The bedrock geology of the Essex quadrangle is complicated by the ductile structures produced

Alleghanian orogeny. Mapping the rocks is made difficult by the very high grade of metamorphism, by

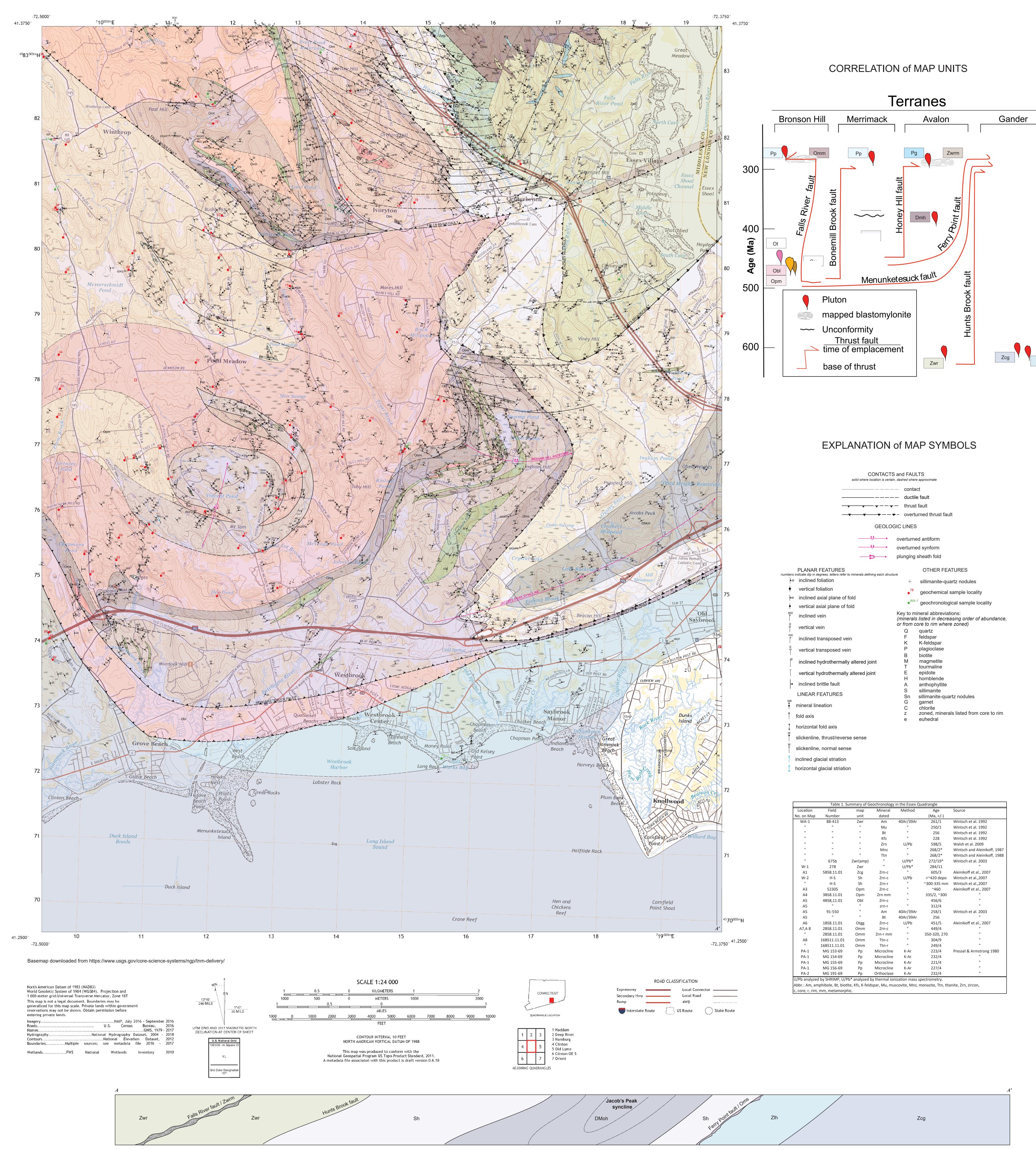
the complicated overprinting of multiple foliations, and by the abundance of migmatites and pegmatites

Rocks of the peri-Gondwanan Gander and Avalon terranes are dominated by plagioclase

The Bronson Hill terrane contains gneisses of granodioritic and tonalitic composition whose

ages of their zircons indicate a Neoproterozoic age. The Bronson Hill terrane is also dominated by

faults that both separate the terranes and also cut across them.



Plagioclase-quartz-biotite-(microcline)-(garnet)-(hornblende) schist and gneiss. Light gray to during the assembly of the rocks of the Gander, Avalon, Bronson Hill and Merrimack terranes during the buff weathering, medium- to coarse-grained, moderately to strongly foliated and layered. The size of quartz and feldspar grains varies with strain from 0.5-2 mm. Biotite comprises 2-10% of the mode and has a strong preferred orientation, forming discontinuous folia. Garnet is a common accessory, with that dominate many outcrops. The rocks of these terranes are juxtaposed by a complex pattern of ductile cm euhedral garnet grains surrounded by white, augen-shaped, biotite-free halos. A volcanoclastic origin s supported for this unit by the following evidence. Some of the compositions in the Ingham Hill fold orthogneisses of granodioritic and tonalitic composition, but also include the Clinton granite gneiss. U-Pb (map) contain so much normative quartz (Wintsch et al., 1990a) that they cannot be unaltered magmatic rocks. Nevertheless, they contain no more than about 77 wt.% SiO₂ (Wintsch et al., 1990a) and so a plagioclase ortho- and paragneisses, dated by zircon geochronology to be Late Ordovician (Aleinikoff et volcanoclastic graywacke is the proposed protolith. Several sillimanite veins are present west of Pequot swamp. Saucer-shaped quartz-sillimanite nodules 1-5 mm thick and up to 10 cm across are common in this unit near fault zones and are interpreted as anticracks (Fletcher & Pollard, 1981) disaggregated by

rather homogeneous chemical compositions on the km scale, together with calc-silicate and amphibolite xenoliths suggest that they are plutonic bodies. This terrane also includes the Middletown complex, an allochthonous package of trondjhemitic to dacitic metavolcanic rocks interleaved with belts of amphibolites and metasediments. The latter include biotite schists, calc-silicate granofels, and rare quartzite and garnet-rich coticule. Detrital zircons with ages between Late Ordovician and Mesoproterozoic (Aleinikoff et al., 2007) confirm that plagioclase gneisses of tonalitic and (anthophyllite-bearing) trondhjemitic compositions are reworked metavolcanic rocks. Through the central part of the quadrangle the Silurian Hebron Formation forms a km-wide, sinuous N-S belt of alternating dm layers of biotite schist and leo- and Mesoproterozoic grains (Aleinikoff et al., 2007).

calc-silicate granofels that separates the Neoproterozoic and Ordovician rocks from one another. Major fault zones are composed of blastomylonitic biotite-garnet-sillimanite schist containing many boudins and tectonic inclusions of pegmatite and amphibolite. Misidentification in the past of these schistose fault rocks as Ordovician metasediments led to complicated stratigraphic interpretations rejected in the present mapping. Strong NNW foliations transpose and attenuate both amphibolite and pegmatite dikes to the extent that they appear parallel to this foliation. Later NNW directed shortening produced map-scale folds, km-long ductile faults, and a second strong axial planar foliation all trending ENE. Many cross faults are too small to be shown on the map, but foliation symbols striking near 290 generally reflect the presence of these structures.

