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U.S. Geological Survey

DESCRIPTION OF MAP UNITS [Major minerals are listed in order of increasing abundance] DSm Polymict metaconglomerate unit (Lower Devonian and Silurian?)— Dark-gray to black, rusty weathering, sulfidic, polymict conglomerate POST-METAMORPHIC INTRUSIVE ROCKS and breccia containing (1) rusty weathering, dark-gray to black, WHITE MOUNTAIN IGNEOUS SUITE

others, 2020), (2) an age of 133±6 Ma from a dike in the North Hartland Dam spillway (McHone and McHone, 2012; Walsh, 2016), and (3) on a regional summary by McHone (1984) for similar dikes throughout New England and Québec] Mafic dikes (Cretaceous)—Aphanitic, dark-gray to black, locally rusty weathering, lamprophyre, camptonite, or diabasic dikes. Six dikes are shown by point symbols on the map, and range from centimeters (cm) up to 2.0 meters (m) thick. The dikes may contain phenocrysts of biotite, amphibole, pyroxene, and olivine, and may contain amygdules filled with dolomite or calcite. Generally, the dikes intrude parallel to steeply dipping joint sets and show variable orientations. The dikes are unfoliated, but may be blocky jointed. Many similar dikes cut the syenite at Mount Ascutney in the adjacent quadrangle to the north (Walsh and others, 2020), so these undated dikes are younger than about 122 Ma

[Dikes are assigned a Cretaceous age based on (1) the 122.2±2 Ma (mega-annum) average

age of the entire Ascutney Mountain igneous complex (Foland and others, 1985; Walsh and

SYN- TO POST-METAMORPHIC ROCKS Silicified zones (Mesozoic)—Very dark gray to white, brecciated and crystallized vein quartz and silicified and brecciated country rock. Vein quartz contains accessory calcite, opaques, chlorite, and muscovite. The unit occurs as approximately 5- to 150-m-thick zones along major Mesozoic faults like the Ammonoosuc and Grantham faults, and along smaller, unnamed faults. The unit is well exposed along the Grantham fault on Gliddens Hill and Quimby Hill, and in the small unnamed stream between the two hills

KDg Quartz veins (Cretaceous to Devonian)—White- to gray-weathering quartz veins. Veins range in size from 0.1 to 5 m thick, and may locally contain small amounts of muscovite, chlorite, graphite, sulfides, and carbonate minerals. A muscovite-kyanite-quartz vein occurs on the east side of Skitchewaug Mountain along U.S. Route 5, 2 kilometers (km) north of the Cheshire toll bridge, where it is shown with a strike-and-dip symbol and labelled as "Ky" on the map. The veins are shown as polygonal map bodies where veins are large enough to map; thickness of the map bodies is locally exaggerated to show location. Outcrop-scale veins may be shown by strike-and-dip symbols or triangles where orientation could not be determined. Large mapped veins are locally associated with Mesozoic brittle faults and mapped separately as silicified zones (Mzsz). The veins are generally steeply dipping and show a preferred north-northeast strike (fig. 3)

PRE- TO SYN-METAMORPHIC ROCKS

TECTONIC MÉLANGE AND FAULT ROCKS Phyllonite (Permian, Carboniferous, Lower Devonian, and Silurian) ray, mylonitic to phyllonitic chlorite-muscovite-quartz rock mapped along the Monroe thrust fault and the Westminster West fault zone in the southern part of the map area where the unit extends into the adjacent Bellows Falls quadrangle. ⁴⁰Ar/³⁹Ar data from this chlorite-zone phyllonite in the adjacent Bellows Falls quadrangle, vielded a white-mica age of ~300 Ma (McWilliams and others, 2013). interpreted to reflect the time of phyllonite formation. White-mica analyses west of the fault, in the biotite zone, yielded cooling ages of ~365 Ma, and analyses east of the fault, in the staurolite zone, yielded cooling ages of ~320 Ma (McWilliams and others, 2013). The unit is well-exposed along Route 5 and Interstate 91 (I–91)

layering, but they locally crosscut the rocks they intrude. Mapped pegmatite is restricted to the eastern part of the map in the sillimanite-muscovite zone where the dikes are deformed by the D2 deformation fabrics in these rocks. On the map, the unit may be shown by a strike-and-dip symbol only, where rock exposure is very (Bradley and others, 2016)

sulfidic graphite-chlorite-biotite-muscovite-quartz schist matrix; and small. Pegmatite ages may range from Late Devonian to Permian (2) gray, plagioclase-biotite-chlorite-muscovite-quartz schist and phyllite matrix. The unit contains rounded to angular pebble- to boulder-size clasts of gray, black, and tan quartzite, pebbly quartzite, **Dbg Bethlehem Granodiorite** (**Devonian**)—Light- to medium-gray, conglomerate, vein quartz, black schist, metavolcanic rocks, gray moderately to strongly foliated, locally massive, porphyritic to calcareous granofels with small vugs, calc-silicate rock, gray-green porphyroclastic, garnet- and muscovite-bearing, biotite granodiorite foliated phyllite, and rare granitoid suggesting the rock is derived gneiss to granite gneiss; locally a hornblende diorite. Also, locally, from the pre-Silurian rocks in the Bronson Hill arc, including the the unit contains outcrop- to map-scale xenoliths of granofels and Albee Formation (not exposed in the map area), Ammonoosuc biotite schist of the Rangeley Formation (Srq). The rock contains Volcanics, and Partridge Formation. The mélange contains angular garnet, muscovite, biotite, K-feldspar, quartz, and plagioclase with clasts and boulders that resemble the Clough Quartzite and Fitch accessory to trace amounts of garnet, myrmekite, monazite, and Formation, indicating that the unit also postdates deposition and zircon; plagioclase and K-feldspar porphyroclasts are commonly 1 to lithification of the Silurian units. At Chestnut Hill, the mélange 3 cm across but decrease to millimeter (mm)-size porphyroclasts near contains angular boulders (up to 0.5 m across) of the Clough the Brennan Hill thrust and in internal shear zones; unit Dbg was Quartzite indicating that its formation postdates deposition of the intruded by felsic aplite and pegmatite dikes. The unit occurs only in Clough Quartzite (Thompson and others, 2012). Some clasts have a the Brennan Hill thrust sheet. Sensitive high-resolution ion metamorphic fabric that indicates the source rocks experienced an microprobe (SHRIMP) analyses yielded U-Pb zircon ages of 401±3 earlier period of deformation. The matrix may be reworked Partridge Ma from Bellows Falls on the Connecticut River in the adjacent Formation or Silurian to Devonian gray phyllite and schist. The belt Bellows Falls quadrangle (Fall Mountain pluton), and 399±3 Ma of rocks is in the stratigraphic position of the Partridge Formation or (sample CS-3025, this report) from a roadcut that is 1 km southeast Clough Quartzite on the east side of the Connecticut Valley trough. of Unity (Mount Clough pluton) (Merschat and others, 2015) The mélange is spatially related to the Monroe thrust fault,

supporting a tectonic origin for this belt of rock (Thompson and

others, 2012; Walsh, 2016). Typical exposures occur at Chestnut Hill

in Springfield (Walsh and others, 1996a, b; Armstrong and others,

1997; Thompson and others, 2012). Similar rocks occur in the North

Hartland quadrangle (Walsh, 2016) at the same structural position,

NEW HAMPSHIRE PLUTONIC SUITE

trondhjemite dikes and sills. The dikes crosscut foliated country rock

and crosscut an early bed-parallel S₁ foliation in the Silurian-

Devonian rocks, and either pre-date or are synchronous with the

development of the S₂ foliation. Well exposed dikes cut the Gile

Mountain Formation on the north bank of the Black River, 1 km west

of Goulds Mill. On the map, the unit may be shown by a

ourmaline-biotite-muscovite-quartz-K-feldspar pegmatite. Pegmatite

layers are largely concordant with the dominant foliation and

strike-and-dip symbol only, where rock exposure is very small

Pegmatite (Devonian)—White- to pink-weathering, massive, ±garnet-

ROCKS OF THE CONNECTICUT VALLEY TROUGH GILE MOUNTAIN FORMATION [Age from McWilliams and others, 2010]

