biotite. These beds are approximately 10 cm to 50 cm thick.

In some areas the gneiss is very feldspathic and compositional layering is poorly defined by 1-5 mm zones of mafic minerals, mainly biotite (438, 353, Table 5). Specimen 353 contains scapolite as an alteration of plagioclase. The proximity of these rocks to granitic bodies such as at Cobble Mountain and the pink granite gneiss sill exposed on Route 4 (17-4, Table 5) indicates they may have undergone contact metamorphism.

The basal contact with the Ellsworth Gneiss is defined by a gradational zone about 10 m to 30 m thick in which gray- to rusty-weathering, locally schistose, garnet-muscovite-biotite-quartz-feldspar gneiss ceases to show rusty-yellow-weathering or patches of red hematite stain. In this zone mica content decreases and hornblende content increases as more typical biotite-hornblende-plagioclase gneiss is approached. This is best seen on the ridge north of Bog Hollow Brook.

Along the contact with the Ellsworth Amphibolite, graphite-bearing calc-silicate rocks and quartz-feldspar gneiss occur. A distinctive fine-grained, greenish-gray hornblende-diopside-scapolite calc-silicate rock (757, Table 5) occurs in Macedonia Brook State Park, but it appears to be of limited extent.

The approximate thickness of the unit ranges from 428 m to 570 m with an average of 519 m. However, it seems to be thickest in the vicinity of Bog Meadow Pond and thinner at the northeast and southwest ends of the mapped area (Plate 1). The West Woods Gneiss was probably derived from well bedded, calcareous sandstones and shales.

Deming Hill Gneiss - Yd

The Deming Hill Gneiss is interpreted to be the youngest Precambrian rock unit in the study area. It is bordered by the West Woods Gneiss to the east and unconformably overlain by the Cambrian Lowerre Quartzite to the west (Plate 1). The ridges and hills east of Swift Pond, Webatuck Creek and Mill Brook provide abundant outcrop and form the western edge of the Housatonic Highlands. The unit extends northeast from East Mountain in the Amenia quadrangle to Deming Hill and the north edge of the Ellsworth quadrangle north of Sharon Mountain Road.

The Deming Hill Gneiss consists predominantly of fine- to medium-grained amphibolites and light- to dark-gray, fine- to medium-grained biotite-quartz-plagioclase gneisses. The gneisses locally contain scattered garnet, hornblende and blue quartz. The type locality for the Deming Hill Gneiss occurs in Mitcheltown along Route 4 (Plates 1 and 2) where several outcrops consist of amphibolite or biotite-quartz-plagioclase gneiss. These two rock types alternate throughout the unit, with thicknesses ranging from less than 0.5 m to greater than 100 m. For example, near Deming Hill and south of Traver Road good exposures suggest continuous sequences of amphibolite ranging from approximately 225 m to 510 m thick. Along Route 4 at Mitcheltown a continuous exposure of garnet-biotite-blue-quartz-plagioclase gneiss is approximately 25 m to 30 m thick. On East Mountain, east of Crane Pond, biotite-quartz-plagioclase gneiss and amphibolite are thinly interlayered with amphibolite beds up to 0.5 m thick.

The amphibolites are dark-gray to dark-green, fine- to medium-grained, massive to well foliated rocks consisting mainly of biotite, hornblende and plagioclase. Other minerals include epidote, sphene, rare garnet, quartz, microcline, apatite, zircon, allanite, ilmenite, magnetite and secondary chlorite, hematite and sericite (387, 403, 1034, Table 6). The rocks are dark-gray- to brown-weathering, forming uniform and massive to less commonly well layered and slabby outcrops. Foliation is locally poorly developed in the coarser-grained amphibolite, but typically it is well developed with pronounced hornblende lineations present. Irregular aggregates or thin lenses of coarse hornblende up to 1 cm long are common. Compositional layering is defined by differences in grain size or relative amounts of hornblende to plagioclase. Distinctive, 1 cm thick quartz-plagioclase layers or clots are locally present in the more massive amphibolite and have a yellow or pink staining on weathered surfaces.

The biotite-quartz-plagioclase gneiss (733, 265, 268, 322, 361, 915, Table 6) is light- to dark-gray, well foliated, and fine- to medium-grained with differing amounts of microcline, epidote, hornblende and scattered garnet. Locally the quartz is pale-blue. Compositional layering is varied and ranges from 1-10 mm alternations of biotite folia and quartz-feldspar segregations (361, Table 6) to well foliated, uniform thicknesses exceeding 4 m. The rocks are typically light-gray- to gray-weathering but light-brown- to brown-weathering rocks are present.

Other subordinate rock types consist of hornblende-biotite schistose gneiss, brown- to rusty-weathering biotite-quartz-feldspar granulite,

Table 6

Estimated Modes of Specimens from the Deming Hill Gneiss

Specimen	Amphibolite			Schistose Gneiss	Biotite-Quartz-Plagioclase Gneiss	
	387	403	1034	347	733	265
Quartz	-	-	tr	12	24	16
Plagioclase	64	6	27	14	62	74
(An%)	(33)	(44)[2]	(32)[2]	(32)[2]	(36)	(29)
Microcline	tr	-	-	16	2	1
Myrmekite	-	-	-	tr	tr	tr
Biotite[5]	6	2	10	41	5	7
Muscovite[6]	-	-	-	-	-	tr
Chlorite[7]	-	tr	tr	-	-	-
Sericite[6]	tr	tr	1	-	-	-
Hornblende[8]	29	91	62	7	6	tr
Epidote[9]	tr	1	tr	5	1	2
Allanite	tr	tr	-	-	tr	tr
Calcite	-	-	-	-	-	tr
Garnet	-	-	-	-	-	tr
Sphene	1	tr	tr	3	tr	tr
Apatite	tr	tr	tr	2	tr	tr
Zircon	tr	tr	tr	tr	tr	tr
Opaques[10]	tr	tr	-	tr	-	-
Rutile	-	-	-	-	-	-
Hematite	tr	tr	-	tr	-	-

*Specimens 915 and 1222 collected from probable intrusive bodies.

[1]Approximately mol. % anorthite in plagioclase determined by Michel-Levy extinction angle method.

Specimens 268 and 915 were determined by the immerson method.

Table 6 (Continued)

Specimen	Biotite-Quartz-Plagioclase Gneiss 268	322	361	915*	1222*
Quartz	15	18	9	14	27
Plagioclase	77	77	54[3]	79[3]	53[3]
(An%)	(26)	(25)	Olig[2]	(27)	(24)[2]
Micricline	2	tr	tr	2	2[4]
Myrmekite	-	tr	-	-	tr
Biotite[5]	4	4	24	3	tr
Muscovite[6]	1	tr	4	1	-
Chlorite[7]	-	-	tr	-	-
Sericite	tr	tr	tr	tr	tr
Hornblende[8]	-	-	-	-	14
Epidote[9]	1	1	1	1	1
Allanite	-	tr	-	tr	2
Calcite	-	-	-	-	-
Garnet	-	-	-	-	-
Sphene	tr	tr	6	tr	1
Apatite	tr	tr	2	tr	tr
Zircon	tr	tr	tr	tr	tr
Opaques[10]	tr	-	tr	tr	tr
Rutile	-	-	-	tr	-
Hematite	tr	-	tr	tr	tr

[2]An% based on few measurements due to scarcity of twinned plagioclase. Specimen 403 contains zoned plagioclase with An% 38 to 49 from core to rim. Specimen 361 is generalized based on optic sign and relief.

[3]Antiperthite.

[4]Perthite.

[5]Biotite pleochroic formula: all specimens pale-yellow (X); Y&Z: 387, 403, 1034, 733, 265, 268, tan, yellow-brown to reddish-brown; 347, 322, 361, 915, 1222, olive-green to dark-brown.

Table 6 (continued)

[6]Includes muscovite interpreted as secondary.

[7]403, mg-rich chlorite. 1034 and 361, Fe-rich chlorite. Chlorite occurs as alteration of biotite.

[8]Hornblende pleochroic formula: 387, pale-green (X), light-green (Y), green (Z), $2V_x$ = 70 degrees; 403, pale-yellow (X), brownish-green (Y), light-green (Z), $2V_x$ = 70 degrees; 1034, pale-yellow (X), light-green (Y), brownish-green to green (Z), $2V_x$ = 60 degrees; 347, pale-greenish-yellow (X), green to brownish-green (Y), light-bluish-green (Z), $2V_x$ = 40 degrees; 733, pale-yellow-green (X), brownish-green to light-green (Y), green to bluish-green (Z), $2V_x$ = 60 degrees; 265, pale-yellow (X), light-green (Y), green (Z); 1222, light-yellow (X), green (Y), deep-blue-green (Z), $2V_x$ = 10 degrees, hastingsite.

[9]Pistacite. Biaxial neg., colorless (X) to pale-yellow-green (Z), birefringence up to 2nd order red. Commonly rims allanite.

[10]Opaques are very minor, consisting mainly of magnetite and ilmenite (commonly rimmed by sphene) altered to hematite.

Description and location of rock specimens. Locations indicated on Plate 2.

387. Dark-gray-weathering, weakly foliated, fine-grained, biotite-hornblende-plagioclase amphibolite. Specimen collected at an elevation of 850 feet, approximately 300 meters west of Deming Hill (northwest area of map).

403. Dark-gray-weathering, weakly foliated, fine- to medium-grained, dark-green to black epidote-plagioclase-hornblende amphibolite. Specimen collected at an elevation of 750 feet on the east side of Lambert Road (northwest area of map).

1034. Dark-gray, well foliated, fine- to medium-grained biotite-plagioclase-hornblende amphibolite. Grain size variation of hornblende defines thin compositional layering. Megacrysts of hornblende up to 1 cm long are common. Specimen collected at an elevation of 900 feet on the west flank of the hill at the northwest end of Hilltop Pond in the Amenia quadrangle (west-central area of map).

347. Dark-gray-weathering with rusty-red stains, fine-grained, well foliated, hornblende-quartz-microcline-plagioclase-biotite schistose gneiss. Epidote locally abundant. Specimen collected at an elevation of 1160 feet on the west side of the east peak of the twin-peaked hill southwest of Ford Pond (northwest area of map).

Table 6 (continued)

733. Gray-weathering, light-gray, well foliated, fine- to medium-grained hornblende-biotite-quartz-feldspar gneiss. Specimen collected at an elevation of 1180 feet on the ridge approximately 955 meters, N30E of the end of Clark Hill Road (west-central area of map).

265. Gray-weathering, well foliated, fine- to medium-grained, gray biotite-blue-quartz-plagioclase gneiss with scattered garnet. Specimen collected on the north side of Route 4 opposite the intersection with Mitcheltown Road (northwest area of map).

268. Light-gray- to light-brown-weathering, fine-grained, well foliated biotite-quartz-plagioclase gneiss. Specimen collected at an elevation of 1110 feet on the south flank of the small hill north of the dam at Ford Pond (northwest area of map).

322. Light-gray- to light-brown-weathering, fine-grained, well foliated, light-gray biotite-quartz-plagioclase gneiss. Biotite occurs in 1 mm seams defining a protomylonitic foliation. Specimen collected at an elevation of 870 feet on the ridge 385 meters south of where Mitcheltown Road crosses Mill Brook (northwest area of map).

361. Gray-weathering, fine-grained, dark-gray and white, thin-layered muscovite-biotite-quartz-plagioclase gneiss. Thin (2-5 mm) compositional layering defined by biotite and quartz-plagioclase segregations. Specimen collected at an elevation of 102 feet on the steep slope southeast of where West Woods Road crosses Mill Brook (northwest area of map).

915. Light-gray- to light-brown-weathering, fine-grained, well foliated, light-colored biotite-quartz-plagioclase gneiss. Specimen collected on small knob in the field south of Traver Road (west-central area of map).

1222. Light-brown-, light-pink- to brown-weathering, well foliated, medium- to very-coarse-grained, biotite-hornblende-quartz-plagioclase gneiss. Black hornblende gives rock a spotted appearance. Texture and local inclusions of amphibolite indicate intrusive origin. Specimen collected at an elevation of 1190 feet on a ridge that rises out of Bog Hollow and crests at a spot elevation of 1231 feet on East Mountain. The ridge also crosses the Dover-Amenia town line at 1000 feet (southwest area of map).

dark-green calc-silicate granulite and feldspathic quartzite. The schistose gneiss consists of fine-grained, gray biotite, quartz and feldspar with minor amounts of hornblende, epidote and sparse garnet (347, Table 6). The biotite-quartz-feldspar granulite and calc-silicate granulite are typically very fine- to fine-grained and locally contain megacrysts of hornblende or garnet up to 2 cm in diameter. They are gray- to rusty-brown-weathering and in some areas have yellow sulphide stains. They tend to occur with thin-layered amphibolites and mafic schistose gneiss. A distinctive pale-bluish-gray, very fine-grained feldspathic quartzite occurs at the northwest end of Hilltop Pond. It is light-gray-weathering and contains minor amounts of biotite and muscovite which create shiny foliation surfaces.

The contact of the Deming Hill Gneiss with the West Woods Gneiss is not exposed and difficult to locate due to poor exposure and abundant granitic gneiss in the contact zone. The approximate thickness of the unit is 2140 m. The Deming Hill Gneiss probably consists of metamorphosed mafic volcanics and subordinate felsic volcanics or interbedded feldspathic sands.

Age and Correlation

Regional correlation of basement rocks in the Housatonic Highlands massif with basement rocks of the Fordham Terrane and Berkshire allochthon is based on lithic similarities and similar stratigraphic position unconformably beneath correlative basal Cambrian quartzites and carbonates (Hall, 1980). The Fordham Gneiss gives isotopic ages of 980 m.y. according to zircon Pb 207/Pb 206 ratios (Grauert and Hall, 1973). Similar zircon studies on a paragneiss unit (Washington Gneiss) from the Berkshire allochthon indicate ages of 1,040 to 1,080 m.y. (Ratcliffe and Zartman, 1976). In both terranes the ages are interpreted to record the end of zircon recrystallization during high grade metamorphism that accompanied the Grenville orogeny. A Rb-Sr whole-rock isochron study of the Fordham Gneiss shows the rock to be at least 1,350 m.y. old (Mose, 1982). The study also shows that the rocks developed strontium isotopic homogenization about 1,100 m.y. ago. This date coincides approximately with the zircon dates given above for the Grenvillian metamorphism.

A comparison and preliminary correlation of Housatonic Highlands basement rocks in the study area and adjacent quadrangles is shown in Figure 5. Four units, the Richards Pond Gneiss, Bread Loaf Mountain Gneiss, Stony Brook Gneiss and the Ellsworth Gneiss, are a continuation of rock units mapped in the Cornwall quadrangle (Gates, 1961). However, in the South Canaan quadrangle, along strike to the north, Gates (1975) could not sustain the subdivisions. The amphibolite unit (pЄhma) in the South Canaan quadrangle may correlate with the amphibolite in the Deming Hill Gneiss.

Three rock units of the Sharon quadrangle (Gates, 1979) probably correlate with rocks of the Deming Hill Gneiss which locally consists of biotite granite gneiss like Gates' unit pЄhb.

In the Kent quadrangle (Jackson, 1980), biotite gneiss (pЄg) is continuous with the Ellsworth Gneiss and may correlate with part of the Bread Loaf Gneiss. Correlation with the intrusive igneous rocks of the

Ellsworth and Amenia Quadrangles This Report	Kent Quadrangle Jackson, 1980	Cornwall Quadrangle Gates, 1961	Sharon Quadrangle Gates, 1979	South Canaan Quadrangle Gates, 1975
Deming Hill Gneiss: amphibolite; gray biotite-quartz-plagioclase gneiss & granitic gneiss (mafic volcanics, arkose &/or felsic volcanics)	p€ha: gray biotite-hornblende gneiss & amphibolite (ferruginous sediments, mafic volcanics &/or dikes)		p€ha: amphibolite & mafic gneiss (mafic volcanics &/or intrusives)	p€hma: amphibolite (mafic volcanics)
West Woods Gneiss: biotite-hornblende-plagioclase gneiss (calcareous arkose & siltstone)	p€c: biotite-diopside-hornblende calc-silicate rock (calcareous sediments)			
Ellsworth Gneiss: gray- to rusty-weathering quartzofeldspathic gneisses with subordinate amphibolite, calc-silicate & aluminous zones (arkose & arenite with some pelites, calcareous beds & mafic volcanics or dikes)	p€g: gray biotite gneiss (sediments)	Unit 5: rusty-weathering quartzofeldspathic biotite gneiss (arkose, shale, mafic volcanics or dikes); banded biotite granite gneiss (felsic volcanics) Unit 4: rusty-weathering quartzofeldspathic biotite gneiss; biotite gneiss; granitic gneiss; amphibolite (similar to above)	p€hp: biotite-quartz-plagioclase paragneiss, feldspathic quartzites & subordinate amphibolite	p€hm: gray- to rusty-weathering biotite-quartz-feldspar gneisses or granitic gneiss; calc-silicate rock; amphibolite; pelitic gneiss p€hmrfg: rusty-weathering biotite-quartz-plagioclase gneiss, locally with sillimanite
Stony Brook Gneiss: light-gray biotite-quartz-plagioclase gneiss (felsic volcanics or intrusive sill)		Unit 3: gray, banded granitic gneiss (felsic volcanic or granitic sill)		p€hmbg: gray and white banded granitic gneiss (felsic volcanics) (All of the above are mainly volcanogenic sediments.)
Bread Loaf Mtn. Gneiss: graphitic quartzofeldspathic gneisses; amphibolite; hornblende-quartz-feldspar gneiss; gray garnet-hornblende-biotite-quartz-plagioclase gneiss; diopside calc-silicate rock (arkose, siltstones +/- calcareous beds, carbonate sands, felsic & mafic volcanics)		Unit 2: rusty-weathering, graphitic quartzofeldspathic gneisses & diopside calc-silicate rock (arkose, black shale & lenses of carbonate)		
Richards Pond Gneiss: light gray biotite-microcline-quartz-plagioclase gneiss (felsic volcanics)		Unit 1: gray, layered granitic gneiss (felsic volcanics)		

Figure 5. Stratigraphic correlation chart for Precambrian stratigraphy mapped in the Housatonic Highlands.

Kent quadrangle will be discussed in the next section.

Any detailed correlation with basement rocks of the Fordham Terrane or Berkshire allochthon is beyond the scope of this work. However, there may be a correlation of the gray- to rusty-weathering muscovite-biotite-quartz-plagioclase gneisses of the Ellsworth Gneiss with the Washington Gneiss of the Berkshire allochthon, as described by Harwood (1975, 1979) and Ratcliffe (1976).

PALEOZOIC ROCKS

The Precambrian rocks are unconformably overlain by Cambrian clastics of the Lowerre Quartzite which in turn are overlain by carbonate bank deposits of the Inwood Marble (Figure 3). The Inwood Marble consists of four members, but only the two oldest members are present in the Housatonic River valley on the east flank of the Precambrian terrane (Plate 1). These rocks are unconformably overlain by calcite marble and schist of the Middle Ordovician Manhattan A. The Lowerre, Inwood and Manhattan A make up an autochthonous sequence that rests on the basement gneisses.

Two regional unconformities are present within the autochthonous sequence. One is the basal unconformity, above the basement gneisses, upon which the Lowerre Quartzite was deposited. The other is the Middle Ordovician unconformity which is marked by the contact of Manhattan A marble or schist with different members of the Inwood Marble.

Allochthonous rocks of the Cambrian Manhattan C and the Everett Formation make up two thrust sheets that rest on the autochthonous Middle Ordovician Manhattan A rocks (Figure 3). The Manhattan C is divided into four members that consist of pelitic schists, schistose granulites, schistose gneiss and amphibolite that occur southeast of the basement gneisses. Pelitic schist of the Everett Formation occurs in limited exposure in the northwest corner of the study area (Plate 1).

Cambrian Lowerre Quartzite - Ꞓl

The Lowerre Quartzite (Merrill, 1896) overlies the Precambrian basement rocks in exposures on the east and west sides of the Housatonic Highlands (Plate 1). Outcrops of Lowerre in the Housatonic River valley occur at the foot of St. John's Ledges and in the riverbed below the mouth of Stony Brook. A small outlier of Lowerre also occurs above St. John's ledges in the keel of a tight syncline (Plate 1). On the western side of the Highlands, Lowerre is continuously exposed on the west flank of East Mountain (Plate 1). North of East Mountain there are three separate exposures of Lowerre Quartzite. It occurs just north of Route 341, at Beebe Brook and east of Mill Brook near Hatch Pond. At St. John's Ledges the Lowerre is approximately 150 m thick and at East Mountain it is 180 to 200 m thick.

The map pattern in the vicinity of St. John's Ledges shows that the base of the Lowerre Quartzite truncates the Precambrian Bread Loaf Mountain Gneiss, the St. John's Ledges Granite Gneiss and the Richards Pond Gneiss. Good exposures of the basal contact, especially on East Mountain, exhibit truncation of foliation and different rock types within the Deming Hill Gneiss. These map scale and outcrop features are evidence of the widespread angular unconformity between the Precambrian rocks and the overlying Lowerre.

The Lowerre Quartzite consists chiefly of massive to moderately foliated, fine-grained, white, tan, or light-gray vitreous quartzite and granular feldspathic quartzite. Locally, thin, micaceous conglomerate beds are present within 1 m of the base. Flattened, white, gray to pale-blue quartz pebbles are up to 5 cm long. The quartzite is typically tan- or light-pinkish-tan- to brown-weathering and locally gray-weathering. Bedding thickness is varied from thin (0.5 cm) lamellae or 10 to 15 cm feldspathic and micaceous beds to typically massive, thick (greater than 1 m), vitreous quartzite. The vitreous quartzite contains over 90% quartz with minor amounts of feldspars, micas, tourmaline, apatite, sphene, zircon, magnetite, ilmenite and sparse pyrite (1258, 934, Table 7).

Locally on East Mountain a well foliated, brown-gray-weathering, fine-grained, tourmaline-graphite-apatite-biotite-microcline-quartz-muscovite schist is interbedded with thin quartzite beds and conglomerate at the base of the unit (1253, Table 7). Ribbon quartz lenses and granulated microcline grains are seen in thin section. Also on East Mountain the predominant vitreous quartzite near the base of the Lowerre passes upward into a more granular variety that is generally more feldspathic and micaceous.

Subordinate amounts of Lowerre exposed along the Housatonic River and in the small inlier consist of slabby-appearing, well foliated, fine-grained, light-gray, tourmaline-muscovite-biotite-microcline quartzite with up to 46% microcline and as much as 1% magnetite and tourmaline (1354, Table 7). Tourmaline occurs as needles up to 2 cm long

Table 7

Estimated Modes of Specimens from the Lowerre Quartzite

Specimen	Western Specimens 1258	934	1253	Eastern Specimens 1354
Quartz	99	96	25	48
Plagioclase	tr	1	-	tr
(An%)[1]	(Ab?)	(Ab?)	-	(?)
Microline	1	2	10	45
Biotite[2]	tr	-	5	2
Muscovite	tr	tr	59	3
Sericite[3]	tr	tr	tr	-
Tourmaline	tr	tr	tr	1
Allanite	-	-	-	tr
Apatite	-	tr	1	tr
Sphene	tr	1	-	tr
Zircon	tr	tr	tr	tr
Magnetite	tr	-	tr	1
Ilmenite	tr	-	tr	tr
Graphite	-	-	tr	-
Hematite[3]	tr	-	tr	tr

[1]Ab? based on relief of grains compared to quartz.

[2]Biotite pleochroic formula: All specimens pale-yellow (X); brown (Y&Z).

[3]Secondary.

Description and location of rock specimens. Locations indicated on Plate 2.

1258. Light-pinkish-tan, massive, very fine-grained, white quartzite. Specimen collected at an elevation of 850 feet on the west side of ridge to the west of Crane Pond (southwest area of map).

934. White to light-tan, massive, clean quartzite. Specimen collected 3 m from the contact with the Precambrian gneiss at an elevation of 770 feet, west of Mill Brook about 880 m south of Hatch Pond (northwest area of map).

Table 7 (continued)

1253. Well foliated, fine-grained, graphite-apatite-biotite-microcline-quartz-muscovite schist. Tourmaline needles are common. Specimen interbedded with clean feldspathic quartzite and conglomerate. Specimen collected at an elevation of 1080 feet on the east side of ridge to the west of Crane Pond (southwest area of map).

1354. Well foliated and well bedded, fine-grained, light-gray, tourmaline-muscovite-biotite-microcline quartzite. Specimen collected on the west bank of the Housatonic River about 215 m down river from the mouth of Stony Brook (southeast area of map).

and pyrite is locally present. Tan, fine-grained, quartz-rich interbeds occur with this feldspathic quartzite.

The eastern and western occurrences of Lowerre Quartzite may be traced along strike southward into the Kent (Jackson, 1980) and Dover Plains (Balk, 1936) quadrangles, respectively. They join around the southern end of the Housatonic Highlands in the Dover Plains quadrangle where the quartzite was mapped by Balk (1936) as the Poughquag Quartzite (Dana, 1872). In Poughquag, New York, located 11 km. southwest of the Housatonic Highlands, the quartzite unconformably overlies Precambrian gneisses of the Hudson Highlands. Lower Cambrian Olenellus fragments and Scolithus tubes occur in the Poughquag Quartzite at Beacon, New York (Knopf, 1927).

North of the study area, the eastern and western occurrences of Lowerre have not been traced into the adjacent Sharon and Cornwall quadrangles mapped by Gates (1979 and 1961, respectively). However, the Precambrian rocks of the northern end of the Housatonic Highlands in the Sharon and South Canaan (Gates, 1975) quadrangles are unconformably overlain by the equivalent Dalton Formation and Cheshire Quartzite. Olenellus occurs in the Dalton Formation in Massachusetts (Emerson, 1917) and in Vermont, Lower Cambrian fossils occur in the Cheshire (Cady, 1945; Shaw, 1945; Stone and Dennis, 1964). The equivalency of the Lowerre Quartzite in the Manhattan Prong with the Dalton Formation, Cheshire Quartzite and Poughquag Quartzite of western New England and eastern New York was proposed by many early workers, including Mather (1843), Merrill (1902) and Agar (1932). More recently, detailed work by Hall (1968, 1976), Dana (1977), Jackson (1980) and Brandon (1981) in southeastern New York and western Connecticut demonstrated the correlation by identification of the unconformity between the Precambrian Fordham Gneiss and Lowerre Quartzite in the Manhattan Prong.

Cambrian-Ordovician Inwood Marble - OЄi

The Inwood Marble was named by Merrill (1890) for exposures of metamorphosed limestones overlying Lowerre Quartzite in the Inwood section of Manhattan Island. Hall (1968) divided the Inwood into five members in the Manhattan Prong. He interpreted the rocks as a sequence of clean carbonate deposits with minor amounts of argillaceous and sandy interbeds laid down in a vast carbonate bank described by Rogers (1968) as extending along the western edge of the Appalachians from Newfoundland to Alabama. In the Ellsworth and Amenia quadrangles the Inwood Marble rests on Lowerre Quartzite and it is divided into four members. From oldest to youngest the members are designated A, B, C and D in accordance with the divisions made by Hall (1968) in the Manhattan Prong and the divisions made by Zen (1966) in the equivalent Stockbridge Formation of western Massachusetts, northwestern Connecticut and the adjacent areas of New York. On the east side of the basement terrane, southward from the vicinity of Cornwall Bridge (Route 4), the Housatonic River is incised into Members A and B (Plate 1). On the west side of the basement rocks all four members are exposed east of Webatuck Creek (Plate 1).

Inwood Member A - Єia. In the Housatonic River valley, Member A is only exposed at Gunn Brook (Plate 1) where it occupies the core of a small anticline. The narrow zone of Member A overlying Lowerre Quartzite is the inferred continuation of mapping done in the Kent quadrangle (Jackson, 1980). West of East Mountain in the Amenia quadrangle, Member A is exposed only in two small outcrops (Plate 1).

Member A of the Inwood is predominantly light-gray-weathering, clean, sparkling-white to light-gray dolomite marble. It is fine- to medium-grained and well bedded with bedding thicknesses from 2 cm to 25 cm. Thick beds of 1 m or more are also common. In the Housatonic valley minor amounts of phlogopite and tremolite (C36, Table 8) are present as well as quartz, calcite and pyrite. The specimen collected from the western exposures contains light-brown phlogopite and minor amounts of quartz, microcline, calcite and pyrite (1167, Table 8).

The approximate thickness for the inferred zone of Member A below St. John's Ledges is 80 m. Jackson (1980) estimated a thickness of 300 m in the eastern part of the Kent quadrangle. The western zone in the Amenia quadrangle is approximately 170 m. Fisher and McLelland (1975) reported about 300 m of the equivalent Stissing Dolostone south of the Amenia quadrangle in Dutchess County, New York. To the north, Zen (1969) estimated a thickness of 230 m for the equivalent Member A of the Stockbridge Formation. The unit is also correlative with the Dunham Dolomite in Vermont (Doll et al., 1961; Zen, 1961; Hall, 1968). Fossils found in the Stissing Dolomite indicate that it is late Early Cambrian (Knopf, 1946) and by correlation (Hall, 1968) Member A is considered of similar age.

<u>Inwood Member B - Ꞓib</u>. In the Housatonic valley Member B is best exposed on the west side of the Housatonic River opposite the mouth of

Table 8

Estimated Modes of Specimens from the Inwood Marble

	Member A		Member B		Member C	Member D	
	Western Specimen	Eastern Specimen	Western Specimen	Eastern Specimen			
Specimen	1167	C36	1351	C95	916	995	1294
Quartz	2	1	12	tr	7	2	tr
Microcline	1	tr	tr	tr	tr	1	6
Phlogopite[1]	3	tr	27	4	1	41	tr
Dolomite	94	99	37	65	92	46	94
Calcite[2]	tr	tr	23	2	tr	8	tr
Diopside	-	-	-	24	-	-	-
Tremolite	-	tr	-	-	-	-	-
Apatite	-	-	tr	-	-	-	-
Sphene	-	-	-	-	-	-	tr
Pyrite	tr	tr	1	4	-	1	tr
Hematite[3]	-	-	tr	1	-	1	-

[1]Phlogopite pleochroism is colorless (X) to pale-yellow (Y&Z).

[2]Carbonate mineralogy determined by chemical staining (Dickson, 1965).

[3]Weathered pyrite.

Description and location of specimens. Locations indicated on Plate 2.

1167. Thick bedded, fine-grained, gray-weathering, white-dolomite marble. Specimen collected from the easternmost exposure of marbles, approximately 835 m. south of benchmark 456 west of East Mountain (southwest area of map).

C36. Well bedded, gray- to tan-weathering, white to light-gray, fine-grained dolomite marble with minor amounts of phlogopite, tremolite quartz and pyrite. Specimen collected at an elevation of 450 feet in Gunn Brook (east-central area of map).

Table 8 (continued)

1351. Well bedded, tan- to brown-weathering, fine-grained, light-brown, blue-gray to purplish-brown, schistose calcite-phlogopite-dolomite marble. Specimen collected west of the road intersection with spot elevation 555 feet near the south-central edge of the Amenia quadrangle (southwest area of map).

C95. Well bedded, tan-weathering, white to light tan, phlogopite-diopside-dolomite marble with minor amounts of calcite and quartz. Pyrite is locally abundant in thin (1-5 mm) zones approximately parallel to bedding. Specimen collected at an elevation of 430 feet in Kent Falls Brook (southeast area of map).

916. Predominantly thick bedded, gray-weathering, light- to dark-gray, fine-grained dolomite marble. Thin (1-5 mm), white quartz layers are common. Specimen collected from a roadcut on Route 41, approximately 500 m south of Amenia Union (west-central area of map).

995. Thin-bedded, tan- to brown-weathering, brown, fine-grained, calcite-phlogopite-dolomite marble. Specimen collected at an elevation of 700 feet on the east side of the hill northwest of Bolland District Cemetary. Outcrop is about 335 m south of small pond on the hill (northwest area of map).

1294. Gray-weathering, light-gray, very fine-grained microcline-dolomite marble with pods and thin layers of white to dull-gray quartz. Specimen collected from a thick (1-1.5 m) interbed near specimen 995 (northwest corner of map).

Guinea Brook and at the falls of Kent Falls Brook (Plate 1). The western exposures are limited to the area west of East Mountain, south of Route 341 (Plate 1).

Member B consists primarily of well bedded, light-gray-, cream- or tan-weathering, fine- to medium-grained dolomite marble (C95, Table 8). Bedding thickness ranges from 2 cm to 1 m and fresh surfaces are uniform or mottled white, light-gray, pale-brown to tan. Minor but characteristic interbeds are thin (1-10 cm), gray- or tan- to rusty-weathering, fine-grained, gray quartzites; thin (2-10 cm), rusty-weathering, black, sulphide-bearing schistose quartzite; thin (1-15 cm), tan- to orange-tan-weathering, well foliated, white, light-brown, bluish-gray to purplish- or reddish-brown, phlogopite-calcite-dolomite-marble (1351, Table 8). Tremolite and diopside are common and tend to be localized in quartzose dolomite beds or near quartzite beds. Pyrite is a common accessory mineral (C95, Table 8). Differential weathering accentuates the bedding, locally producing a ribbed appearance. Lithic similarities between the eastern and western exposures are more striking than differences, thus adding confidence to their correlation across the basement terrane.