DESCRIPTION OF MAP UNITS minerals are listed in order of decreasing abundance parentheses indicate uncommon or rare occurrence

Pp | Pegmatite. White to buff weathering, coarse- to very coarse-grained, poorly to moderately foliated plagioclase-quartz-K-feldspar-(muscovite)-(garnet) granite in the Hebron Formation, and microcline quartz-plagioclase-(biotite)-(tourmaline) granite in all other units. Most dikes and sheets are up to two m wide and five m long and are too small to show at the 1:24,000 scale. Bodies generally lack mineralogical and textural zoning, but textures and the strength of overprinting foliation and mineralogical layering are highly variable. Larger pegmatites commonly intrude ductile fault zones, especially in the Bonemill Brook, Honey Hill, Hunts Brook, and Falls River faults. These occur in tandem bodies ductilely deformed at high temperatures with internal shearing with bands of quartz-sillimanite nodules, or with cataclastic foliation and layering parallel to the trace of the host fault where deformation occurred at a moderate temperature. Younger pegmatites commonly form boudins and the margins of rotated blocks may be streaked with quartz rods and/or muscovite north of Falls River Fault. Tan to pink weathering, massive, unfoliated, K-feldspar-plagioclase-(biotite)-(quartz) dikes 10-50 cm thick strike -N70°E and dip -60°NW are common in all rocks north of the Falls River fault.

9 Permian granite Ivoryton. White to tan weathering, medium-grained, sucrosic, quartz-plagioclase-microcline-(hematite) granite. Rock is unfoliated and weakly layered. Mapped only in one dike 600 m NE of Ivoryton. Included with Monson gneiss of Lundgren (1964). Assigned a Permian age by correlation with dated rocks in

Book Hill (Table 1).

Essex. Buff to salmon weathering, medium- to coarse-grained, unfoliated, massively weathering quartz-plagioclase-orthoclase-magnetite-biotite gneiss and granofels. Weak foliation is defined by a preferred orientation of evenly disseminated, sparse biotite. Locally contains conspicuous red spots around magnetite crystals. Unit includes a porphyritic phase with 1 cm euhedral K-feldspar phenocrysts. One body dated by monazite U-Pb method s from the buckled dike at the base of Book Hill on Conn. Rt. 9 (locality WA-1, map, Table 1) is 278 Ma (Wintsch & Aleinikoff, 1987). The age establishes a Permian age for the late deformation in the Essex area, which deforms both the dike and the host gneiss. Not mapped separately by Lundgren (1964).

Amphibolite. Black, massively weathering, medium-grained, well-foliated hornblende-plagioclase amphibolite. Multiple origins are likely. Individual bodies may be metavolcanic where they occur intimately intercalated among metasedimentary units. However, they may have been emplaced as dikes that have been transposed into the foliation by high strain. This appears to be the case in the Middletown complex unit Omh where crosscutting relationships are still visible in low strain rocks. High

DMoh Schist of Obed Heights. This unit is a medium-grained, gray weathering, quartz-plagioclase-biotite ± magnetite schist and granofels. The biotite content is locally high enough that the rock becomes schistose, mylonitic, and garnet-bearing. Pegmatites in the center of the body on the hill of Obed Heights fill boudin necks and otherwise cut the foliation but are themselves not foliated. However, the rock becomes increasingly pinstriped and mylonitic on the northern and southern margins, where all pegmatites and veins are all strongly transposed into the single mylonitic foliation. This age relationship suggests that the foliation on the margin of the body post-dates the pegmatites, dated in the Old Lyme quadrangle as ~275 Ma (Walsh et al., 2007). A Late Devonian or younger age of deposition of the greywacke(?) protolith is indicated by the ages of detrital zircon grains as young as Late Devonian (Aleinikoff, pers. comm.).

FeO/MgO ratios show the amphibolites are derived from tholeiitic basalts.

Hebron Formation. Olive green to gray weathering, medium-grained plagioclase quartz-biotite-hornblende-(epidote)-(diopside)-(clinozoisite) granofels, and dark violet, medium to fine grained, well foliated plagioclase-quartz-biotite schist. Small amounts of pyrite are present locally, which cause the rock to weather a rusty brown. Lithologies are interlayered on a 1-10 cm scale. North of Centerbrook olive gray, flaggy weathering, medium-grained, and well-foliated quartz-plagioclasebiotite schist dominates. In metasomatically altered fault zones fibrolite is intergrown with biotite, especially east of Deep River and north of Centerbrook. South of the Falls River fault, a pale buff to gray weathering medium grained quartzplagioclase-biotite granofels with minor biotite-quartz-plagioclase schist dominates; hornblende-bearing rocks are rare. Here layers of uniform granofels 2-10 cm thick are separated by 1 mm thick biotite schists. The rock is pervasively isoclinally folded, and all foliation is parallel to axial planes of these folds. The top of the unit is cut out by the Bonemill Brook fault and the base is cut out by the Honey Hill fault. In rocks defining the Westbrook syncline the banding thickens to 10-20 cm thick, where calcareous compositions contain clinopyroxene, and biotite schists become brown and granofelsic. This

unit includes most of Lundgren's (1963) Hebron Formation and some of his units in the Putnam gneiss.

Bronson Hill Terrane Oblm Blastomylonitic schist with blastocataclastic granitic pegmatites derived from Obl in the core of

Obl Boulder Lake gneiss. This is a medium to dark gray weathering generally weakly foliated plagioclase – quartz granofels and gneiss. Plagioclase + quartz typically make up ¾ of the rocks with hornblende + biotite making up 10 to 30%, with trace magnetite. Grain size is typically 1-2 mm, and most outcrops contain amphibolite and calc-silicate inclusions from 5-15 cm long which have an angular, blocky shape except near ductile faults where they become strongly attenuated. Named informally by Lundgren & Thurrell (1973) in the Clinton quadrangle. Based on chemical compositions Webster & Wintsch (1987) carried this as a mappable unit across the southern parts of the Clinton and Essex quadrangles, as proposed by Lundgren & Thurell (1973) and confirmed by Aleinikoff et al. (2007). These studies show that the gneiss is a calc-alkaline granodiorite to tonalite of Late Ordovician age (456 ± 6 Ma). It is more mafic than other nearby gneisses, containing generally <70 wt.% SiO2. Most of its compositions cluster between 4 and 5 wt.% FeO and establish a negative slope against FeO/MgO (Fig. 1). Such trends are most easily explained by the fractionation of pyroxenes, and possibly also amphibole that remove MgO > FeO from silicate liquids. Fractionation of

clinopyroxene could explain not only the behavior of FeO-MgO (Fig. 1) but also the falling FeO/TiO2

ratio (Fig. 2). TiO2 is incompatible in clinopyroxene, but compatible in hornblende.