but on the north and east side of the Meridan antiform (fig. 1) DSm? Pebbly phyllite unit (Lower Devonian and Silurian?)—Gray, Metasedimentary Rocks plagioclase-biotite-chlorite-muscovite-quartz schist to phyllite matrix Dgq Feldspathic quartzite, granofels, and metapelite member (Lower with small angular to rounded polymict pebbles (<1 cm diameter) and rare cobbles (<15 cm diameter). The unit is distinctly gray with **Devonian**)—Light-gray, tan-weathering, massive, micaceous, non-rusty weathering, which is similar to most of the Littleton feldspathic quartzite and micaceous plagioclase-quartz granofels Formation, but it also resembles a fine-grained equivalent of unit interbedded with lesser dark-gray carbonaceous chlorite-biotite-DSm. The map unit occurs between unit DSm to the west and the muscovite-plagioclase-quartz slate, phyllite, or schist. Locally, Partridge and Littleton Formations to the east and is interpreted as an slightly calcareous rock contains round-weathering pits as much as a older, more distal phase of the mélange that was subsequently few cm across. Quartzite and granofels comprise approximately 50 to overridden by unit DSm and the Monroe thrust fault. The unit is 90 percent of the unit in beds that generally range in thickness from exposed near the junction of Crown Point Road and Spencer Hollow 2 to 100 cm. In the core of the Meriden antiform, the unit consists Road. The map-unit label is queried "?" because the fine-grained largely of quartzite, locally with 10 percent or less of metapelite. nature of the rock and its similarity to other gray phyllite units make Layering becomes "pinstriped" near the Monroe thrust fault. The it problematic and difficult to distinguish and map separately; the lower contact is gradational with the Waits River Formation and the polymict clasts are characteristic but not readily visible at all outcrops upper contact is either, (1) a facies change, where it is in contact with upper members of the Gile Mountain Formation, or (2) tectonic, where it is in contact with the Ammonoosuc Volcanics and Partridge Formation. The unit is well-exposed on the south side of the Little Granite (Devonian)—Massive to moderately well foliated, Sugar River in North Charlestown ±garnet±microcline-muscovite-biotite-quartz-plagioclase granite to

Dgqs Gray quartzite and metapelite member (Lower Devonian)—Darkto light-gray, lustrous, locally sulfidic, carbonaceous chlorite±garnet± biotite-plagioclase-quartz-muscovite schist and phyllite, interbedded with thin gray quartzite, tan to gray feldspathic quartzite, and gritty micaceous plagioclase-quartz granofels. Quartzite is generally less than 50 percent of the unit. The unit is similar to the phyllite and schist member (DSws) of the Waits River Formation, but has more quartzite beds; it is also similar to member Dgq, but it has fewer quartzite beds. Typical exposures occur in the Black River east of Springfield and on the south end of Calavant Mountain in

CONTOUR INTERVAL 6 METERS

NATIONAL GEODETIC VERTICAL DATUM OF 1929

[Age from McWilliams and others, 2010] Metasedimentary Rocks DSwl Limestone and schist member (Lower Devonian and upper Silurian)—Dark- to light-gray, locally sulfidic and rusty weathering, lustrous, carbonaceous chlorite±garnet±biotite-plagioclase-quartzmuscovite schist and phyllite with characteristic interbedded dark-blue-gray, punky-dark-brown weathering, impure siliceous limestone or marble, quartz-rich calcareous schist, and gray calcareous to non-calcareous quartzite. The phyllite contains less than 10 percent chlorite and plagioclase, accessory biotite and garnet porphyroblasts in the garnet zone, and rare biotite porphyroblasts in the biotite zone. The limestones contain trace to 5 percent muscovite, 20 to 40 percent quartz, and 60 to 80 percent calcite with accessory plagioclase, pyrite, opaques, graphite, tourmaline, and apatite. The unit is distinguished from the adjacent metasedimentary units by the abundance of brown-weathered limestone and rusty weathering calcite-bearing schist. Beds of limestone range in thickness from 1 cm to 1.5 m and may constitute as much as 10 to 90 percent of an exposure; bedding in the metapelite is generally not visible. Contacts with adjacent units are gradational to sharp as the limestone beds decrease in abundance and thickness, either gradually or abruptly. Contacts with unit DSws are interpreted as facies changes and may not necessarily imply stratigraphic order. The unit is well-exposed along the Black River near downtown Springfield DSws Gray phyllite and schist member (Lower Devonian and upper

WAITS RIVER FORMATION

Silurian)—Dark- to light-gray, fine-grained, lustrous, carbonaceous chlorite-muscovite-plagioclase-quartz schist and phyllite. In places, the unit is interbedded with thin gray quartzite, tan to gray feldspathic quartzite, and gritty plagioclase-quartz granofels. Beds range in thickness from 3 to 10 cm. Locally, the unit contains trace amounts of very thin (1- to 2-cm thick) brown-weathering limestone beds. The schist contains biotite and garnet in the western part of the map. The unit is similar to the gray quartzite and metapelite member (Dgqs) of the Gile Mountain Formation, but generally has fewer quartzite layers. Typical exposures occur along Weathersfield Center Road near the junction with Town Farm Road Metavolcanic Rocks

Swv Laminated schist and granofels member (Lower Devonian and **upper Silurian**)—(1) Heterogeneous, laminated (mm-scale) to layered (cm-scale), green and white, in places rusty weathering, fine- to medium-grained, muscovite±biotite-chlorite-quartz-plagioclase schist; (2) silvery-green, fine- to medium-grained, muscovite±biotite-chloritequartz-plagioclase schist; (3) gray-green, medium-grained, muscovite± biotite-chlorite-quartz-plagioclase granofels; (4) gray to light gray, \pm carbonate \pm garnet-biotite-chlorite-muscovite-quartz-plagioclase granofels in 5-cm- to 2-m-thick beds with coarse (1- to 8-mmdiameter) plagioclase and quartz porphyroclasts; (5) green, finegrained, quartz-epidote-chlorite-plagioclase schist or greenstone; and (6) silvery-gray, rusty weathering, calcite-muscovite-chlorite-quartzplagioclase schist. In places, the unit is pitted where it contains accessory carbonate; it also contains accessory ilmenite porphyroblasts and porphyroclasts 1 to 5 mm in diameter. The unit is interpreted as a heterogenous assemblage of metamorphosed volcaniclastic and primary volcanic rocks. Typical exposures occur along Spencer Hollow Road north of Goulds Mill

DSwqc Polymict conglomerate member (Lower Devonian and upper

Silurian)—Creamy-white- to light-gray-weathering, massive to

weakly layered, typically clast-supported, quartz-pebble and cobble

conglomerate. Where present, the matrix around clasts consists of

ilmenite, chlorite, muscovite, and quartz and is usually 1 to 5 mm

thick and discontinuous. Pebbles consist of angular to rounded, 1-mm- to 10-cm-diameter clasts of (1) light- to bluish-gray, vitreous quartzite, or (2) white to buff-gray quartz derived from veins. The unit is mapped in one place on an unnamed hill in the Springfield Town Forest area between unit members DSwvq and DSwv in the southern part of the map. The unit is lithologically similar to the lower unit of the Clough Quartzite (Scqc) Metavolcaniclastic members (Lower Devonian and upper