A thickness of approximately 210 m is estimated for Member B in the Housatonic valley between Member A in the core of the small anticline (Plate 1), and the unconformity that truncates Member B to the east. Jackson (1980) estimated a thickness of 300 m in the Kent quadrangle. West of East Mountain, the thickness of Member B between the contacts with Members A and C is estimated at 80 m. Fisher and McLelland (1975) estimated a thickness of 300 m for the equivlent Pine Plains Formation south of the Amenia quadrangle. To the north, in the Bashbish Falls quadrangle, Zen (1969) estimated a 200 m thickness for the equivalent Unit b of the Stockbridge Formation. Member B is also correlative with the Winooski Dolomite and at least part of the Monkton Quartzite of Western Vermont (Doll et al., 1961; Zen, 1961; Hall, 1968).

Inwood Member C - Ɛic. Exposures of Member C are limited to the region west of the basement rocks in the study area (Plate 1). In the southern part of this area, Member C overlies Member B, whereas to the north it is in fault contact with Lowerre Quartzite. Prominent exposures occur along Route 41 and in Mill Brook near Amenia Union.

Member C of the Inwood is a massive to thin-laminated, fine-grained, gray-weathering, battleship gray to white dolomite marble. Thin (1 cm.), white, recrystallized chert layers or white and gray laminations define bedding which ranges in thickness from 5 mm to 50 cm but is typically 5 cm to 50 cm. Massive beds 1 m or more in thickness are common. Minor amounts of phlogopite, calcite, quartz and microcline are present (916, Table 8) and pyrite, tremolite and diopside occur locally. In some places diopside megacrysts stand out on weathered surfaces. Rusty- or gray-weathering quartzite beds, 2-10 cm thick, and gray to black, fine-grained siliceous schists are present in a few exposures. The rock weathers with crumbly surfaces that typically form low, rounded pavement surfaces.

The lack of adequate control makes thickness estimates unreliable in the study area. To the north in the Bashbish Falls quadrangle, Zen

(1969) estimated a thickness of 230 m for the equivalent Unit C of the Stockbridge Formation. To the south, Fisher and McLelland (1975) reported a thickness of 300-400 m for the equivalent Briarcliff Dolostone. Member C is also correlative with the Clarendon Springs Dolomite and Danby Formation of western Vermont (Doll et al., 1961; Zen, 1961; Hall, 1968). Fossils found in the Briarcliff Dolomite (Knopf, 1946) indicate that it is Late Cambrian and thus Member C is considered of similar age.

<u>Inwood Member D - Oid</u>. Rocks of Member D occur in a narrow zone between Webatuck Creek and Mill brook west of the basement massif (Plate 1). Promiment exposures occur at Sharon Country Club and the small hills about 1 km north of Amenia Union. The unit is bordered to the east and west by Member C forming a syncline with Member D in the core.

Member D is characterized by a variety of interlayered marbles and thin-bedded quartzites. The diversity of rock types is represented by cream-, tan-, to light-brown-weathering, fine- to medium-grained, tan to light-brown and white, locally crossbedded (10 cm sets), sandy, calcite-dolomite marble; gray-, tan-, to brown-weathering, fine-grained, thin-laminated, silty, blue-gray, gray, brown and white phlogopite-calcite-dolomite marble (995, Table 8); light-gray-weathering, light-gray, very fine- to fine-grained, massive dolomite marble with 1-2 cm, white quartzite layers (1294, Table 8); massive, cream- to tan-weathering, white dolomite marble; gray- or orange-tan-weathering, fine-grained quartzite with beds 2-10 cm thick. Beds of massive marbles are interbedded with intervals of thin-laminated, impure marbles on a scale of 0.5-1.5 m. Bedding in the tan, sandy dolomite marbles ranges in thickness from 1-15 cm. Accessory minerals include muscovite, microcline and pyrite.

The contact with Member C appears to be locally marked by interbedding of rock types common to both units. This is seen in outcrops on either side of the road, 600 m northwest of Amenia Union.

The minimum thickness of the unit is calculated by allowing for doubling of the unit in the syncline and using an average dip of 48 degrees. Values of 43 m and 88 m were obtained for two locations north of Amenia union. Zen (1969) estimated a thickness of 0-80 m for Unit d of the equivalent Stockbridge Formation in the Bashbish Falls quadrangle. Knopf (1946) estimated a thickness of 106 m for the equivalent Halcyon Lake Formation near Stissing Mountain, northwest of the study area. Member D is also correlative with part of the Shelburne Formation of western Vermont (Doll et al., 1961; Zen, 1961; Hall, 1968). Fossils in the Halcyon Lake Formation (Knopf, 1946) indicate that it is Early Ordovician and by correlation Member D is considered of similar age.

Middle Ordovician Manhattan A - Oma

Merrill (1890) proposed the name Manhattan Schist for the varied sequence of schists and amphibolite that overlie the Inwood Marble on Manhattan Island in New York City. In the Manhattan Prong area of southeastern New York, Hall (1968a, 1968b) made three divisions of these rocks in which the physically lowest unit, Manhattan A, consists of a dark-gray Schist Member with a Calcite Marble Member at the base. Dana (1977), Jackson (1980) and Brandon (1981) also recognized these members in western Connecticut. In the Ellsworth quadrangle Manhattan A is mapped as 2 rock units where the Calcite Marble can be mapped separately.

Exposures of Manhattan A are limited to 2 small areas east and west of the Precambrian basement rocks. In the Housatonic River valley, outcrops of the Calcite Marble and Schist Members occur between Millard Brook and Wilford Pond near Route 7 (Plates 1 and 2). A 0.5 m horizon of the Schist Member also is exposed in Kent Falls Brook. Limited exposure of the two members occurs in the northwest corner of the Ellsworth quadrangle near Route 343.

<u>Calcite Marble Member - Omam</u>. The rocks are typically tan-weathering, white, medium-grained, phlogopite-calcite marble. Intervals of light-gray-weathering and light-gray to light-tan calcite marble with quartz masses up to 4-6 cm across are associated with tremolite and phlogopite concentrations. In the outcrops located southwest of Wilford Pond in the eastern part of the map area (Plates 1 and 2), a 5-10 cm thick bed of fine-grained, light-brown, feldspathic quartzite is present. Other minerals present in minor amounts include microcline, plagioclase, dolomite, sphene, pyrite, magnetite and secondary hematite as a replacement of pyrite (Table 9, 596, C30). Bedding thickness is varied from 5 cm to 1 m and foliation is defined by locally abundant light-brown phlogopite. Natural exposures are pitted and soft to the hammer due to the leaching of calcite.

The basal contact of the Calcite Marble Member is not exposed, but in the Housatonic valley it rests on Inwood Member B and it is locally absent around Kent Falls (Plate 1). The western zone is shown resting on Inwood Member D, but it may rest directly on Inwood Member C. The approximate thickness of the Calcite Marble Member in the area of Wilford Pond, calculated for an average dip of 64 degrees, is 90 m. About 10 km to the southwest, Jackson (1980) calculated a thickness of 90-120 m for the same rock unit.

Schist Member - Omas. The rocks are typically well foliated, fine-grained, dark-gray- to rusty-yellow-weathering, dark-gray, muscovite-biotite-feldspar schist or schistose granulite. Pyrite is locally abundant and commonly weathered to hematite. The western exposure of the Schist Member is a graphite-bearing phyllitic schist that contains up to 2% garnet (595, Table 9). Other minerals observed in thin section study include allanite, tourmaline, apatite, sphene, zircon, ilmenite, chalcopyrite, pyrrhotite and secondary chlorite (595, 1681, Table 10).

The Schist Member overlies the Calcite Marble Member except in the area of Kent Falls (Plate 1) where it rests on Inwood Member B. As previously mentioned, the thickness of the Schist Member at Kent Falls is about 0.5 m which is not a complete thickness because it is truncated by a thrust fault that marks the contact with the overlying Manhattan C. In the western exposure, the thickness cannot be calculated with any certainty, but it may be less than 20 m based on the proximity to the Everett Formation that truncates the Manhattan A along a thrust fault.

Gates (1979) mapped the same sequence of calcite marble and schist as the Walloomsac Formation in the adjacent Sharon quadrangle. Hall

Table 9

Estimated Modes of Specimens from the Manhattan A

	Schist Member		Marble Member	
	W Specimen	E Specimen	W Specimen	E Specimen
Specimen	595	1681	596	C30
Quartz	34	26	7	1
Plagioclase	7	44[2]	tr	tr
(An%)[1]	(Olig?)	(56)	(?)	(?)
Microcline	-	tr	2	1
Biotite[3]	31	27	-	-
Phlogopite[4]	-	-	1	3
Muscovite	25	-	-	-
Sericite[5]	tr	tr	-	-
Chlorite[5]	-	-	-	-
Calcite[6]	-	-	90	89
Dolomite	-	-	-	tr
Tremolite	-	-	-	6
Garnet	2	-	-	-
Allanite	tr	tr	-	-
Tourmaline	tr	tr	-	-
Apatite	tr	tr	-	-
Sphene	-	1	tr	tr
Zircon	tr	tr	-	-
Graphite	tr	-	-	-
Magnetite	tr	-	-	-
Ilmenite	1	tr	-	-
Pyrite	tr	2	tr	tr
Chalcopyrite	-	tr	-	-
Pyrrhotite	tr	tr	-	-
Hematite[5]	tr	tr	tr	tr

W = Western E = Eastern

[1]Approximate mol. % anorthite in plagioclase determined by Michel-Levy extinction angle method.

Specimen 595 determined by optic sign (-) and relief.

[2]Antiperthite.

Table 9 (continued)

[3]Biotite pleochroism: Pale-yellow (X); reddish-brown (Y&Z).

[4]Phlogopite is slightly pleochroic: colorless to pale yellow-brown.

[5]Secondary. Fe-chlorite (abnormal blue interference) in 1691.

[6]Carbonate mineralogy determined by chemical staining (Dickson, 1965).

Description and location of specimens. Locations indicated on Plate 2.

595. Dark-gray- and rusty-weathering, gray to dark-gray, well foliated, graphitic garnet-muscovite-biotite-quartz schist. Specimen collected from low outcrops in the pasture northwest of Route 343 in the northwestern corner of the Ellsworth quadrangle (northwest area of map).

1681. Well foliated, dark-gray-weathering, dark-gray, biotite-quartz-plagioclase schistose granulite. Specimen collected along the southeast side of Route 7, about 140 m south of Wilford Pond (east-central area of map).

596. Light-gray- to light-tan-weathering, fine- to medium-grained, light-gray calcite marble. Specimen collected from the same location as 595 (northwest area of map).

C30. Tan- to light-gray-weathering, medium-grained, light-tan or white, phlogopite-tremolite-calcite marble. Specimen collected on the northwest side of Route 7 across from 596 (east-central area of map).

(1968) equated the Walloomsac Formation with the Manhattan A on the basis of lithic similarity and the unconformity at its base. Further north in the Bashbish Falls quadrangle, Zen (1969) estimates a thickness of 500 m for the Walloomsac Formation. In the adjacent areas of Dutchess County, New York, the same sequence is mapped as the Balmville Limestone and the Walloomsac Formation (Fisher, 1962; Knopf, 1962). Fisher and McLelland (1975) estimate thicknesses of 0-30 m. for the Balmville Limestone and about 500 m for the Walloomsac Formation. The Manhattan A is also equated (Hall, 1968) with the Whipple Marble Member and the Ira Formation of western Vermont (Doll et al., 1961; Zen, 1961). Fossils in these correlative units are Middle Ordovician.

The contact of the Manhattan A with the 2 different members of the Inwood Marble is interpreted as an unconformity based on the well documented existence of the widespread Middle Ordovician unconformity beneath these rocks, or their equivalents, in the region (Cady, 1945; Brace, 1953; Fisher, 1962, 1977; Zen, 1967, 1969; Hall, 1968). Zen (1967) interprets the unconformity and subsequent deposition of easterly derived black shales as the result of the foundering of the carbonate bank environment and the onset of the bathymetric reversal that preceded the Taconian Orogeny.

Cambrian Manhattan C - Єmc

Hall's (1968) three-member division of the Manhattan Schist in the Manhattan Prong of southeastern New York includes an assemblage of sillimanite-bearing, feldspathic schists, schistose gneisses and minor thin amphibolites called Member C, commonly known as the Manhattan C.

These rocks overlie the Middle Ordovician Manhattan A and they are interpreted to be older than and in thrust fault contact with the Manhattan A (Hall, 1968). A Rb-Sr whole-rock isochron of 554 ± 59 m.y. (Rose, et al., 1985) for a part of the Manhattan C in the Manhattan Prong indicates an age no younger than Cambrian.

In the Ellsworth quadrangle the Manhattan C is exposed only in the southeast corner of the map where it overlies the Schist Member of the Manhattan A (Plate 1). Flanders Mountain, most of Kent Falls State Park, the various areas of Wyantenock State Forest and Whitcomb Hill are all underlain by Manhattan C.

The Manhattan C consists of four members that occur in two thrust sheets. The lower, Waramaug thrust sheet, contains the Schistose Gneiss, Schistose Granulite and Amphibolite Members. The higher, Above All thrust sheet, contains the Warren Member. The names of the members follows the nomenclature developed by Dana (1977) and Jackson (1980) in the New Preston and Kent quadrangles, respectively. The stratigraphic sequence is not known in these rocks, therefore they will be described in their physical order from lowest to highest.

Schistose Gneiss Member - Ɛmcgn. The lowest member is a well foliated, coarse-grained, reddish-brown- to tan-weathering, gray garnet-sillimanite-plagioclase-quartz-biotite-muscovite schist or schistose gneiss. Staurolite, tourmaline, apatite, zircon, magnetite and ilmenite are common accessory minerals (C43, Table 10). Bedding is indistinct and rounded, nubby-weathering surfaces, caused by relatively resistant sillimanite nodules and sillimanite-rimmed garnets up to 1.5 cm across,

Table 10

Estimated Modes of Specimens from Members of the Manhattan C

	Sch. Gneiss Member	Sch. Granulite Member		Warren Member		Amphibolite Member
Specimen	C43	1567	1635	C2	764	C55
Quartz	11	31	42	45	20	7
Plagioclase	8	34	21	34	26	36
(An%)[1]	(Olig)	(28)	(27)	(32)	(46)	(Olig)
Biotite[2]	22	25	13	9	16	tr
Muscovite	39	8	16	20	21	-
Chlorite[3]	-	-	-	-	tr	-
Sillimanite	15	-	3	-	13	-
Staurolite	tr	-	tr	-	tr	-
Garnet	5	-	4	tr	3	-
Hornblende	-	-	-	-	-	50
Tourmaline	tr	tr	1	tr	tr	-
Apatite	tr	1	tr	tr	tr	tr
Sphene	-	-	tr	-	-	tr
Zircon	tr	tr	tr	tr	tr	-
Allanite	-	-	-	-	-	tr
Epidote	-	-	-	-	-	tr
Magnetite	tr	1	tr	2	tr	-
Ilmenite	tr	-	1	tr	1	7
Pyrite	-	-	-	-	tr	-
Graphite	-	-	tr	-	-	-
Hematite[4]	tr	tr	tr	tr	tr	-

Sch. = Schistose.

[1]Approximate mol. % anorthite in plagioclase determined by Michel-Levy extinction angle method. An % of specimens 1567 and 1635 based on few measurements due to the scarcity of twinned grains. Specimens C43 and C55 were approximated by use of optic sign (negative) and relief versus quartz (indices overlap). An % of C2 determined by the immersion method.

Table 10 (continued)

[2]Biotite pleochroic formula: All specimens pale-yellow (X); C43, 1635, 764, C55 reddish-brown (Y&Z); 1567 and C2 brown and green to brown, respectively for Y&Z.

[3]Fe-rich chlorite indicated by abnormal blue birefringence. Chlorite occurs as a secondary alteration of biotite.

[4]Secondary.

Description and location of specimens. Locations indicated on Plate 2 in the southeast portion of map area.

C43. Coarse-grained, red-brown-weathering, gray, sillimanite-garnet-plagioclase-quartz-biotite-muscovite schist. Garnet-cored sillimanite nodules up to 2 cm diameter are abundant. Specimen collected at an elevation of 620 feet in Kent Falls Brook.

1567. Well foliated, fine-grained, gray-weathering, gray, muscovite-biotite-quartz-plagioclase schistose granulite. Specimen collected from low outcrops in fields 95 m east of Wilson Road and about 265 m north of the Ellsworth quadrangle boundary.

1635. Well foliated, fine-grained, gray- to yellow-tan-weathering, gray sillimanite-garnet-biotite-muscovite-plagioclase-quartz schistose granulite. Thin (1-3 mm) quartz-plagioclase layers and small gray megacrysts of plagioclase are common. Gray plagioclase is caused by graphite inclusions. Specimen collected 95 m east of the 1160 foot elevation in Deep Brook.

C2. Well foliated, gray-weathering, gray, fine- to medium-grained, magnetite-garnet-biotite-muscovite-plagioclase-quartz schistose granulite. Specimen collected at an elevation of 1300 feet, about 120 m north of the Ellsworth quadrangle boundary in the southeast corner of the map.

764. Well foliated, gray-weathering, light-gray to gray, fine- to coarse-grained garnet-sillimanite-biotite-muscovite-plagioclase-quartz schist with small (2-5 mm) garnets and local thin (5 mm) quartz lenses. Specimen collected in a small roadcut on an unnamed road, about 765 m east of the intersection with Wilson Road.

C55. Well foliated, dark-gray to black, ilmenite-quartz-plagioclase amphibolite with a strong linear fabric. Specimen collected at an elevation of 1120 feet on the southeast side of the second saddle along the ridge northwest of Whitcomb Hill.

characterize the rock. Two photos of this rock type are shown in Figure 6. Up to 5 cm thick, discontinuous quartz layers and lenses are locally present and possibly mark bedding. There are also rare beds of brown-weathering, fine-grained, gray calc-silicate rock.

The thrust fault contact with Manhattan A is well exposed in Kent Falls Brook (Plate 1). Good exposure of the Schistose Gneiss Member is provided northeast of Kent Falls Brook, along the northwest flank of Flanders Mountain and on the steep slope east of Wilford Pond (Plates 1 and 2).

Schistose Granulite Member - Ꞓmcgr. This member is a varied and intergradational assemblage of gneiss, schistose granulite and schist with minor amounts of amphibolite. A gray- to tan-weathering, well foliated, fine-grained, light-gray, muscovite-biotite-quartz-plagioclase gneiss to schistose granulite (1567, Table 10) is the main rock type. Fine (2-5 mm) lavender garnet and fibrous sillimanite, that locally forms small lenticular nodules and a prominent lineation, are common but not present everywhere. They are more abundant in the muscovite-rich schistose granulite horizons (1635, Table 10). White to gray plagioclase augen up to 10 mm long by 5 mm wide are a local, but characteristic, feature of the Schistose Granulite Member. The grayness of the plagioclase is caused by minute inclusions of graphite (1635, Table 10). Plagioclase augen and sillimanite nodules are dimensionally oriented in the prominent foliation. Accessory minerals include staurolite, tourmaline, apatite, sphene, zircon, magnetite and ilmenite. Up to 2 cm thick, discontinuous layers of quartz and 3 mm to 15 cm thick a.

b.

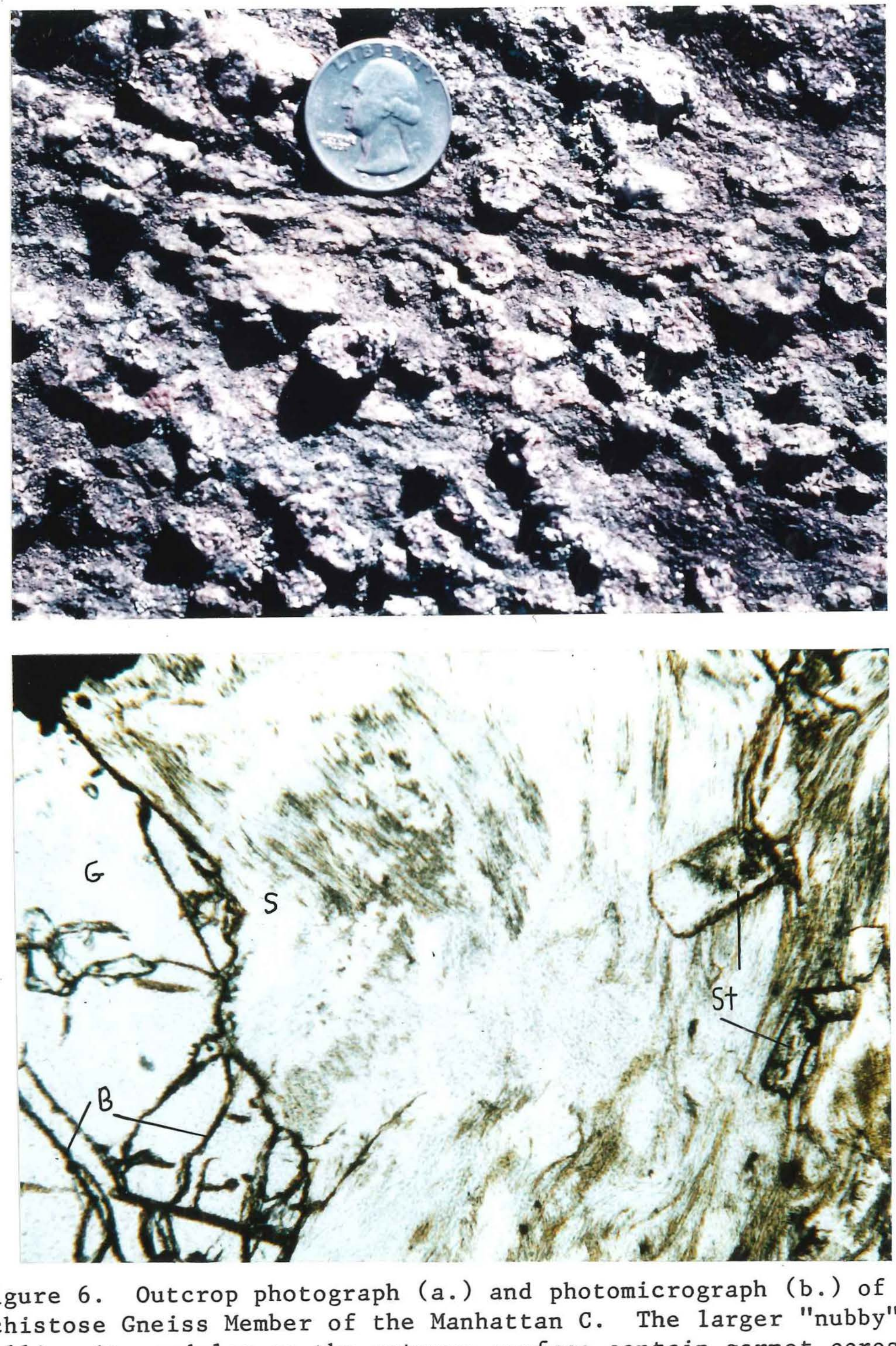


Figure 6. Outcrop photograph (a.) and photomicrograph (b.) of the Schistose Gneiss Member of the Manhattan C. The larger "nubby" sillimanite nodules on the outcrop surface contain garnet cores as seen in the photomicrograph. The field of view is approximately 1 cm across. S=Sillimanite, St=Staurolite, G=Garnet, B=Biotite.

alternations of darker-gray, micaceous layers and lighter-gray feldspathic layers suggest bedding which is typically obscure. Fine-grained, 5-10 cm beds of green and white, well foliated, calc-silicate rock are rare and thin layers of dark-green to black amphibolite are locally present. Smooth-weathering surfaces are typical of the biotite-quartz-plagioclase-rich gneisses while the more pelitic zones have rough or nubby surfaces due to garnet, sillimanite nodules, or plagioclase augen. The basal contact with the Schistose Gneiss Member can be approached within 5 m on the west side of Flanders Mountain and appears to be gradational over 5 m to 10 m.

Amphibolite Member - Ɛmca. A uniform, dark-greenish-gray to black, fine- to medium-grained amphibolite occurs within the Schistose Granulite Member and holds up much of the topographic high areas including Whitcomb Hill and the prominent ridges between Kent Falls Brook and Millard Brook (Plate 1). The Amphibolite Member consists of biotite-quartz-plagioclase-hornblende gneiss with garnet, epidote, apatite, sphene, allanite and up to 7% ilmenite as accessory minerals (C55, Table 10). Similar to that in the Schistose Granulite Member, plagioclase locally forms small augen oriented in the plane of the foliation. Outcrops are black and slabby due to splitting of the rock along foliation.

Observed contacts are sharp and apparently conformable. The amphibolite is probably of igneous origin, but whether it represents volcanic or intrusive rocks is uncertain. The amphibolite predates the formation of the prominent foliation based on outcrop observations where the foliation cuts across the contact between amphibolite and Schistose

Granulite.

Warren Member - Єmcw. The Warren Member was named by Dana (1977) for the town of Warren where typical exposures occur. In the Ellsworth quadrangle it is exposed in the southeast corner of the map and it is the only rock unit in the Above All thrust sheet. The contact with the Schistose Gneiss Member is sharp and exposed in the fields east of Wilson Road. It consists of well foliated, medium- to coarse-grained, tan- to reddish-brown- or gray-weathering, gray, garnet-biotite-muscovite-plagioclase-quartz schist to schistose granulite. Locally it contains abundant fibrous sillimanite and sillimanite nodules up to 1 cm. long in the plane of the foliation (764, Table 10). Muscovite on foliation surfaces gives a sparkling aspect to the rock. Magnetite forms up to 2% of the rock in some places (C2, Table 10) and other accessory minerals include staurolite, tourmaline, apatite, zircon, ilmenite, pyrite and secondary chlorite. Discontinous layers or pods of quartz up to 3 cm, but typically less than 1 cm thick are characteristic. Reddish-lavender garnets up to 5 mm in diameter are scattered throughout the rock, rarely exceeding 5% and locally not present at all. Bedding is indistinct but may be represented by the thin quartz lenses and alternation of more or less aluminous layers. Mineralogy and texture of the rock is very similar to the Schistose Gneiss; however, the Schistose Gneiss is generally more uniform, coarser grained, less well foliated, contains less quartz pods and the larger sillimanite nodules show less orientation in the foliation.

The allochthonous nature of the Manhattan C and the imperfect knowledge of the complex fold geometry make thickness estimates difficult and unreliable. In the Kent quadrangle, Jackson (1980) estimated a thickness of 1000 m. In the New Preston quadrangle, Dana (1977) estimated a thickness of 1150 m for the Waramaug thrust sheet.

Based on lithic similarity, similar stratigraphic position and regional continuity, Hall (1968, 1976) correlates the Manhattan C with the Waramaug Formation (Gates and Christensen, 1965) of western Connecticut and the Hoosac Formation of western Massachusetts (Hatch et. al., 1968). This correlation would also include the Hoosac Formation of Vermont (Skehan, 1961; Dodd et. al., 1961) according to Norton (1976). Significantly, porphyroblastic gray or black plagioclase, due to graphite inclusions, and generally indistinct bedding are features common to both the Hoosac (Norton, 1976) and the Schistose Granulite Member of the Manhattan C described above.

The regional correlation and evidence of pelitic interbeds similar to Manhattan C rocks within eastern exposures of Lowerre Quartzite led Hall (1976) to propose the facies transition from western, thin basal miogeoclinal clastics and carbonates to eastern, eugeoclinal, or slope, deposits. Thus the Manhattan C is considered to be an eastern facies equivalent of the Cambrian Lowerre Quartzite and Inwood Marble that was laid down mainly on Grenville basement and subsequently thrust onto the Manhattan A (Hall, 1979). The amphibolite, Manhattan B, described by Hall (1968) as occurring within the schistose gneiss at or near the thrust in the White Plains - Glenville area, probably correlates with the

Amphibolite Member in the Ellsworth quadrangle.

Everett Formation - Ꞓe

Hobbs (1893) introduced the name Everett Schist for the green schist in Mount Washington, southwestern Massachusetts and adjacent parts of New York and Connecticut. Zen (1966) recognized similar rocks of different metamorphic grades and included them in the Everett.

In the Ellsworth quadrangle the Everett has limited exposure west of Sharon Valley Road in the northwest corner of the map (Plate 1). It overlies the Manhattan A Marble Member and probably only 20 m of Everett is present in the area. More extensive areas of exposure occur to the north in the Sharon quadrangle and to the west of the map area in the Amenia quadrangle. The contact with the Manhattan A can be closely approached but it is not exposed.

The Everett Formation consists of well foliated, green to greenish-gray, fine-grained, phyllitic schist and fine- to coarse-grained quartzose schist. Lustrous, silvery or green-gray surfaces are typical of the phyllitic schist due to the abundance of muscovite and chlorite. Staurolite (up to 5 mm long) and garnet (up to 3 mm) are common, but they are more abundant in the quartzose schist which also contains scattered megacrysts of plagioclase. The quartzose schist (599, Table 11) consists of garnet, staurolite, biotite, plagioclase, muscovite and quartz with accessory chlorite, ilmenite, tourmaline, epidote, allanite, apatite and zircon. Thin (1 cm), discontinuous quartz layers are common in the quartzose schist but definite bedding is not apparent.

Based on lithic similarity, Zen (1969) equates the Everett Formation

Table 11

Estimated Mode of Specimen from the Everett Formation

Quartzose Schist

	599
Quartz	38
Plagioclase	15
(An%)[1]	(Olig)
Biotite[2]	9
Muscovite	28
Sericite[3]	tr
Chlorite[4]	1
Staurolite	5
Garnet	3
Tourmaline	tr
Epidote	tr
Allanite	tr
Apatite	tr
Zircon	tr
Ilmenite	1

[1]Oligoclase determined by optic sign (negative) and relief versus quartz (indices overlap). Twinned plagioclase is rare.

[2]Biotite pleochroic formula: pale-yellow (X); tan (Y&Z).

[3]Secondary.

[4]Fe- and Mg- (minor) rich chlorite indicated by abnormal blue and brown interference, respectively.

Description and location of specimen. Location indicated on Plate 2 in the northwest portion of the map area.

599. Well foliated, brown-gray-weathering, fine- to coarse-grained, gray to dull-green, garnet-staurolite-biotite-plagioclase-muscovite-quartz schist with porphyroblasts of garnet and staurolite. Specimen collected in the northwest corner of the Ellsworth quadrangle about 75 m west of benchmark 522.

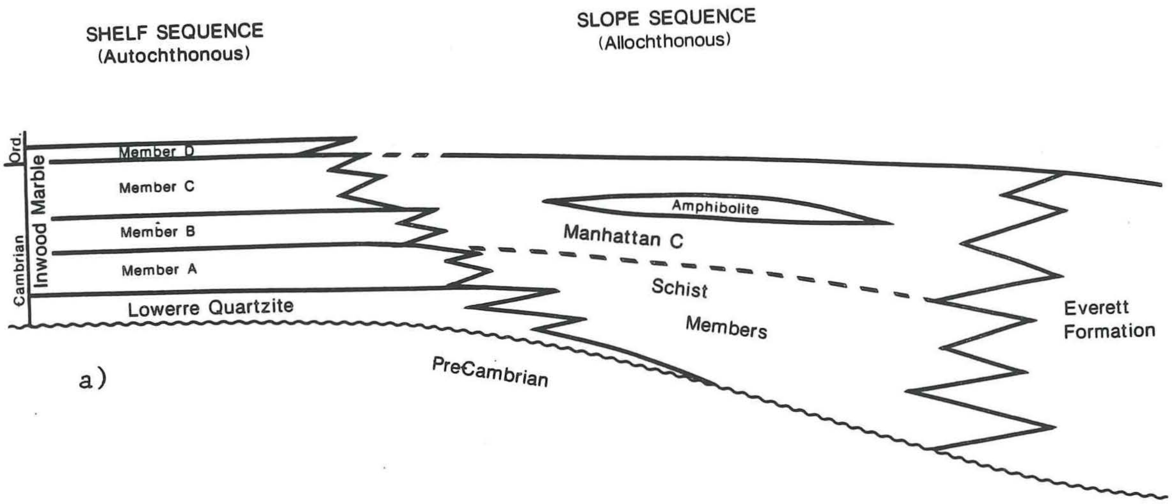
with the Greylock Schist of western Massachusetts (Herz, 1958), with the Mount Anthony Formation of southwestern Vermont (MacFayden, 1956; Hewitt, 1961) and with the Hoosac and part of the Pinney Hollow Formations of southern Vermont (Doll et al., 1961). In Dutchess County, New York, it is correlated with the Elizaville Argillite and Nassau Formation (Fisher and McLelland, 1965; Fisher, 1977). Ratcliffe and Hatch (1980) also correlate it with parts of the Nassau Formation and the Rensselaer Graywacke. The correlation with the Hoosac Formation by Zen (1969) makes the Everett Formation a possible equivalent of the Manhattan C found in the southeast corner of the Ellsworth quadrangle. This possibility has been previously suggested by Fisher and McLelland (1975) and Jackson (1980). The age of the Everett Formation is uncertain, but it is considered to be Early Cambrian to Late Precambrian by most of the workers referenced above.

Regional correlation and detailed mapping of the base of the Everett Formation led Zen (1966, 1967, 1969, 1971) to interpret the mass as an allochthonous sheet, thrust over the autochthonous Middle Ordovician rocks and the Cambrian-Ordovician carbonate bank sequence. Correlatives of the Everett Formation are interpreted as proximal to distal slope facies (Fisher, 1977), similar to the depositional environment proposed for the Manhattan C.