Pond Meadow gneiss. This unit underlies the NW portion of the Essex quadrangle. Sodic plagioclase and quartz make up >90% of this rock, with biotite and minor magnetite the major mafic minerals. Whereas biotite generally follows a moderate to strong preferred orientation that defines a schistosity, it generally does not occur in biotite-rich folia or layers, such that the outcrops generally appear massive and poorly layered. However, where the rock is strongly deformed, foliation is better developed and pegmatites are transposed into the foliation. There are outcrops in which porphyroclasts of coarse (1 cm) K-feldspar clasts are dispersed into the foliation suggesting the recrystallization of a cataclastic texture. Oscillatory zoning in its zircons are consistent with a magmatic origin, but the small number of reliable analyses place the age of crystallization only at approximately 460 Ma (Aleinikoff et al., 2007). Equivalent to the 'eastern gneiss' of Webster & Wintsch (1987). The chemical composition of the Pond Meadow gneiss straddles the tonalite to the trondhjemite fields (Webster and Wintsch 1987), and its compositions define a rock series suggesting that it is a plutonic body. The positive trends of FeO with FeO/MgO and FeO/TiO2 (FIGs) show a drop in the concentration of FeO with rises in the relative concentrations of both MgO and TiO2. This could be explained by the fractionation of magnetite. Another body of gneiss extends WNW from the Vincent Pond structure and probably extends into the Clinton quadrangle. Geochronology is equivocal, but the abundance of inclusions of amphibolite and less common calc-silicate rocks (see also Lundgren and Thurrell, 1973) leads us to infer that the protolith of Obl intruded Opm. Contacts west and north of the Vincent Pond structure reflect this interpretation.

Turkey Hill Complex (Ot) Gneisses north of Ivoryton (Turkey Hill belt of Lundgren, 1963) constitute a complex of rocks dominated by intrusive igneous granodiorite and tonalite. However, they also contain granitic gneisses, aplite dikes, amphibolites, and four small peridotite bodies. Even within the plagioclase gneisses there is a range of compositions, some overlapping with the Boulder Lake gneiss, some with the Pond Meadow gneiss, and others with unique compositions (Figs. 1, 2). With this range of rock types and compositions the rocks between the Hebron Formation to the east, the Boulder Lake gneiss to the south, and the Middletown complex to the west justify the informal name 'Turkey Hill complex.'

Monson gneiss. Light to medium gray, medium-grained (0.5-1.0 mm), massively weathering, well foliated, locally moderately layered plagioclase-quartz –biotite orthogneiss of tonalitic to granodioritic, composition. It is the dominant rock type in the Turkey Hill complex. It has an interlayered contact with Omm along the western contact. On the eastern margin of the unit, near the ductile Bonemill Brook fault, a conspicuous compositional banding parallel to foliation is defined by alternating biotite-rich and biotite-poor layers each approximately 3 mm thick. The biotite-poor layers commonly host a conspicuous, subhorizontal lineation of biotite streaks, and quartz-feldspar rods are common but less conspicuous. Concordant lenses and boudins of dark gray to black medium-grained granular hornblende-plagioclase-biotite amphibolite constitute 10% of most outcrops.

Granite gneiss of Ivoryton. Tan to buff weathering, medium- to coarse-grained, weakly foliated quartz-K-feldspar-plagioclase-biotite gneiss and granofels. Contacts are not exposed; age is 451 ± 5 Ma (Aleinikoff et al. 2007). Mapped only in Otm northeast and east of Ivoryton. Included with Monson gneiss of Lundgren (1964). Otp | Peridotite. Dark green to black, massively weathering, unfoliated, medium-grained olivine-clino-

pyroxene-amphibole-(garnet) peridotite. Thin, black, well foliated hornblende schist and amphibolite separate the peridotite from host Otm. Mapped as four small bodies north and west of Ivoryton. Bodies cored by olivine (Fo68)-clino pyroxene-am phibolite, 45-48 wt.% S i02. Normative compositions are lherzolite; margins are garnet amphibolite.

The Middletown Complex includes rocks mapped as Middletown Formation by Lundgren (1963, 1964). It contains several metavolcanic and metasedimentary rocks all ductilely deformed at high metamorphic grade. The complex is bound by ductile faults, and is completely cut out north of the Ingham Hill fold by the Bonemill Brook fault. The top and bottom are undefined, it lacks any cohesive internal stratigraphy, and its thickness is unknown. It is thus elevated to the status of a complex. It is made up of a heterogeneous group of rocks in which plagioclase-quartz-microcline-biotite±garnet schist is interlayered with rocks are widely scattered (Figs. 1,2) reflecting the heterogeneous protoliths and degree of sedimentary reworking of these rocks. Massive to foliated to pinstriped amphibolite sheets, some garnet-bearing, varying in thickness from a few centimeters to several meters are intercalated throughout complex. Omm Blastomylonitic schist with blastocataclastic granitic pegmatites derived from Om in hanging wall

of Falls River Fault. Blastomylonitic schist and gneiss. Medium and dark gray, strongly weathered and friable, medium- and coarse-grained biotite -plagioclase-sillimanite-quartz-(garnet) schist, locally with conspicuous K-feldspar and plagioclase augen. Mapped only along the Falls River fault west of Ivoryton. Biotite-rich mylonitic schists, locally with conspicuous sillimanite lineations dominate the unit. A small (30 x 30 m) inclusion of massive ultramafic rock (Omu) and amphibolite boudins and tectonic inclusions suggest complicated tectonic mixing in the unit. Included by Lundgren (1964) with the Monson gneiss.

0.5-20 mm grains making up 0-2% of the rock. Exposures north of Brushy Hill Pond feature abundant 1-2

Plagioclase-quartz-anthophyllite-biotite-garnet schist. Anthophyllite grains comprise 1-30% of the mode, are typically elongate green to brown blades 1 cm to as much as 10 cm long, and define a moderate to strong lineation. The largest grains occur at the transposed margins of quartz-plagioclase-(biotite) pegmatites, where the anthophyllite grains themselves may be folded. Less commonly, anthophyllite occurs as disseminated pale blue-green subequant 1-2 mm grains defining the foliation of rusty-weathering, buff-colored schist. Geochemistry shows a trondjhemitic composition. A volcanic origin is supported the presence of broken and rounded zircons with U-Pb ages of 449 ± 4 Ma mixed with

pervasive 5-10 mm thick banding is caused by alternating biotite + hornblende-rich and poor layers. Amphibolite sheets up to 50 cm thick containing euhedral, stretched plagioclase phenocrysts truncate the dominant foliation and/or are conspicuously folded; these are interpreted to have been basaltic dikes. The unit is distinguished from other plagioclase gneisses in the field by its pervasive thin layering and its relatively uniformly high (~ 5%) hornblende content. Mapped as Cedar Lake belt of Monson gneiss (undifferentiated) by Lundgren (1964). Rock correlated here with 'eastern' tonalitic paragneiss of Webste & Wintsch, (1987) and Middletown complex "Lower member" of Deasy & Wintsch (2019). Orthoamphibole granofels. One small body is mapped on the north shore of Brushy Hill Pond

rthoamphibole granofels, a massive rock comprised of >90% black, equant, ~1 mm orthoamphibol