MAP LOCATION

Silurian)—DSwvq consists of mm- to cm-scale laminations of limey- to non-limey carbonaceous schist and biotite-chloritemuscovite-plagioclase-quartz granofels that may represent water-lain intermediate to felsic volcanics. DSwsv consists of very well bedded, limey, carbonaceous schist; calcareous quartzite; and well-laminated (mm-scale) quartz-plagioclase schist horizons. The units appear to be an admixture of pelitic and volcanic water-lain sediments, and are located in the southern part of the map where they are extrapolated from the Bellows Falls quadrangle (Armstrong, 1997) Felsic volcanic member (Lower Devonian and upper Silurian)— (3- to 50-cm-thick), epidote-muscovite-chlorite-quartz-plagioclase-

Heterogeneous unit consisting of (1) silvery-green to green ±calcite±epidote-muscovite-quartz-chlorite-plagioclase phyllite or schist; (2) light-gray to whitish-pale-green, fine-grained, layered feldspathic schist and granofels, locally with 1- to 3-mm-diameter quartz and plagioclase porphyroclasts interpreted as phenocrysts; (3) gray-green, massive, fine- to medium-grained, muscovite-chloritequartz-plagioclase feldspathic granofels with 1- to 3-mm diameter quartz and sausseritized plagioclase porphyroclasts that are interpreted as phenocrysts of epidote and actinolite pseudomorphs after pyroxene; and (4) green to dark-green, fine-grained, quartz-plagioclase-epidote-chlorite schist or greenstone (less than 10 percent of exposures). The unit contains accessory sulfides and is interpreted as metamorphosed volcaniclastic sedimentary rocks, crystal tuffs, dacitic to andesitic flows, and mafic volcaniclastic sedimentary rocks. A sample of a metafelsite (VT/Sp1-85) that was collected from a roadcut on the south side of Route 11 near Goulds Mill yielded a thermal ionization mass spectrometry (TIMS) U-Pb zircon age of 423±4 Ma (Aleinikoff and Karabinos, 1990; Hueber and others, 1990). The dated metafelsite is interpreted as a dike (Aleinikoff and Karabinos, 1990) or alternatively a volcanic horizon (Walsh and others, 1996a, b)

g Large-garnet and hornblende-garbenschiefer schist member (Lower Devonian and upper Silurian)—Silvery gray to light-gray, in places rusty weathering, epidote-biotite-chlorite-muscovite-garnethornblende-quartz-plagioclase schist with distinctive 1- to 5-cm-long sprays of hornblende and 1- to 5-cm-diameter garnet porphyroblasts. The unit is interpreted as metamorphosed pelitic sedimentary rock with a volcaniclastic component of intermediate to mafic composition and is interlayered with units DSws and DSwl, and all metavolcanic units on the map. The unit is well exposed on Pudding Hill in the southwest corner of the map Hornblende-plagioclase gneiss member (Lower Devonian and upper Silurian)—Dark-green, medium- to coarse-grained, ±garnet-epidotechlorite-hornblende-plagioclase gneiss with roughly equal percentages

of hornblende and plagioclase. The unit varies from a massive, weakly

foliated and very coarse-grained gneiss to a well-layered gneiss. The

massive variety may be partly intrusive where intergrowths of

hornblende with matrix plagioclase are ubiquitous, and these

intergrowths reflect replacement of a primary ophitic texture. Contacts

with surrounding units are sharp. Unit exposures north of Hunt Road

in Windsor are of the well-layered variety

wa Amphibolite and greenstone member (Lower Devonian and upper Silurian)—(1) Dark-green to green, fine-grained, massive epidotechlorite-hornblende-plagioclase amphibolite gneiss with 1- to 3-mm-diameter, white, sausseritized, plagioclase porphyroclasts; and (2) laminated to massive, epidote-carbonate-actinolite-chloriteplagioclase greenstone. Generally, the laminated greenstone is intercalated with unit DSwv, and the massive greenstone and amphibolite have sharp contacts with adjacent units. In the northwestern part of the map, the greenstone is interlayered with unit DSwv on a 1- to 3-cm-scale over a distance of several meters along the contact. The amphibolite crops out in the western part of the map where the rocks are at a higher metamorphic grade, and there it contains layers of greenstone similar to those found to the eastern part of the map. The unit is well exposed at roadcuts on the north side of Route 11 just west of I–91 DSwc | Conglomeratic quartzite and gray phyllite member (Lower Devonian and upper Silurian)—Dark-gray, plagioclase-biotite chlorite-muscovite-quartz schist and phyllite with zones of (1) matrix-supported, angular to rounded 1-mm- to 3-cm-diameter pebbles of clear to yellowish-gray, highly recrystallized,

coarse-grained quartzite and possible vein quartz; and (2) rounded deformed pebbles to cobbles (25-cm-diameter) of bluish-gray quartzite, light-gray quartzite, quartz pebble conglomerate, and rare greenish-gray metasiltstone. Clasts are only rarely sorted by size, and graded beds are rare, although some graded conglomerate beds occur. Matrix material is also found as disarticulated, 1- to 25-cm-long by 2- to 5-cm-thick clasts within well- to poorly-sorted and graded conglomerate layers, which appear to be early-stage autoclastic conglomerates. The unit occurs in two places along Spencer Hollow Road where it is in contact with metavolcanic rocks of members DSwv and DSwa NORTHFIELD FORMATION

DSn Schist member (Silurian)—Dark-gray to silvery gray, carbonaceous, fine-grained, muscovite-biotite-plagioclase-quartz schist or phyllite marked by conspicuous small garnets that are 1 to 2 mm in diameter that form small bumps on the foliation surfaces. Garnets are commonly partially to completely replaced by chlorite and albite SHAW MOUNTAIN FORMATION haw Mountain Formation (Silurian)—Heterogeneous unit of (1) interbedded rusty, slabby quartz-amphibolite, gray quartzite, quartz-pebble conglomerate, feldspathic granofels, biotite schist; and (2) punky weathering, massive to pinstriped, calcareous granofels,

locally with small (<1-cm-wide) weathering calcite pits. The unit is

exposed discontinuously along the unconformity at the base of the

Connecticut Valley trough ROCKS OF THE BRONSON HILL ANTICLINORIUM LITTLETON FORMATION

Metasedimentary Rocks Schist member (Lower Devonian)—Silvery gray to dark-gray, fine- to medium-grained, biotite-chlorite-muscovite-quartz schist, minor carbonaceous muscovite-quartz schist, and interbedded muscovite schist and micaceous quartzite (metaturbidite). Locally, rusty weathering is present, and in such places, it is extremely difficult to distinguish this unit from the Partridge Formation. The unit contains characteristic garnet and large (cm-scale) staurolite at higher metamorphic grade. Locally, the garnet is completely pseudomorphed

by chlorite. Staurolite typically has retrograde muscovite±chlorite

1-cm- to 1-m-thick; and (3) white to gray, muscovite-bearing quartz-pebble to quartz-cobble metaconglomerate. Extremely rare, faintly visible cross-beds are locally preserved. Clasts are typically elongated with aspect ratios commonly exceeding 10:1; clasts consist dominantly of vein quartz and gray to white quartzite. Contacts are typically sharp, and the unit may contain magnetite and, at higher metamorphic grade, it may contain chloritoid, garnet, staurolite, and sillimanite. Locally, the unit is mylonitic along the Northey Hill shear zone. Fossils described by Boucot and others (1958) and Boucot and Thompson (1963) occur in the upper part of the Clough Quartzite (Scql, where mapped separately) and include tetracorals, brachiopods, pelycypods, and a possible trilobite; fossils support a Llhandovery (early Silurian) age. The unit is well exposed on Perry Mountain Scs Rusty muscovite schist member (Silurian)—Rusty orange weathering, gray to silvery gray, medium- to coarse-grained, chlorite-