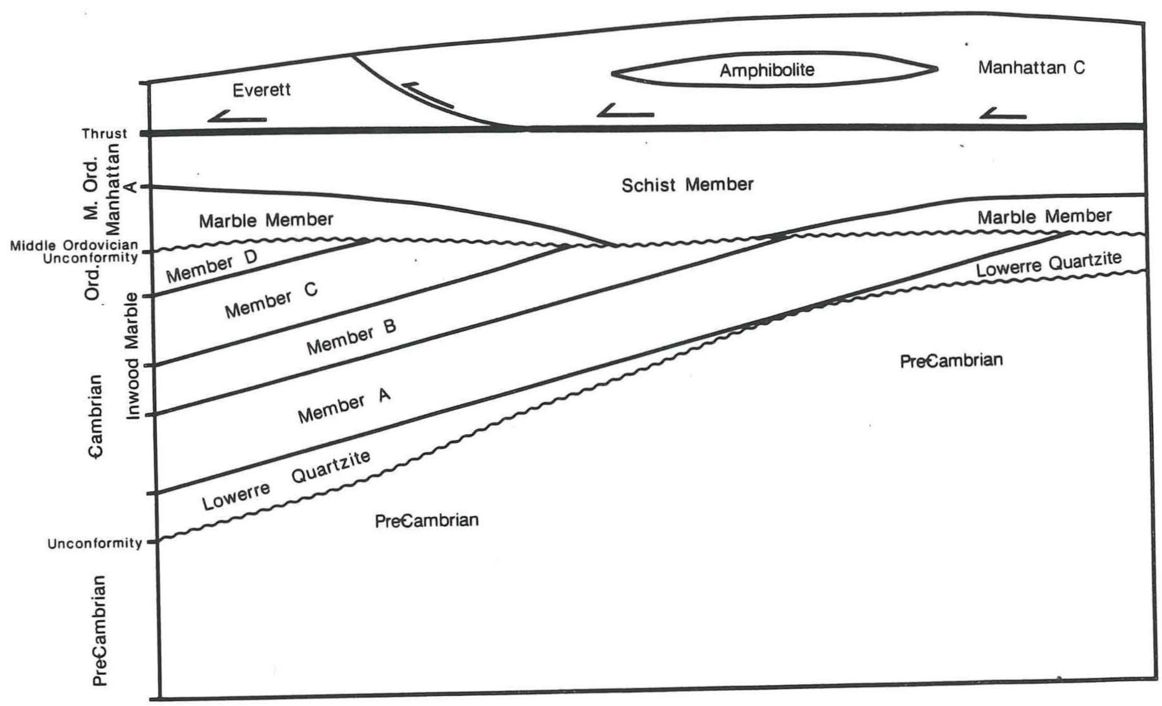
DEPOSITIONAL HISTORY

The Cambrian Lowerre Quartzite was deposited on an angular unconformity developed on the folded Precambrian gneisses of the Housatonic Highlands. The Lowerre represents basal conglomerate, arkose and clean quartz sand of the autochthonous shelf sequence that was subsequently overlain by carbonate bank deposits of the Cambrian-Ordovician Inwood Marble (Figure 7). In parts of the Kent quadrangle (Jackson, 1980) and parts of the Manhattan Prong, Inwood Member A rests directly on the basement gneisses (Hall, 1968; Brandon, 1981). Hall (1968) interprets these relations as indicative of a topographically irregular erosional surface with deposits of Lowerre clastics filling the lows and the succeeding Inwood carbonates onlapping onto the highs.

Deposition of Middle Ordovician Manhattan A Marble and Schist followed a period of tilting, block faulting and erosion of the carbonate bank (Figure 7). In the northwest corner of the Ellsworth quadrangle, Manhattan A Marble rests on the Inwood Member D (Plate 1), but in the Housatonic valley, both Schist and Marble Members of the Manhattan A lie on Inwood Member B and Members C and D are missing. These relations are interpreted as evidence of the Middle Ordovician unconformity that has been recognized throughout western New England and Eastern New York (Cady, 1945; Zen, 1967; Hall, 1968). In parts of the Kent quadrangle, the Manhattan A overlies Lowerre Quartzite (Jackson, 1980) and to the east in the New Preston quadrangle, the Manhattan A Marble rests on Inwood Member A (Dana, 1978). In the Manhattan Prong, Manhattan A Marble or Schist locally occurs in contact with Inwood Marble, Lowerre Quartzite or Fordham Gneiss (Hall, 1968; Brandon, 1981). To the north of the study area in the Sharon quadrangle, Zen (Zen and Hartshorn, 1966) reported an outcrop of Walloomsac schist (= Manhattan A) overlying truncated beds of the Stockbridge Formation (= Inwood). The distribution of rock units



a)



b)

Figure 7. Schematic diagrams showing: a) the stratigraphy and facies relationships for Paleozoic rocks through the Lower Ordovician, and b) the Middle Ordovician structural configuration following Taconian thrusting.

beneath the Middle Ordovician unconformity in the Ellsworth and Kent quadrangles is consistent with the erosional beveling of a generally westward tilted shelf sequence prior to deposition of the Manhattan A (Figure 7).

Cambrian rocks of the Manhattan C and Everett Formation are interpreted to have been deposited unconformably on Grenvillian basement, east of the Lowerre Quartzite as part of the slope sequence. Pelitic beds similar to Manhattan C schists occur within the Lowerre Quartzite in the Kent quadrangle (Jackson, 1980) and in the Manhattan Prong (Hall, 1976). These schist interbeds support the idea of a facies transition from western clean Lowerre Quartzite to eastern schists of the Manhattan C. The Manhattan C and Everett now rest on autochthonous Middle Ordovician Manhattan A rocks as allochthonous thrust slices.

METAMORPHOSED INTRUSIVE IGNEOUS ROCKS

Precambrian intrusive igneous rocks exposed in the Ellsworth and Amenia quadrangles include three plutons of granitic gneiss, named for areas of their occurrence, and a small area of ultramafic rock. Approximately concordant granitic gneiss sills and lit par lit intrusions are also abundant and, although they occupy a large cumulative volume of the rocks, they were not mapped. Instead, emphasis was placed on mapping the stratigraphic rock units. Specimens collected from some of the unmapped bodies will be discussed below. All of the rocks are classified using the nomenclature of Streckeisen (1973).

Ultramafic Rock - Yu

A single outcrop of ultramafic rock occurs on the southeast side of North Kent Brook within well layered biotite-hornblende-plagioclase gneiss of the Bread Loaf Mountain Gneiss (Plate 1). The exposure is about 8 m wide and it is inferred to be a lenticular body. No contacts with the surrounding rock are exposed.

The ultramafic rock consists mainly of medium- to coarse-grained olivine with lesser amounts of anthophyllite, serpentine, cummingtonite, talc, phlogopite, chlorite, magnetite and pyrite (616, Table 12). Locally olivine is less prominent than in specimen 616. Phlogopite occurs as scattered flakes best seen on typically dark-gray to dull-green fresh surfaces. Weathered surfaces are dark-brown and nubby with radiating sprays of fibrous anthophyllite. The rock is massive to faintly foliated.

The age of this rock is uncertain and no similar rocks are known in the map area. Jackson (1980) mapped a similar ultramafic rock body in the northwest corner of the Kent quadrangle. He noted a zone of cataclasis along one of the contacts.

Sharon Mountain Granodiorite Gneiss - Ysm

The Sharon Mountain Granodiorite Gneiss occurs as a mappable body in a northeast-trending zone between Hamlin Pond and Route 4 (Plate 1). Agar (1929) named rocks of this area the Sharon Mountain Quartz Diorite. It intrudes the Ellsworth Gneiss as a sheet and creates an oblong map pattern approximately 1 km wide by 5 km long. Choosing an average dip of 37 degrees, the thickness through the area of widest exposure is

Table 12

Estimated Modes of Specimens from Metamorphosed Intrusive Igneous Rock Units

	Sharon Mountain Granodiorite Gneiss			Ellsworth Granodiorite Gneiss		Ultramafic Rock
Specimen	16-6	9-4	18-1	285	254	616
Quartz	47	33	32	48	6	-
Plagioclase	21	52	45[3]	37	75	-
(An%)[1]	(26)[2]	(27)	(28)	(30)	(27)	-
Microcline	29[4]	1	17[4]	5	14[4]	-
Myrmekite	tr	-	tr	tr	1	-
Biotite[5]	2	12	5	9	2	-
Phlogopite	-	-	-	-	-	1
Muscovite[6]	1	2	1	tr	1	-
Sericite[6]	tr	tr	tr	tr	tr	-
Chlorite[7]	tr	-	-	-	-	3
Serpentine[6]	-	-	-	-	-	9
Talc[6]	-	-	-	-	-	1
Olivine[8]	-	-	-	-	-	78
Anthophyllite[6]	-	-	-	-	-	6
Cummingtonite[9]	-	-	-	-	-	1
Hornblende[10]	-	-	-	-	-	-
Garnet	tr	-	-	1	-	-
Epidote[11]	tr	tr	tr	tr	tr	-
Allanite	tr	tr	tr	tr	tr	-
Apatite	tr	tr	tr	tr	1	-
Sphene	tr	tr	tr	-	-	-
Zircon	tr	tr	tr	tr	tr	-
Magnetite	-	-	-	tr	-	1
Ilmenite[12]	tr	tr	tr	tr	tr	-
Pyrite	-	-	-	-	-	tr
Hematite[6]	-	-	-	-	-	-
100 Qtz/Qtz+ Fspr	48	38	34	53	2	-
100 Plag/Plag+ Kspr	42	98	73	88	84	-

Table 12 (Continued)

Specimen	St. John's Ledges Granite Gneiss 610	614	609b	691	699	706	713	Silver Hill Tonalite Gneiss 2-5
Quartz	40	28	30	23	46	1	29	48
Plagioclase	13	21	20	20	3	18	8	46
(An%)[1]	(26)	(28)	(25)	(29)	(26)[2]	(30)	(28)	(30)
Microcline	45[4]	48[4]	44	51[4]	48[4]	78[4]	59[4]	1
Myrmekite	tr	-	tr	tr	tr	tr	tr	-
Biotite[5]	2	1	5	5	3	2	2	1
Phlogopite	tr	1	tr	tr	tr	tr	1	
Muscovite[6]	tr	1	tr	tr	tr	tr	1	2
Sericite[6]	tr	tr	tr	tr	-	tr	tr	tr
Chlorite[7]	tr	tr	tr	-	tr	1	tr	tr
Serpentine[6]	-	-	-	-	-	-	-	-
Talc[6]	-	-	-	-	-	-	-	-
Olivine[8]	-	-	-	-	-	-	-	-
Anthophyllite[6]	-	-	-	-	-	-	-	-
Cummingtonite[9]	-	-	-	-	-	-	-	-
Hornblende[10]	tr	-	-	tr	-	-	-	-
Garnet	-	-	-	-	-	-	-	-
Epidote[11]	tr	tr	tr	1	tr	tr	tr	tr[9]
Allanite	tr	tr	tr	tr	tr	tr	tr	-
Apatite	tr	tr	tr	tr	tr	tr	tr	tr
Sphene	tr	tr	1	tr	tr	tr	tr	tr
Zircon	tr	tr	tr	tr	tr	tr	tr	tr
Magnetite	tr	tr	-	tr	-	-	1	2
Ilmenite[12]	tr	1	tr	tr	tr	-	-	-
Pyrite	-	-	-	-	-	-	-	-
Hematite[6]	tr	tr	tr	tr	tr	tr	tr	tr
100 Qtz/Qtz+ Fspr	41	29	32	24	47	1	30	51
100 Plag/Plag+ Kspr	22	30	31	28	6	19	12	98

[1]Approximate mol.% anorthite in plagioclase determined by Michel-Levy extinction angle method.

Table 12 (continued)

[2]An% based on few measurements due to scarcity of twinned plagioclase.

[3]Antiperthite.

[4]Perthite.

[5]Biotite pleochroic formula: All specimens pale-yellow (X); Y&Z: 16-6, 18-1, 285, 254, 609b, 699, reddish-brown, green near garnet; 9-4, 610, 614, 691, 706, 613, olive-green to dark-brown.

[6]Secondary.

[7]All chlorite is Fe-rich except specimens 614, Fe/Mg=1, and 616, Mg-rich.

[8]Olivine: Fo 75-80, $2V_x$=85.

[9]Secondary Cummingtonite identification based on common occurrence of (100) twinning.

[10]Hornblende pleochroic formula: light-yellow-green (X), light-green (Y), deep-blue-green (X); specimen 691, $2V_x$=30-40 degrees, Hastingsite.

[11]Pistacite. Biaxial neg., colorless (X) to yellow-green (Z), birefringence up to 2nd order yellow.

[12]Ilmenite commonly rimmed by sphene. 614 contains exsolved hematite.

Description and location of rock specimens. Locations indicated on Plate 2.

16-6. Poorly foliated, light-gray, fine-grained, garnet-muscovite-biotite-plagioclase-microcline-quartz gneiss. Specimen collected on the northeast side of hill about 1300 m east of benchmark 1316 on Route 4 (northeast area of map).

9-4. Poorly foliated, light-gray to gray, fine-grained muscovite-microcline-biotite-quartz-plagioclase gneiss. Specimen collected south of Sharon Mountain Road opposite Hamlin Pond (northeast area of map).

18-1. Poorly foliated, light-gray, fine-grained, muscovite-biotite-plagioclase-microcline-quartz gneiss. Specimen collected 190 m southwest of sharp bend in Bound Road (central area of map).

Table 12 (continued)

285. Gray-weathering, poorly foliated, fine- to coarse-grained, garnet-muscovite-biotite-microcline-plagioclase-quartz gneiss. Specimen collected on low hill northeast of Peck Pond and south of the bend in West Woods Road (central area of map).

254. Gray-weathering, poorly to moderately-foliated, fine- to coarse-grained, muscovite-biotite-quartz-microcline-plagioclase gneiss. Specimen collected on low hill southeast of West Woods Road near the head of Guinea Brook (central area of map).

616. Brown-weathering, massive to poorly foliated, dark-gray, tremolite-phlogopite-talc-chlorite-anthophyllite-serpentine-olivine ultramafic rock. Specimen collected about 25 m east of North Kent Brook from the 680 foot elevation in the brook (south-central area of map).

610. Moderately to well foliated, pink, hornblende-biotite-plagioclase-quartz-microcline gneiss. Specimen collected at an elevation of 600 feet on the slope between North Kent Brook and Stewart Hollow Brook (south-central area of map).

614. Massive to moderately foliated, fine- to medium-grained, pink, biotite-plagioclase-quartz-microcline gneiss. Specimen collected on east flank of narrow ridge about 400 m northeast of North Kent Brook (south-central area of map).

609b. Moderately foliated, pink, biotite-plagioclase-quartz-microcline gneiss. Specimen collected at an elevation of 850 feet on the steep slope southwest of Stewart Hollow Brook (south-central area of map).

691. Moderately foliated, medium- to coarse-grained, light-gray to light-pink, hornblende-biotite-plagioclase-quartz-microcline gneiss. Specimen collected at the southern summit of Caleb's Peak (south-central area of map).

699. Poorly foliated, fine- to medium-grained, white to light-gray, biotite-plagioclase-quartz-microcline gneiss. Specimen collected at an elevation of 1100 feet, approximately 380 m north of Caleb's Peak (south-central area of map).

706. Massive to moderately foliated, medium- to coarse-grained, pink, biotite-quartz-plagioclase-microcline gneiss. Specimen collected on a small hill east of Choggam Brook near the southern edge of the Ellsworth quadrangle (south-central area of map).

Table 12 (continued)

713. Massive to moderately foliated, light-gray to light-pink, medium-grained, biotite-plagioclase-quartz-microcline gneiss, locally with abundant magnetite. Specimen collected at the top of Pond Mountain (south-central area of map).

2-5. Light-tan-weathering, poorly foliated, fine- to medium-grained, magnetite-studded, plagioclase-quartz gneiss. Specimen collected at an elevation of 1100 feet at the southwest end of Silver Hill (east-central area of map).

approximately 600 m. The contact with the Ellsworth Gneiss is not exposed but it can be approached within 50 m near the east end of Bound Road (Plate 1).

The rock is light-gray, uniform, fine- to medium-grained, poorly- to moderately-foliated gneiss consisting mainly of quartz, plagioclase, microcline microperthite and biotite (16-6, 9-4, 18-1, Table 12). Fine-grained, scattered garnet and hornblende are locally present and accessory minerals include epidote, allanite, apatite, sphene and ilmenite with secondary muscovite and chlorite. Outcrops have smooth rounded surfaces and appear homogeneous, except for zones of varied biotite content and quartz-feldspar veining. The three specimens plot as granite, granodiorite and tonalite in Figure 8.

Outcrops of similar rock types occur at the northern end of the Deming Hill Gneiss and in Macedonia Brook State Park within the Ellsworth Gneiss (803, Table 4). These occurrences suggest a complex distribution of the granodiorite gneiss within the stratigraphy. The age of the granodiorite is uncertain.

<u>Ellsworth Granodiorite Gneiss - Yeg</u>

The Ellsworth Granodiorite Gneiss intrudes the Ellsworth Gneiss in an elongate sheet-like body that crops out southeast of West Woods Road (Plate 1). Although the foliation is apparently concordant with the surrounding rocks, the map pattern indicates a discordant relationship relative to the contact between the Ellsworth Gneiss and the West Woods Gneiss, in that the granodiorite is closer to this contact toward the southwest. The approximate thickness of the intrusive across a map width

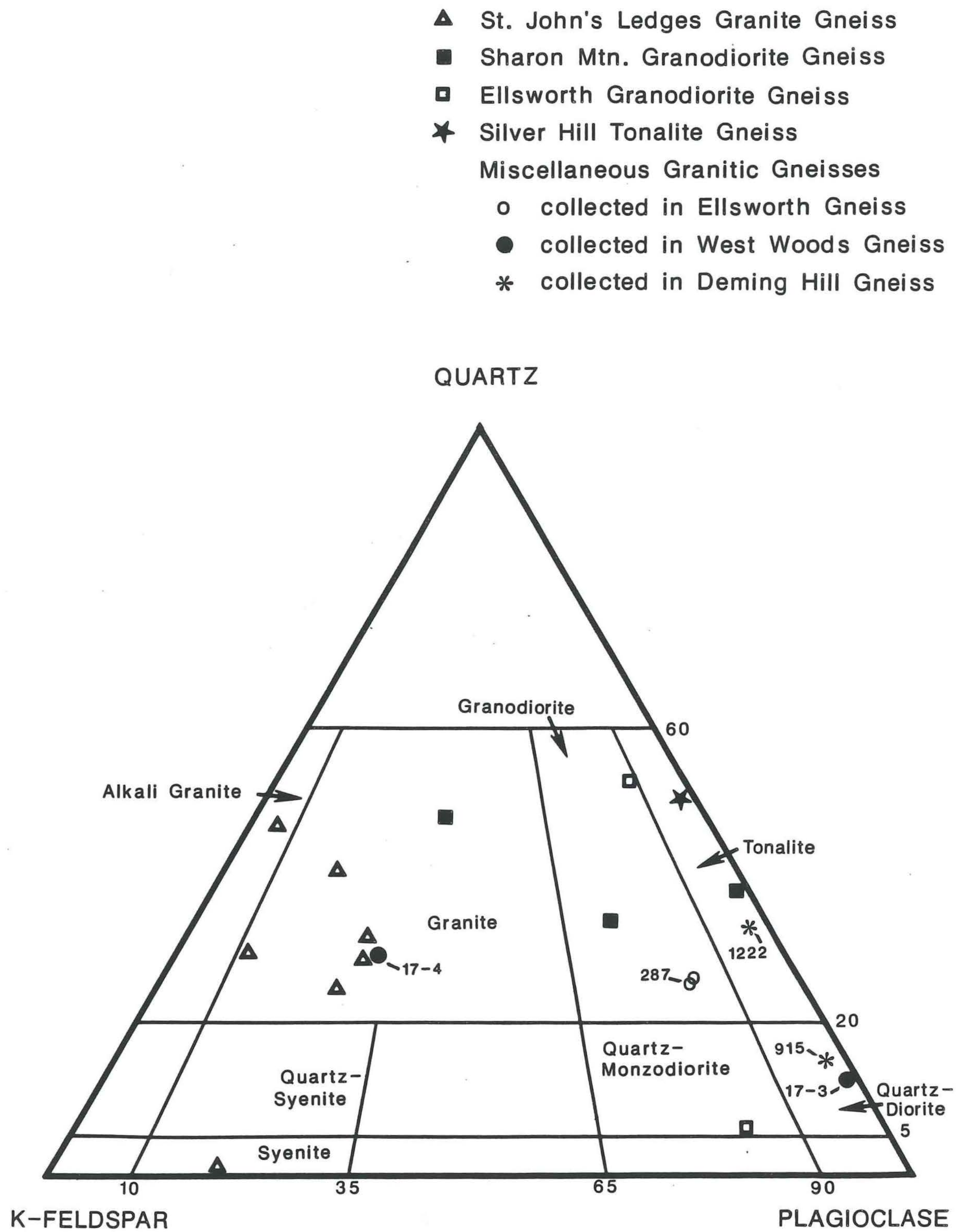


Figure 8. Plot of modal quartz, plagioclase, and K-feldspar (normalized to 100%) for metamorphosed intrusive igneous rocks in the study area. Plot is adapted from Streckeisen (1973).

of 330 m with an average dip of 66 degrees is 301 m.

Rocks of the Ellsworth Granodiorite Gneiss are typically medium- to coarse-grained, faintly to well foliated, garnet-biotite-microcline microperthite-quartz-plagioclase gneiss. Accessory minerals include epidote, allanite, apatite, zircon, magnetite, ilmenite and secondary muscovite (285, 254, Table 12). Mylonitic textures are common with rounded lenticular or irregular-shaped megacrysts of plagioclase surrounded by a fine-grained matrix of quartz, plagioclase and microcline. Biotite mainly occurs in irregular masses or lenticular pods. Red garnet is locally abundant with grains up to 3 mm in diameter. Outcrops weather with rough, light-gray surfaces on which plagioclase grains stand out. Biotite patches give a black spotted or streaked aspect to the rock surface. The two specimens plot as granodiorite and quartz-monzodiorite in Figure 8. Specimen 287 (Table 4, Figure 8) is a garnet-hornblende-biotite-microcline-quartz-plagioclase gneiss with crystals of plagioclase up to 2 cm long in a dark-gray, fine-grained matrix. This rock plots as a granodiorite and occurs in two exposures along the eastern contact of the Ellsworth Granodiorite Gneiss. It may represent a porphyritic dike rock associated with the Ellsworth Granodiorite Gneiss. The age of these rocks is uncertain.

St. John's Ledges Granite Gneiss - Ysj

The St. John's Ledges Granite Gneiss is named for the prominent exposures along the steep dip slopes from St. John's Ledges northeast to Stewart Hollow Brook (Plate 1). The granite gneiss also holds up Caleb's Peak and Fuller Mountain west of the ledges. The map pattern shows that the granite intrudes the Bread Loaf Mountain Gneiss and is in contact with the Ellsworth Gneiss to the west. At the bottom of St. John's Ledges cliffs the granite is unconformably overlain by the Cambrian Lowerre Quartzite (Plate 1).

The St. John's Ledges Granite Geniss is a pink or light-gray to light-pink, poorly foliated to well foliated, fine- to medium-grained biotite-quartz-plagioclase-microcline microperthite gneiss (610, 614, 609b, 691, 699, 706, 713, Table 12). Hastingsitic hornblende is present in small amounts (610, 691) and magnetite and ilmenite are locally abundant in small masses or as disseminated grains. Accessory minerals include epidote, allanite, apatite, sphene, zircon and secondary muscovite, chlorite and hematite. Hematite is exsolved from ilmenite in Specimen 614. In the area of Caleb's Peak the rock is medium- to coarse-grained with microcline augen up to 5 mm long. Mylonitic textures of recrystallized microcline crystals surrounding larger corroded microline grains are commonly seen in thin section. The modes plot chiefly in the granite field (Figure 8) except for two which plot as alkali granite and syenite.

The St. John's Granite Gneiss is continuous into the Kent quadrangle where it was mapped by Jackson (1980) as his Pink Granitic Gneiss unit. He also mapped the Pink Granitic Gneiss in the Precambrian rocks of the Fordham Terrane southeast of the Housatonic Highlands. Dana (1977) also mapped the Pink Granitic Gneiss in the Fordham Terrane in the New Preston quadrangle. Dana (1977) and Jackson (1980) tentatively correlated the Pink Granitic Gneiss with the ferrohastingsite-bearing Yonkers Gneiss and the pink Pound Ridge Granite Gneiss in the Manhattan Prong. These gneisses are also unconformably overlain by the Lowerre Quartzite.

Long (1969) obtained Rb-Sr ages of 575 ± 30 m.y. for the Yonkers Gneiss. Grauert and Hall (1973) analyzed zircons from the Yonkers Gneiss that give ages of 511 m.y. for Pb-206/U-238 and 515 m.y. for Pb-207/ U-235. They interpreted the U-Pb dates as reflecting the effects of Taconian and Acadian metamorphism on rocks of a primary age consistent with Long's (1969) whole rock isochron. Recently, Mose (1981) reported Rb-Sr ages of 541 ± 43 m.y. for the Yonkers Gneiss. Mose (1975) also determined a Rb- Sr isochron of 596 ± 19 m.y. for the Pound Ridge Granite Gneiss.

Another possible correlation may be made with the Tyringham Gneiss (Emerson 1898, 1899) of the Berkshire Massif (Figure 1). It is a pinkish-gray, granite to granodiorite gneiss containing hastingsitic amphibole (Ratcliffe and Zartman, 1976). Ratcliffe and Zartman (1976) obtained U-Pb ages from zircons of 1.08 b.y. to 1.04 b.y. for Pb-207/ Pb-206.

Estimated modes of specimens collected from other probable intrusive igneous rocks are plotted in Figure 8. Specimen 17-4 (Table 5) plots as a granite and comes from a pink granite gneiss sill in the West Woods Gneiss. This rock type also occurs in the Deming Hill Gneiss and may correlate with the St. John's Granite Gneiss. Specimens 268 and 915 (Table 6) plot as quartz diorite and they are typical of much of the fine- to medium-grained granitic gneiss in the Deming Hill Gneiss. Specimen 1222 (Table 6) is a hastingsite tonalite gneiss (Figure 8) that was collected from East Mountain in the Amenia quadrangle. It also occurs north and south of Clark Hill Road. On East Mountain it contains inclusions of the amphibolite country rock and it is cut by medium- to coarse-grained biotite granite gneiss. Specimen 17-3 (Table 5) is a garnet-augite-hornblende quartz diorite (Figure 8). It probably represents a small dike intruded into the West Woods Gneiss.

Silver Hill Tonalite Gneiss - Ysh

The Silver Hill Tonalite Gneiss is characterized by abundant magnetite disseminated in a leucocratic, light-gray to light-pinkish-brown-weathering, granitic gneiss. The gneiss occurs in a northeast trending zone about 3.5 km long extending from Buck Hill across Silver Hill to Bread Loaf Mountain (Plate 1). Intrusive contacts with the Bread Loaf Mountain Gneiss are not exposed but the mineralogical composition, the distribution of magnetite-bearing gneiss and its position relative to the upper and lower contacts of the Bread Loaf Mountain Gneiss suggest an intrusive origin for the Silver Hill Gneiss. The thickness of the sheet of Silver Hill Tonalite Gneiss is 400 m at the thickest area on the east flank of Buck Hill but it is only 210 m on Silver Hill where the best control on the upper and lower contacts exists.

The estimated mode of Specimen 2-5 (Table 12) plots in the tonalite field as shown in Figure 8. This specimen, collected at the southwest end of Silver Hill, contains 2% magnetite and represents the more magnetite-rich leucocratic variety of the gneiss. It probably doesn't represent the range of feldspar compositions because there are outcrops of magnetite-rich, light-pink granitic gneiss associated with these rocks along Route 4, on the south flank of Bread Loaf Mountain and on the southeast flank of Buck Hill. Blocks of the magnetite-rich gneiss at the base of Buck Hill show thin magnetite veins (up to 2 cm) or discontinuous layers parallel to the poorly developed foliation. On Bread Loaf Mountain and parts of Buck Hill the Silver Hill Gneiss exhibits higher mafic mineral content with compositional layering defined by thin zones spotted or layered with medium-grained hornblende or patches of biotite. An outcrop of dark, medium-grained amphibolite occurs within the mapped area of Silver Hill Gneiss on Bread Loaf Mountain. Similar amphibolite is present within the Bread Loaf Mountain Gneiss about 250 m to the northeast of the Silver Hill Gneiss contact. This relationship may indicate that the Silver Hill intruded amphibolites within the Bread Loaf Mountain Gneiss. However, the Silver Hill may represent metamorphosed felsic volcanics and the amphibolites, corresponding metamorphosed mafic volcanics. The intrusive interpretation for the origin of the magnetite-rich leuco-gneiss is favored, however, by the absence of the rocks along strike to the southwest (Plate 1).

STRUCTURAL GEOLOGY

INTRODUCTION

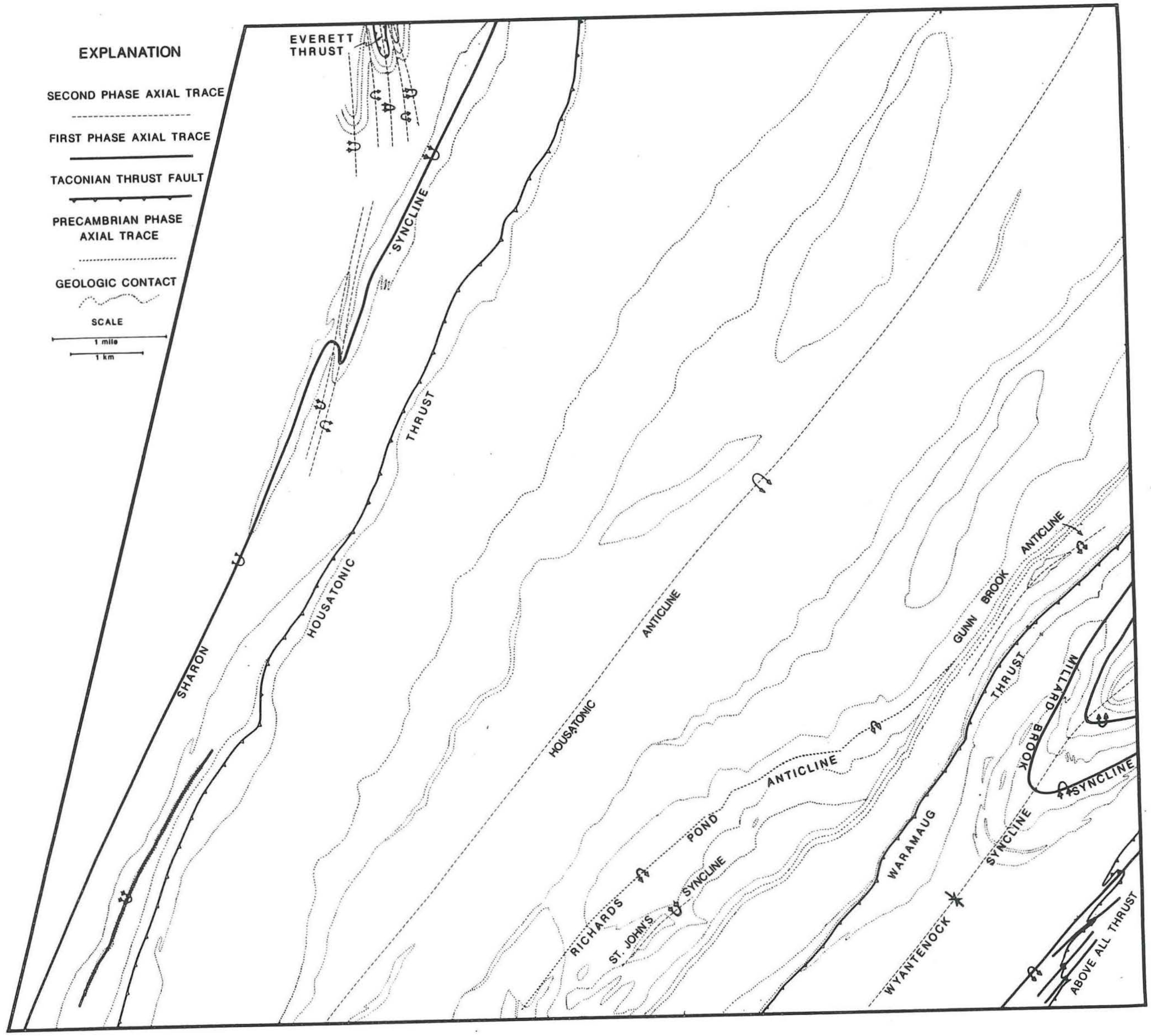
The geologic map pattern in the Ellsworth-Amenia area is the product of at least four major phases of folding and the development of four thrust faults. The general configuration of the stratigraphic units defines a northeast-trending anticlinorial basement uplift of previously deformed Precambrian rocks which is thrust westward on the overturned west limb. The anticlinorium is flanked on the east and west by multiply folded autochthonous Cambrian and Ordovician cover rocks and overlying Taconian thrust sheets which occupy major northeast trending synclines with associated minor anticlines (Figure 9 and Plate 1).