Plagioclase-quartz-hornblende-biotite schist and minor massively weathering black amphibolite.

ight and dark gray, slabby weathering, medium-grained, uniformly well layered and strongly foliated. A

Ultramafic rock containing primarily amphibole with small grains of clinopyroxene and ra Biotite-sillimanite-garnet-quartz-plagioclase schist. Several bodies are mapped throughout the Middletown Complex and are strongly associated with the ductile fault zones that juxtapose the Middletown Complex against other units. Biotite commonly forms prominent streaks and sillimanite commonly

exposures on the south shore of Brushy Hill Pond and by the strong association of this unit with quartzite

and garnet-quartz granofels (i.e. near the Menunketesuck estuary, west of Pequot swamp, and in expo-

sures northwest of Ivoryton). Quartzite. Small lenses occur north of Lord Pond in the north central portion of the quadrangle and west of Pequot swamp. These are massive granular to weakly foliated rocks with >90% quartz, finely sseminated biotite, and minor accessory garnet and/or feldspar. Coticule. Granular quartz-garnet granofels occurs as several lenses within the pelitic paraschist

Oms in the southern half of the map area. This rock is massive to weakly foliated, containing euhedral,

pale pink to red, 0.5-1.5 mm garnet and fine-grained quartz with a weak to strong shape preferred orient

tion. Interpreted to be derived from coticule or a coticule-like protolith (e.g., Baijot et al. 2011).

Granite gneiss of Millstone Hill. Light pink to gray weathering, medium- to coarse-grained K-feldspar-quartz-plagioclase-biotite gneiss and granofels. Locally migmatitic, and strongly foliated near shear zones. Contacts are now defined by ductile faults, but locally cross-cutting relationships apparent further east (Goldsmith, 1985), and a possible Devonian age (Aleinikoff & Wintsch, unpub.) suggest that it is intrusive into Avalonian gneisses. Included in the Potter Hill gneiss of the S terling Plutonic Group of Rogers (1985), and mapped as Sterling Granite Gneiss by Lundgren (1963).

Waterford Complex (Zw) The Waterford complex is composed of several intrusive igneous bodies strongly attenuated by strain along the Honey Hill fault caused by the tectonic wedging of the Avalon terrane into the Gander terrane (Wintsch et al., 2014). In the immediate footwalls of the Honey Hill fault the schists and granofelsic rocks are conspicuously banded, but in the interior father than ~ 1 km from the fault rocks become more ranofelsic, and locally migmatitic. Relative age relationships are uncertain.

Blastomylonitic schist. Medium to dark gray, coarse-grained, well foliated and layered, blastom lonitic and mylonitic plagioclase-quartz-biotite-garnet-sphene-rutile gneiss, and biotite-sillimanite-(gar net)-(quartz)-(plagioclase) schist. Rock contains conspicuous boudins and tectonic inclusions of pegmatite and amphibolite, both folded within the schists along axes plunging 50° to N40E, parallel to a penetrative sillimanite lineation. This rock grades north into Zwr. Mapped only along and immediately above the Falls River fault in Essex. Similarities in ratios among elements with low differential mobility, and mass balance calculations using whole rock chemical analyses of the gneiss and schists show that the schists are derived from the Rope Ferry Gneiss (Zwr) through metamorphic differentiation and limited metaso matism (Dipple et al., 1990). Mapped as part of the Putnam gneiss by Lundgren (1964), but given no stratigraphic significance in this study.

Rope Ferry gneiss. Light to medium gray weathering, medium-grained, variably foliated

plagioclase-quartz-hornblende-biotite-magnetite-sphene-gneiss and granofels. Inclusions of amphibolit are present in most outcrops and are locally abundant. Their shape is highly dependent on strain, and may have aspect ratios from 2.5:1to 100:1; long axes typically plunge NE (Wintsch, 1985, stop 1). Inclusions of layered calc-silicate granofels occur with amphibolite near the power line 100 m south of Viney Hill Brook, Essex, suggesting that all inclusions are xenoliths, and that this gneiss is an orthogneiss. Multiple foliations exist; each is defined by a preferred orientation of hornblende and biotite, but foliation is better defined and more conspicuous in the younger foliations. Mineral streaking lineations are most strongly developed in younger foliations, which are parallel to high angle strike slip faults that cut the unit. Amphibolite is a common accessory rock type. The unit is distinguished from the Boulder Lake Gneiss by a lower MgO content and the lack of magnetite. Zircons from a sample of Rope Ferry Gneiss from the base of Book Hill on Conn. Rt. 9 (Wintsch, 1985, stop 2a; locality WA-1, map) have been dated by thermal ionization mass spectrometry as approximately 620 Ma (Wintsch and Aleinikoff, 1987), but reanalysis b SHRIMP analysis refines this age to be 598 ± 5 Ma (Aleinikoff, 2003, cited in Walsh et al. 2009). Included with Ordovician Monson Gneiss by Lundgren (1964).

Jennings Pond lithofacies. Medium gray weathering medium- to coarse- grained well-foliated and ell layered plagioclase-quartz-hornblende-biotite gneiss interlayered with variable amounts of dark grav to black, massive to well foliated, medium grained hornblende-plagioclase amphibolite. The upper contact of the unit is everywhere cut by the Honey Hill fault. South of Chester the unit contains locally onspicuous randomly oriented (retrograde) muscovite. The unit is bound entirely by faults, which cut out both the top and bottom of the unit, and limit its lateral extent to the Falls River fault in the south. Mapped as part of the Putnam gneiss of Lundgren (1963).

Hope Valley alaskite. Cream to tan, massively weathering, medium- to fine- grained, poorly foliated to massive K-feldspar-plagioclase-quartz (biotite) gneiss and granofels. Microcline augen up to 1 n diameter and 5 cm long are elongate in the foliation and commonly exhibit Carlsbad twins. Thes are interpreted to be relic phenocrysts. In some rocks the phenocrysts are deformed into augen shapes up to 2 cm long, and in others 0.5 to 1 mm K-feldspar grains occur in elongate clusters 2-3 cm long. These observations suggest that the protolith was a porphyrite granite with variably flattened K-feldspar phenocrysts. Where strongly deformed this unit contains less biotite and few feldspar porphyroclasts and is therefore difficult to distinguish from Dmh and Pg. Included in the Hadlyme belt of Monson Gneiss by Lundgren (1963). Mapped as Zsh, part of the Sterling Complex by Rodgers (1985). Occurs as a single outcrop at the northern map boundary. Exposed only in one outcrop on the northern margin of the quadrangle on the west side of Book Hill.