CORRELATION OF MAP UNITS

POST-METAMORPHIC INTRUSIVE ROCKS

WHITE MOUNTAIN IGNEOUS SUITE

SYN- TO POST-METAMORPHIC ROCKS

PRE- TO SYN-METAMORPHIC ROCKS

NTRUSIVE SUITE

ntrusive Complex

FITCH FORMATIO

TECTONIC MÉLANGE

AND FAULT ROCKS

NEW HAMPSHIRE PLUTONIC SUITE

ROCKS OF THE

CONNECTICUT VALLEY TROUGH

Metasedimentary Rocks

FORMATION

FORMATION

MORETOWN FORMATION

SHAW MOUNTAIN Ss

PRE-SILURIAN COVER SEQUENCE ROCKS

ON THE CHESTER DOME [Includes rocks of the Shelburne Falls arc in the Moretown slice]

CRAM HILL FORMATION

CORE ROCKS OF THE CHESTER DOME

MOUNT HOLLY COMPLEX

gneiss of the Mount Migmatitic Rocks

Holly Complex

Metasedimentary and

Metavolcanic Rocks

IGNEOUS SUITE

Baileys Mills

tonalitic gneiss

Intrusive and

rims and locally exhibits complete replacement by muscovite±

chlorite especially near lower-greenschist facies faults; partial to

complete replacement of staurolite by muscovite and sillimanite

occurs at higher metamorphic grade. The unit is in fault-contact with

the Clough Quartzite or the Partridge Formation along much of the

Northey Hill shear zone and unconformably overlies the Clough

Quartzite and Fitch Formation. The unit is in gradational contact with

unit Dlq and is locally conformable with the Fitch Formation in the

eastern part of the map. Typical exposures occur along I-91

(biotite-grade), in Hubbard Hill State Forest (staurolite-grade), and on

Metaconglomerate member (Lower Devonian)—Gray to dark-gray,

fine-grained, matrix-supported, quartz-pebble conglomerate and

polymict conglomerate with gray phyllite matrix. The unit may locally

contain felsic volcanic clasts or volcaniclastic rock. The unit occurs

within the DI member of the Littleton Formation located 300 m east of

the Crown Point Cemetery in Springfield. Thickness of the unit is as

Interbedded quartzite and schist member (Lower Devonian)—(1)

Silvery gray to dark-gray, micaceous quartzite; (2) micaceous quartzite

interbedded with biotite-muscovite-quartz schist; and (3) carbonaceous

schist. Quartzite layers are distinctly "sandy" or rough to the touch.

The unit contains characteristic garnet and large (cm-scale) staurolite

or quartz-muscovite-fibrolite knots at higher metamorphic grade;

garnet is locally pseudomorphed by chlorite. Staurolite typically has

retrograde muscovite±chlorite rims and locally exhibits complete

replacement by muscovite±chlorite at lower metamorphic grades and

partial replacement by muscovite±sillimanite at higher metamorphic

grade. Locally, the unit is magnetite-rich near the contact with the

Fitch Formation; the contact with the Fitch Formation is locally conformable but largely unconformable, and the lower contact is

unconformable with the Clough Quartzite. The contact between units

DI and DIq is gradational and interpreted as a facies change; DIq is

typically the lowest unit in the Littleton Formation in the eastern part

of the map, but in places, it is interfingered with unit Dl. Typical unit

exposures occur on Unity Mountain near Marshall Pond (muscovite-

Ietadiabase dike (Silurian)—Massive, medium-grained, very

lark-green to black and white, ±garnet-calcite-epidote-chlorite-

biotite-hornblende-plagioclase metadiabase. The unit is shown on the

map as several small bodies within the Clough Quartzite or Fitch

Formation on Skitchewaug Mountain, Rattlesnake Hill, and Breed

Hill; rarely observed unit contacts with the surrounding host rocks are

sharp. It is unclear if the rock bodies are unequivocally dikes in all

cases because the contacts are largely obscured. Thirteen observed

dikes are correlated with the Comerford Intrusive Complex that has

been dated at 419±1 Ma from samples collected in the Connecticut

Silurian)—Gray to dark-greenish-gray, medium-grained, ±magnetite±

actinolite/tremolite-carbonate-muscovite-biotite-plagioclase-quartz

granofels and schist. Locally, the unit contains distinctive calcareous

pods that are 1 to 3 cm across and irregular dissolution cracks and

pits that are locally aligned along bedding. Locally, the unit also

contains (1) calc-silicate pods consisting of garnet, quartz, actinolite,

and diopside at higher metamorphic grade east of the Grantham fault;

(2) variably rusty to bronze-weathering, medium-grained carbonate-

biotite-quartz schist with carbonate pods and layers 2 cm to 10 cm

thick; and (3) gray to light-gray, medium-grained, biotite-chlorite-

garnet-muscovite-quartz schist and micaceous quartzite with

distinctive high-relief weathering, white quartz-rich knots, pods,

layers or pebbles. Pods are composed predominantly of quartz and

muscovite, but may contain chlorite, garnet, magnetite, and biotite;

the pods may represent pseudomorphs after earlier staurolite or

andalusite. Disseminated magnetite is common in all rock types.

Millimeter- to cm-scale magnetite layers locally occur near the

contact with the Littleton Formation and Clough Quartzite. The unit

is well exposed at an active quarry on the northwest side of

Gray to black granofels member (Lower Devonian and upper

Silurian)—Massive, gray, ±magnetite±actinolite/tremolite±chlorite±

muscovite-garnet-biotite-plagioclase-quartz granofels to massive, black

to 5-mm-size garnet porphyroblasts and occurs as resistant horizons

within unit Sf where it is mapped separately on Skitchewaug Mountain

rusty weathering, gray to dark-gray or black, sulfidic, ±calcite-

plagioclase-chlorite-biotite-muscovite-quartz schist and granofels

with locally distinct biotite porphyroblasts. The unit contains rare

calcareous lenses that are parallel to bedding and it also contains

trace amounts of graphite and zircon. The unit is interbedded with

metasedimentary rocks (Sf) and is exposed on Skitchewaug

Mountain, especially south of the quarry and radio tower, where it is

mapped separately. Similar rusty schist occurs throughout the Fitch

Formation but was not mapped separately. The schist resembles the

Layered quartzite member (Silurian)—Dark- to light-gray, well-

bedded, vitreous quartzite with beds 1 to 25 cm thick. The unit

contains rare calcareous partings and poorly preserved fossils

(Boucot and others, 1958) that possibly represent relict coquina beds

(Thompson and others, 1993). The unit occurs as the upper part of the

Clough Quartzite on Skitchewaug Mountain where it is mapped

separately, and it locally contains thin, interbedded, biotite-spotted,

Undifferentiated (1) massive, poorly bedded, weakly foliated,

light-gray, orange-weathering quartzite with minor muscovite; (2)

well-bedded, gray to orange, micaceous quartzite with beds from

Undifferentiated conglomerate and quartzite member (Silurian)-

magnetite-garnet-biotite-quartz granofels. The unit contains distinct 1

Skitchewaug Mountain in Springfield, just east of I–91

Sfrs Rusty schist member (Lower Devonian and upper Silurian)—Very

Partridge Formation (Op), but is locally calcareous

CLOUGH QUARTZITE

River Valley about 80 to 120 km up river (Rankin and others, 2007)