The tectonic events responsible for the deformations in the Ellsworth-Amenia area is attributed to the Grenvillian, Taconian and Acadian orogenies (Figure 10). At least one phase of probable Grenvillian folding is indicated by the repetition of stratigraphic units around an isoclinal fold hinge and the truncation of the folded units by the unconformity beneath the overlying Cambrian Lowerre Quartzite. Separate Taconian thrust faults transported the Everett and two slices of Manhattan C rocks westward over the autochthonous cover rocks. Major isoclinal folding occurred after thrust sheet emplacement and was responsible for the prominent axial plane schistosity and mineral lineations that developed synchronously with peak Taconian metamorphism. Uplift and thrusting of basement gneisses over the cover rocks probably occurred during these Taconian events. Folding attributed to Acadian deformation folded the isoclinal Taconian folds and thrust sheets producing steeply dipping northeast to north-northwest trending axial plane cleavage. Late stage folding produced open folds with a northwest trending axial plane cleavage.

Names of major folds and thrust faults in the Ellsworth-Amenia area are chosen from nearby geographic localities or, if previously named by other workers in the region, the existing name is used. These features are shown on the tectonic map of the area in Figure 9. Analysis of structural geometry was aided by dividing the area into fifty small

Figure 9.

Tectonic map of the Ellsworth-Amenia area showing thrust faults and axial traces of major folds.



DEFORMATIONAL PHASES	DESCRIPTION	IGNEOUS INTRUSION	OROGENY
D_5 (Third-Phase Paleozoic Folds)	Open third-phase folds; northwest axial plane slip cleavage		Acadian ?
D_4 (Second-Phase Paleozoic Folds)	Major tight to open folds; upright north to northeast axial plane cleavage Possible staurolite grade metamorphism (Jackson, 1980)		Acadian
D_3 (First-Phase Paleozoic Folds)	Major isoclinal folds; axial plane foliation throughout area; prominent mineral lineations; peak metamorphism to sillimanite grade Housatonic thrust brings basement up over cover rocks (?)	Candlewood Lake Pluton (442 m.y.) pre-dates foliation in Kent (Jackson, 1980; Mose, 1982)	Taconian
D_2 (Taconian Thrust Faults)	Everett, Waramaug and Above All Thrusts bring slope sequence over shelf deposits; folds identified by Dana (1977) in New Preston quadrangle pre-date Above All Thrust		
	Middle Ordovician Unconformity		
	Erosion across the carbonate bank due to block faulting results in Manhattan (A) deposition on different Inwood members		
	Basal Unconformity		
D_1 (Precambrian Folds)	Major isoclinal folds; foliation sub-parallel to gneissic layers; granulite facies metamorphism	St. John's Granite and other granites post-date at least one pC foliation; timing of other plutons uncertain	Grenvillian

Figure 10. Sequence of tectonic events in the Ellsworth-Amenia area.

subareas based on the distribution of outcrop measurements of minor structural elements around major map scale features. These subareas were combined where beta diagrams for early foliation and bedding showed similar patterns. Twenty-three subareas were created in this manner as shown in Figure 11 that also shows representative orientations of minor structural features. Beta diagrams, equal area plots of linear features, and poles to axial plane features were prepared for each subarea and incorporated into Plates 3 and 4.

MAJOR PRECAMBRIAN FOLDS

A Precambrian isoclinal anticline is truncated beneath the Cambrian Lowerre Quartzite along the west side of the Housatonic River valley in the Ellsworth quadrangle (Figure 9). The fold is named after Richards Pond which occupies the axial region of the fold near the fold hinge (Plate 1). The contact between the Bread Loaf Mountain and Richards Pond defines the anticlinal fold hinge which plunges steeply south-southeast.

The plunge of the fold is determined by the beta diagram for compositional layering in the Bread Loaf Mountain Gneiss shown in Plate 3 (sub-area N). The anticlinal geometry of the fold served as the basis for the ordering of the stratigraphic units discussed earlier. The anticline is overturned toward the west indicating that all of the gneisses west of the anticline are inverted. The axial trace of the fold passes beneath the Lowerre Quartzite along strike to the northeast as does the contact between the Richards Pond and Bread Loaf Mountain on the southeast limb of the anticline. The axial trace trends southwest into

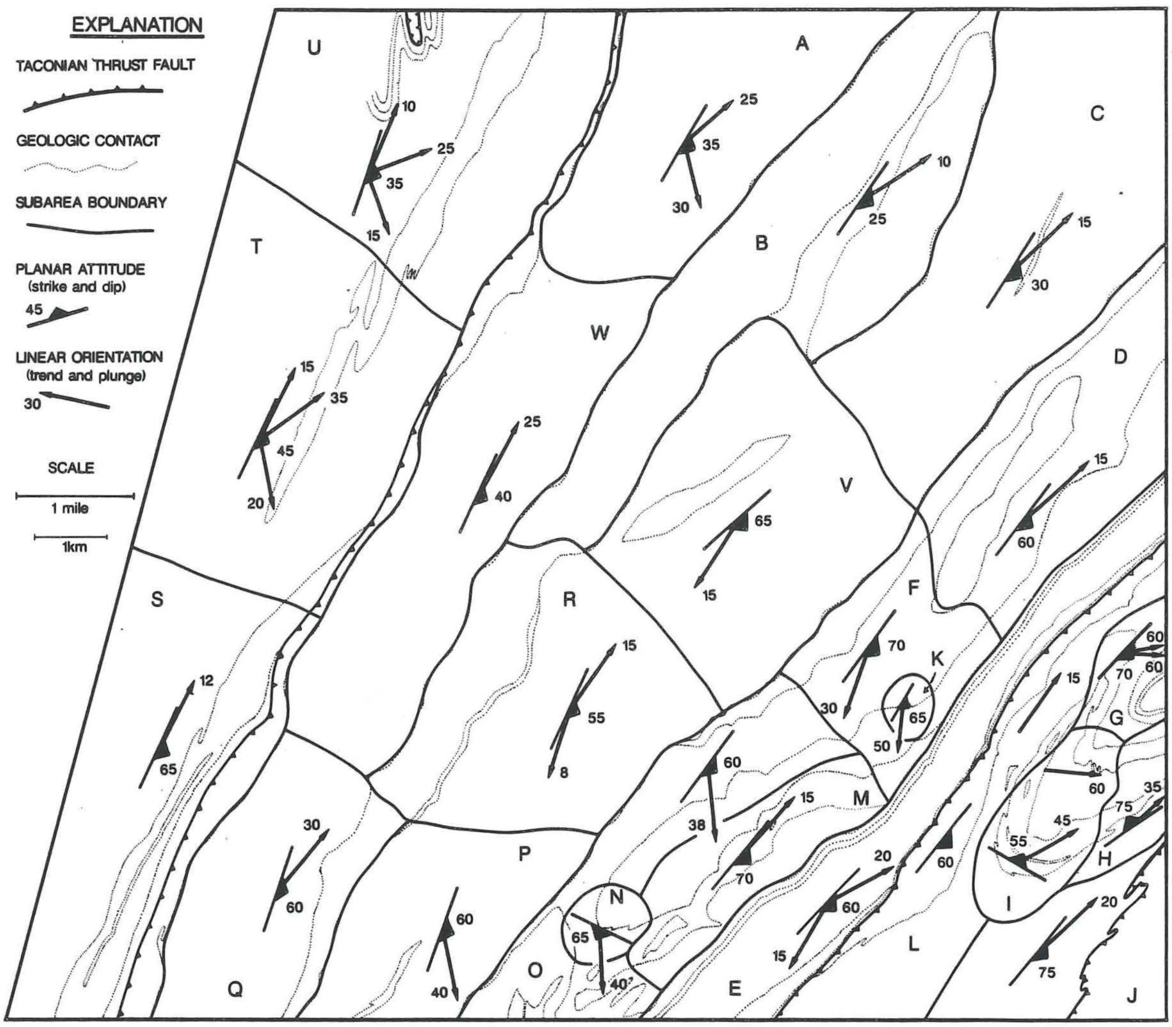


Figure 11. Map of subarea divisions (A through W) showing representative attitudes of foliation, bedding, mineral lineations and fold axes for each subarea.

the Kent quadrangle through the Bread Loaf Mountain Gneiss and the intrusive St. John's Ledges Granite Gneiss (Figure 9).

The absence of other Precambrian map-scale isoclinal folds may be explained in two ways. The first possibility is that the Richards Pond anticline represents a major fold and evidence for closure of the Ellsworth Gneiss and overlying units may be evident south of the study area. The second explanation involves possible thrusting or other dislocations within the Precambrian terrane associated with Grenvillian or Paleozoic deformation. The zone along the contact between the Ellsworth Gneiss and Bread Loaf Mountain Gneiss, and respective contacts with the Stony Brook Gneiss are areas for further study regarding possible thrust fault zones.

TACONIAN THRUST FAULTS

Four separate major thrust faults occur in the Ellsworth-Amenia area (Plate 1). These faults are named the Everett Thrust, Waramaug Thrust, Above All Thrust, and the Housatonic Thrust. They will be discussed in this order which agrees with the general chronology and stacking order of correlative thrust slices in northwestern Connecticut and southwestern Massachusetts (Ratcliffe and Harwood, 1975; Ratcliffe, 1979) (Figure 9). There is little evidence in the study area concerning the relative timing of movement on these faults. However, regional relationships indicate that the most western thrust slices in the cover rocks were emplaced along the earliest and lowest thrusts, followed by successively younger and higher thrusts toward the east. These thrusts were succeeded by the basement thrusts.

Everett Thrust

The Everett thrust is exposed in a small area in the northwest corner of the Ellsworth quadrangle (Plate 1). The allochthonous pelitic schist of the Cambrian Everett Formation overlies the Middle Ordovician Manhattan A schist member in the keel of a small map-scale second phase syncline (D_4, Figure 10). Extensive areas of Everett schist occur to the north in the Sharon quadrangle (Gates, 1979) and further northward in Massachusetts. Zen (1967) assigned these rocks to the Everett slice, one of the numerous Taconic slices present in eastern New York and western New England.

Waramaug Thrust

The Waramaug thrust is exposed as a linear northeast trending fault trace on the southeast side of the Housatonic River valley (Plate 1). Stratigraphic evidence for thrust faulting exists in the contact between the Middle Ordovician Manhattan A and the overlying Cambrian Manhattan C. The presence of only 50 cm of the Schist Member of the Manhattan A between the Manhattan C Schistose Gneiss Member and Member B of the Inwood Marble at Kent Falls State Park seems best explained by tectonic thinning of the Manhattan A. Structural evidence for the fault exists in the truncation of the contact between the Schistose Gneiss and Schistose Granulite members of the Manhattan C on the west flank of Flanders Mountain (Plate 1). The Waramaug Thrust is folded by the earliest phase of Paleozoic folding to the south in the Kent quadrangle (Jackson, 1981).

Above All Thrust

The Above All thrust is mapped as the contact between the Schistose Granulite and Warren Members of the Manhattan C (Plate 1). No evidence for thrusting exists in the Ellsworth quadrangle. However, the contact is shown as a thrust based on truncation of Manhattan C units along the contact about 2 miles to the southwest in the New Preston quadrangle (Dana, 1978). Early phase map-scale folds along the contact shown in Figure 9 indicate early movement along the thrust similar to the Waramaug Thrust.

Housatonic Thrust

The Housatonic thrust occurs along the western edge of the basement terrane in the Ellsworth and Amenia quadrangles (Plate 1). Map-scale evidence for thrusting is shown by the contact of Lowerre Quartzite against different members of the younger Inwood Marble along the fault trace. The Lowerre Quartzite occurs on the hanging wall of the thrust as shown on cross-sections A-A' and B-B' (Plate 5). Lowerre appears overturned to the west nearly everywhere except for local areas of west dip on East Mountain. Later phases of folding and posssibly minor faults contribute to the variations in dip. The map pattern of Lowerre between the fault and basement rocks indicates thickening caused by folding or stacking of minor fault slices as well as thinning probably caused by shearing and attenuation along the fault surface. Shearing between Lowerre and basement gneisses is locally indicated by mylonitic foliation near the contact which probably represents small amounts of localized detachment and strain.

Inwood Marble members close to the fault occur in the footwall and they are steeply overturned to the west along the west side of East Mountain. Footwall exposures of Inwood near the fault are scarce to the north but dips in general appear gentler (sub-area U, Figure 11) than areas to the south and northern outcrops of Lowerre in the hanging wall have moderate east dips. These observations are depicted in cross-sections A-A' and B-B' as a change from a steeply dipping fault south of South Amenia to a gentler dipping fault toward the north end of the study area.

MAJOR PALEOZOIC FOLDS

First-Phase Folds

The Millard Brook and Sharon synclines are two first-phase folds identified in the Ellsworth and Amenia quadrangles. Their axial traces are shown in Figure 9 with the axial traces of minor first-phase folds. Repetition of the Amphibolite and Schistose Granulite Members of the Manhattan C defines the Millard Brook syncline (Plate 1). The recumbent isoclinal syncline is overturned toward the southwest and the axial surface has been folded by the second-phase Wyantenock syncline (Figure 9). An anchor-shaped map pattern is created due to fold interference with the steeply dipping northeast trending axial plane of the Wyantenock syncline. The interference pattern suggests that if the effects of the later folding were removed the Millard Brook axial surface would generally strike west-northwest and dip gently northeast.

The Sharon syncline is a stratigraphic syncline delineated by the isoclinal folding of Inwood Marble Members D and C (Plate 1). The fold is overturned toward the northwest and plunges gently northeast creating the narrow zone of Member D which occupies the axial region of the fold. The axial surface of the Sharon syncline is folded by a phase two fold north of Amenia Union (Figure 12, Plate 1).

The parallelism between the axial trace of the Sharon syncline and the fault trace of the Housatonic thrust suggests their contemporaneous development. If so, this implies later development of the Housatonic thrust compared with the folded Waramaug and Above All thrusts. Furthermore, the different orientations of the first phase Sharon syncline and Millard Brook syncline may be explained by the influence of different tectonic effects experienced by hanging wall and footwall domains during basement uplift and subsequent thrusting associated with the Housatonic thrust.

Second-Phase Folds

Basement-cover relations in the Housatonic Highlands generally define a doubly-plunging large-scale anticlinorium which is thrust westward on the overturned west limb. This geometry is caused by refolding of thrusted basement and cover rocks by a large-scale second-phase fold referred to here as the Housatonic anticline (Figure 9). The Housatonic anticline may represent a composite structure of several smaller anticlines and synclines that converge as they plunge northeast and southwest. Basement stratigraphy does not define the Housatonic

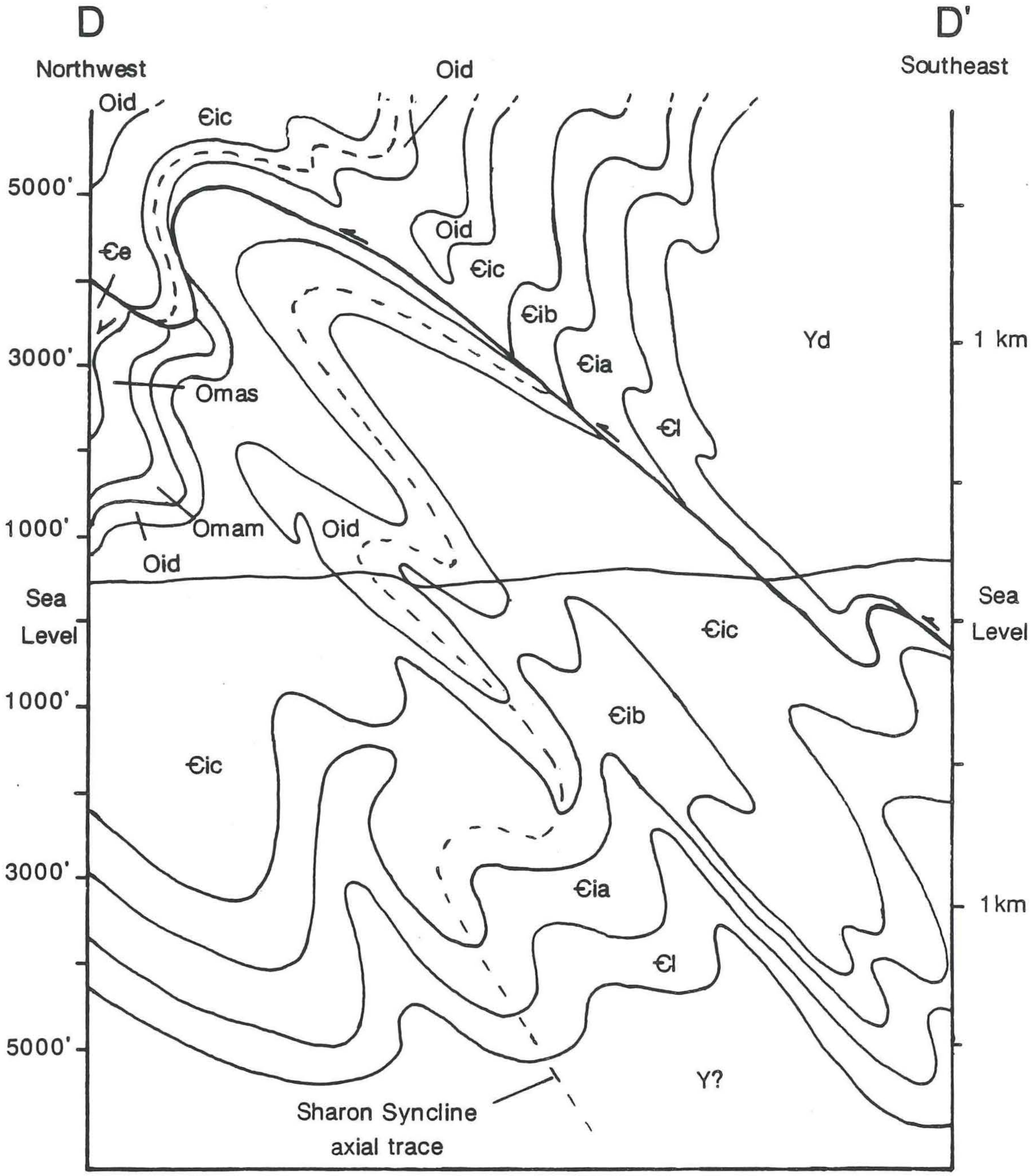


Figure 12. Cross section D - D' (see Plate 1) through refolded Sharon Syncline.

anticline, which suggests that the axis or axes are near horizontal in the map area and that the exposed gneisses occur on the limbs of the folds. Cross-sections A-A' and B-B' (Plate 5) diagramatically depict this interpretation.

The east limb of the Housatonic anticline forms the west limb of the second phase Wyantenock syncline (Figure 9) which is defined in the Manhattan C (Plate 1). The fold plunges moderately northeast and the axial plane trends northeast and appears nearly vertical (Figure 9, Plate 5, A-A'). The Wyantenock syncline appears tightest in the axial region around Whitcomb Hill (Plate 1) as depicted in section A-A' (Plate 5) and is progressively more open toward the southwest with little influence where the axial plane crosses section C-C' (Plate 5).

A couple of small second-phase map-scale folds occur in the Housatonic valley (Plate 1, Figure 9). The Gunn Brook anticline brings Inwood Marble Member A up into the core of a shallow doubly plunging anticline that is overturned toward the west. The St. John's syncline exposes an isolated body of Lowerre in the keel of an overturned fold (Plate 5, B-B'). The syncline plunges gently northeast with a steep east-dipping axial plane.

The Sharon syncline in the Amenia quadrangle is refolded by a second-phase fold (Figure 9). The fold axis plunges northeast with a west side up sense of motion and the axial trace trends north-northeast and dips moderately to the east. Figure 12 shows a cross-section through this fold and the "hook" type interference pattern created by the subparallel axial planes of the two folds.

Third-Phase Folds

Third-phase folds are primarily evident as minor structural features in the Ellsworth and Amenia quadrangles. The minor features exhibit north- to northwest-trending axial plane cleavage that typically dips moderately northeast with fold axes that plunge northeast or southeast. Map-scale evidence for this phase of folding may exist in the North Kent area (Plate 1) where a pronounced change in the strike of several Precambrian units and overlying cover rocks suggests the influence of late stage open folds.

MINOR STRUCTURAL FEATURES

Precambrian Folds

Minor structural features in Precambrian rocks associated with Precambrian folds are difficult to distinguish from younger features produced by Paleozoic deformations. Truncation of gneissic foliation in outcrops exposing the unconformable contact between Lowerre and basement indicates that Precambrian penetrative deformation occurred but overprinting of Paleozoic fabrics and rotation of Precambrian structural elements toward parallelism with younger features makes correlation of minor features with Precambrian folding uncertain.

Gneissic foliation parallel to compositional layering in the Bread Loaf Mountain gneiss defines a prominent beta maximum (subarea N, Plate 3) in the hinge region of the Richards Pond anticline. The fold axis indicated by the beta maximum plunges 50 degrees south-southeast which is approximately parallel to a prominent hornblende mineral lineation and minor isoclinal fold axes measured in the same area (Plate 4). A weak axial plane foliation accompanies several of the minor folds which appears at a high angle to compositional layering.

A comparison of sub-areas within the basement terrane shows that beta maxima for sub-areas O and P (Plate 3) closely coincide with the maximum in sub-area N. Sub-areas O and P show a stronger influence from Precambrian folding near the Richards Pond anticlinal hinge than other areas which exhibit girdles with gently northeast- or southwest-plunging maxima that probably reflect the overprint of Paleozoic second-phase folding.

Taconian Thrust Faults

Minor structural features which appear related to Taconian thrust faults are associated with the Everett and Housatonic thrusts. A prominent east-west trending quartz lineation occurs in the Manhattan A schist member immediately beneath the Everett thrust surface (Figure 13). This lineation does not appear related to any minor folds, thus it is interpreted as a fault-related feature. Prominent east-west trending quartz lineations also occur in the Lowerre Quartzite on the upper plate of the Housatonic thrust (Figure 13). These lineations are best developed where they are associated with a mylonitic foliation locally developed in the Lowerre and Deming Hill Gneiss adjacent to their mutual contact.

First-Phase Paleozoic Folds

Minor features associated with first-phase folds in the Ellsworth

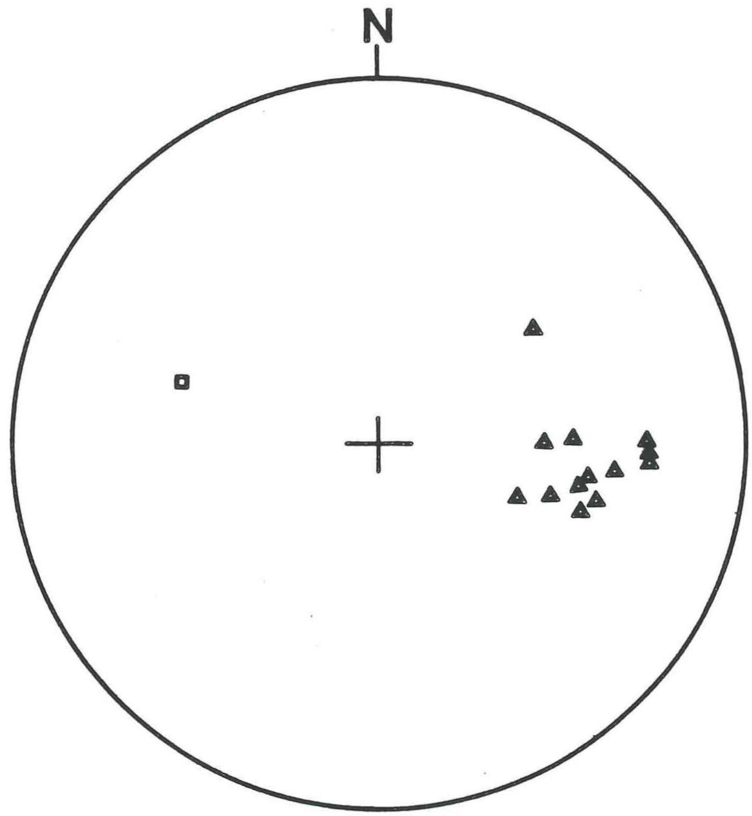


Figure 13. Equal area projection of east-plunging quartz lineations (▲, n=13) in the Lowerre Quartzite and Manhattan A Schist Member and a pole to mylonitic foliation (◘, n=1) in the Lowerre Quartzite. The features probably formed during Taconian thrusting related to the Everett and Housatonic Thrusts.

and Amenia quadrangles include isoclinal folds, the predominant foliation and mineral lineations. A few isoclinal folds were observed in the Manhattan C schists and Inwood Marble and their orientations are shown on equal area plots in Figure 14. The pervasive foliation throughout the area is formed by the preferred orientation of micas parallel to the axial plane of the isoclinal folds. This foliation is typically subparallel to bedding, in the cover rocks, or the gneissic foliation in the Precambrian rocks. Mineral lineations associated with first-phase folds are only identified in the Manhattan C rocks where prominent sillimanite lineations occur in the schists and the amphibolite member has a pronounced linear fabric of parallel hornblende and plagioclase grains. These lineations are parallel to axes of first phase isoclinal folds or intersection lineations of foliation on bedding. The sillimanite lineation is the result of the preferred orientation of elongate sillimanite needles and sillimanite nodules in the plane of the foliation. The hornblende lineation appears to be parallel to the sillimanite lineation in outcrops containing both. Hornblende lineation forms the dominant fabric in amphibolite due to the lack of platy minerals to form a strong foliation. The general eastward plunge of these lineations is shown in Figure 14 (Plot b). First phase lineations associated with the western area of Inwood Marble are limited to some intersection lineations of bedding with foliation as shown in Figure 14 (Plot a). The variety of linear orientations shown in Figure 14 is the result of rotation caused by later folding.

a)

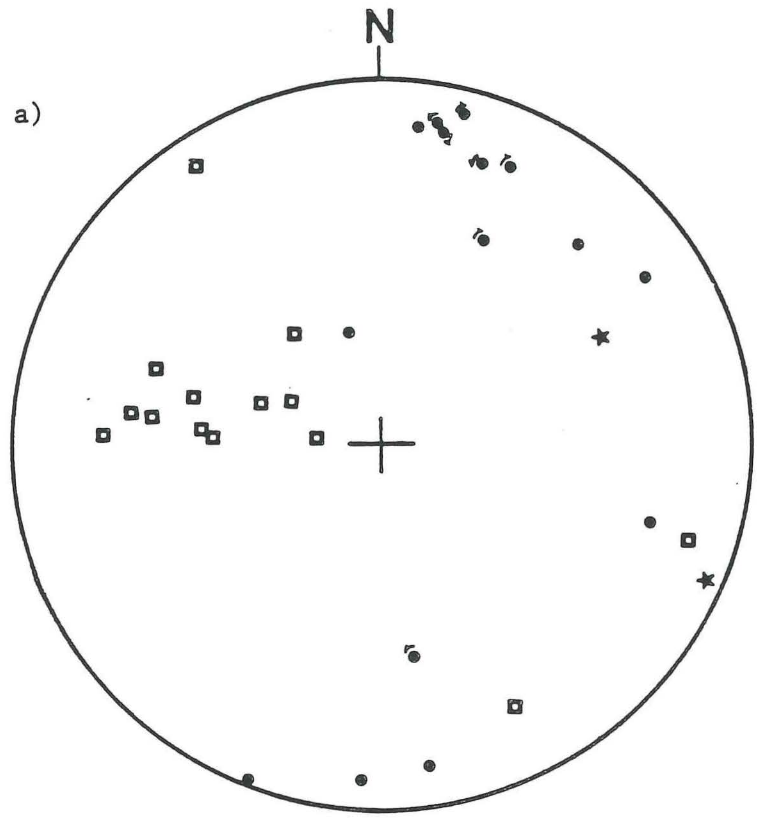


Figure 14. Equal area projections of minor structural features related to first-phase folds in cover rocks.

Fold axis with rotation sense

Mineral lineation

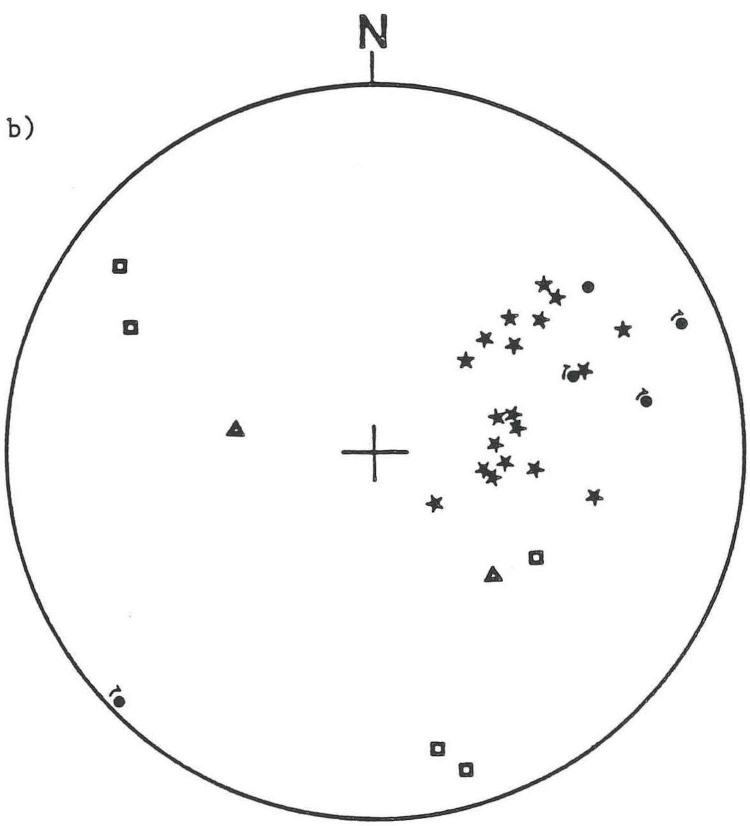
Foliation

Axial plane

a) Measured west of Housatonic basement rocks:
n=15, n=2
n=14

b) Measured east of Housatonic basement rocks:
n=5, n=19
n=5, n=2

b)



Second-Phase Folds

Second-phase folds such as the map-scale Wyantenock syncline (Figure 9) and associated minor folds are the most commonly observed minor folds in the Ellsworth-Amenia area. The orientation of girdles and beta maxima in most of the sub-areas (Plate 3) are the result of second-phase folding of the early foliation. The variation in trend and plunge of the beta maxima shown in Plate 3 is reflected in the plot of minor folds in the cover rocks (Figure 15) which may plunge steeply to the northeast or gently north-northeast to south-southwest. Second-phase minor folds are tight to open folds that exhibit a combination of similar and parallel fold style. These folds are typically asymmetrical and overturned toward the west with an east over west sense of rotation. Exceptions to that rotation sense occurs on the east limb of the Wyantenock syncline where a west over east rotation agrees with the map-scale feature. In the Lowerre and Inwood rocks of the Housatonic valley and Manhattan C rocks the folds have steep axial planes that locally dip steeply to the west, but generally they dip southeast to east (Figure 15, Plot b). An axial plane slip cleavage is developed in most schistose rocks or phlogopitic marbles, but is weakly developed or absent in granular rocks such as the Precambrian gneisses or purer marbles.

Lineations associated with second-phase folds are primarily represented by parallel alignment of micas, hornblende and quartz. The orientation of these minor features is plotted in Figure 15.

Third-Phase Paleozoic Folds

The first- and second-phase foliations or cleavage are deformed by

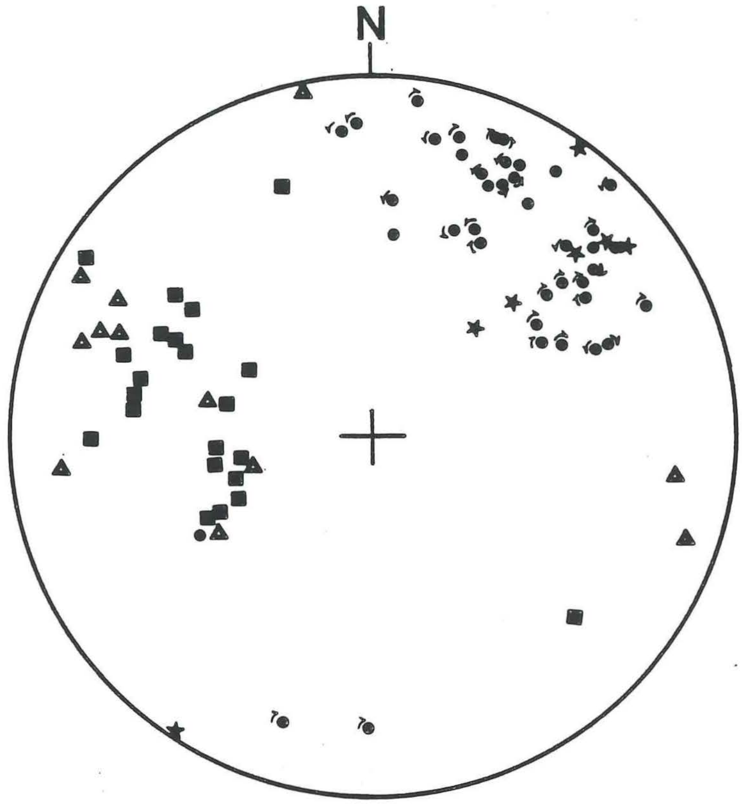
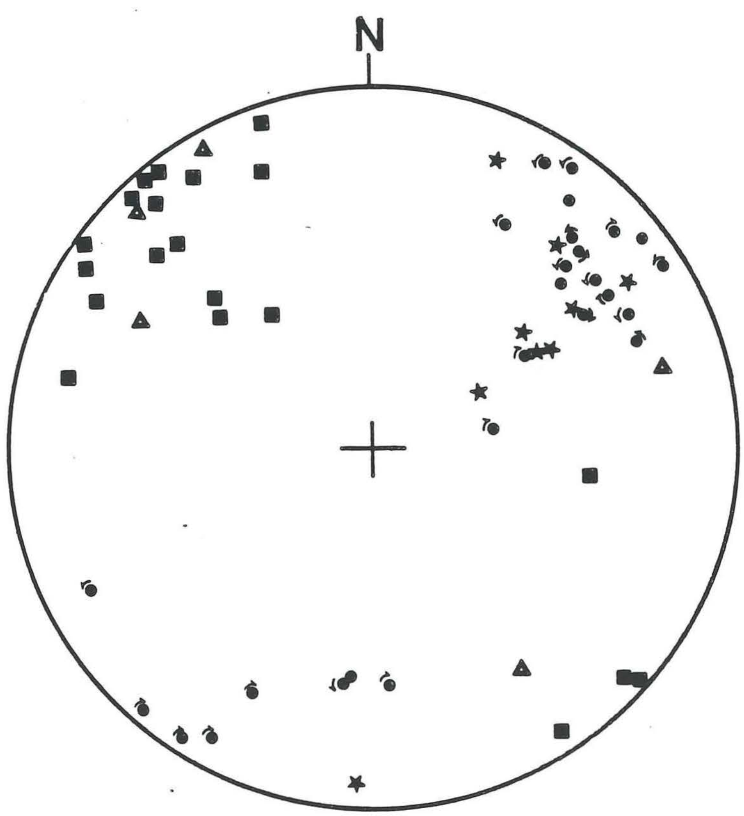


Figure 15. Equal area projections of minor structural features related to second-phase folds in cover rocks.