Lord Hill gneiss. The gneiss of Lord Hill is mapped as a continuation of that gneiss from the O yme quadrangle (Walsh et al. 2009). In the Essex quadrangle it is so strongly deformed and interleave with other rock types that is best describe as a lithodeme. It is dominated by a plagioclase-quartz-biotite granofels with variable amounts of K-feldspar and minor biotite. Grains are ½ to 1 mm in diameter, and have aspect ratios of 2:1 or even 3:1 where strain is high. Both biotite and ovoid grains of feldspar and quartz define a weak foliation. A conspicuous banding parallel to this foliation is caused by the intercala tion of both cream to salmon K-feldspar-bearing granofels and biotite-rich schist. Where these are abundant intrafolial folds with 060 plunging axes are common, and are parallel to mineral streaking (especialong Rt. 1 in Westbrook. Another common occurrence banding is caused by the interlayering of plagioclase -quartz granofelses with variable amounts of biotite and less commonly hornblende (e.ş Rocks exposed on Kelsey Point and in Saybrook Manor are considered part of this unit, though re strongly invaded by pegmatite. The grain size K-feldspar in the pegmatite is up to 20 cm, but most are so strongly deformed that porphyroclasts up to 15 cm in diameter record the formed presence of crosscut ting pegmatites. These dikes are so strongly comminuted that small fragments become completely intermixed with the plagioclase granofels. This gives the rock the appearance of granitic gneiss, and was correlated by Lundgren (1964) with the Clinton granite gneiss. However, a foliated cataclasite derived om plagioclase granofels with intruded pegmatite is the preferred lithologic assignment in this study.

Clinton granite gneiss. The Clinton Granite gneiss of Lundgren (1964) is composed of equant rains of quartz-plagioclase-K-feldspar in a granofels with minor biotite defining a weak foliation. As its ductile fault contact with the Boulder Lake gneiss is approached, grain size falls from 1-2 mm to ½ to 1 mm, and the rock becomes weakly differentiated into foliation-parallel K-feldspar rich bands 1 grain thick, separated by bands of quartz + plagioclase 2 to 3 mm thick. The rock contains crosscutting pegmatites that climb in the foliation to the east, suggesting normal motion. The margins contain up to 10% biotite, suggesting local derivation. The Clinton granite gneiss is exposed only in the extreme SW corner of the quadrangle. Lundgren (1964) includes the gneisses at Kelsey Point in this unit, but we assign these

The geology of the Essex quadrangle records the assembly of rocks belonging to several large terranes (Aleinikoff et al., 2007; Walsh et al., 2007; Wintsch et al., 2014). To the northeast lie rocks of the Avalon terrane, rocks in the southeast relate to the Gander terrane, and rocks in the west are part of the Bronson Hill terrane. Before mylonitic rocks and ductile schists were recognized as major terrane bound-

aries, the units were correlated with one another, forcing the interpretation of large-scale fold nappes. In

this study we reinterpret the bedrock geology in the context of ductile mylonitic schists, and with the aid

of new geochemical and geochonological data collected since 1975. Many previous stratigraphic assign ments of map units are not supported by this mapping, and so new names are introduced. These are all informal and used to help describe the rocks mapped. Some structures are also named informally. NOTES ON GEOCHEMISTRY Granular plagioclase schist, gneiss, and especially granofels underlie much of the Essex quadrangle. Their mineralogy is monotonous with plagioclase + quartz comprising 80-90 modal % of the rocks (Webster and Wintsch, 1987). Minor minerals within domains do differ, with hornblende, biotite, anthophyllite, or magnetite dominating locally, and garnet and K-feldspar at higher (anatectic) grades. Howev-

er, their similar granodioritic to tonalitic compositions, medium gray color, and massive to coarsely layer nature makes discrimination of mappable facies in the field difficult, and most mappers did not identify boundaries (e.g. Mikami and Digman, 1957; Lundgren, 1963; 1964). Many tonalitic rock bodies lie in regions isolated by ductile faults, or by other distinct lithologies, and so have been described within their geological domains (Lundgren, 1963). Only Lundgren and Thurrell (1973) mapped the Boulder Lake facies within the domain of 'plagioclase gneiss.' Given their similarity in the field, and in the absence of geochemistry and geochronology, Rodgers (1985) followed previous workers and correlated all the plagioclase gneisses as a single stratigraphic unit: Monson Gneiss. This led to complicated interpretations of large overturned fold nappes (e.g. Lundgren, 1962, Dixon and Lundgren, 1968) not supported by subsequent mapping. Since this work was completed several studies have provided geochemistry and geochronology of many of the bodies. This work has led to the identification of several geochemical faces and two age groups. Whole-rock geochemistry has been used to identify five geochemical phases of plagioclase gneiss within the Killingworth done (Webster and Wintsch, 1987), and zircon geochronology has revealed Late Ordovician and Late Neoproterozoic ages for two groups of rocks (Wintsch and Aleinikoff, 1984; Aleinikoff et al. (2007).

In this work we supplement these data with many more whole-rock chemical analyses (Tables 2 and 3, locations on map). Within the Essex quadrangle we now discriminate five map units based in part on the distribution of units on the map and in part on geochemistry. The systematic variations of chemical compositions of the Rope Ferry gneiss, the Boulder Lake gneiss, and the Pond Meadow gneiss are consistent with magmatic fractionation on the scale of km. In particular, the chemical relationships among FeO, MgO, and TiO2 (Table 2), all with relatively low mobility during metamorphism, support this interpretation (Figs. 1 and 2; Wintsch et al. 1990a; 1990b; Aleinikoff et al., 2007). In contrast, the distribution of minor and trace elements (Table 3) found useful by Webster and Wintsch (1987) are less useful

Small folds and ductile faults from the cm to the m scale are present in most outcrops excep those exposing massive gneiss and granofels; most are too small to be mapped. Map-scale structures are described below. A complication arises from the Chester anticline exposed in the Deep River quadrangle to the north (Wintsch, 1985; Deasy and Wintsch, 2019). Structural relationships well exposed there show that the Hebron Formation is folded around the Avalon terrane such that the NNW striking limb is overturned. This limb extends south into the Essex quadrangle through the village of Centerbrook and south to Prospect Hill. Only where it is refolded around the Jacobs Peak syncline is the Hebron Formation right side up. This begs the question of what is the topping direction of the Middletown complex. Accordingly, the Ingham Hill fold is identified as an antiform, in spite of the fact that it is structurally overlain by the

One of the most significant features of the map area is the abundance of ductile faults. These are

characterized by strongly foliated gneisses and schists, commonly intruded by pegmatites. Transposition and comminution of the pegmatites into the dominant mylonitic foliation produces a blastomylonitic that define terrane boundaries. Most faults produce pervasive planar and linear fabrics in the rocks, but have unproven displacement. Many unnamed ductile faults with displacements of only a few meters cut all the rocks in the hanging wall of the Falls River fault. More important and named faults are described

Honey Hill fault. The Honey Hill fault forms the structural top of the Avalon terrane in southern Connecticut, but joins with the Lake Char (eastern Connecticut) and the Bloody Bluff fault (eastern Massachusetts) to form a regional scale terrane boundary with major displacement (Wintsch et al., 1992; 2014). In the Essex quadrangle it defines the southwestern boundary of the Avalon terrane against the Hebron Formation of the Merrimack terrane. Displacement is probably 100s of km (Wintsch et al., 2014), with much of the hanging wall Hebron Formation and the footwall Avalon terrane cut out. The fault zone is defined by biotite-rich blastomylonite with many tectonic inclusions of pegmatites and amphibolites.