Metasedimentary Rocks

Sf Gray granofels and schist member (Lower Devonian and upper

LAKE MEMPHREMAGOG INTRUSIVE SUITE

Comerford Intrusive Complex

Metaplutonic Rocks

sillimanite metamorphic grade)

much as 10 m, but is exaggerated on the map to show its location

Unity Mountain (muscovite-sillimanite grade)

Kd Mafic dikes

KDq Quartz veins

Aetasedimentary Rocl

FITCH FORMATION

Metasedimentary Rocks

AKE MEMPHREMAGOG

NTRUSIVE SUITE

Intrusive Complex

Metaplutonic Rocks

ROCKS OF THE BRONSON HILL ARC

PLUTONIC SUITE

ROCKS OF THE BRONSON

HILL ANTICLINORIUM

RANGELEY FORMATION

Metasedimentary Rocks

5, 1 km northeast of the Cheshire Toll Bridge in Springfield; it also

of the Partridge Formation at the south end of Skitchewaug Mountain

Quartzite member (Ordovician)—Dark-gray to black quartzite

occurs as a massive granofels unit that is tens of meters thick at the top

terbedded with dark-gray sulfidic schist. The unit contains cm-scale,

layered black and white, carbonaceous quartzite with biotite and garnet

porphyroblasts and trace amounts of muscovite, chlorite, and tourmaline

weathering, plagioclase-quartz-biotite-muscovite schist with

retrograded garnet porphyroblasts and trace amounts of ilmenite,

opaques, graphite, and chlorite interlayered with dark-gray sulfidic

schist. The unit contains sub-mm-size quartz fragments interpreted as

phenocrysts. Light-colored layers, as much as 40 cm thick, occur

within dark-gray schist (Op) along the contact with unit Opq on the

Gray-green chlorite-amphibole schist and amphibolite member

(Ordovician)—Interlayered amphibolite (Opa), minor sulfidic schist

amphibole schist characterized by very dark green amphibole/tremolite

porphyroblasts that occur as dark-gray weathered spots. In thin section,

the chlorite is almost colorless with very low birefringence and is

probably magnesium-rich, possibly antigorite. The amphibole/tremolite

is very pale green to very pale brown with little pleochroism. The rock

contains trace amounts of opaques, sphene, apatite, quartz, plagioclase,

tale, and serpentine (antigorite). Crosscutting carbonate veins contain

black, coarse-grained, actinolite-plagioclase greenstone or hornblende-

assemblage of rock types consisting of (1) dark-greenish-gray, fine to

medium-grained, plagioclase-biotite-chlorite-quartz schist to phyllite,

(2) layered to massive greenstone and amphibolite (locally with

garbenschiefer texture), (3) felsic quartz-plagioclase granofels

(metafelsite), (4) limonite-muscovite quartzite, and (5) sulfidic

quartz-plagioclase schist. Locally, the rocks contain minor carbonate,

magnetite, and sulfides. All rocks are locally rusty to very rusty

gray-green, bluish-green, silvery gray green, and green and white

layered. In the garnet metamorphic zone or higher, the rocks are

weathering. At sub-garnet metamorphic grade, the rocks are green,

darker-green, gray-green to black, and black and white layered.

Locally, the rocks contain pods and lenses of epidote, plagioclase and

lesser quartz phenocrysts, deformed pillows, fiamme (eutaxitic

texture), and volcanic breccia. The unit is interpreted as a

heterogeneous, metamorphosed sequence of volcanic and

volcaniclastic rocks, crystal tuffs, dacitic to andesitic flows, and

mafic volcanic and volcaniclastic rocks. Internal contacts are variable

and are either sharp or gradational by intercalation; contacts with the

Partridge Formation are generally sharp, but are locally gradational

ack, locally rusty weathering, massive to thickly layered, ±carbonate

±magnetite-chlorite-actinolite-epidote-plagioclase greenstone, schistose

greenstone, or hornblende-plagioclase amphibolite. Epidote nodules

and layers are common, and the unit rarely contains deformed

pillows. Overall, the unit is interpreted to be submarine metabasalt,

but it may in part consist of mafic sills. At higher metamorphic grade,

the rock contains appreciable amphibole and locally it exhibits

Bimodal metavolcanic rock member (Ordovician)—Interlayered

greenstone, greenschist, green phyllite, and metamorphosed felsic

volcanic and possible intrusive rocks. Typically, the unit consists of

distinctly banded rocks of green and white (below garnet metamorphic

grade) and dark-green to black and white (at and above garnet

metamorphic grade). Locally, the unit is sulfidic and rusty weathering.

Also locally, the felsic volcanic rocks contain quartz and (or)

plagioclase phenocrysts. The unit is interpreted as a heterogeneous,

metamorphosed sequence of volcanic and volcaniclastic rocks, crystal

tuffs, dacitic to andesitic flows, and mafic volcanic and volcaniclastic

rocks. Contacts are gradational with unit Oa of the Ammonoosuc

Volcanics and is distinguished from Oa by the distinct alternating

layering of felsic and mafic rocks. The unit is in tectonic contact with

the rocks of the Connecticut Valley trough along the Monroe thrust

fault. Generally, the unit is well exposed in areas of abundant outcrop,

PRE-SILURIAN COVER SEQUENCE ROCKS ON THE CHESTER DOME

[Includes rocks of the Shelburne Falls arc in the Moretown slice]

CRAM HILL FORMATION

Metasedimentary Rocks

Ochb Black quartz-phyllite and ironstone member (Ordovician)—Dark-

gray- to dull-black-weathering, very fine grained, siliceous phyllite

and phyllitic metasiltstone. The unit (1) forms thin beds of splintery,

steel-gray-weathering, sulfidic cummingtonite-magnetite-plagioclase-

quartz amphibolite as much as 3 m thick; and (3) contains

discontinuous beds of very rusty, manganiferous garnet-bearing

brown- to whitish-tan weathering, fine-grained biotite-garnet-

muscovite schist and carbonaceous phyllite. The unit contains beds

that are rich in tiny 1- to 2-mm-diameter garnets that are similar to

the garnet-rich phyllites of the Northfield Formation (DSn), and it

also contains coticule (identified by a lower case "c" on the map).