- Fold axis with rotation sense
- Mineral lineation
- Cleavage
- Axial plane

a) Measured west of Housatonic basement rocks:
● n=40, ★ n=7
■ n=22, ▲ n=12

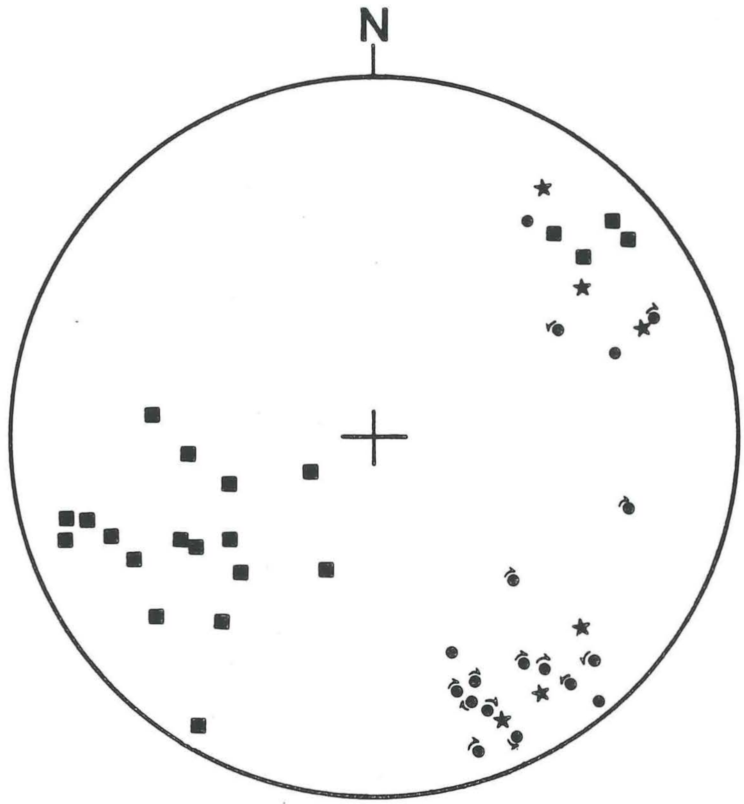
b) Measured east of Housatonic basement rocks:
● n=26, ★ n=9
■ n=20, △ n=5



third-phase folds that have an axial plane slip cleavage that is prominently developed in the well bedded Member D of the Inwood Marble. These folds plunge gently southeast or northeast. The slip cleavage typically strikes northwest and dips moderately northeast as shown in Figure 16 (Plot A), but southwest dip locally occurs. Biotite lineations occur parallel to open southeast-plunging third-phase folds that locally create basin and dome interference patterns with second-phase minor folds that plunge gently northeast.

METAMORPHISM

At least three phases of regional metamorphism are recognized in southwestern New England and southeastern New York. Grenvillian granulite facies metamorphism of the basement rocks preceded Ordovician and Devonian metamorphisms that accompanied the Taconian and Acadian orogenies, respectively. Figure 17 shows the regions where the highest grade assemblages are interpreted to belong to either Taconian or Acadian metamorphisms and it shows the areas of overprinted Grenvillian basement. The Ellsworth and Amenia quadrangles straddle Grenvillian basement in an area where inferred Taconian metamorphism progrades eastward from the staurolite zone up to the sillimanite K-feldspar zone (Plate 1). No sillimanite-K-feldspar-bearing assemblages were seen, but the isograd mapped by Jackson (1980) in the Kent quadrangle is extrapolated through the southeast corner of the Ellsworth quadrangle (Plate 1) where sillimanite zone assemblages are common in the Manhattan C schists. Staurolite zone assemblages occur in the northwest corner of the Ellsworth quadrangle in the Everett Formation. Based on the location of



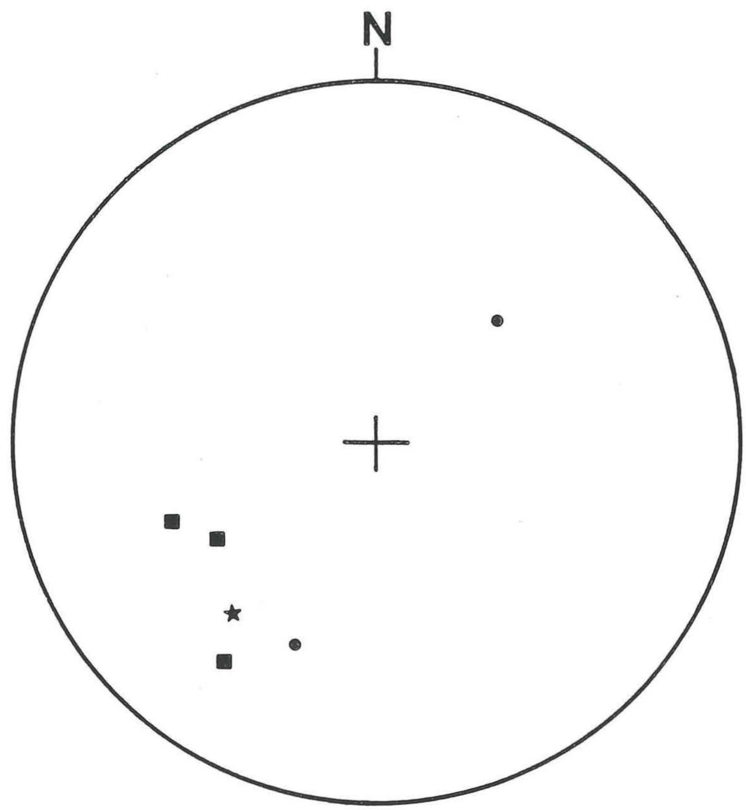


Figure 16. Equal area projections of minor structural features related to third-phase folds in cover rocks.
- Fold axis with rotation sense
- Mineral lineation
- Cleavage

a) Measured west of Housatonic basement rocks:
- n=18, n=6
- n=21

b) Measured east of Housatonic basement rocks:
- n=2, n=1
- n=3

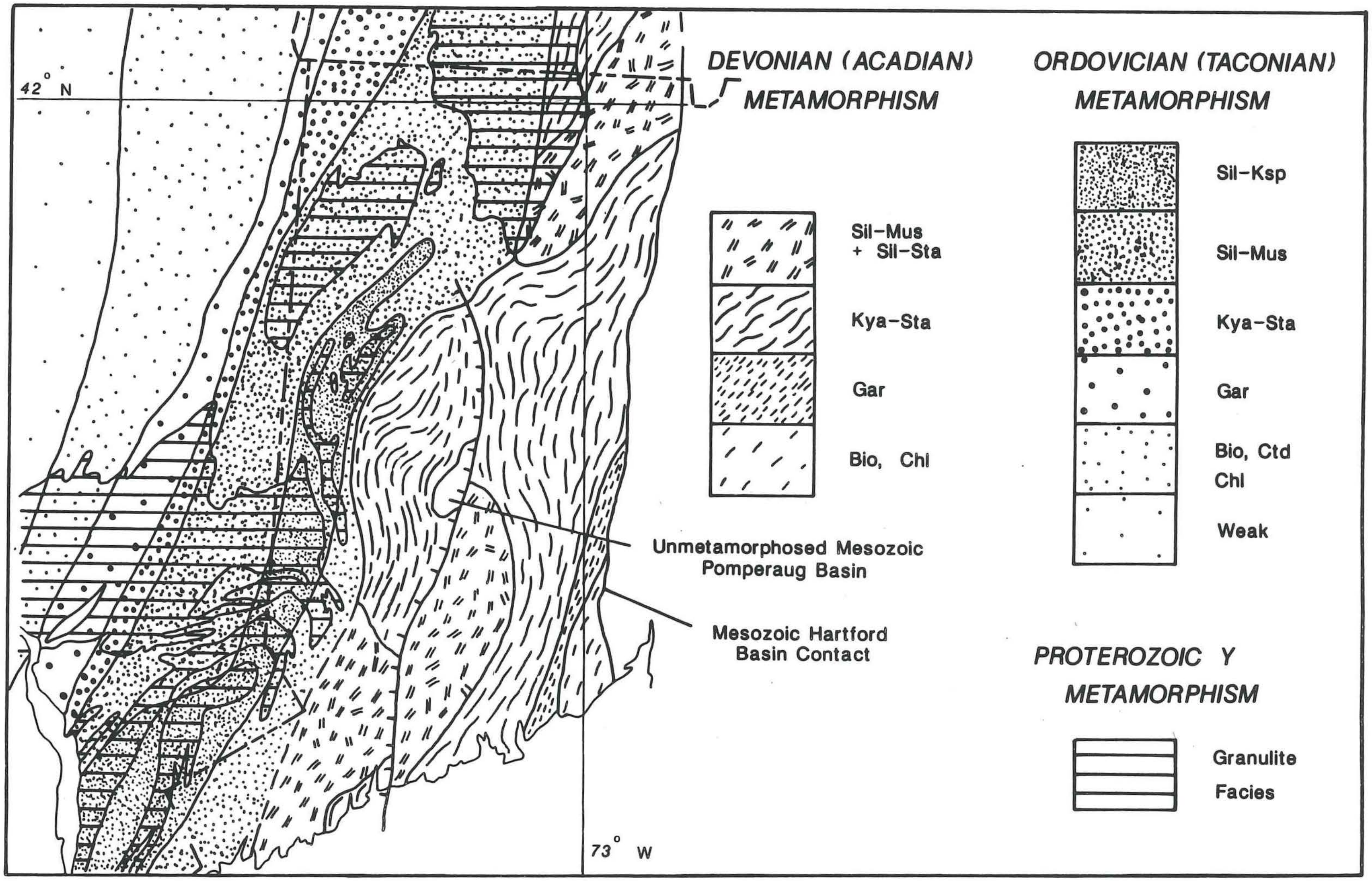


Figure 17. Regional metamorphic map of western Connecticut, southeastern New York and southwestern Massachusetts. Metamorphic zones or facies are ascribed to Grenvillian, Taconian or Acadian events with no attempt to portray overlap between Paleozoic metamorphisms (adapted from Robinson, 1983).

these assemblages and the position of the sillimanite isograd mapped by Balk (1936) and refined by Vidale (1974) in the Dover Plains quadrangle, the basement rocks in the Ellsworth and Amenia quadrangles most likely lie within the Taconian sillimanite zone as shown in Figure 17. Acadian overprinting of the Cambrian-Ordovician rocks is not fully understood but its effects are suggested by textural evidence and a few Devonian mineral dates in the region (Long, 1962; Zen, 1966).

PRECAMBRIAN REGIONAL METAMORPHISM

Evidence for Precambrian metamorphism is based on structural features with associated fabrics and interpreted relict mineral textures. The truncation of the Richards Pond anticline by the basal Paleozoic unconformity indicates a period of intense Precambrian folding and suggests probable metamorphism. Hornblende and biotite lineations and axial plane foliation to minor folds interpreted to be associated with the anticline support the idea of Precambrian metamorphism accompanying folding.

Locally preserved augite (1437, 809, 17-3, Table 5) containing "001" and "100" lamellae (Jaffe et al., 1975) of hornblende formed by replacement of pigeonite exsolution lamellae suggest metamorphism under granulite facies conditions similar to those described by Jaffe (1973) for the Monroe quadrangle in the Hudson Highlands. Figure 18 shows these features in specimen 17-3. The fineness of the three sets of lamellae and their relative orientations are similar to those seen in other metamorphic rocks (Jaffe et al., 1975; Robinson, 1980) argue in favor of their origin from low temperature exsolution during metamorphism. Hall

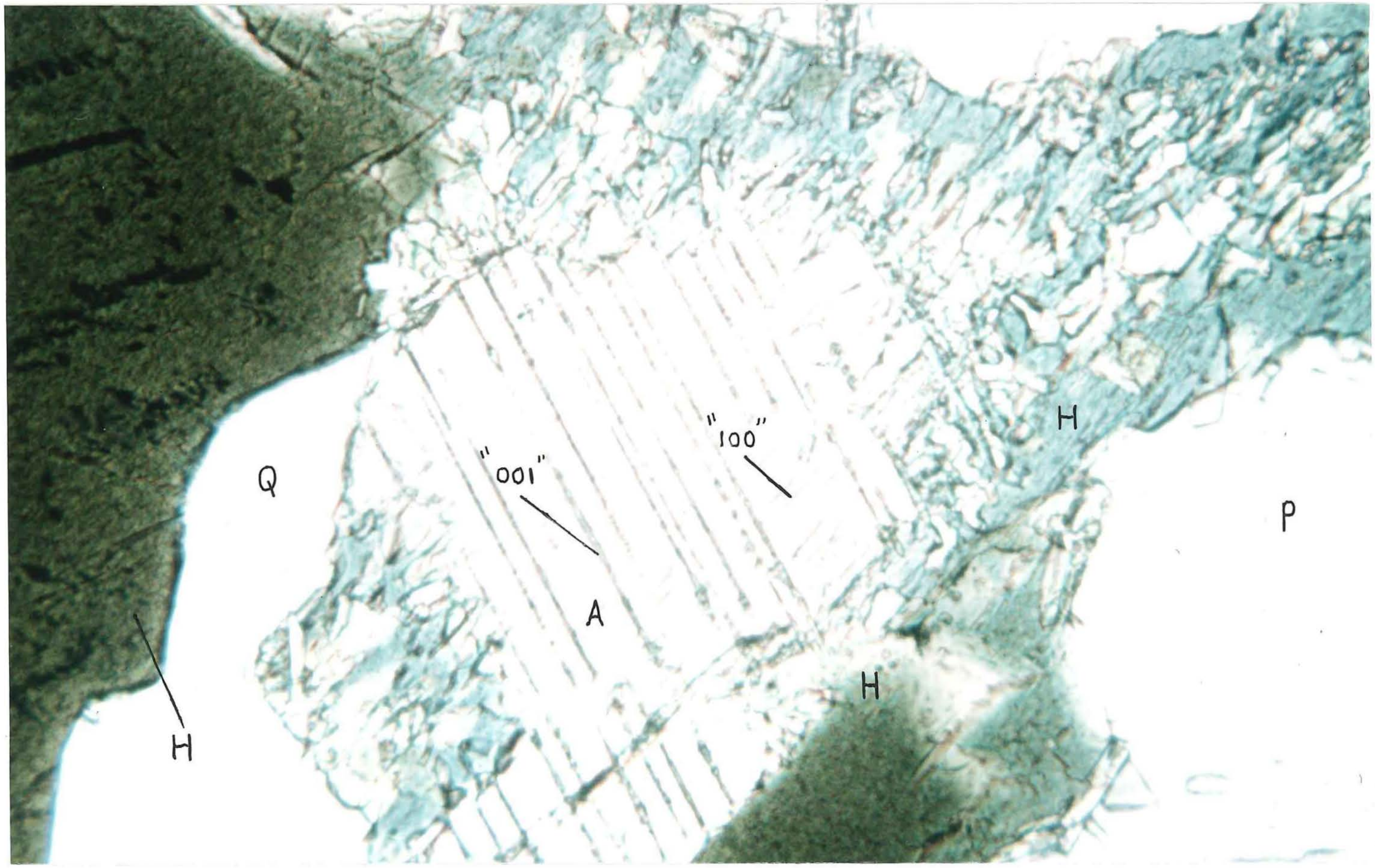


Figure 18. Photomicrograph of metamorphosed quartz-diorite (Specimen 17-3). Augite exhibits "001" and "100" lamellae of hornblende which has replaced pigeonite exsolution lamellae. The retrograded pyroxene exsolution lamellae are indicative of granulite facies conditions. The field of view is approximately 80 mm across. A=Augite, H=Hornblende, Q=Quartz, P=Plagioclase.

(1968) also described retrograded pyroxene exsolution lamellae in the Fordham Gneiss of the White Plains area. In the Hudson Highlands, Jaffe and Jaffe (1973) report pyroxene exsolution took place below metamorphic peak conditions of 700-800°C and pressures on the order of 2-4 kbar under relatively dry conditions with P H_2O much less than P total. Robinson (1980) places exsolution temperature around 600°C.

PALEOZOIC REGIONAL METAMORPHISM

Mineral Assemblages

Common mineral assemblages for rocks of various compositions in the Ellsworth and Amenia quadrangles are listed in Table 13. The increase in metamorphic grade from northwest to southeast is demonstrated by assemblages in pelitic rocks. In the northwest corner of the Ellsworth quadrangle staurolite zone assemblages (27, Table 13) are present in the Everett Formation (Plate 1). In the southeast part of the quadrangle sillimanite zone assemblages (24, Table 13) are the highest grade seen in the Manhattan C. Assemblage (24) indicates metamorphism below the breakdown of staurolite, or staurolite may have formed during a later, lower grade event. Textures exhibiting fresh staurolite grown across fibrolite suggest the second explanation (Figure 6).

Carbonate assemblages (12) and (31) indicate metamorphism below the reaction diopside + calcite + forsterite = monticellite + CO_2. These assemblages occur in the Precambrian marble body (Plate 1) and in the Inwood Marble on both sides of the Precambrian outcrop area. Phlogopite is found in all Paleozoic assemblages and tremolite is common, especially around quartzite beds or small quartz masses.

TABLE 13

List of Major Mineral Assemblages

Precambrian Rocks

Composition	Mineral Assemblage
Quartzofeldspathic rocks All assemblages include: quartz, plagioclase and biotite	1) Microcline muscovite (retrograde) epidote, sphene and garnet (Yr: 1-10, 11-1, 567, 655, 648; Yb: 911, 2-1, 2-4; Yw: 438) 2) Microcline and scapolite (Ys: 5-3, 199) 3) Microcline, muscovite retrograde), garnet and hornblende (Ye: 879, 17-2, 1783a, 1683, 791, 16-2, 524, 527, 796, 901, 803; Yd: 733, 265, 268, 322, 361)
Quartzite All assemblages include: quartz	4) Quartz-plagioclase-microcline± biotite, muscovite (retrograde) and sphene (Ye: 523, 6-1) 5) Quartz-sillimanite-biotite-muscovite (retrograde) (Ye: 922, 922a)
Calc-silicate All assemblages include: hornblende	6) Plagioclase-diopside-biotite-epidote-sphene±quartz (Yb: 609, 698) 7) Quartz-plagioclase-biotite-marialite (Ye: 626, Yw: 353) 8) Quartz-biotite-garnet-plagioclase, microcline, epidote and sphene (Ye: 7-9, 237b, 238, 853) 9) Quartz-diopside-marialite-clinozoisite-sphene (Yw: 757) 10) Quartz-plagioclase-microcline-biotite-epidote (Yw: 1-15, 9-2)

Table 13 (Contined)

Carbonate	11) Ferroan calcite-diopside-actinolite-clinozoisite-quartz-microcline-sphene (Ye: 5-7)
Mafic rocks All assemblages include: hornblende	12) Quartz-plagioclase-cummingtonite-garnet (Ye: 237a) 13) Plagioclase-cummingtonite-biotite (Ye: 6-3) 14) Quartz-plagioclase-biotite-clinozoisite-ilmenite (Ye: 1682) 15) Quartz-plagioclase-biotite-garnet±microcline, epidote and sphene (Yb: 617; Ye: 526, 287; Yw: 17-3) 16) Quartz-plagioclase-biotite-epidote-sphene±microcline (Yb: 2-2, 1562, 10-1; Yd: 347) 17) Plagioclase-epidote-sphene± augite, ilmenite and quartz (Yw: 1437, 809, 844) 18) Quartz-augite (Yw: 17-3) 19) Plagioclase-biotite-epidote-sphene (Yd: 387, 403, 1034)
Ultramafic rocks	20) Olivine-anthophyllite-cummingtonite-talc-serpentine-chlorite-phlogopite-magnetite (Yu: 616)

Paleozoic Rocks

Quartzite	21) Quartz-plagioclase-microcline ± biotite, muscovite and sphene (Є1: 1354, 1253) 22) Quartz-microcline-biotite-muscovite±tourmaline and magnetite (Є1: 1354, 1253)

Table 13 (continued)

Pelitic rocks All assemblages include: quartz, plagioclase and biotite	23) Garnet and muscovite (Omas: 595, 1681) 24) Muscovite-sillimanite-staurolite-garnet (Єmgn: C43; Єmgr: 1635; Єmcw: 764) 25) Magnetite (Єmcgr: 1567) 26) Muscovite-garnet-magnetite (Єmcw: C2) 27) Muscovite-staurolite-garnet (Єe: 599)
Carbonate All assemblages include: phlogopite	28) Dolomite-phlogopite-microcline± calcite and quartz (Єia: 1167; Єib: 1351; Єic: 916; Єid: 995, 1294) 29) Dolomite-tremolite-phlogopite-quartz (Єia: C36) 30) Calcite-tremolite-phlogopite-microcline (Єmam: C30) 31) Dolomite-calcite-diopside-phlogopite-quartz (Єib: C95) 32) Calcite-phlogopite-quartz-microcline (Єmam: 596)
Mafic rocks	33) Quartz-plagioclase-biotite-hornblende-ilmenite (Єmca: C55)

Calc-silicate rocks occur as thin beds, discontinuous lenses or boudins. Specimens typical of the West Woods Gneiss (11, Table 13) are also included under calc-silicate assemblages. Minerals characteristic of these rocks are hornblende, diopside, garnet and locally scapolite. Quartz, plagioclase and biotite are commonly present. In many places diopside masses are rimmed by hornblende suggestive of retrograde events involving the hydration of diopside.

Mafic compositions are represented mainly by amphibolites and mafic gneisses. Hornblende and plagioclase are present in all but one of the assemblages and biotite and epidote are commonly present.
Assemblage (18) is shown in Figure 18 for a probable quartz diorite dike (17-3, Table 5). Augite is not in contact with plagioclase so the reaction forming hornblende can probably be generalized as augite + plagioclase + water = hornblende. Assemblage (15) applies to the same specimen but indicates minerals that coexist with plagioclase. This assemblage may demonstrate the Paleozoic (Taconian?) amphibolite facies (Turner, 1969) overprint of the Grenvillian granulite facies metamorphism discussed earlier for this specimen.

The ultramafic body in the Bread Loaf Mountain Gneiss is represented by assemblage (20). The complex assemblage probably resulted from the hydration of an olivine-orthopyroxene rock.

Conditions of Peak Metamorphism

Sillimanite zone assemblages in pelitic cover rocks indicate the highest grade of Paleozoic metamorphism in the Ellsworth and Amenia quadrangles. Southward along strike in the Kent quadrangle, Jackson

(1980) reports K-feldspar coexisting with sillimanite and it is assumed that the assemblage probably exists in the southeast part of the Ellsworth quadrangle. Vidale (1974), in a regional metamorphic study, characterized the occurrence of coexisting K-feldspar and sillimanite as "spotty" (p. 304) and attributed it to the dependence of the reaction muscovite + quartz = sillimanite + orthoclase + H_2O on bulk chemistry and PH_2O for appropriate P-T conditions. This reaction has been suggested for other areas of New England along the sillimanite-K-feldspar isograd (Evans and Guidotti, 1966; Lundgren, 1966). However, the reaction muscovite + quartz = K-feldspar + sillimanite + biotite + vapor may be more realistic in that it considers the phengite component of muscovite (Tracy, 1978). Figure 19 shows Day's (1973) experimental muscovite + quartz breakdown curve for a pure H_2O fluid phase and pure K end-member starting materials. Day's temperatures are maxima that Kerrick (1972) demonstrated could be depressed by reducing PH_2O or adding sodium to the muscovite.

The occurrence of diopside in the carbonate rocks is represented in Figure 19 by the reaction tremolite + calcite + quartz = diopside + CO_2 + H_2O. Metz (1970) considers it the primary reaction forming diopside in the progressive metamorphism of siliceous dolomites. The curve indicates equilibrium temperatures and pressures for X CO_2 = 0.1 corresponding to the lowest temperatures presented by Metz (1970).

Also shown in Figure 19 is the granite melting curve of Luth, Jahns and Tuttle (1964) and the aluminum silicate triple points of Richardson et al. (1969) and Holdaway (1971). The superimposed curves define a

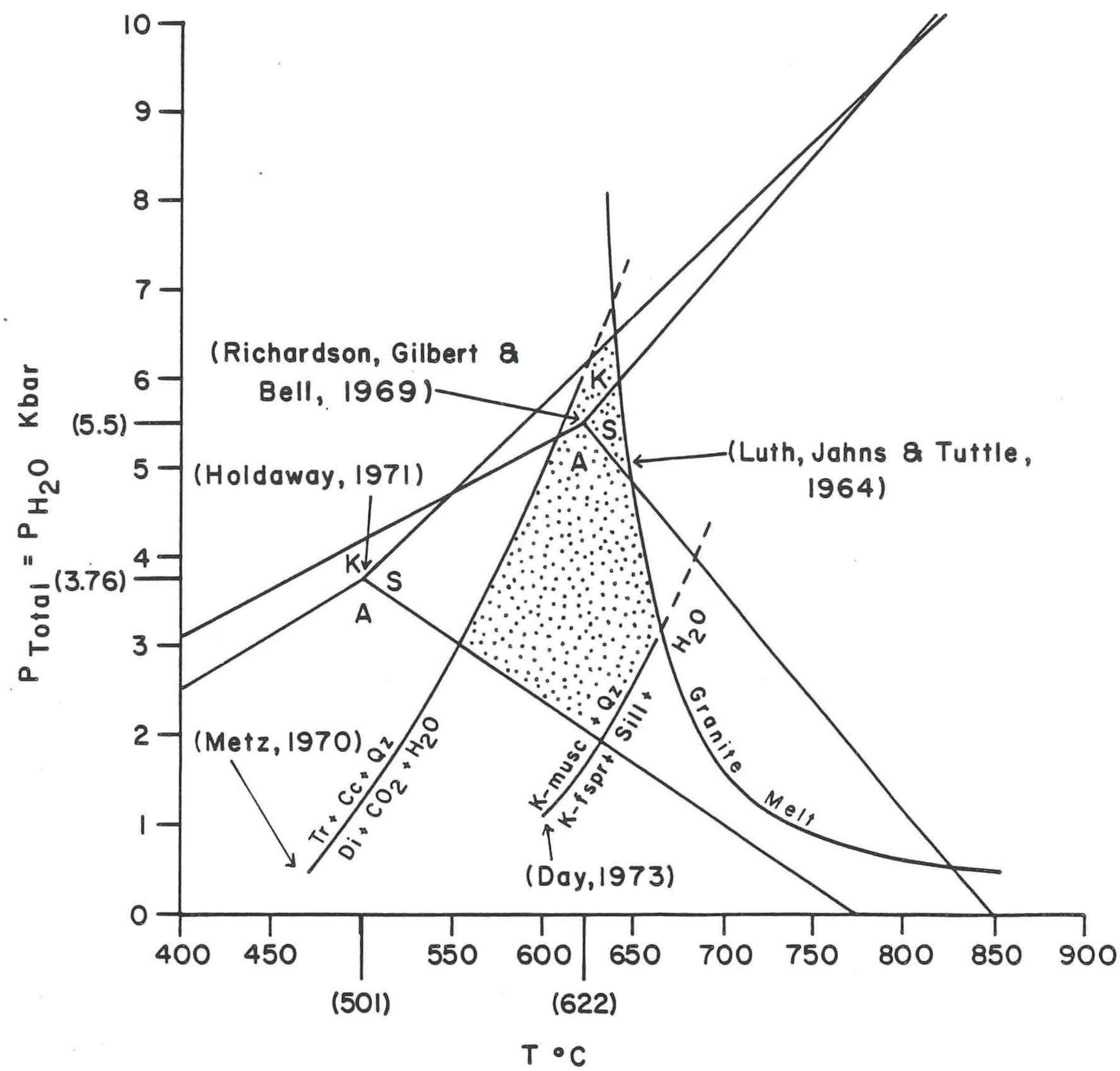


Figure 19. Pressure-temperature diagram showing the aluminum silicate triple points of Richardson, Gilbert and Bell (1969) and Holdaway (1971); the diopside forming reaction of Metz (1970) for X CO_2=0.1; the K-muscovite dehydration reaction of Day (1973) for $P_{H_2O}=P_{total}$; and the granite melting curve of Luth, Jahns and Tuttle (1964) for X H_2O= 1. The stippled region indicates possible P-T conditions for peak metamorphism of the cover rocks in the Ellsworth and Amenia quadrangles.

region in P-T space giving a general estimate of conditions during the peak of metamorphism. Richardson's et al. (1969) curve indicates pressures and temperatures around 5.5 kbar and 630°C, respectively. Holdaway's (1971) curve gives a range of pressures and temperatures from around 2-5 kbar and 550-650°C, respectively.

Relations Between Structural Features and Metamorphism

Multiple sets of mineral lineations, typically hornblende, biotite, quartz or muscovite, within the basement rocks are difficult to differentiate with respect to specific phases of deformation and metamorphism. However, hornblende lineations which parallel the fold axis for the Richards Pond anticline are possibly related to Grenvillian metamorphism.

Sillimanite crystals and small sillimanite nodules lie in the plane of the foliation and form a prominent lineation which parallels first phase (Phase D-3, Figure 10) Taconian isoclinal fold axes and foliation-bedding intersections in the Paleozoic rocks. The occurrence of sillimanite nodules in the plane of the foliation may be explained by the preferred nucleation of sillimanite on biotite which replaces garnet during prograde metamorphism (Yardley, 1977). If replacement of garnet by biotite occurred during a phase of penetrative deformation which created the foliation, the biotite flakes would tend to lie in the plane of the foliation. The subsequent replacement of biotite by sillimanite would leave the resultant sillimanite nodule also oriented in the foliation plane. Yardley (1977) also noted reaction textures in which "thin felts" of sillimanite extended out into the foliation from the edges of the pseudomorphs. Large sillimanite nodules in the Manhattan C typically contain garnet cores with biotite occurring along cracks and grain margins (Figure 6). Therefore, the smaller nodules probably represent garnets that have been partially or completely replaced by biotite followed by sillimanite. A prominent hornblende lineation in the Amphibolite Member of the Manhattan C is also parallel to the sillimanite lineation.

Garnet and staurolite in the Everett Formation and Manhattan A Schist in the northwest corner of the Ellsworth quadrangle contain inclusion trails of quartz and opaque minerals which are parallel to the external foliation. The external foliation is deformed around the edges of the garnet and staurolite, but no rotation of the grains was seen in the specimens studied. The foliation appears to have been enclosed and preserved in the growing garnet and staurolite and subsequently bent around the megacryst as it grew out into the fine-grained matrix. These different features described from sillimanite zone and staurolite zone rocks in the study area support the idea that peak conditions of prograde metamorphism closely followed the development of the foliation associated with Taconian (Phase D-3, Figure 10) isoclinal folding.

A second, weaker hornblende lineation parallels second phase (Phase D-4, Figure 10) fold axes in the Paleozoic rocks and second phase slip-cleavage has biotite grains associated with it that lie in the plane of the cleavage. The features are probably related to Acadian metamorphism in the area. Dana (1977) also associated hornblende lineations in the Manhattan C with Acadian folding in the Lake Waramaug area.

Retrograde Metamorphism

Alteration of biotite to Fe- or Mg-rich chlorite is commonly seen in thin sections of rocks throughout the study area (Tables 1-12). Alteration of sillimanite to muscovite is also commonly present in the Manhattan C and in one pelitic zone (Assemblage 5, Table 13) in the Ellsworth Gneiss. This retrograde metamorphism was probably caused, at least in part, by Acadian metamorphism.