Connecticut, and joins with the Honey Hill fault in the vicinity of Viney Hill. Together with the Lake Char (eastern Connecticut) and the Bloody Bluff fault (eastern Massachusetts they form a regional scale terrane boundary with major displacement (Wintsch et al., 1992; 2014). In the Essex quadrangle the Hunts Brook fault defines the contact the Rope Ferry gneiss of the Avalon terrane with the Hebron Formation of the Merrimack terrane. Displacement is probably 100s of km (Wintsch et al., 2014), with much of the Hebron Formation in the hanging wall and the Avalon terrane in the footwall are cut out. Th fault zone is defined by biotite-rich blastomylonite with many tectonic inclusions of pegmatites and amphibolites. Walsh et al. (2009) map a rusty schist structurally below Zwr as a rusty weathering schist and schistose gneiss at Obed Heights as DSohrs. We consider this part of the lithodemic, mylonitic Hunts

Menunketesuck fault. The Menunketesuck fault is a terrane-bounding fault that separates rocks of the southwest part of the quadrangle. The fault is not well exposed, but lies just west of the Menunketesuck River in the town of Clinton. Rocks close to it are strongly foliated and moderately lineated with biotite streaks, and contain tectonic inclusions of the pegmatite (Wintsch et al., 2005, Stop 10). The fault defines part of the major tectonic boundary (including the Ferry Point fault) between peri-Gondwanan terranes and Ganderian cover terranes including the Merrimack terrane.

Ferry Point fault. The Ferry Point fault separates rocks of the Merrimack terrane from those of the Gander zone. It is recognized and named in the Old Lyme quadrangle (Walsh et al., 2009), but poorly exposed in both the Old Lyme and Essex quadrangles. In the Essex quadrangle it separates the gneiss at Lord Hill (named in the old Lyme quadrangle) from blastomylonitic schists and gneisses probably derived from the Hebron Formation in the southeast, and from the Boulder Lake gneiss of the Bronson Hill

Bonemill Brook fault. The Bonemill Brook fault is a regional fault that separates rocks of the Bronson Hill terrane from those of the Merrimack terrane. First named in northern Connecticut (Pease, 1982) it extends from at least southern Massachusetts through Cremation Hill in Haddam, Connecticut (London, 1989) to the southern Essex quadrangle where from north to south it puts the Hebron Formation against rocks mapped as Monson gneiss (Turkey Hill complex) of the Bronson Hill terrane. Its extension south of the Falls River fault places the Hebron Formation against the first the Boulder Lake gneiss and then the Middletown complex, completely cutting out the Turkey Hill complex. Fault rocks are pervasively migmatized, and on the western margin are dominated by strongly foliated and lineated amphibole and plagioclase gneisses where isoclinal, intrafolial folds are common. On the east side of the fault Hebron Formation rocks are also strongly foliated and layered, where the dominant NNW trending (overturned) foliation is buckled into a NE trending axial plane foliation.

Falls River fault. The Falls River fault cuts across the northern part of the quadrangle forming a concave to the north outcrop pattern. It is well exposed in the north-bound entrance ramp to Rt. 9 at interchange 3 in Essex. Here a blastomylonitic biotite-garnet-sillimanite schist is interlayered with feldspathic migmatites and pegmatites, and includes ultramafic and amphibolite inclusions. The bulk composition of this fault zone calculated by a weighted average approaches that of the Rope Ferry gneiss (Dipple et al., 1990). This compositional similarity together with the gradational northern contact of the schist with the Rope Ferry gneiss confirms its derivation largely from the Rope Ferry gneiss. Foliations north of the fault are transposed in a left-lateral sense, whereas foliations south of the fault in the Hebron Formation south of Centerbrook are largely axial planar, defining an Sn+1 foliation there. A penetrative lineation all along the fault of sillimanite needles, amphibole blades, biotite streaks, and fold axes plunging 30-50° to 045 together with left-lateral drag show motion is sinistral. Displacement on the fault is difficult to establish because the fault cuts both the Rope Ferry gneiss and the Hebron Formation with little displacement, whereas rocks of the Turkey Hill and Middletown complexes to the north and the Boulder lake and Pond Meadow gneisses on the south are both cut out by the fault.

Jacobs Peak syncline. The Jacobs Peak syncline was originally mapped as the Westbrook syncline by Lundgren (1964) across the southern part of the quadrangle. It was identified by the U-shaped outcrop pattern of the Silurian Hebron Formation around Jacobs Peak between Prospect Hill and Beacon Hill. The present mapping confirms this pattern and recognizes an overturned isoclinal fold plunging ~50° ENE. The rocks in the core of this fold are here mapped as schists of Obed Heights of Late Devonian or younger age. These rocks define a pattern of ages with the youngest rocks in the core of the fold, confirming the structure as an overturned isoclinal syncline. The syncline is not mapped as far west as Westbrook Center because the repetition of the Boulder Lake gneiss is better explained by faulting. The local name "Jacobs Peak syncline" is thus preferred.

Ingham Hill antiform. The Ingham Hill antiform is an overturned fold defined by folded layers of metasediments and metavolcanics of the Middletown complex in the central part of the quadrangle. This complex is isolated by faults and in the absence of topping directions it cannot be identified as an anticline. It is cored by a lobe of Boulder Lake gneiss in the west, and structurally overlain by the Hebron

Vincent Pond basin. The Vincent Pond basin is defined both by a core of Middletown complex rocks and foliations that define a doubly plunging with a vertical northern limb. Dominant foliation is clearly folded with dips facing inward on the north, east, south, and southwest sides of the structure. Closure on the NW side of the structure is not certain because of lack of outcrop. The structure is surrounded on three sides by the Boulder Lake gneiss, but by the Pond Meadow gneiss on the northwest. Strong foliations cutting this mixture of intrusive and extrusive igneous rocks obscures contact relationships among them. What is certain is that this structure is relatively late because most pegmatites and migmatites are also foliated. The symmetrical structure of the basin with a Brimfield schist core mantled by Middletown gneiss as closure of foliations around the structure allows the possibility that the basin represents the nose of a large

Chester anticline. The Chester anticline mapped in the Deep River quadrangle (Deasy & Wintsch, 2019) is not exposed in the Essex quadrangle, but its overturned limb formed by ENE dipping Hebron Formation rocks is exposed in Centerbrook. The southern continuation of this structure requires all of the rocks of the Hebron Formation to be overturned south to Beacon Hill where the north-dipping limb of the Jacobs Peak fold is right side up.