The unit grades laterally into a darker-gray to slightly rusty

weathering siliceous phyllite or schist that contains discontinuous

layers of steel-gray quartzite. The rock closely resembles phyllite and

schist in the Whetstone Hill member of the Missisquoi Formation

(Ratcliffe and others, 2011). Locally, the unit contains a distinctive

steel-gray- to yellow-tan-weathering quartzite and quartz-pebble

conglomerate (Ochq) as much as 2 m thick, and is transitional

quartzite and pinkish layers of coticule that are 1 to 2 cm thick

hs Papery thin schist and phyllite member (Ordovician)—Pale-gray-

highly fractured rock; (2) contains beds of pale-gray-green- to

Weathersfield Bow

downwards into unit Ochv

especially on Barber Mountain and along U.S. Route 5, north of

garbenschiefer texture. The unit is well exposed on Perry Hill

Greenstone and amphibolite member (Ordovician)—Dark-green to

Greenstone and amphibolite member (Ordovician)—Dark-green to

AMMONOOSUC VOLCANICS

Oa Undifferentiated volcanic member (Ordovician)—Heterogeneous

(Op), and very pale gray-green, silvery gray weathering, chlorite-

northwest side of Hubbard Hill in Charlestown

minor amounts of talc, tremolite, and chlorite

Metafelsite volcanic member (Ordovician)—Silvery, rusty tan

biotite-plagioclase-muscovite-quartz schist characterized by garnet porphyroblasts, and less abundant staurolite porphyroblasts. The unit occurs within the upper part of the Clough Quartzite (Scql) on Skitchewaug Mountain, as mapped horizons within unit Scq, or elsewhere on the map at the top of the Clough Quartzite along the contact with the Littleton Formation Scqc Metaconglomerate member (Silurian)—Light-gray to creamywhitish-gray, massive, polymict conglomerate and lesser schistose to granulose, light-gray to buff-colored, chlorite-muscovite-plagioclasequartz quartzite layers that are similar to vitreous quartzite beds in the overlying unit Scql. Pebble to cobble, and rare boulder-size clasts, consist of vitreous gray and white quartzite, vein quartz, and rare quartzose schist. The proportion of matrix to clasts varies, but the majority of the unit is clast-supported. The unit contains rare layers of gray, carbonaceous, sulfidic schist similar to the rusty schist units in the Partridge or Fitch Formations. Where mapped separately of Skitchewaug Mountain, the unit occurs at the base of the Clough Quartzite and is well exposed on Skitchewaug Mountain, along Route 5, and on the west slopes of Rattlesnake Hill. The contact with the

underlying Partridge Formation is a sharp unconformity RANGELEY FORMATION Metasedimentary Rocks in the Brennan Hill Thrust Sheet Srg Quartzite, calc-silicate, and schist member (Silurian)—Lightgreenish-gray- to light-gray-weathering, light-greenish-gray to white, strongly foliated quartzite to granofels, calc-silicate, and muscovite schist that consists of quartz, clinopyroxene, biotite, plagioclase, zoisite, iron- and titanium-oxides, and trace amounts of calcite and zircon; the calc-silicate contains greenish-black clinopyroxene, zoisite, and biotite that define the dominant foliation (S_n) . Quartz pebbles are 1 to 2 cm across and consist of undulose subgrains with serrated edges. The contact with the underlying Partridge Formation is not exposed; the contact with the Bethlehem Granodiorite (Dbg) is intrusive and locally mylonitic. Exposures in the map area are limited, and the unit is best exposed on the west side of Hedgehog Hill near Sleeper Brook in Unity

ROCKS OF THE BRONSON HILL ARC OLIVERIAN PLUTONIC SUITE Ogd Granodiorite, trondhjemite, and tonalite of the Sugar River (Ogd) and Unity (Ogdu) plutons (Ordovician)—Gray, gray- to orange-

weathering, fine- to medium-grained, ±garnet±hornblende-chloritebiotite-K-feldspar-plagioclase-quartz granodiorite, trondhjemite, and tonalite; accessory minerals include magnetite and apatite. Locally, the unit is enriched in magnetite near the contact with the Ammonoosuc Volcanics, which suggests contact metasomatism. Also locally, the unit contains xenoliths of coarse-grained garnetcordierite-biotite-gedrite granofels that contain minor chlorite, magnetite, plagioclase, and apatite; the xenoliths were observed at the following two locations (labelled as "Ged" on the map; samples CS-3211 and CS-3454 in the database): (1) near the northeastern contact of the Unity pluton with the Ammonoosuc Volcanics (Oa) about 0.25 miles southwest of Pike Hill, and (2) approximately 0.75 miles south-southeast of Alden Hill. Enclaves and xenoliths of amphibolite are present locally within the plutons, and dikes cut the adjacent host rock that demonstrates that the rocks intruded the Ammonoosuc Volcanics. The unit is mapped as the Sugar River pluton (Ogd) in the northern part of the map, and mapped as the Unity pluton (Ogdu) in the east-central part of the map. The plutons yielded U-Pb SHRIMP zircon ages of 460±3 Ma (Sugar River pluton) (Valley and others, 2015; Walsh and others, 2020, in the adjacent Mount Ascutney quadrangle) and 446±6 Ma (Unity pluton; sample CS-3009) (Valley and others, 2020, in the Springfield quadrangle). The Sugar River pluton (Ogd) is well exposed in an unnamed stream located south of Newport Road, and the Unity pluton (Ogdu) is well exposed in the Little Sugar River near Quaker City

PARTRIDGE FORMATION Op Sulfidic schist member (Ordovician)—Dark-gray to light-gray and grayish-black, rusty weathering, sulfidic graphite±sillimanite± staurolite±garnet-ilmenite-plagioclase-biotite-chlorite-quartzmuscovite phyllite and schist. Locally, the unit contains light- to dark-gray, micaceous quartzite in thinly laminated layers or boudins; and dark-gray to black, quartzite beds that are mapped separately as unit Opq. The unit also contains rare 1- to 3-m-thick, dark-green, epidote-chlorite-hornblende-plagioclase amphibolite as dikes or metavolcanic layers that are mapped as unit Opa. Small quartzite (Opq) and amphibolite (Opa) bodies are exaggerated in size on the map to show their locations. Contacts with the Ammonoosuc Volcanics are generally sharp, but may be gradational within a few meters. Contacts with the Clough Quartzite are very sharp and rocks are phyllonitic to mylonitic along the Northey Hill shear zone Opg Gray granofels member (Ordovician)—Undivided (1) dark-gray to gray, massive, staurolite-garnet-plagioclase-chlorite-muscovite-quartz granofels with quartz clasts; and (2) gray titanite-quartz-calcite-biotitechlorite-plagioclase-amphibole calc-silicate rock; and (3) altered amphibolite. The unconformable contact with the overlying Clough Quartzite is sharp. Detrital zircons from a granofels sample (SP-2485)

collected 1 m below the contact with the Clough Quartzite yielded a

maximum depositional age (MDA) of 452 Ma (Walsh and others,

2017). The unit is interpreted as volcaniclastic rock and it occurs as 1- to

2-m-thick horizons in the sulfidic schist member (Op) along Route

¹U.S. Geological Survey;

²Madison River Group;

⁴Aera Energy

³U.S. Geological Survey, retired;

uartzite and quartz-pebble conglomerate as much as 2 m thick. The unit occurs along the contacts with units Ochs, Ochb, Ochg, and Ochv Metavolcanic Rocks

Greenstone member (Ordovician)—Medium-green to gray-green, highly foliated, hornblende-plagioclase greenstone that is marked by distinctive irregular clots or indistinct patches of more plagioclase-rich inclusions (as much as 3 cm in length) set in a more uniform amphibolite matrix. The unit is interpreted as basaltic- to andesitic-tuff breccia and volcaniclastic rock. The unit is mapped at five locations just below the unconformity at the base of the Connecticut Valley trough Hornblende-plagioclase-quartz granofels member (Ordovician)-Light-gray-weathering, medium- to coarse-grained garnet-biotite hornblende-plagioclase-quartz granofels. The unit is (1) marked by abundant sprays of large hornblende as much as 5 cm in length; (2) is interbedded with layers of biotitic amphibolite and hornblende-garnet amphibolite; and (3) contains coticule (identified by a lower case "c" on the map). The contact with unit Ochq is gradational by intercalation. The unit is mapped on an unnamed hill southwest of downtown Springfield where it passes into the adjacent Chester

quadrangle (Ratcliffe, 2000b) elsic and mafic volcaniclastic rock member (Ordovician)—A eterogeneous unit consisting of well layered, light-gray-weathering felsic biotite-hornblende-quartz-plagioclase gneiss intimately interlayered with darker-gray-green hornblende-biotite-plagioclase amphibolite and hornblende-plagioclase granofels and gneiss. Th proportion of felsic to mafic layers varies greatly, and the thickness of the mafic layers, which are generally subordinate, ranges from one to several meters. The rusty weathering biotite-muscovite-quartz schist, feldspathic granofels, and layers of coticule that are present throughout the unit indicate a collection of volcanic, volcaniclastic, and interbedded metasedimentary rocks; for this reason, the unit is interpreted as a member of the Cram Hill Formation. The contact relations with the underlying units are uncertain, but it may disconformably overlie the Moretown Formation and trondhjemite (Ontd) of the North River Igneous Suite. The unit occurs below the unconformity at the base of the Connecticut Valley trough. A sample of a felsic volcanic rock (sample SP450, this report) that was collected about 2.8 km north-northeast of North Springfield Reservoir and about 1.2 km west of Weathersfield Center Road, yielded a U-Pb SHRIMP zircon age of 483±3 Ma (Aleinikoff and others, 2011)