AEROMAGNETIC INTERPRETATION

INTRODUCTION

The aeromagnetic map for the Ellsworth quadrangle was studied as an aid to understanding the geology of the area. During field work the magnetic grain and the various anomalies indicated by the aeromagnetic map (Figure 20) were compared with the rock units and structure of the area to determine if these features are expressions of the exposed rocks or caused by deeper magnetic bodies. A correlation between observed geology and magnetic data could then be used to extrapolate structural trends or discriminate rock units in unmapped areas or where outcrops were absent.

METHODS

Aeromagnetic data for the Ellsworth quadrangle was obtained from the U. S. Geological Survey Geophysical Investigations map. This map is

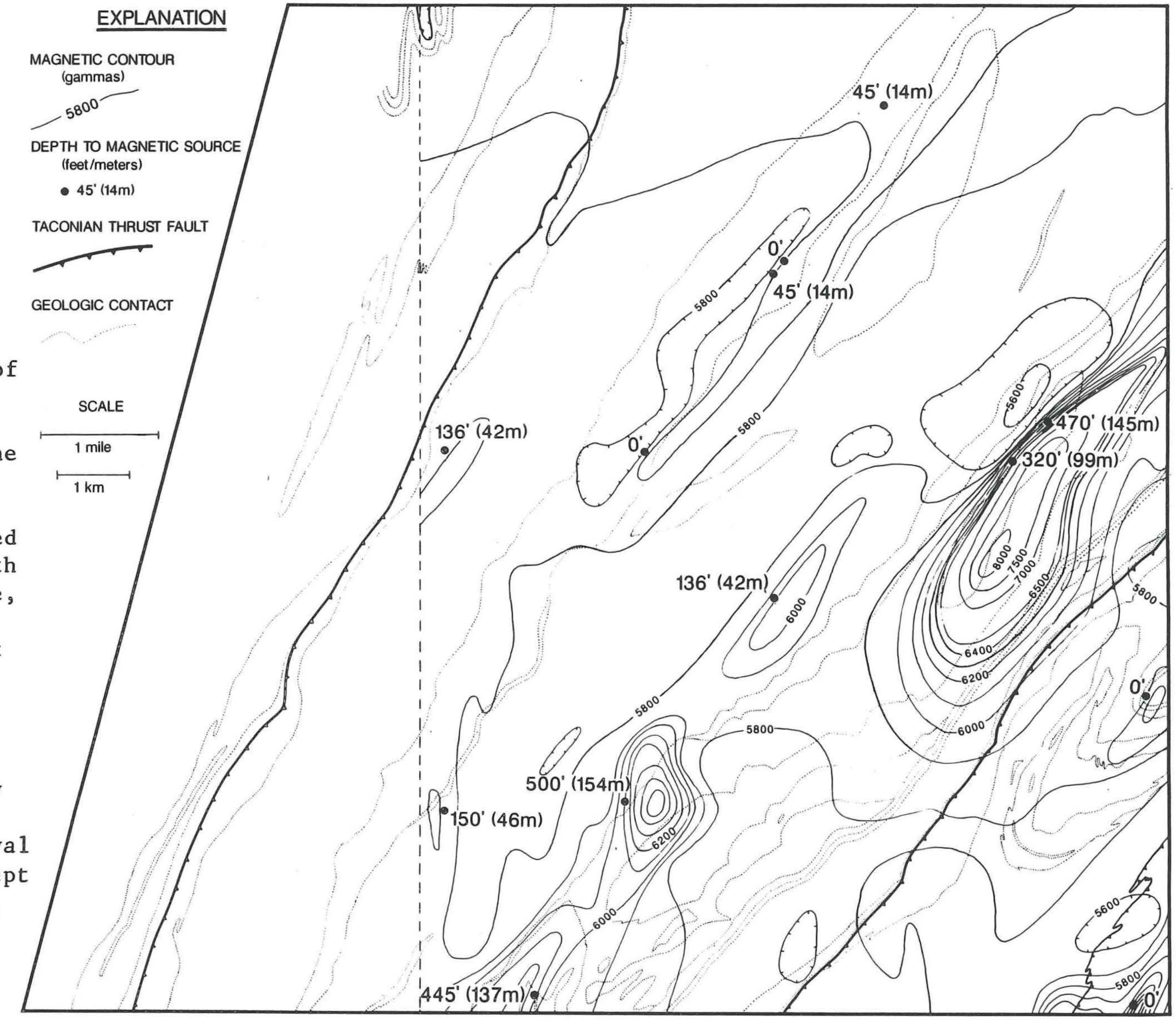


Figure 20. Aeromagnetic map of the Ellsworth quadrangle superimposed on the bedrock geologic map (dotted contacts). Numbered dots indicate depth to magnetic source, calculated by the "horizontal extent of the maximum gradient" method (Vacquier, et al., 1951). Total magnetic intensity is in gammas and the contour interval is 100 gammas except above 6500 gammas, where the contour interval is 500 gammas.

available as a 7.5' quadrangle at 1:24,000 scale. The aeromagnetic survey was flown at 500 feet above the ground along east-west flight lines spaced approximately 1/2 mile apart.

The magnetic field measured by the aeromagnetic survey is the result of the induced and remanent magnetization in the rocks and reflects the variations in the amount of magnetic minerals. Remanent, or permanent magnetization effects are not considered in this study and it is assumed that induced effects predominate in the area. The induced magnetization (I) is the product of the earth's ambient field intensity (F) and the magnetic susceptibility (K) of the rocks.

Susceptibility is a unit of magnetic intensity being produced in a field of one gauss (c.g.s. units). Positive susceptibilities are referred to as paramagnetic and negative susceptibilities are called diamagnetic. Paramagnetic materials include native iron, nickel, cobalt, ferro-alloys and ferrimagnetic minerals. Magnetite (Fe_3O_4) is the most common ferrimagnetic mineral, thus aeromagnetic measurements reflect the magnetite content in the rocks.

The magnetite content of the rocks in the Ellsworth quadrangle was qualitatively estimated in the field by crushing rock specimens and drawing the magnetite grains out with a magnet. This provided an immediate comparison of the magnetite content of exposed rocks with the aeromagnetic map. Later, polished thin sections permitted estimates of magnetite content in selected specimens.

Magnetic susceptibility measurements were also taken in the field to provide a comparison of the rock units. A minimum of five susceptibility measurements were taken at each of the sixty-two sample sites using a Bison Magnetic Susceptibility System (Model 1301) with an external coil. The data are presented in Table 14 and the sample sites are plotted on Figure 21. Some rock specimens that were measured in the field were cored and cut into cylinders for susceptibility measurements with the interior coil of the Bison Susceptibility Bridge. The internal coil measurements provided a check on the reliability of the field data.

Depths to magnetic sources were calculated for twelve anomalies in the Ellsworth quadrangle. The method of the "horizontal extent of the maximum gradient" (Vacquier et al., 1951) was used to provide maximum depth estimates shown on Figure 20.

AEROMAGNETIC PATTERNS

The aeromagnetic pattern for the Ellsworth quadrangle is shown superimposed over the geologic map in Figure 20. The general grain of the magnetic data is strikingly parallel to the northeast trend of the rock units. Several parallel, elongate highs of magnetic intensity with corresponding lows on their northwest side are the predominant features of the area over the Precambrian rocks. This pattern indicates vertical to southeast dipping magnetic bodies which agrees with the strike and dip of the rocks. Profiles across the area are shown in Plate 5.

The largest of the magnetic highs occurs in the region of Bread Loaf Mountain, Silver Hill and Buck Hill (Plate 1) and approximately coincides with the area underlain by the magnetite-rich Silver Hill Tonalite Gneiss. Depth estimates across the maximum gradient (Figure 20) indicate

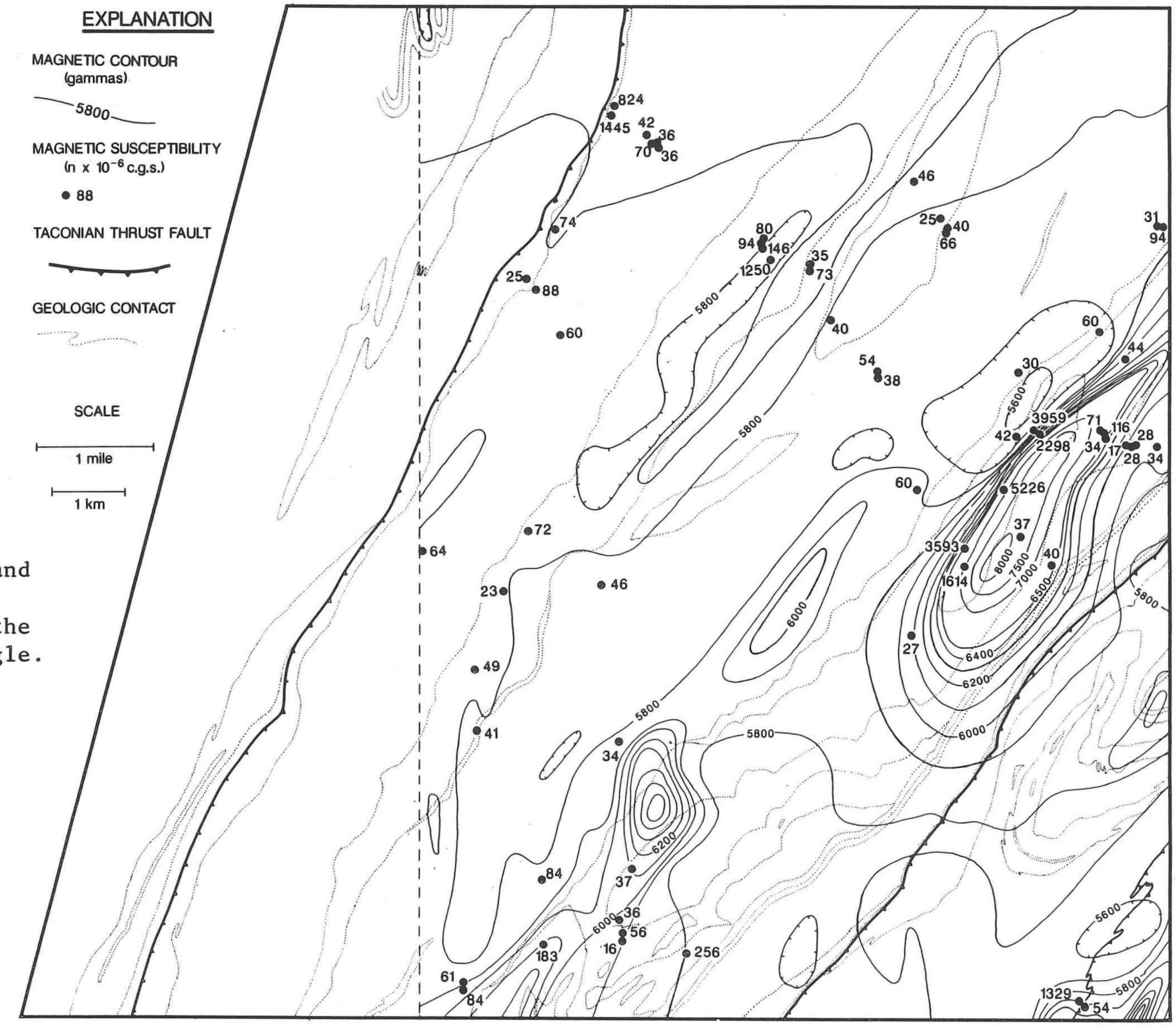


Figure 21. Location of magnetic susceptibilty measurements plotted on the aeromagnetic (solid contours) and geologic (dotted contours) map of the Ellsworth quadrangle. susceptibility measurements are n x 10^{-6} (c.g.s.).

Table 14

Station	Unit/Rock Description	Average Susceptibility (.000001 c.g.s.) (n=no. of measurements averaged)	
1-10	light-gray bio-qtz-plag gneiss	34.2	(n=5)
1-11	light-gray bio-qtz-plag gneiss	28.2	(n=5)
1-11	light-gray bio qtz-plag gneiss	27.8	(n=5)
1549	light-gray bio-qtz-plag gneiss	40.0	(n=5)
1398	light-gray bio-qtz-plag gneiss	36.7	(n=10)
779	light-gray bio-qtz-plag gneiss	36.0	(n=10)
	Bread Loaf Mountain Gneiss		
1-11	brown-weathering bio-qtz-plag gneiss	17.4	(n=5)
2-1	fine-grained, dk-gray, gar-bio gneiss	71.0	(n-5)
2-1	fine-grained, dk-gray, gar-bio gneiss	116.3	(n=6)
2-2	light-gray bio-qtz-plag gneiss	33.6	(n=7)
5-1	pink granite gneiss	2298.0	(n=6)
5-1	pink granite gneiss	3959.0	(n=10)
3-1	rusty-weath, graph. bio-qtz-plag gneiss	42.0	(n=8)
1561	rusty-weath, bio-qtz-plag gneiss	37.0	(n=14)
911	brown-weath, fine-gr. bio-qtz-plag gneiss	26.9	(n=8)
695	gray bio-plag gneiss	55.6	(n=10)
698	coarse-grained biotite granite gneiss	15.9	(n=10)
	Stony Brook Gneiss		
5-4	medium-grained bio-qtz-plag gneiss	60.0	(n=10)
	Ellsworth Gneiss		
17-2	lt-gray med-gr layered bio-qtz-plag gneiss	30.0	(n=8)
18-9	gray biotite gneiss	54.2	(n=6)
18-9	gray biotite gneiss	37.8	(n=6)
17-10	med-grained bio-qtz-plag gneiss	35.0	(n=6)
17-10	med-grained bio-qtz-plag gneiss	73.4	(n=9)
6-1	fine-grained biotite quartzite	31.0	(n=10)
921	gray, garnet-diopside calc-silicate	94.0	(n=10)
1517	layered brown-weath bio-qtz-plag gneiss	40.0	(n=10)
1517	layered brown-weath bio-qtz-plag gneiss	66.0	(n=10)
12-10	well layered gar-bio-qtz-plag gneiss	60.0	(n=10)
1563	gray bio-plag gneiss	45.5	(n=10)
808	dk-gray, diopside-qtz calc-silicate	40.5	(n=11)

Table 14 (continued)

879	layered bio-qtz-plag gneiss	61.3	(n=10)
879	amphibolite	84.0	(n=5)
718	pink granite gneiss	183.0	(n=10)
1392	gray biotite gneiss	84.0	(n=10)
782	gray biotite gneiss	34.4	(n=10)
	West Woods Gneiss		
17-8	layered bio-hornblende-plag-gneiss	80.0	(n=5)
17-8	layered bio-hornblende-plag-gneiss	94.0	(n=5)
17-8	gray gar-bio-aug-hblde-qtz-plag gneiss (see Table 5 - specimen 17-3)	146.0	(n=9)
512	layered bio-diopside-hlbde-plag gneiss	72.0	(n=6)
744	granitic zone in West Woods Gneiss	23.0	(n=5)
17-9	lt-pink, med-grained granite gneiss	1250.0	(n=8)
830	layered bio-hblde-plag gneiss	49.1	(n=10)
	Deming Hill Gneiss		
265	gray, fine-gr, qtz-rich bio-plag gneiss	69.8	(n=5)
265	gray, fine-gr, qtz-rich bio-plag gneiss	36.3	(n=5)
265	gray, fine-gr, qtz-rich bio-plag gneiss	36.0	(n=6)
263	dark-gray, fine-grained amphibolite	41.8	(n=10)
588	light-pink granite gneiss	824.0	(n=10)
588	light-pink granite gneiss	1444.7	(n=8)
939	gray, med-gr, bio-qtz-plag gneiss	74.0	(n=5)
392	med-grained, uniform bio-qtz-plag gneiss	60.0	(n=7)
726	amphibolite	64.0	(n=5)
	Silver Hill Tonalite Gneiss		
1555	white granitic qtz-plag-gneiss	1614.0	(n=5)
216	lt-gray, med-gr, bio-qtz-plag gneiss	3593.0	(n=13)
1559	cream colored, med-gr., feldspathic granitic gneiss w/ dissem. magnetite	5226.0	(n=12)
	Sharon Mountain Granodiorite Gneiss		
1-14	light-gray bio-qtz-plag gneiss	46.0	(n=10)
9-17	light-gray bio-qtz-plag gneiss	25.0	(n=11)
1509	light-gray bio-qtz-plag gneiss	40.0	(n=12)

Table 14 (continued)

	Lowerre Quartzite		
947	tan-weathering vitreous quartzite	25.0	(n=5)
	Manhattan C - Warren Member		
1566	tan-weath, med-gr, sill-gar-musc-bio-qtz-plag schist	53.6	(n=10)
	Manhattan C - Schistose Granulite Member		
1567	gray bio-hblde-plag amphibolite in bio-qtz-plag schist	1328.8	(n=10)

depths of 470' (144 m) to the magnetic unit but consistently high magnetic susceptibility in these rocks (Table 14) and the local presence of magnetite veins up to 5 cm thick in loose blocks on the east flank of Buck Hill indicate the source is present at the surface. Furthermore, Percival (1842) noted magnetic iron and "a vein of some extent" in this area. Pink, magnetite-rich granite gneiss also occurs in the area of this anomaly and susceptibilities measured in these rocks is comparable to those measured in the Silver Hill Tonalite Gneiss (Station 5-1, Table 14).

Depth estimates associated with the maximum gradient of other anomalies indicate near-surface depths (Figure 20) for the causative bodies which typically have surface expression as granite gneisses with relatively higher magnetite contents than the surrounding rocks.

The small anomalies associated with Manhattan C rocks in the southeast corner of the Ellsworth quadrangle are caused by magnetic rocks at or near the ground surface (Figure 20). A local concentration of magnetite in the schists of the Warren Member accounts for the anomaly in the corner of the map. However, no rocks containing high magnetite content were located near the anomaly to the north. The low intensity area in the northwest part of the map corresponds to the non-magnetic Inwood Marble units.

MAGNETIC SUSCEPTIBILITIES

The magnetic susceptibility data is grouped by rock unit in Table 14 and plotted on the aeromagnetic map in Figure 21. The range of values for most of the samples, except the highly magnetic Silver Hill Tonalite, granite gneisses and amphibolite within the Manhattan C, does not exceed 200 x 10 -6 (c.g.s.). These values are typical for gneisses, schists and sedimentary rocks (Lindsley, 1966). There does not appear to be sufficient variation of susceptibility within, or between, the Precambrian units to create a susceptibility contrast which would be measured by the aeromagnetic survey. The predominant expression arises from contrasting susceptibilities between various intrusive granitic rocks and the surrounding metamorphosed sedimentary and volcanic rocks.

CONCLUSIONS

A low intensity magnetic pattern interrupted by local high magnetic anomalies characterizes the Ellsworth quadrangle. The grain of the magnetic pattern parallels the structural trend of the rock units in the Precambrian terrane but little structural correlation is seen between the low intensity magnetic pattern and the cover rocks. The magnetic lows are associated with Precambrian metamorphosed sedimentary and volcanic rocks and Cambrian-Ordovician quartzites, marbles, schists and amphibolites of typically low magnetic susceptibility (Table 14). Local anomalies are associated with granitic gneisses in the Precambrian terrane and locally magnetite-rich schists of the Cambrian Manhattan C. This agrees with the generally low magnetic pattern associated with Precambrian rocks in the Fordham Terrane, Hudson Highlands and Berkshire Highlands which have local high anomalies associated with granitic gneisses (Harwood and Zietz, 1977).

Aeromagnetic interpretations of western Massachusetts by Griscom and Bromery (1968) indicate that the northern and western areas of the Berkshire Highlands are composed of a thin allochthonous thrust sheet of Precambrian rocks. Harwood and Zietz (1974) suggested that the low magnetic expression on the west side of the Housatonic Highlands indicated possible thin gently dipping Precambrian rocks that steepened toward the east into a possible root zone. Highly magnetic granite gneiss located near the Housatonic thrust in the Deming Hill Gneiss (Station 588, Table 14 and Figure 21) shows no large anomalous aeromagnetic response. The granite gneiss may be very thin above the fault plane which probably dips gently beneath a thin zone of thrusted basement rocks. However, the eastern anomaly, which has been shown to have an exposed source, does not necessarily indicate a root zone even though dips steepen toward the east as interpreted by Harwood and Zietz (1974).

GEOLOGIC HISTORY

Precambrian sedimentary volcanic and intrusive rocks constitute "North American" (Hall and Robinson, 1982) basement in the Ellsworth-Amenia area. These rocks underwent at least one phase of Grenvillian (1100 m.y. ago) folding (Phase D-1, Figure 10) and granulite facies metamorphism. There are at least two phases of Precambrian intrusive activity, one of which preceeded and another followed an intervening penetrative deformation. Erosion of the Grenvillian gneisses occurred after uplift and Late Precambrian (820 m.y. ago) rifting associated with the opening of the Iapetus Ocean (Rankin, 1976).

Basal Cambrian arkosic and clean quartz sands of the Lowerre Quartzite were laid down unconformably on the basement in a near shore environment. The clean Lowerre sands gave way in a basinward direction to the equivalent pelitic slope facies of the Manhattan C and the shales of the Everett Formation. Mafic volcanic flows also were deposited at this time along with the Manhattan C.

The Lowerre Quartzite was succeeded by Cambrian through Lower Ordovician carbonate bank deposits of the Inwood Marble. Tilting and block faulting of the carbonate bank and subsequent erosion created the widespread Middle Ordovician unconformity at the onset of the Taconian orogeny. At the same time, to the east of the study area, fragments of oceanic crust and its sedimentary and volcanic cover were obducted over the continental slope clastic sequence (Robinson and Hall, 1980). The obduction presumably resulted from the closing of the Iapetus oceanic basin, of uncertain width, along an east-dipping subduction zone. The basin separated North American basement from an eastern basement which Robinson and Hall (1980) refer to as the Bronson Hill plate.

Continued closing of the ocean during the Middle Ordovician caused intense tectonism which resulted in westward thrusting of the Everett and Manhattan C slope deposits over the Manhattan A schist along the Everett, Waramaug and Above All thrusts (Phase D-2, Figure 10). Further deformation caused uplift and westward thrusting of basement over the carbonate bank and Manhattan A rocks along the Housatonic thrust. The thrusting of the basement overturned the autochthonous cover and probably occurred during Taconian isoclinal folding. Taconian folding occurred approximately with contemporaneous peak regional metamorphism about 442 m.y. ago (Mose and Nagel, 1982; Jackson and Hall, 1982). It produced large-scale isoclinal folds (Phase D-3, Figure 10) and the predominant axial plane foliation throughout the area.

Acadian deformation is probably recorded in the second phase folds (Phase D-4, Figure 10) which produced an axial plane slip cleavage. The Acadian orogeny may have resulted from convergence between the Bronson Hill plate and the Avalon plate (Robinson and Hall, 1980), during the Devonian (about 410 to 370 m.y. ago). The two "plates" are interpreted by Robinson and Hall (1980) as two parts of a previous single plate consisting of Late Precambrian basement. The zone of most intense Acadian deformation and metamorphism occurred to the east of the study area but large scale upright folds and possible staurolite grade metamorphism (Jackson, 1980) affected the Ellsworth-Amenia area. The third phase folds (Phase D-5, Figure 10) which formed with another slip cleavage may have formed later during the Acadian or Alleghenian orogenies.

Mesozoic rifting occurred during the opening of the Atlantic Ocean. This rifting resulted in the formation of the Hartford and Pomperaug Basins (Figure 2). Triassic and Jurassic sediments, volcanics and intrusives fill these basins, but associated faults, dikes and jointing are common throughout New England and eastern New York. Many of the brittle faults and joints in the Ellsworth and Amenia area were probably formed during that time.

Late Pleistocene glaciation covered the area with a continental ice sheet which shaped much of the present-day landscape. The rounded hills and ridges of the highlands were created by the scraping of ice over the bedrock. Many of the poorly drained low areas in the highlands have only a thin layer of till covering the bedrock. The valleys underlain by carbonate rocks were more deeply eroded than the crystalline rocks of the highlands. During melting of the ice, outwash sands and gravels were deposited in these low areas. Since the Pleistocene, the landscape has been slightly altered by fluvial erosion and agricultural development.

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PLATE 1

BEDROCK GEOLOGIC MAP, ELLSWORTH AND AMENIA QUADRANGLES, WESTERN CONNECTICUT AND EASTERN NEW YORK

EXPLANATION

Contact: Location accurate where solid, approximate where dashed, inferred where dotted.

Fault: Location accurate where solid, approximate where dashed, inferred where dotted.

Metamorphic isograd: Inferred projection from adjacent quadrangles. (teeth in high grade rocks)
St - Staurolite
Ky - Kyanite
S - Sillimanite
SK - Sillimanite/K-feldspar

89 Strike and dip of bedding, dot shows stratigraphic top as indicated by cross bedding.

83 Strike and dip of dominant metamorphic foliation.

29 Trend and plunge of mineral lineation.

34 Trend and plunge of fold axis.

INTRUSIVE IGNEOUS ROCKS

Precambrian

Ysj — St. John's Ledges Granite Gneiss
Ysj: Weakly foliated, medium-grained, light-pink, quartz-microcline granite. Locally containing microcline augen up to 5 mm long and hastingsitic hornblende.

Ysm — Sharon Mountain Granodiorite Gneiss
Ysm: Light-gray, weakly foliated, fine- to medium-grained biotite-microcline-quartz-plagioclase-granodiorite. Smooth, uniform, rounded outcrops are typical.

Yeg — Ellsworth Granodiorite Gneiss
Yeg: Medium- to coarse-grained, garnet-biotite granodiorite gneiss. Outcrops weather with rough, light-gray surfaces on which plagioclase grains stand out. Biotite occurs in patches.

Ysh — Silver Hill Tonalite Gneiss
Ysh: Light-tan to light-gray, fine grained quartz-plagioclase tonalite gneiss mapped as a unit based on the presence of abundant disseminated magnetite. Rare magnetite segregations up to 2 cm thick occur at Buck Hill and hornblende occurs locally in thin (1 cm) discontinuous segregations or disseminated grains near the contacts.

Yu — Ultramafic Rock
Yu: Coarse-grained, massive, dark-gray to dull-green anthophyllite-olivine rock with lesser amounts of serpentine, talc, phlogopite, chlorite, magnetite and pyrite. The outcrop is brown-weathering with radiating clusters of fibrous anthophyllite.

STRATIFIED ROCKS

Autochthonous Rocks

Ordovician

Omas, Omam — Manhattan A
Omas: Schist Member: Well foliated, fine-grained, dark-gray muscovite-biotite-feldspar schist or schistose granulite with abundant garnet in the western exposures.
Omam: Marble Member: Well foliated, tan-weathering calcite marble.

UNCONFORMITY

Oid — Inwood Marble
Oid: Member D: Well foliated, thin-bedded, tan, white, brown or blue-gray dolomite marble. Interbeds of tan, sandy, calcite-dolomite marble 2-10 cm thick, locally crossbedded, quartzites and schistose phlogopite marble are characteristic.

Cambrian

Ꞓic: Member C: Fine-grained, gray dolomite marble with thin (1cm), white quartz (recrystallized chert) layers. Outcrops have rounded, crumbly-weathering surfaces.
Ꞓib: Member B: Well bedded, light-gray- or tan-weathering dolomite marble. Minor, thin interbeds of quartzite are charcteristic.
Ꞓia: Member A: Fine-grained, well bedded, white dolomite marble.

Ꞓl — Lowerre Quartzite
Ꞓl: Fine-grained, tan, vitreous quartzite and granular feldspathic quartzite with a basal pebble conglomerate not more than 1 m thick.

UNCONFORMITY

Allochthonous Rocks

Cambrian

Ꞓe — Everett Formation
Ꞓe: Dull-green to greenish-gray, fine-grained chlorite-muscovite, phyllitic schist and biotite-plagioclase-muscovite quartzose schist with staurolite and garnet porphyroblasts. Quartz-plagioclase segregations are common.

Manhattan C
Ꞓmcw: Warren Member: Medium- to coarse-grained, tan- to reddish-brown-weathering. sillimanite-garnet-biotite-muscovite-plagioclase-quartz schist and granulite locally with abundant sillimanite nodules. Large muscovite flakes give a sparkling aspect to the rock. Locally it contains up to 2% magnetite.
Ꞓmcgr: Schistose Granulite Member: Gray-weathering, fine-grained, light-gray muscovite-biotite-quartz-plagioclase schistose granulite and gneiss. Locally it contains lavender garnets and fibrous sillimanite that form small nodules. Gray plagioclase augen up to 1 cm are a local, but distinctive feature.
Ꞓmca: Amphibolite Member: Dark-greenish-gray to black, fine- to medium-grained, biotite-quartz-plagioclase-hornblende amphibolite with accessory garnet, epidote and up to 7% ilmenite. Small plagioclase augen are common.
Ꞓmcgn: Schistose Gneiss Member: Medium- to coarse-grained, reddish-brown-weathering staurolite-garnet-sillimanite-plagioclase-quartz-biotite-muscovite schistose gneiss and schist. Abundant sillimanite nodules and sillimanite-rimmed garnet porphyroblasts up to 2 cm create typical nubby-weathering surfaces.

Precambrian

Yd — Deming Hill Gneiss
Yd: Dark-gray to dark-green, fine- to medium-grained, biotite-hornblende-plagioclase amphibolite and gray, fine- to medium-grained, biotite-quartz-plagioclase gneiss. Locally the gneiss contains scattered garnets and blue quartz.

Yw — West Woods Gneiss
Yw: Dark-gray and white layered, fine- to medium-grained, biotite-hornblende-plagioclase gneiss. Mafic and felsic segregations up to 10 cm thick define layering which is locally absent, giving way to uniform, gray, well foliated biotite-plagioclase gneiss.

Ye, Yem, Yea — Ellsworth Gneiss
Ye: Well layered, gray- to locally rusty-weathering, fine- to medium-grained muscovite-biotite-quartzofeldspathic gneisses. Locally they are graphitic and contain garnet. Subordinate but common rock types are thin-bedded gray to blue-gray quartzites, various fine-grained calc-silicate rocks and rare schistose sillimanite-bearing gneiss or sillimanite-quartz granulite.
Yem: Diopside-calcite marble.
Yea: Dark-gray to black, fine- to medium-grained biotite-hornblende-plagioclase amphibolite, locally with augite or scattered garnet.

Ys — Stony Brook Gneiss
Ys: Light-gray, well foliated, fine- to medium-grained biotite-quartz-plagioclase gneiss with characteristic augen of subhedral plagioclase up to 5 mm.

Yb — Bread Loaf Mountain Gneiss
Yb: An undivided assemblage of rusty-weathering, graphitic quartzofeldspathic gneiss and schistose gneiss; garnet-hornblende-biotite-quartz-plagioclase gneiss; amphibolite and minor occurrences of green graphitic diopside calc-silicate rock.

Yr — Richards Pond Gneiss
Yr: Light-gray biotite-microcline-quartz-plagioclase gneiss characterized by discontinuous white felsic layering up to 10 cm thick.

Geology mapped by Jonathan L. Burr, 1979 - 1981

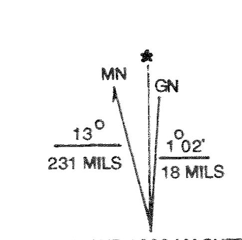
SCALE 1:24000

1 — 1/2 — 0 — 1 MILE

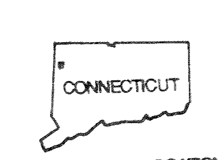
1000 — 0 — 1000 — 2000 — 3000 — 4000 — 5000 — 6000 — 7000 FEET

1 — 0 — 1 KILOMETER

CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL



UTM GRID AND 1969 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET



QUADRANGLE LOCATION

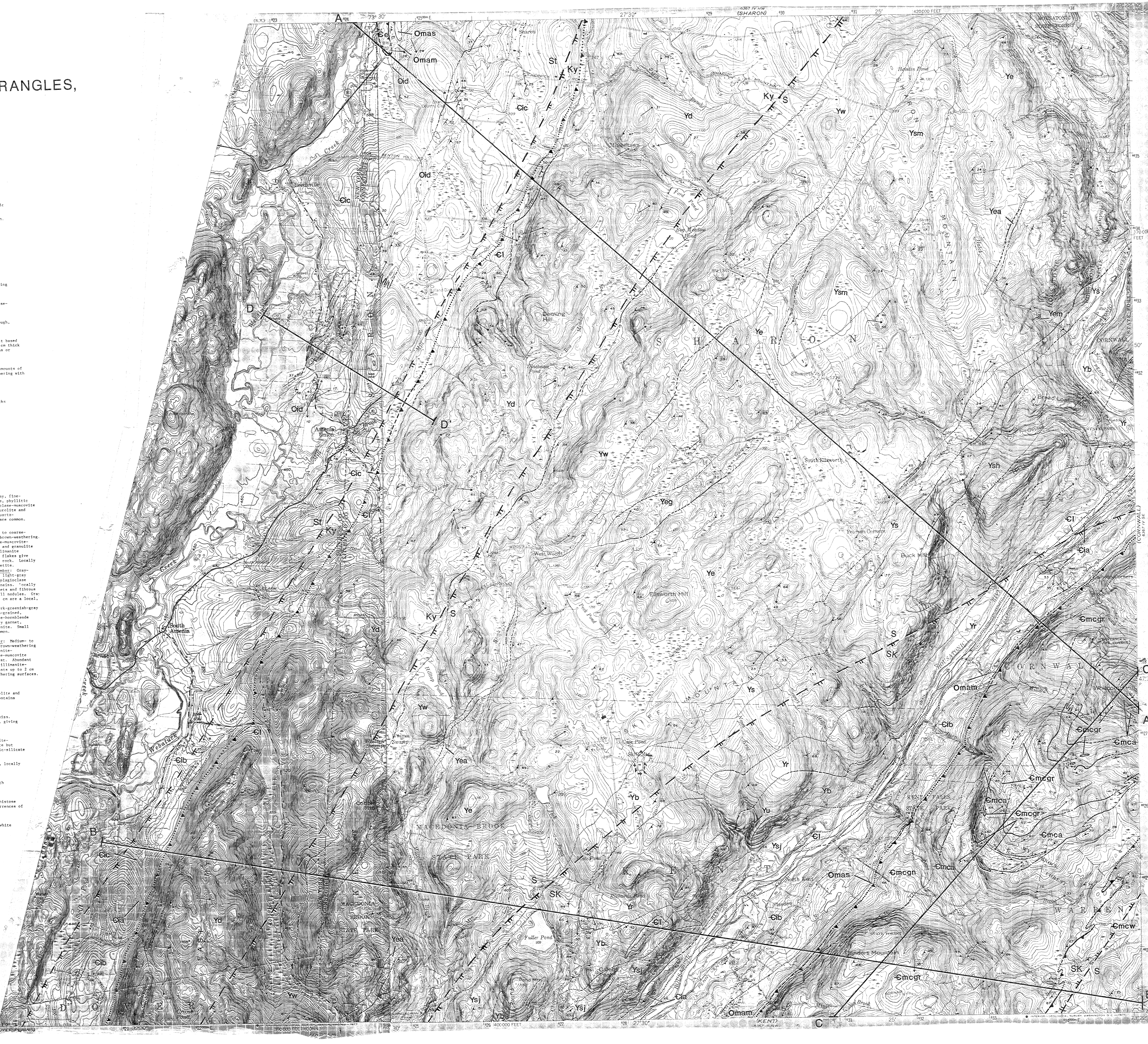


PLATE 2

BEDROCK OUTCROP MAP, ELLSWORTH AND AMENIA QUADRANGLES

EXPLANATION

Area of bedrock outcrop.