NOTES ON METAMORPHISM

The metamorphic grade of the rocks in the Essex quadrangle is everywhere in the upper amphibo lite facies, above the second sillimanite isograd; partial melting is common (Lundgren, 1966). Sillimanite occurs in many rocks where metasomatism has caused the loss of alkali elements, leaving residual aluminum to form sillimanite and commonly also garnet (Wintsch and Andrews 1988; Dipple et al., 1990). Sillimanite schists may be seen in the northbound entrance ramp to Rt. 9 at interchange 3, and pervasively cutting a large pegmatite at the corner of Rt. 145 and Old Clinton Road west of Westbrook. Sillimanite needles generally forms a moderate to strong foliation and lineation showing that its crystalli zation was syntectonic. The occurrence of sillimanite is not interpreted here to reflect a sedimentary protolith with an aluminous bulk composition. Regional northward tilting has probably produced a gradient in maximum pressure of 100 MPa or more, but this is not apparent in the metamorphic assem blages in these rocks. Sillimanite is pervasive throughout the quadrangle and the second sillimanite isograd mapped by Lundgren (1964) has not been recovered in the present mapping. Metamorphic intensity reached a maximum during the collision of rocks of the Avalon and Gander terranes with those of the Bronson Hill terrane during the Alleghanian orogeny. Maximum pressures probably reached 1.5 GPa, and temperatures reached nearly 750°C (Wintsch et al., 2003; Walsh et al. 2007). Peak pressure conditions may have been reached as early as 335 Ma, migmatites probably developed by 300 Ma, pegmatites intruded near 285 Ma, and metamorphic fabrics probably crystallized between ~300 and 250 Ma, the ages of syntectonic titanite in the Middletown complex (Table 1).

REFERENCES CITED

Survey of Connecticut, OF19-1, 1:24,000 scale.

Aleinikoff, J.N., Wintsch, R.P., Tollo, R. P., and Unruh, D.M., Fanning, C.M., and Schmitz, M. D. (2007) Ages and origins of rocks of the Killingworth Dome, south-central Connecticut; implications for the tectonic evolution of southern New England: American Journal of Science 307, pp.63-118. Baijot, M., Hatert, F. and Fransolet, A.M., (2011) Mineralogical and geochemical study of pseudocoticul from the Stavelot Massif, Ardennes (Belgium), and redefinition of coticule: European Journal of Mineralogy, 23, pp.633-644. Deasy, R. T., and Wintsch, R. P., (2019) Draft Bedrock Geologic Map of the Deep River Quadrangle, New London and Middlesex Counties, Connecticut, USA: State Geological and Natural History

mobility in a ductile fault zone through multi-sample mass balance: Journal of Metamorphic Geology, 8, 645-661. Dixon, H.R., and Lundgren, L.W. (1968) Structure of eastern Connecticut: in Zen, E-an, White, W.S., Hadley, J.B. and Thompson, J.B., Jr., eds., Studies of Appalachian Geology northern and mari time: New York, Wiley Interscience Publishers, 219-229.

Fletcher, R.C., and Pollard, D. D., (1981) Anticrack model for pressure solution surfaces: Geology, 9

Goldsmith, R. (1985) Bedrock geologic map of the Old Mystic and part of the Mystic Quadrangles,

Dipple, G.M., Wintsch, R.P., and Andrews, M.S. (1990) Identification of the scales of differential element

London, D. (1989) Bedrock geology of the Moodus seismic area, south-central Connecticut: State Geological and Natural History Survey of Connecticut, Report of Investigations. 11, 25p. Lundgren, L., Jr. (1962) Deep River area, Connecticut: Stratigraphy and structure: American Journal of Science 260, 1-23. Lundgren, L., Jr. (1963) The bedrock geology of the Deep River quadrangle: State Geological and Natural History Survey of Connecticut Quadrangle, Report 13, 40p., map. Lundgren, L., Jr. (1964) The bedrock geology of the Essex Quadrangle: State Geological Natural History Survey of Connecticut Quadrangle Report 15, 38p., map. Lundgren, L., Jr. (1966) Muscovite reactions and partial melting, southeastern Connecticut: Journal of

Lundgren, L.W. and Thurrell, R.F. (1973) Bedrock geology of the Clinton Quadrangle: State Geological

Connecticut, New York and Rhode Island: U.S. Geol. Survey Map I-1524, scale 1:24,000.

and Natural History Survey of Connecticut, Quadrangle Report 29, 22p., map. Mikami, H.M. and Digman, R.E., (1957) The bedrock geology of the Guilford 15-minute quadrangle and a portion of the New Haven quadrangle: State Geological and Natural History Survey of

American Journal of Science 307 pp.168-215.

Pease, M.H. (1982) The Bonemill Brook Fault, eastern Connecticut, in Joesten, R., and Quarrier, S.S., eds., Guidebook for field trips in Connecticut and south-central Massachusetts: State Geological Natural History Survey of Connecticut Guidebook 5, 263-287. Pressel, D.C., and Armstrong, R.L. (1980) K-Ar dates for granitic rocks and the Honey Hill fault, south eastern Connecticut: Contributions to geochronology in Connecticut, II: State Geological and Natural History Survey of Connecticut, Report of Investigations. 10, 1-4. Rodgers, J. (1985) Compiler, Bedrock Geological Map of Connecticut: State Geological and Natural History Survey of Connecticut, scale 1:125,000, two sheets.

Walsh, G.J., Aleinikoff, J.N., and Wintsch, R.P., (2007) Origin of the Lyme Dome and implications for the

timing of multiple Alleghanian deformational and intrusive events in southern Connecticut:

Walsh, G.J., Scott, R.B., Aleinikoff, J.N. and Armstrong, T.R., (2009) Bedrock Geologic Map of the Old Lyme Quadrangle, New London and Middlesex Counties, Connecticut: U.S. Geological Survey, Scientific Investigations Map No. 3052, 25 p. Webster, J.R. and Wintsch, R.P. (1987) Petrochemistry and origin of the Killingworth dome rocks, Bron son Hill anticlinorium, south-central Connecticut: Geological Society of America 98, 465-474.

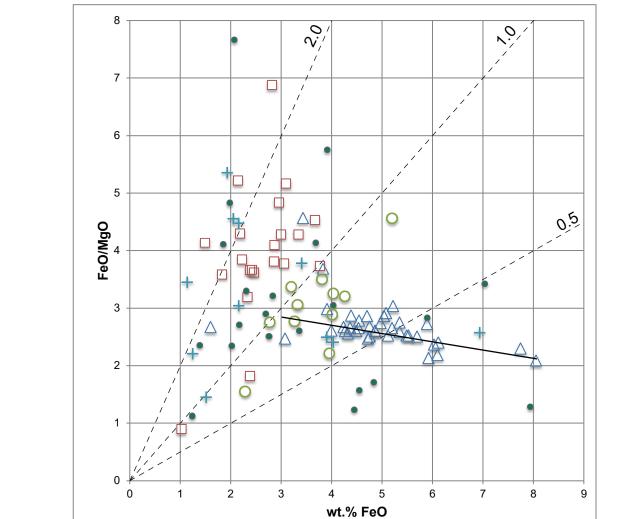
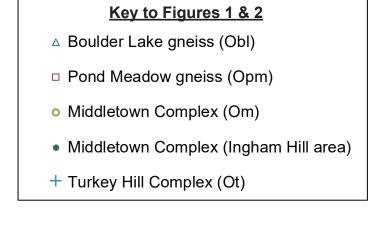


Figure 1. A plot of wt. % FeO(total) against FeO(total)/MgO (see Table 2) comparing the distribution of compositions of four plagioclase gneiss bodies in the Essex quadrangle as presented here (open symbols and +) and by Wintsch et al. (1990a, solid green dots). Dashed lines with slopes of 0.5, 1.0 and 2.0 are given for reference. The band of points with a negative slope of ~-0.2 produced by analyses of Boulder Lake gneiss (blue triangles) is consistent with the magmatic fractionation pyroxenes, and the tight cluster suggests these rocks are part of a single pluton. The band of orange squares created by samples of Pond Meadow gneiss with a slope of near 1.5 define a band consistent with the fractionation of magnetite, while the narrow range of compositions suggests the samples define a single pluton distinct from that of the Boulder Lake. The compositions of samples of rocks from the Middletown complex from the Vincent Pond structure and from north of Ivoryton (open green circles) generally fall between the fields of the other two gneisses, showing that they are also unique. Other sample compositions of rocks from the Turkey Hill complex and Ingham Hill area of the Middletown complex scatter widely, suggesting that these complexes are composed of rocks of varied magmatic and sedimentary origins.