NORTH RIVER IGNEOUS SUITE Trondhjemite gneiss (Ordovician)—Principally, light-gray- to chalky-white-weathering, massive, medium-grained biotite±garnetquartz-plagioclase trondhjemite gneiss. The unit lacks the mafic layers that are present in unit Ochv of the Cram Hill Formation and is interpreted as intrusive into unit Omhfs of the Moretown Formation along the contact with Ochv. Alternatively, the rock may be

MORETOWN FORMATION Metasedimentary Rocks Iornblende fascicle schist member (Ordovician to Cambrian)ight-gray to gray-green, chlorite-muscovite-biotite-plagioclasequartz schist and granofels characterized by (1) conspicuous sprays of hornblende; (2) distinctive, large (5-mm- to 1-cm-diameter)

porphyroblasts of cross-foliation biotite; (3) abundant irregular layers of coticule that are 1 to 2 cm thick; and (4) abundant layers of light-gray, pinstriped biotite-quartz granofels similar to the "pinstriped" granofels member (Omp) of Ratcliffe and others (2011) Omp Pinstriped granofels member (Ordovician to Cambrian)-Light-gray to pale-green, whitish-gray weathering, chlorite-biotiteplagioclase-quartz granofels and tectonically pinstriped granofels and feldspathic biotite quartzite. Locally, the granofels layers contain abundant fascicles of hornblende, or hornblende-plagioclase layers that are 1 to 5 cm thick. The contact with the hornblende fascicle schist (Omhfs) is gradational

Black schist member (Ordovician to Cambrian)—Dark-gray to silvery gray, garnet-biotite-muscovite carbonaceous schist, and associated rusty weathering muscovite-biotite-quartz schist. The unit contains layers that are rich in small garnets (1 to 2 mm in diameter), which resemble phyllites of the Whetstone Hill Member of the Moretown Formation (Ratcliffe and others, 2011)

Green schist and granofels member (Ordovician to Cambrian) rincipally, light-green to pale-gray-green, lustrous, chloritebiotite-muscovite-quartz schist and light-gray feldspathic granofels interbedded on a scale of 10 cm. Locally, the unit contains coarse-grained garnet schist and widespread thin beds as much as 10 cm thick of pinstriped chlorite-muscovite-plagioclase-quartz schist and granofels identical to unit Omp. The unit also contains beds of coticule that are 1 to 2 cm thick (identified by a lower case "c" on the map) or layers of abundant dark-green well-foliated amphibolite. Distinctive porphyroblasts of cross-foliation biotite occur throughout the rock; these porphyroblasts and the very thin feldspathic layers are regionally characteristic of the Moretown or Stowe Formations and are absent from the Pinney Hollow Formation (Ratcliffe and others, 2011) with which these rocks have been incorrectly correlated by Thompson and others (1993). The unit is in fault contact with Mesoproterozoic rocks at its base and is in upwards-gradational contact with, and bedded with, the black schist unit (Omb). The unit is well exposed on the east side of the Springfield Reservoir Metavolcanic Rocks

Amphibolite (Ordovician to Cambrian)—Dark-green, highly foliated pidote-biotite-hornblende and hornblende-plagioclase amphibolite. The unit varies from highly foliated and epidote-podded to a more granular rock consisting of approximately 70 percent hornblende and 30 percent plagioclase

CORE ROCKS OF THE CHESTER DOME MOUNT HOLLY COMPLEX

Intrusive and Migmatitic Rocks Baileys Mills tonalitic gneiss (Mesoproterozoic)—Coarse-biotite flecked, light-gray to whitish-gray-weathering, medium-grained biotite-quartz-plagioclase gneiss that has a distinctive non-gneissic igneous-appearing texture in less-sheared rocks. The rock contains numerous inclusions of coarse-biotite amphibolite that is mapped as unit Ya that may be, in part, comagmatic dikes of metagabbro. The unit passes into lighter-gray, more leucocratic, biotite trondhjemite gneiss. The unit yielded a U-Pb SHRIMP zircon age of 1,383±13 Ma (Ratcliffe and others, 1991; Aleinikoff and others, 2011) and is

exposed along Reservoir Road in the northwest corner of the map Metasedimentary and Metavolcanic Rocks Biotite-quartz-plagioclase gneiss (Mesoproterozoic)—A heterogeneous assemblage of dark- to medium-gray, non-rusty weathering, quartz-rich biotitic gneisses, which are all characterized by having abundant plagioclase and epidote and little or no microcline. Other distinctive rock types include (1) light-gray-weathering magnetitemuscovite-biotite-plagioclase-quartz gneiss containing thin layers of hornblende-spotted gneiss; (2) a very dark-gray, biotite-rich plagioclase-quartz gneiss commonly associated with epidote quartz gneiss. Muscovite is a common accessory in most rocks and small garnet may be present as well. The biotite-plagioclase-quartz gneiss contains numerous layers of other distinctive rocks that are regionally interlayered throughout the Mount Holly Complex. Where the rock is thick enough to map, units Ya, Ybg, and Y²rs, are

mapped separately. The unit is best exposed on Butterfield Hill in the northwest part of the map and it is also exposed to the south and west of Springfield Reservoir Amphibolite (Mesoproterozoic)—Dark-green- to dull-gray-weathering, fine- to coarse-grained biotite-hornblende and hornblende-garnet plagioclase amphibolite commonly associated with units Y²rs or Ybg Y²rs **Quartz schist and gneiss (Mesoproterozoic)**—Dark-brown to gray, rusty weathering gneiss and schist containing abundant layers of schistose quartzite, biotite-garnet quartzite, and rusty sulfidic amphibolite. Locally, the unit passes into a muscovite-rich, lustrous, chlorite-garnet-schist that is mapped in the adjacent Chester and Cavendish quadrangles as unit Yrs (Ratcliffe, 1995a, b; 2000a, b). The unit is exposed on Butterfield Hill

EXPLANATION OF MAP SYMBOLS [Taconic, Acadian, Neo-Acadian, and Alleghanian, refer to orogenic events and not to divisions of geologic time] ——— Contact—Approximately located; dotted where concealed by water. In cross section, dotted where projected above the ground surface;

projections are based on structural measurements of surface Outcrops—Areas of exposed bedrock or closely spaced contiguous bedrock exposures examined in this study; some areas are enlarged to

[Approximately located; dotted where concealed by water. In cross section, dotted where projected above the ground surface] **★**—**★** Thrust fault—Includes ductile Acadian D, faults (Monroe and