Area of abundant outcrops separated by surficial cover.

238 Specimen locality mentioned in text.

SCALE 1:24000

1 1/2 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 0 1 KILOMETER

CONTOUR INTERVAL 10 FEET

DATUM IS MEAN SEA LEVEL

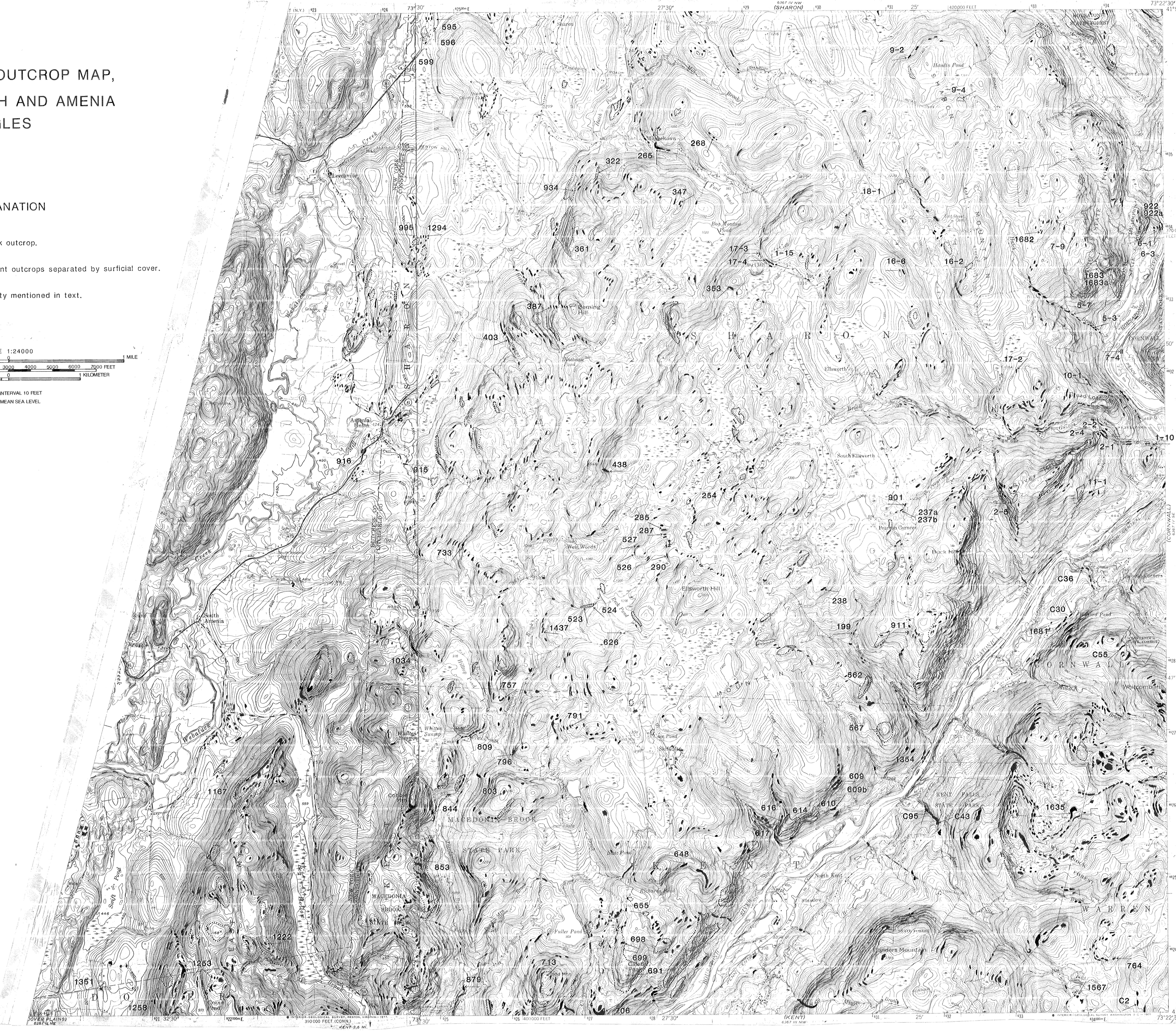


PLATE 3

MAP OF BEDDING AND FOLIATION PLANES

EXPLANATION

MAP SYMBOLS

Strike and dip of bedding.

Overturned bedding determined by crossbedding in Inwood Marble and inferred from structural position in Lowerre Quartzite

Strike and dip of foliation defined primarily by compositional layering in Precambrian gneisses and schistosity in Paleozoic cover rocks.

EQUAL AREA NETS

Letter denotes subarea located on map.

Lefthand net: contoured plot of poles to bedding and foliation (pi diagram).

Righthand net: contoured plot of plane intersections (beta diagram).

N = number of measurements.

C.I. = contour interval.

SCALE 1:24000

CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL

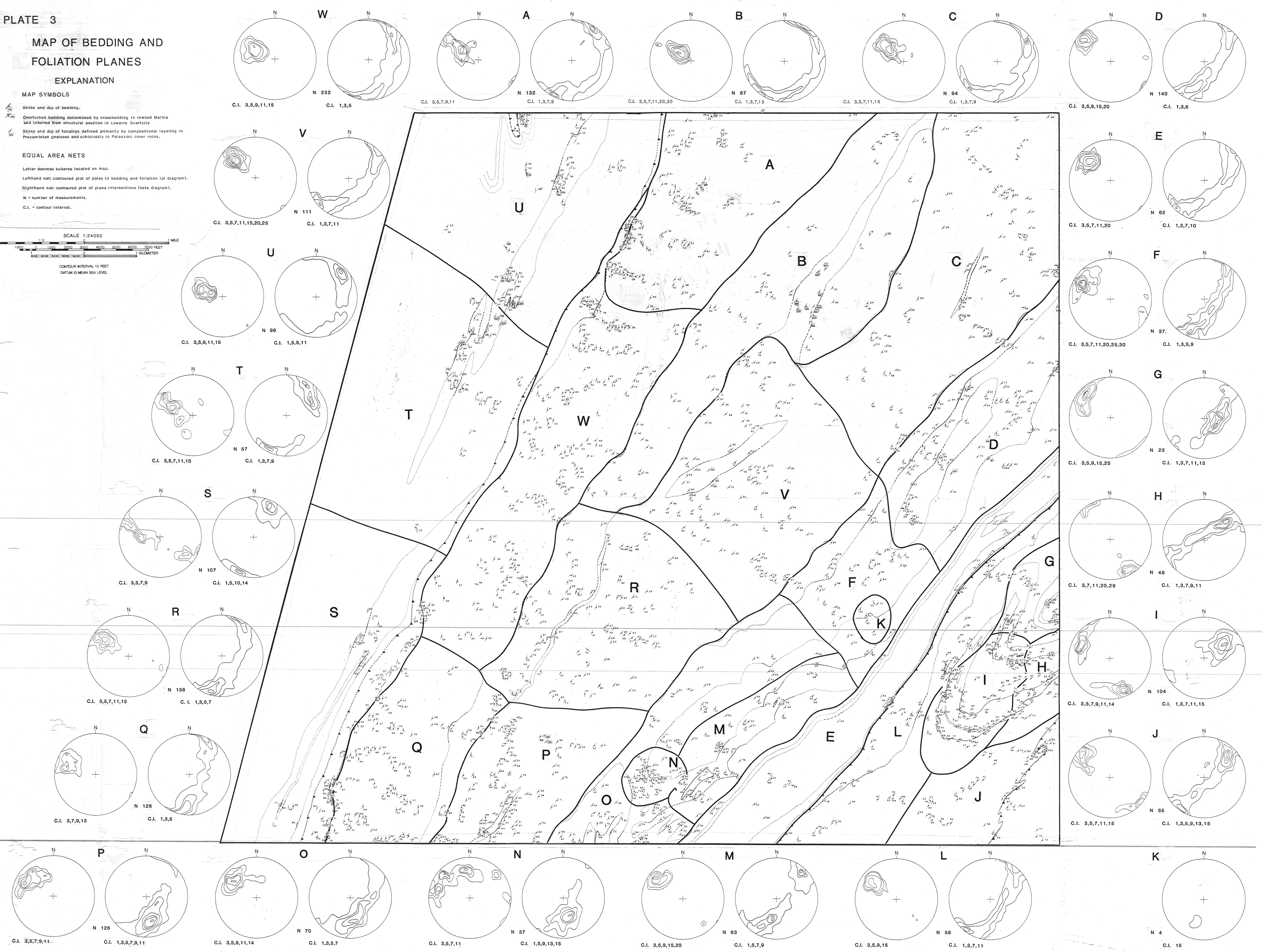


PLATE 4

MAP OF MINOR LINEAR AND AXIAL PLANE FEATURES

EXPLANATION

MAP SYMBOLS *

Trend and plunge of fold axis with sense of rotation where identified: clockwise, counterclockwise, neutral.

Trend and plunge of lineation.

Strike and dip of axial plane foliation.

Strike and dip of axial plane cleavage.

Strike and dip of axial plane cleavage or axial plane with no planar fabric identified.

* Symbols may be combined.

EQUAL AREA NETS

Letter denotes domain located on map.

Lefthand net: fold axes and lineations.

Fold axis with sense of rotation where identified: clockwise, counterclockwise, neutral.

○ Crenulation axis.

■ Lineation.

□ Cleavage intersection with foliation.

Righthand net: poles to axial planes.

● Foliation.

■ Cleavage.

▲ Cleavage or no planar fabric identified.

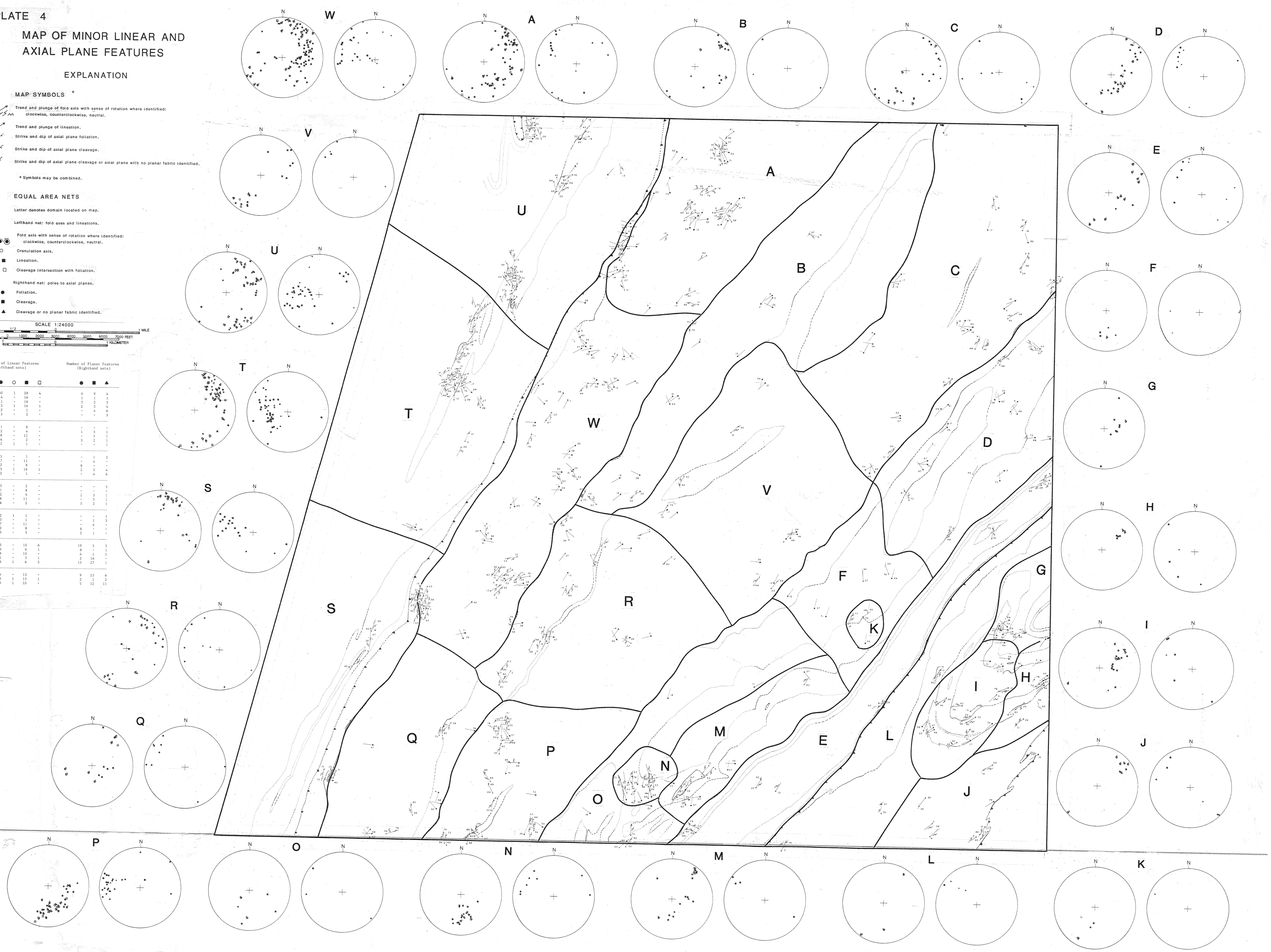
SCALE 1:24000

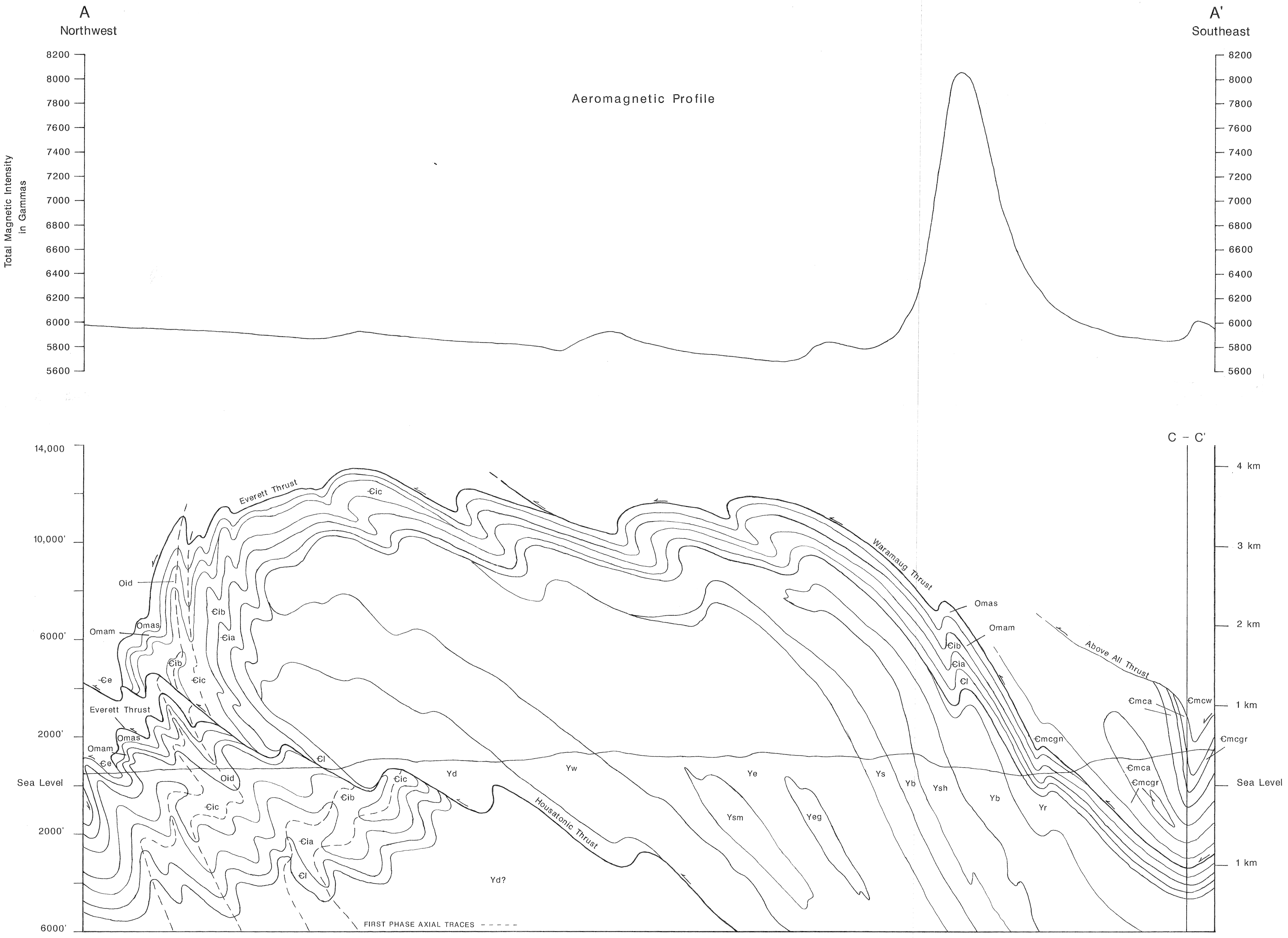
1 — 1/2 — 0 — 1 MILE

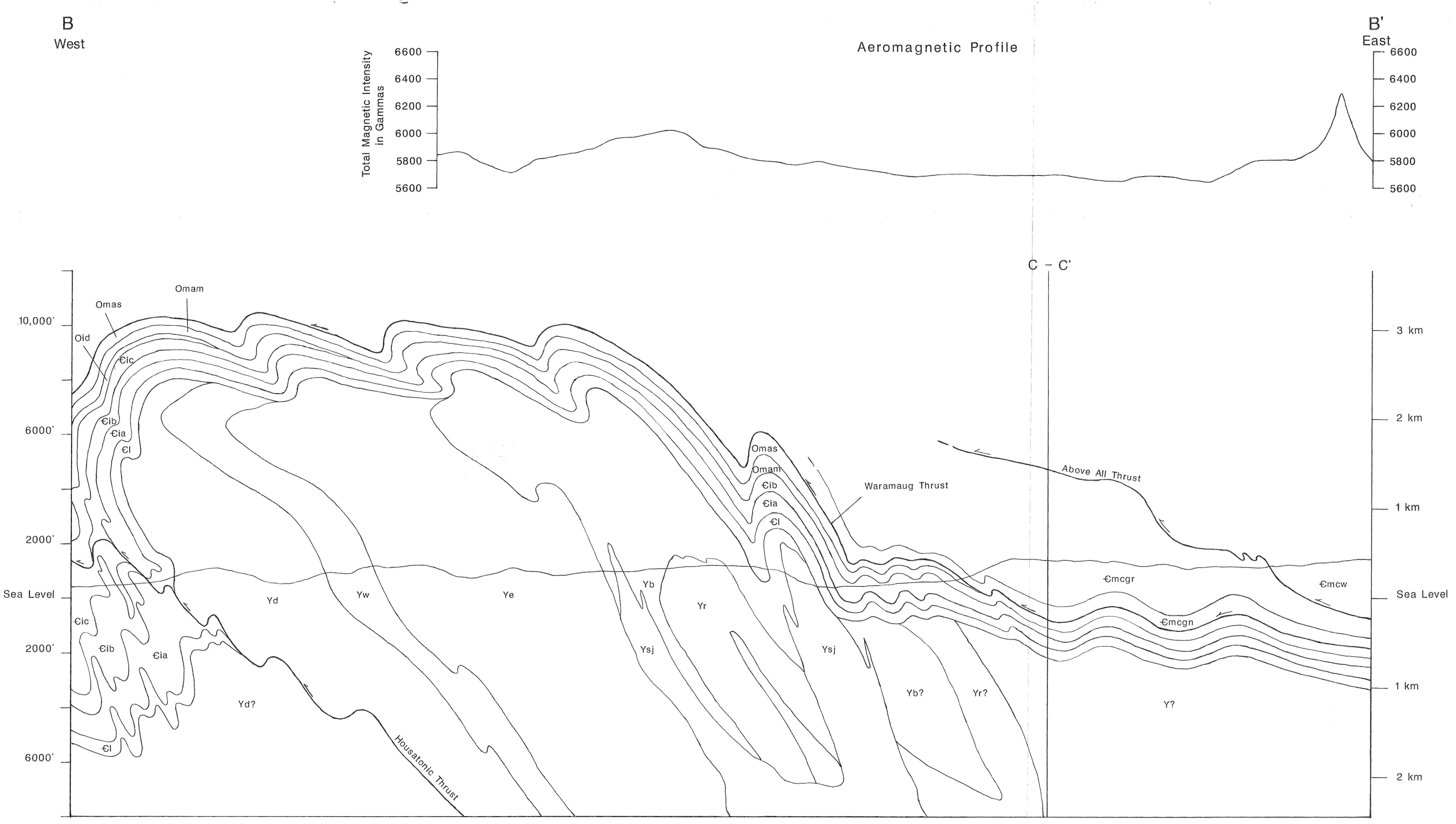
1000 — 0 — 1000 — 2000 — 3000 — 4000 — 5000 — 6000 — 7000 FEET

1 — 0 — 1 KILOMETER

Subarea	Number of Linear Features (Lefthand nets) ●	○	■	□	Number of Planar Features (Righthand nets) ●	■	▲
A	30	1	28	4	6	9	4
B	4	-	16	-	1	1	1
C	11	-	16	-	3	2	3
D	13	1	16	1	2	3	4
E	12	-	1	-	-	4	6
F	3	-	2	-	-	-	3
G	1	-	8	-	-	-	-
H	2	-	4	-	1	3	1
I	8	-	11	-	-	5	1
J	6	-	2	-	3	2	1
K	2	1	1	-	-	-	1
L	3	-	1	-	-	1	3
M	7	-	11	-	-	4	-
N	12	-	8	-	8	-	-
D	13	1	16	1	2	3	4
E	12	-	1	-	-	4	6
F	3	-	2	-	-	-	3
G	1	-	8	-	-	-	-
H	2	-	4	-	1	3	1
I	8	-	11	-	-	5	1
J	6	-	2	-	3	2	1
K	2	1	1	-	-	-	1
L	3	-	1	-	-	1	3
M	7	-	11	-	-	4	-
N	12	-	8	-	8	-	-
O	3	-	3	-	2	1	-
P	23	-	10	6	19	5	3
Q	6	-	6	1	8	-	1
R	18	-	10	-	4	1	5
S	21	-	3	1	2	16	-
T	38	1	6	5	15	27	1
U	36	-	13	-	9	23	6
V	3	1	13	1	2	1	2
W	33	1	55	-	5	12	11







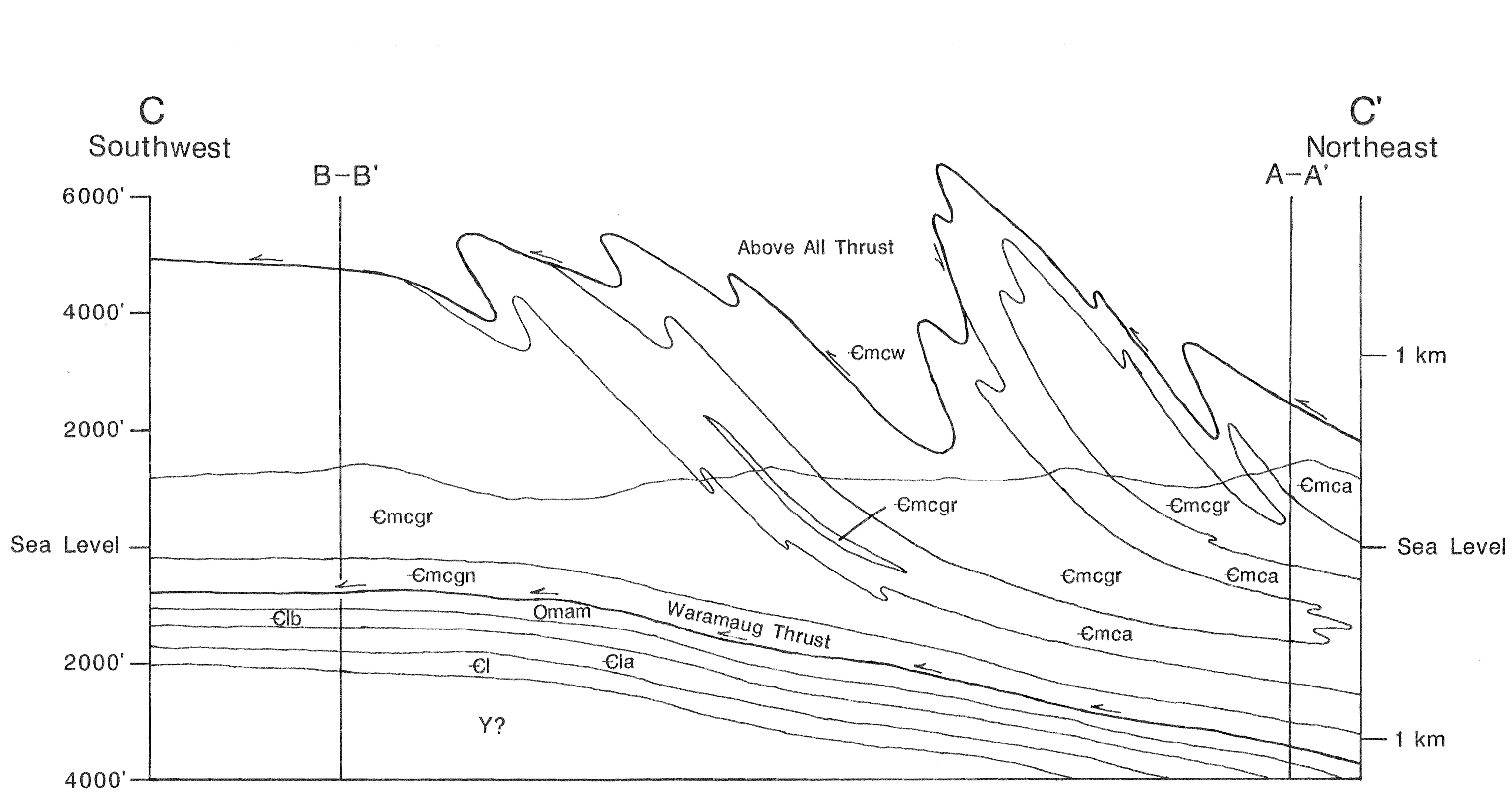


PLATE 5
STRUCTURAL CROSS-SECTIONS AND AEROMAGNETIC PROFILES

LINES OF CROSS-SECTION ARE SHOWN ON GEOLOGIC MAP (PLATE 1).
D - D' SHOWN IN FIGURE 12.

Bedrock Geology of the Ellsworth and Eastern Part of the Amenia Quadrangles, Connecticut and New York (1986)

Jonathan L. Burr

Plate 1

EXPLANATION of MAP SYMBOLS

Contact: Location accurate where solid, approximate where dashed, inferred where dotted.

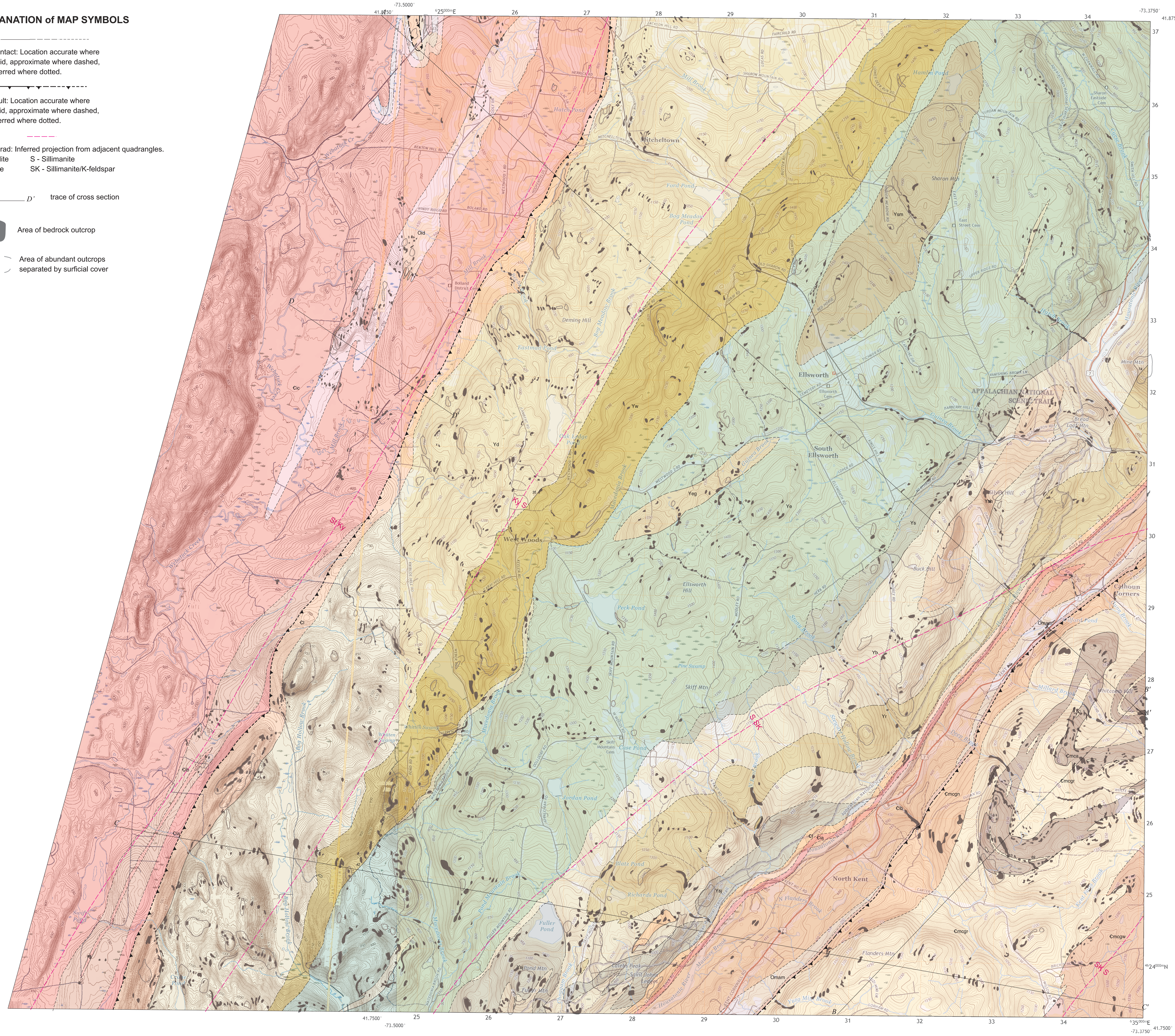
Fault: Location accurate where solid, approximate where dashed, inferred where dotted.

Metamorphic isograd: Inferred projection from adjacent quadrangles.
St - Staurolite S - Sillimanite
Ky - Kyanite SK - Sillimanite/K-feldspar

D ______ D' trace of cross section

Area of bedrock outcrop

Area of abundant outcrops separated by surficial cover



INTRUSIVE IGNEOUS ROCKS

Precambrian

Ysj	St. John's Ledges granite gneiss Ysj: Weakly foliated, medium-grained, light-pink, quartz-microcline granite. Locally containing microcline augen up to 5 mm long and hastingsitic hornblende.
Ysm	Sharon Mountain granodiorite gneiss Ysm: Light-gray, weakly foliated, fine- to medium-grained biotite-microcline-quartz-plagioclase granodiorite. Smooth, uniform, rounded outcrops are typical.
Yeg	Ellsworth granodiorite gneiss Yeg: Medium- to coarse-grained, garnet-biotite granodiorite gneiss. Outcrops weather with rough, light-gray surfaces on which plagioclase grains stand out. Biotite occurs in patches.
Ysh	Silver Hill tonalite gneiss Ysh: Light-tan to light-gray, fine grained quartz-plagioclase tonalite gneiss mapped as a unit based on the presence of abundant disseminate magnetite. Rare magnetite segregations up to 2 cm thick occur at Buck Hill and hornblende occurs locally in thin (1 cm) discontinuous segregations or disseminated grains near the contacts.
Yu	Ultramafic rock Yu: Coarse-grained, massive, dark-grey to dull-green anthophyllite-olivine rock with lesser amounts of serpentine, talc, phlogopite, chlorite, magnetite and pyrite. The outcrop is brown-weathering with radiating clusters of fibrous anthophyllite.

STRATIFIED ROCKS

Autochthonous Rocks

Ordovician

Manhattan A

Omas	Omas: Schist Member: Well foliated, fine-grained, dark-gray muscovite biotite-feldspar schist or schistose granulite with abundant garnet in the western exposures.
Omam	Omam: Marble Member: Well foliated, tan-weathering calcite marble.

UNCONFORMITY

Inwood marble

Oid	Oid: Member D: Well-foliated, thin-bedded, tan, white, brown or blue-gray dolomite marble. Interbeds of tan, sandy, calcite-dolomite marble 2-10 cm thick, locally crossbedded, quartzites and schistose phlogopite marble are characteristic.

Cambrian

€ic	€ic: Member C: Fine-grained, gray dolomite marble with thin (1 cm), white quartz (recrystallized chert) layers. Outcrops have rounded, crumbly-weathering surfaces.
€ib	€ib: Member B: Well bedded, light-gray- or tan-weathering dolomite marble. Minor, thin interbeds of quartzite are characteristic.
€ia	?€ia: Member A: Fine-grained, well bedded white dolomite marble.
€l	Lowette quartzite €l: Fine-grained, tan, vitreous quartzite and granular feldspathic quartzite with a basal pebble conglomerate not more than 1 m thick.

UNCONFORMITY

Allochthonous Rocks

Cambrian

€e	Everett formation €e: Dull-green to greenish-gray, fine-grained chlorite-muscovite, phyllitic schist and biotite-plagioclase-muscovite quartzose schist with staurolite and garnet porphyroblasts. Quartz-plagioclase segregations are common.
€mcw	Manhattan C €mcw: Warren Member: Medium- to coarse-grained, tan- to reddish-brown-weathering, sillimanite-garnet-biotite-muscovite-plagioclase-quartz schist and granulite locally with abundant sillimanite nodules. Large muscovite flakes give a sparkling aspect to the rock. Locally it contains up to 2% magnetite.
€mcgr	€mcgr: Schistose Granulite Member: Gray-weathering, fine-grained, light-gray muscovite-biotite-quartz-plagioclase schistose granulite and gneiss. Locally it contains lavendar garnets and fibrous sillimanite that form small nodules. Gray plagioclase augen up to 1 cm are a local, but distinctive feature.
€mca	€mca: Amphibolite Member: Dark-greenish-gray to black, fine- to medium-grained, biotite-quartz-plagioclase-hornblende amphibolite with accesory garnet, epidote and up to 7% ilmenite. Small plagioclase augen are common.
€mcgn	€mcgn: Schistose Gneiss Member: Medium- to coarse-grained, reddish-brown-weathering staurolite-garnet-sillimanite-plagioclase-quartz-biotite-muscovite schistose gneiss and schist. Abundant sillimanite nodules and sillimanite-rimmed garnet porphyroblasts up to 2 cm create typical nubby-weathering surfaces.

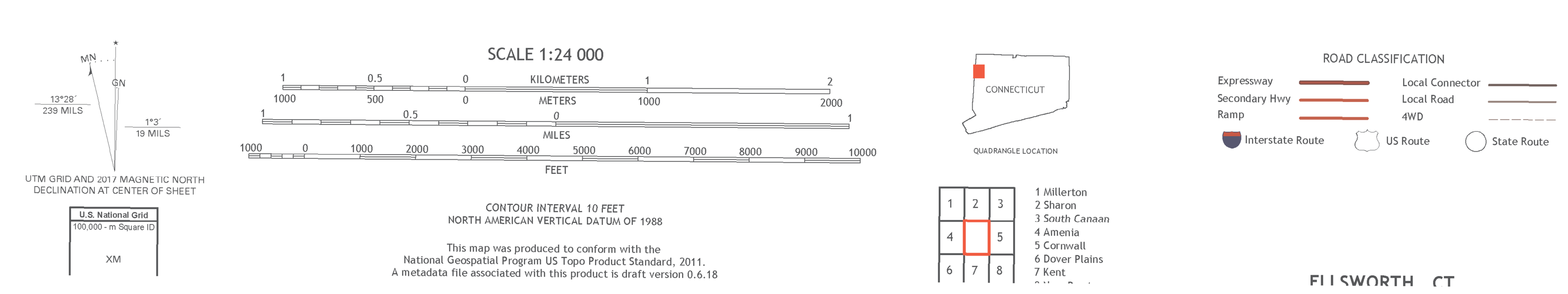
Precambrian

Yd	Deming HIll gneiss Yd: Dark-gray to dark-green, fine- to medium-grained, biotite-hornblende-plagioclase amphibolite and gray, fine- to medium-grained, biotite-quartz-plagioclase gneiss. Locally the gneiss contains scattered garnets and blue quartz.
Yw	West Woods gneiss Yw: Dark-gray and white layered, fine-to medium-grained, biotite-hornblende-plagioclase gneiss. Mafic and felsic segregations up to 10 cm thick define layering which is locally absent, giving way to uniform, gray, well foliated biotite-plagioclase gneiss.
Ye, Yem, Yea	Ellsworth gneiss Ye: Well layered, gray- to locally rusty-weathering, fine- to medium-grained muscovite-biotite-quartzofeldspathic gneisses. Locally they are graphitic and contain garnet. Subordinate but common rock types are thin-bedded gray to blue-gray quartzites, various fine-grained calc-silicate rocks and rare schistose sillimanite-bearing gneiss or sillimanite-quartz granulite. Yem: Diopside-calcite marble Yea: Dark-gray to black, fine- to medium-grained biotite-hornblende-plagioclase amphibolite, locally with augite or scattered garnet.
Ys	Stony Brook gneiss Ys: Light-gray, well foliated, fine- to medium-grained biotite-quartz-plagioclase gneiss with characteristic augen of subhedral plagioclase up to 5 mm.
Yb	Bread Loaf Mountain gneiss Yb: An undivided assemblage of rusty-weathering, graphitic quartzofeldspathic gneiss and schsitose gneiss; garnet-hornblende-biotite-quartz-plagioclase gneiss; amphibolite and minor occurrences of green graphitic diopside calc-silicate rock.
Yr	Richard Pond gneiss Yr: Light-gray biotite-microcline-quartz-plagioclase gneiss characterized by discontinuous white felsic layering up to 10 cm thick.

Burr, Jonathan L., 1986. Bedrock Geology of the Ellsworth and Eastern Part of the Amenia Quadrangles, Connecticut and New York. M.S. Thesis, University of Massachusetts, Amherst, MA, USA, 155p., 1:24,000 scale map, 5 plates. Connecticut Geological and Natural History Survey, Hartford, CT, 2019, Quadrangle Report, QR41, PDF; GIS geodatabase [GeMS format] www.ct.gov/deep/geology

GIS data available as GeMS format geodatabase

Digital Compilation of The Bedrock Geological Map and Report of Ellsworth and Amenia Quadrangles, Connecticut supported by the U.S. Geological Survey, National Geological and Geophysical Data Preservation Program and the Connecticut Geological Survey, Department of Energy and Environmental Protection. Award No. G18AP00097



Bedrock Geology of the Ellsworth and Eastern Part of the Amenia Quadrangles, Connecticut and New York (1986)

Jonathan L. Burr

Plate 2

EXPLANATION of MAP SYMBOLS

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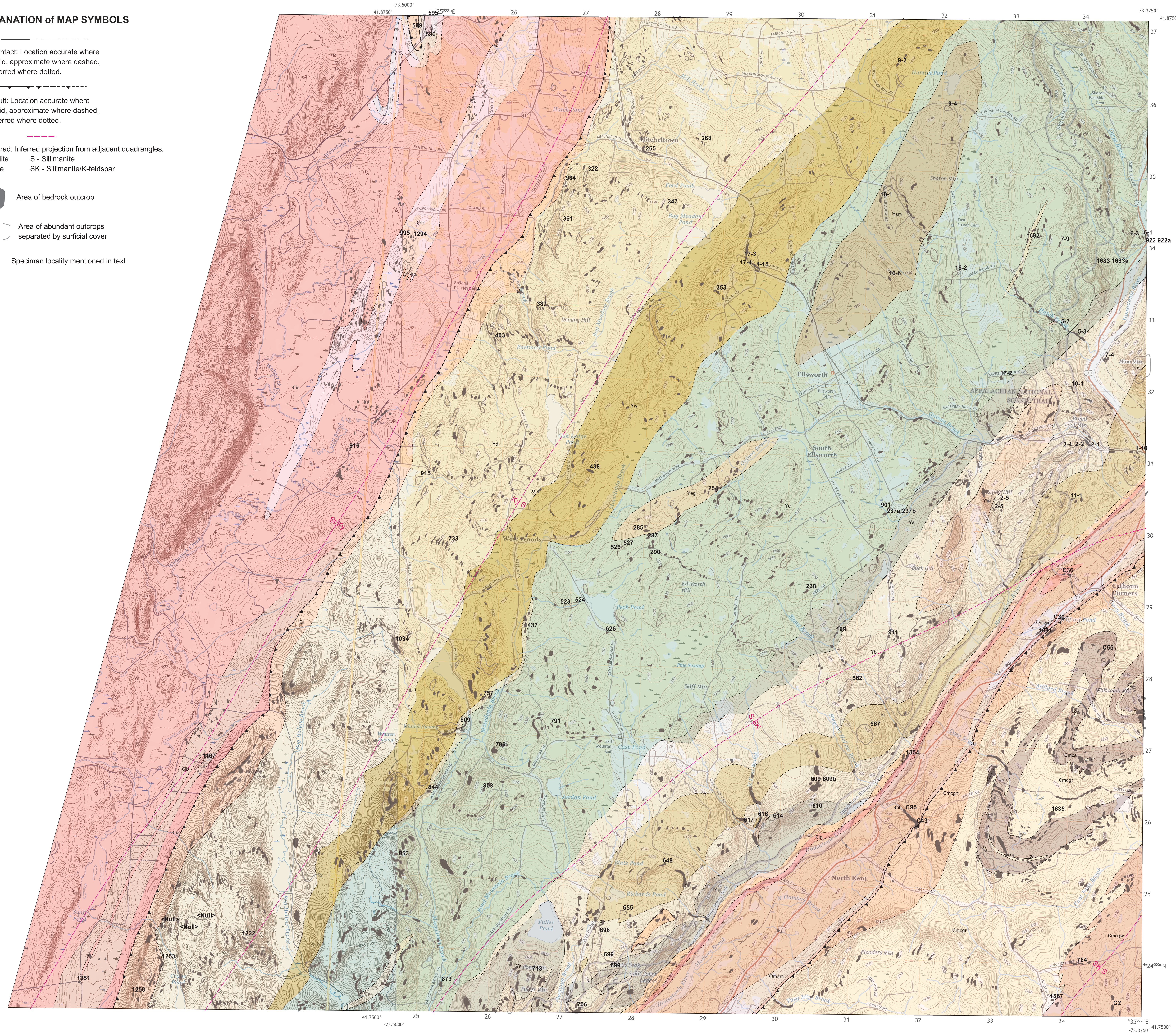
St - Staurolite   S - Sillimanite
Ky - Kyanite   SK - Sillimanite/K-feldspar

Area of bedrock outcrop

Area of abundant outcrops separated by surficial cover

238 Speciman locality mentioned in text



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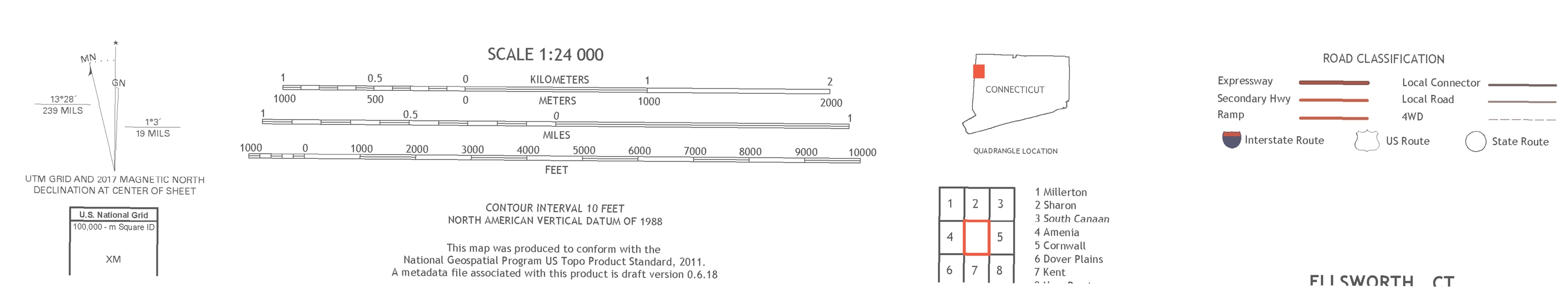

INTRUSIVE IGNEOUS ROCKS

Precambrian

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Ysj: Weakly foliated, medium-grained, light-pink, quartz-microcline granite. Locally containing microcline augen up to 5 mm long and hastingsitic hornblende.

Ysm — Sharon Mountain granodiorite gneiss

Ysm: Light-gray, weakly foliated, fine- to medium-grained biotite-microcline-quartz-plagioclase granodiorite. Smooth, uniform, rounded outcrops are typical.

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Yu — Ultramafic rock

Yu: Coarse-grained, massive, dark-grey to dull-green anthophyllite-olivine rock with lesser amounts of serpentine, talc, phlogopite, chlorite, magnetite and pyrite. The outcrop is brown-weathering with radiating clusters of fibrous anthophyllite.

STRATIFIED ROCKS

Autochthonous Rocks

Ordovician

Manhattan A

Omas — Omas: Schist Member: Well foliated, fine-grained, dark-gray muscovite biotite-feldspar schist or schistose granulite with abundant garnet in the western exposures.

Omam — Omam: Marble Member: Well foliated, tan-weathering calcite marble.

UNCONFORMITY

Inwood marble

Oid — Oid: Member D: Well-foliated, thin-bedded, tan, white, brown or blue-gray dolomite marble. Interbeds of tan, sandy, calcite-dolomite marble 2-10 cm thick, locally crossbedded, quartzites and schistose phlogopite marble are characteristic.

Cambrian

Ꞓic — Ꞓic: Member C: Fine-grained, gray dolomite marble with thin (1 cm), white quartz (recrystallized chert) layers. Outcrops have rounded, crumbly-weathering surfaces.

Ꞓib — Ꞓib: Member B: Well bedded, light-gray- or tan-weathering dolomite marble. Minor, thin interbeds of quartzite are characteristic.

Ꞓia — ?Ꞓia: Member A: Fine-grained, well bedded white dolomite marble.

Lowette quartzite

Ꞓl — Ꞓl: Fine-grained, tan, vitreous quartzite and granular feldspathic quartzite with a basal pebble conglomerate not more than 1 m thick.

UNCONFORMITY

Precambrian

Yd — Deming HIll gneiss

Yd: Dark-gray to dark-green, fine- to medium-grained, biotite-hornblende-plagioclase amphibolite and gray, fine- to medium-grained, biotite-quartz-plagioclase gneiss. Locally the gneiss contains scattered garnets and blue quartz.

Yw — West Woods gneiss

Yw: Dark-gray and white layered, fine-to medium-grained, biotite-hornblende-plagioclase gneiss. Mafic and felsic segregations up to 10 cm thick define layering which is locally absent, giving way to uniform, gray, well foliated biotite-plagioclase gneiss.

Ye, Yem, Yea — Ellsworth gneiss

Ye: Well layered, gray- to locally rusty-weathering, fine- to medium-grained muscovite-biotite-quartzofeldspathic gneisses. Locally they are graphitic and contain garnet. Subordinate but common rock types are thin-bedded gray to blue-gray quartzites, various fine-grained calc-silicate rocks and rare schistose sillimanite-bearing gneiss or sillimanite-quartz granulite.

Yem: Diopside-calcite marble

Yea: Dark-gray to black, fine- to medium-grained biotite-hornblende-plagioclase amphibolite, locally with augite or scattered garnet.

Ys — Stony Brook gneiss

Ys: Light-gray, well foliated, fine- to medium-grained biotite-quartz-plagioclase gneiss with characteristic augen of subhedral plagioclase up to 5 mm.

Yb — Bread Loaf Mountain gneiss

Yb: An undivided assemblage of rusty-weathering, graphitic quartzofeldspathic gneiss and schsitose gneiss; garnet-hornblende-biotite-quartz-plagioclase gneiss; amphibolite and minor occurrences of green graphitic diopside calc-silicate rock.

Yr — Richard Pond gneiss

Yr: Light-gray biotite-microcline-quartz-plagioclase gneiss characterized by discontinuous white felsic layering up to 10 cm thick.

Allochthonous Rocks

Cambrian

Everett formation

Ꞓe — Ꞓe: Dull-green to greenish-gray, fine-grained chlorite-muscovite, phyllitic schist and biotite-plagioclase-muscovite quartzose schist with staurolite and garnet porphyroblasts. Quartz-plagioclase segregations are common.

Manhattan C

Ꞓmcw — Ꞓmcw: Warren Member: Medium- to coarse-grained, tan- to reddish-brown-weathering, sillimanite-garnet-biotite-muscovite-plagioclase-quartz schist and granulite locally with abundant sillimanite nodules. Large muscovite flakes give a sparkling aspect to the rock. Locally it contains up to 2% magnetite.

Ꞓmcgr — Ꞓmcgr: Schistose Granulite Member: Gray-weathering, fine-grained, light-gray muscovite-biotite-quartz-plagioclase schistose granulite and gneiss. Locally it contains lavendar garnets and fibrous sillimanite that form small nodules. Gray plagioclase augen up to 1 cm are a local, but distinctive feature.

Ꞓmca — Ꞓmca: Amphibolite Member: Dark-greenish-gray to black, fine- to medium-grained, biotite-quartz-plagioclase-hornblende amphibolite with accesory garnet, epidote and up to 7% ilmenite. Small plagioclase augen are common.

Ꞓmcgn — Ꞓmcgn: Schistose Gneiss Member: Medium- to coarse-grained, reddish-brown-weathering staurolite-garnet-sillimanite-plagioclase-quartz-biotite-muscovite schistose gneiss and schist. Abundant sillimanite nodules and sillimanite-rimmed garnet porphyroblasts up to 2 cm create typical nubby-weathering surfaces.

Bedrock Geology of the Ellsworth and Eastern Part of the Amenia Quadrangles, Connecticut and New York (1986)

Jonathan L. Burr

Plate 3

EXPLANATION of MAP SYMBOLS

Contact: Location accurate where solid, approximate where dashed, inferred where dotted.

Fault: Location accurate where solid, approximate where dashed, inferred where dotted.

Metamorphic isograd: Inferred projection from adjacent quadrangles.
St - Staurolite S - Sillimanite
Ky - Kyanite SK - Sillimanite/K-feldspar

Area of bedrock outcrop

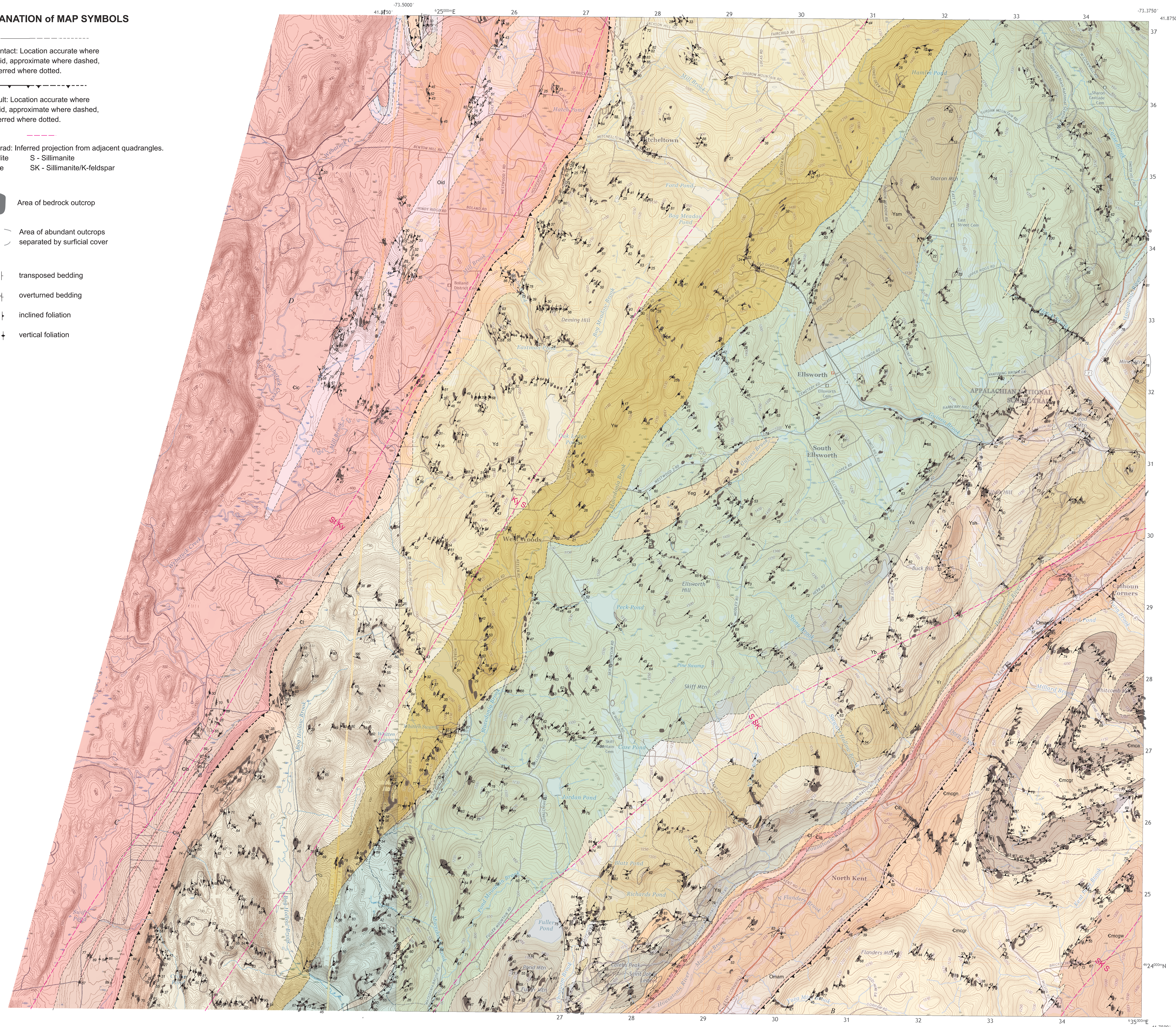
Area of abundant outcrops separated by surficial cover

transposed bedding

overturned bedding

inclined foliation

vertical foliation



INTRUSIVE IGNEOUS ROCKS

Precambrian

Ysj — St. John's Ledges granite gneiss

Ysj: Weakly foliated, medium-grained, light-pink, quartz-microcline granite. Locally containing microcline augen up to 5 mm long and hastingsitic hornblende.

Ysm — Sharon Mountain granodiorite gneiss

Ysm: Light-gray, weakly foliated, fine- to medium-grained biotite-microcline-quartz-plagioclase granodiorite. Smooth, uniform, rounded outcrops are typical.

Yeg — Ellsworth granodiorite gneiss

Yeg: Medium- to coarse-grained, garnet-biotite granodiorite gneiss. Outcrops weather with rough, light-gray surfaces on which plagioclase grains stand out. Biotite occurs in patches.

Ysh — Silver Hill tonalite gneiss

Ysh: Light-tan to light-gray, fine grained quartz-plagioclase tonalite gneiss mapped as a unit based on the presence of abundant disseminate magnetite. Rare magnetite segregations up to 2 cm thick occur at Buck Hill and hornblende occurs locally in thin (1 cm) discontinuous segregations or disseminated grains near the contacts.

Yu — Ultramafic rock

Yu: Coarse-grained, massive, dark-grey to dull-green anthophyllite-olivine rock with lesser amounts of serpentine, talc, phlogopite, chlorite, magnetite and pyrite. The outcrop is brown-weathering with radiating clusters of fibrous anthophyllite.

STRATIFIED ROCKS

Autochthonous Rocks

Ordovician

Manhattan A

Omas — Omas: Schist Member: Well foliated, fine-grained, dark-gray muscovite biotite-feldspar schist or schistose granulite with abundant garnet in the western exposures.

Omam — Omam: Marble Member: Well foliated, tan-weathering calcite marble.

UNCONFORMITY

Inwood marble

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Cambrian

Єic — Єic: Member C: Fine-grained, gray dolomite marble with thin (1 cm), white quartz (recrystallized chert) layers. Outcrops have rounded, crumbly-weathering surfaces.

Єib — Єib: Member B: Well bedded, light-gray- or tan-weathering dolomite marble. Minor, thin interbeds of quartzite are characteristic.

Єia — ?Єia: Member A: Fine-grained, well bedded white dolomite marble.

Lowette quartzite

Єl — Єl: Fine-grained, tan, vitreous quartzite and granular feldspathic quartzite with a basal pebble conglomerate not more than 1 m thick.

UNCONFORMITY

Allochthonous Rocks

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Yem: Diopside-calcite marble

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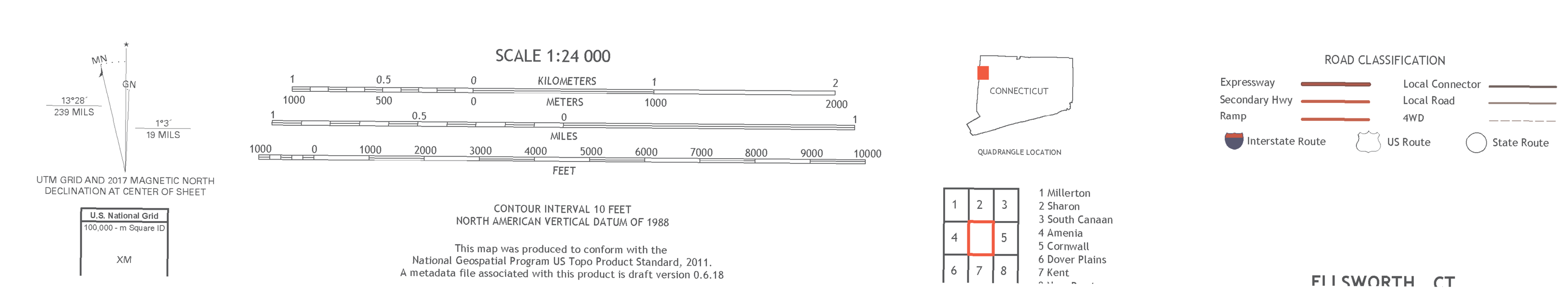
Burr, Jonathan L., 1986. Bedrock Geology of the Ellsworth and Eastern Part of the Amenia Quadrangles, Connecticut and New York. M.S. Thesis, University of Massachusetts, Amherst, MA, USA, 155p., 1:24,000 scale map, 5 plates. Connecticut Geological and Natural History Survey, Hartford, CT, 2019, Quadrangle Report, QR41, PDF; GIS geodatabase [GeMS format] www.ct.gov/deep/geology

GIS data available as GeMS format geodatabase

Digital Compilation of The Bedrock Geological Map and Report of Ellsworth and Amenia Quadrangles, Connecticut supported by the U.S. Geological Survey, National Geological and Geophysical Data Preservation Program and the Connecticut Geological Survey, Department of Energy and Environmental Protection. Award No. G18AP00097



ELLSWORTH, CT

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Jonathan L. Burr

Plate 4

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Area of bedrock outcrop

Area of abundant outcrops separated by surficial cover

axial planar cleavage

axial plane of fold, with or without cleavage

axial planar foliation

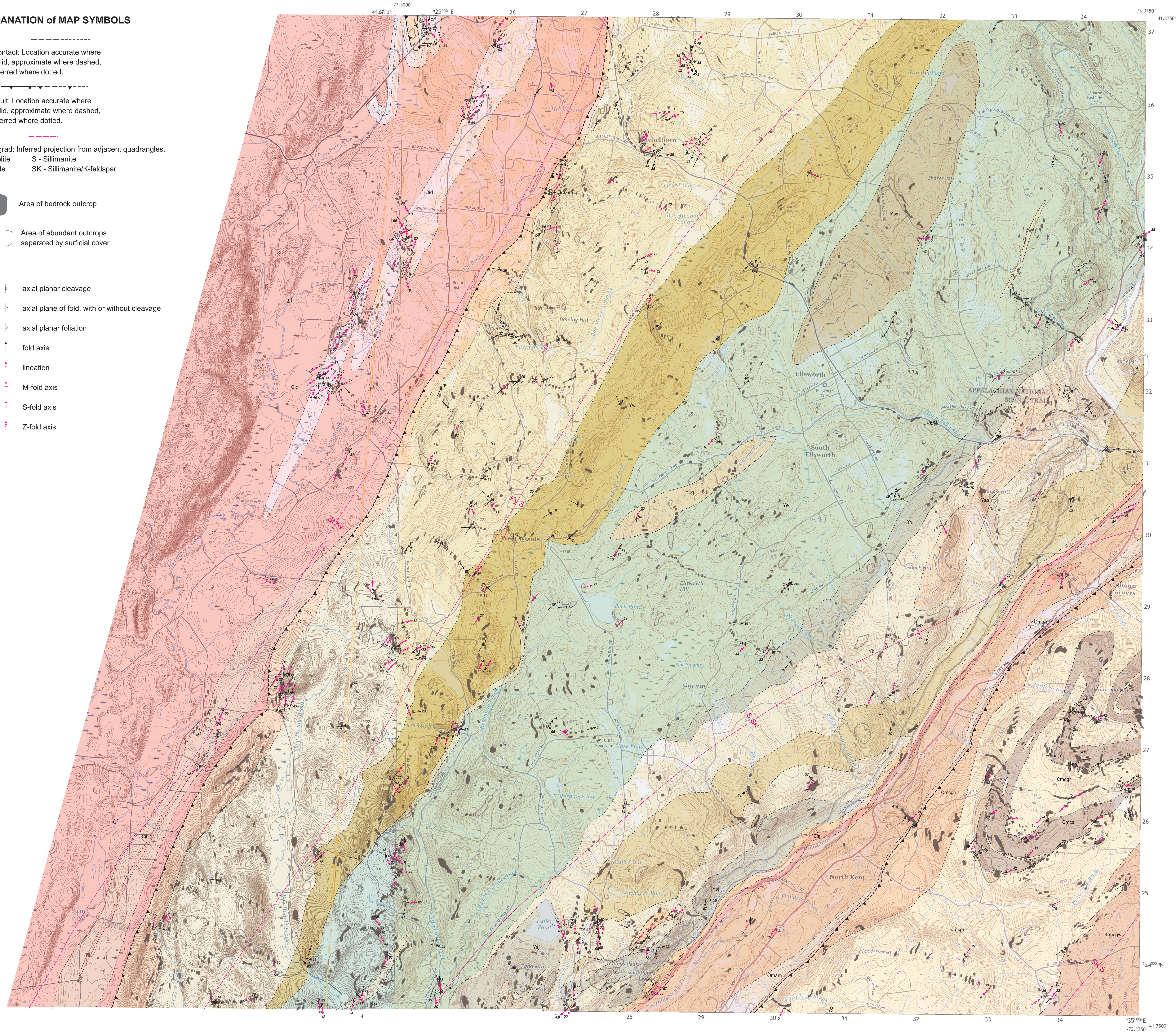
fold axis

lineation

M-fold axis

S-fold axis

Z-fold axis



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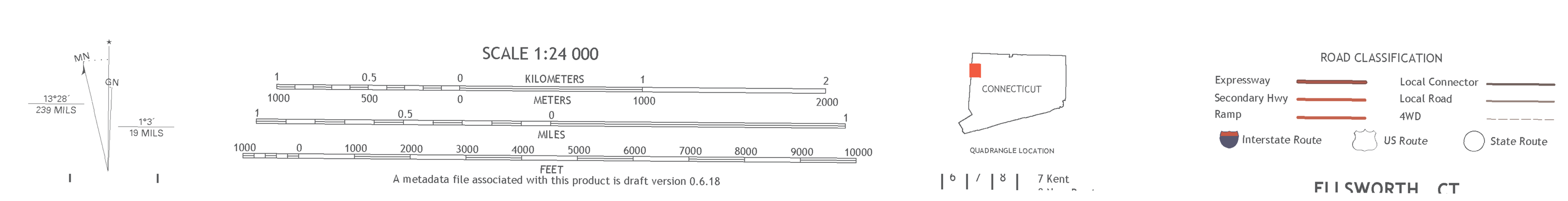

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