Brennan Hill thrust faults) and the Keyes Mountain thrust fault, which is likely a Taconic fault (possibly a reactivated Acadian D₁ fault). Parallel to the Acadian S₁ foliation. Sawteeth on upper plate $\stackrel{\longleftarrow}{=} \frac{0}{D}$ Post-peak metamorphic, strike-slip fault or shear zone lower (Alleghanian)—Steeply dipping, lower-greenschist chlorite zone that is parallel to the S₂ or younger foliation; arrows indicate relative motion where known; U, upthrown side; D, downthrown side. Includes the Sumner Falls shear zone, the Northey Hill shear zone, and the Woodbury Road and Skitchewaug Mountain faults. Locally,

brittlely re-activated Brittle fault (Mesozoic)—Steeply dipping, arrows indicate relative motion where known. U, upthrown side; D, downthrown side, where known. Includes the Ammonoosuc fault zone and Grantham fault. Indicated as Mesozoic (Mz) on map FOLDS

[Location is known or inferred; dotted where concealed by water. Symbols show trace of axial surface and direction of dip of limbs] Axial trace of F₁ fold (Acadian, nappe-stage) Recumbent anticline

Synform (dome-stage or younger)

Recumbent syncline Axial trace of F, fold (Acadian or Alleghanian, early dome-stage) Antiform Axial trace of F₃ or younger fold (Alleghanian to Mesozoic) Antiform (dome-stage or younger)

MINOR FOLDS Folds in pre-Silurian rocks of the Moretown slice and Chester dome Strike and dip of inclined axial surface of minor isoclinal fold of schistosity or gneissosity that is parallel to the composite first and second generation schistosity; probably Taconic; arrow shows bearing and plunge of hinge line of fold. Minor folds are concentrated near and parallel to the Keyes Mountain thrust fault between the core gneisses and pre-Silurian cover rocks of the

Quartzite member (Ordovician)—Steel-gray- to yellow-tan-weathering Strike and dip of inclined axial surface of minor fold that is parallel to non-penetrative cleavage; arrow shows bearing and plunge of hinge line of fold. May correlate with F₂ or F₂ folds in rocks that are east of the Moretown slice Folds in rocks that are east of the Moretown slice

> Strike and dip of folded axial surface of F₁ fold that is parallel to S₁ foliation—Isoclinal, rootless folds; Acadian nappe-stage Strike and dip of axial surface of F₂ fold that is parallel to S₂ foliation—Tight to isoclinal, locally rootless folds; Acadian early Inclined

Vertical Strike and dip of kink bands (S_4) —Locally a crenulation cleavage. Associated with low-amplitude, long-wavelength folds with variable fold hinge orientations. Mesozoic age Inclined

PLANAR FEATURES

[Symbols may be combined; point of intersection shows location of measurement]

Strike and dip of bedding Inclined Inclined, showing tops from graded beds or pillows Inclined, overturned showing tops Strike and dip of quartz vein (KDq)

Inclined → Vertical ♦ Location only, no orientation measured Strike and dip of mafic dike (Kd) Inclined

⊢ Vertical

Vertical Strike and dip of granite dike (Dg) Strike and dip of pegmatite dike (Dp) Inclined Vertical

Planar features in pre-Silurian rocks of the Moretown slice or in the Chester dome in the northwestern part of the map Strike and dip of vertical Mesoproterozoic gneissosity Strike and dip of inclined penetrative schistosity; either Taconic or a Taconic-Acadian composite foliation

Strike and dip of inclined penetrative schistosity of undetermined ag Vertical Strike and dip of schistosity of undetermined age that is parallel to compositional layering

Inclined, deformed Strike and dip of nonpenetrative spaced (zonal) cleavage or crenulation cleavage; may correlate with S₂ or S₃ in rocks east of Planar features in rocks east of the Moretown slice

or compositional layering; Acadian Inclined, deformed Strike and dip of foliation (S_2) —Variable across the map, less penetrative to the west, zonal in the east; Acadian to Alleghanian

Strike and dip of layer-parallel schistosity (S₁)—Parallel to bedding

Penetrative schistosity Mylonitic or phyllonitic S_2 to S_3 foliation

Strike and dip of dominant foliation (S_n)—Not age specific, but either S_1 or a composite S_1 - S_2 foliation expressed as a schistosity where the S₂ strike and dip of foliation is penetrative Inclined → Vertical

Strike and dip of late crenulation cleavage (S₃ or S₄)—Associated with open folds and a crenulation lineation which post-date the dominant schistosity; most apparent in fine-grained metapelites; Neo-Acadian, Alleghanian, or younger. Cleavage is either S_3 or S_4 . Folds often display sinistral (counterclockwise) sense of rotation

⊩ H Vertical LINEAR FEATURES [Symbols may be combined; point of intersection shows location of measurement] \longrightarrow 29 Bearing and plunge of F_1 minor fold axis

→ 35 Bearing and plunge of L₂ intersection lineation—Intersection between the S_1 and S_2 foliations Bearing and plunge of F, minor fold axis—Fold axis of tight, isoclinal, or rootless fold associated with S₂

Bearing and plunge of mineral lineation—Aggregate lineation or grain lineation associated with the dominant foliation (S_n) ; consists of quartz, plagioclase, biotite, muscovite, chlorite, staurolite, or Bearing and plunge of object lineation—Lineation composed of elongate objects such as pebbles and quartz or plagioclase

phenocrysts; generally associated with the dominant foliation (S_n) Bearing and plunge of rods—Lineation composed of elongate quartz rods associated with the dominant foliation (S_n). The symbol is used for the rocks in the Moretown slice and Chester dome where it may

Bearing and plunge of F_3 or F_4 minor fold axis—Fold axis of late, open fold or crenulation lineation • Isograd or tectonic metamorphic boundary—Approximate boundary

between rocks with biotite and (or) actinolite or locally chloritoid (in Scq) in the biotite zone; garnet and (or) hornblende in the garnet zone; staurolite in the staurolite zone; sillimanite-muscovite assemblages in the sillimanite zone. Orthoclase locally occurs with migmatite and sillimanite-muscovite assemblages in the Brennan Hill thrust sheet. Rocks of the Mount Holly Complex in the Chester dome probably reached hornblende-granulite facies metamorphism during Mesoproterozoic events, but experienced re-metamorphism during the Paleozoic in the staurolite-kyanite assemblage zone. No boundary is shown between rocks in the biotite and chlorite zone. Locally, regional sub-biotite zone rocks are present in the Connecticut Valley trough. Additionally, local retrograde deformation and metamorphism has resulted in lower-greenschist facies assemblages within and adjacent to shear zones. These zones are marked "lower greenschist" on the geologic map Mine, Prospect, or Quarry—Abandoned mine or prospect (see list of

names below). The location listed as "uncertain" was located by GPS during mapping, but land-use changes made it difficult to confirm if the site was truly the location of the abandoned mine. Locations listed as "approximate" are from the Mineral Resource Data System (MRDS) database and were not confirmed during mapping. Locations listed as "confirmed" were located by GPS during mapping

Copper and sulfur 10081616 Uncertain Hubbard-Neal Mine Copper and sulfur 10088745 Approximate Copper and sulfur 10198562 Approximate 10198286 Confirmed Sargeant Mica Mine Feldspar and mica 10150537 Confirmed Chandler Mills Mine Feldspar and mica 10125772 Confirmed

★ Active quarry (aggregate) **☆** Inactive quarry (aggregate or slate)

Geochronology sample location—Showing sample number and uranium-lead (U-Pb) zircon age (with uncertainty of 2 sigma) in millions of years before present (Ma, mega-annum) by sensitive high-resolution ion microprobe (SHRIMP) or thermal ionization mass spectrometry (TIMS) (table 1)