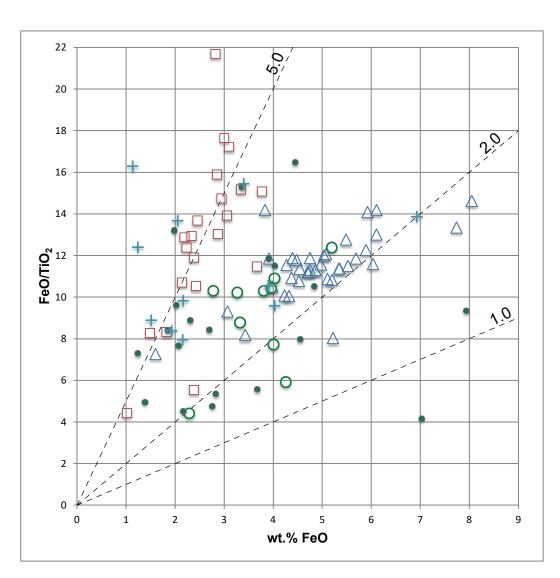
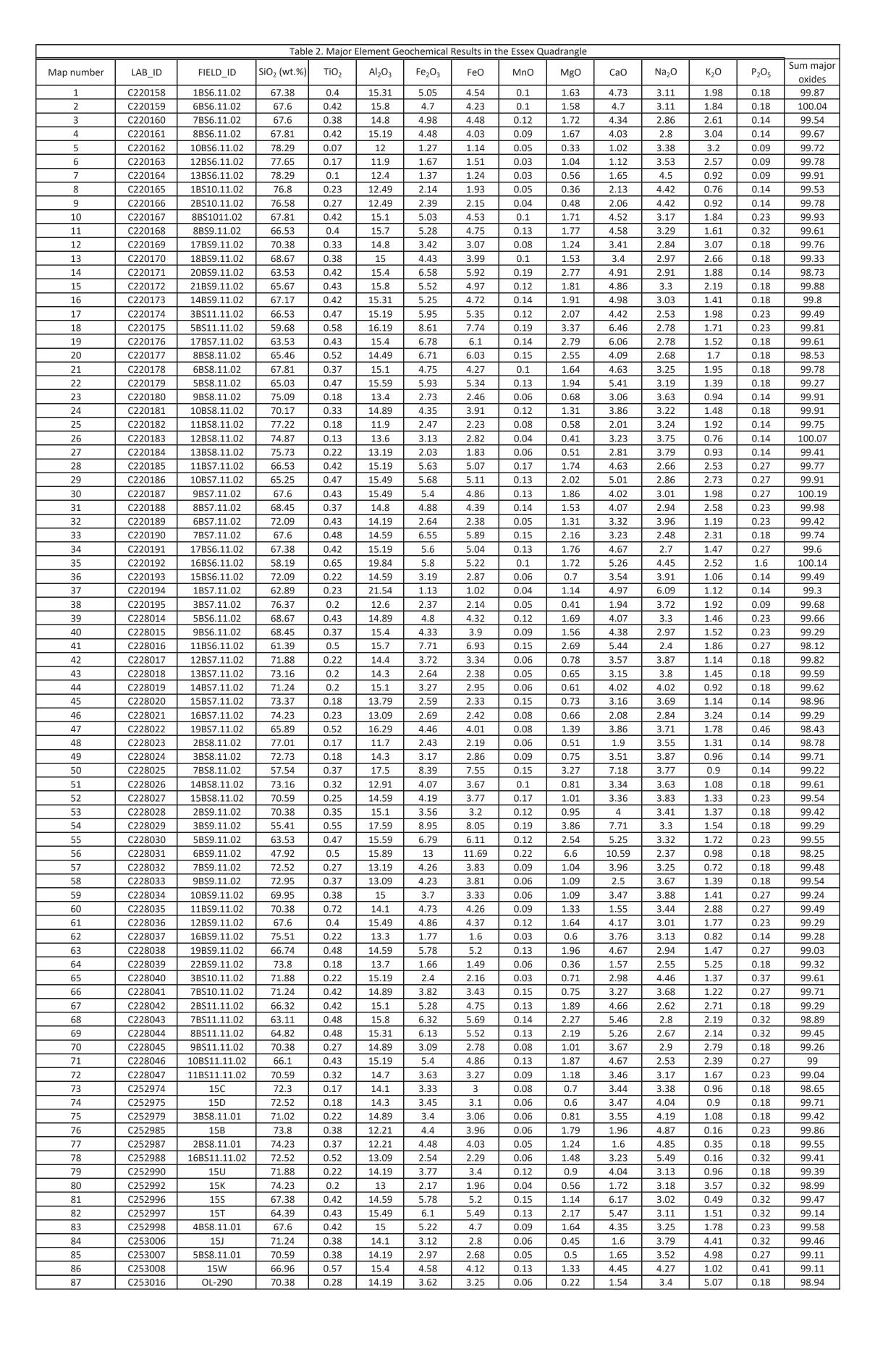


Figure 2. A plot of wt. % FeO(total) against FeO(total)/TiO2 (see Table 2) comparing the distribution of compositions of four plagioclase gneiss bodies as given in Figure 1. Dashed lines with slopes of 1.0, 2.0 and 5.0 are given for reference. The bands of points with a positive slopes produced by analyses of Boulder Lake and Pond Meadow gneisses are consistent with the magmatic fractionation of magnetite, but from distinctly unrelated magmas. The scatter of points defined by analyses of rocks from the Middletown and Turkey Hill complexes confirms the interpretation that the samples have diverse

sedimentary and volcanic origins.



| Manana | LABID | בובו בי וב | C a /12 12 12 1 | C | Ca | 7.0 | Dh | C., | 7.0 | Ca | Do | l a | Co | Na | Con | г | Th | VIa | 1 | 116 | То | Th |
|---------|--------------------|--------------|-----------------|--------------|------|------|------|------|------|-------|------|------|------|----------|------|-------|-------|-------|--------|-------|--------|-------|
| Map no. | LAB_ID | _ | Sc (ppm) | | Со | Zn | Rb | Sr | Zr | Cs | Ва | La | Ce | Nd | Sm | Eu | Tb | Yb | Lu | Hf | Та | Th |
| 39 | C228014 | 5BS6.11.02 | 21.7 | 7.62 | 10.9 | 54.3 | 109 | 149 | 120 | 6.09 | 105 | 39.3 | 51.9 | 26.7 | 5.18 | 0.642 | 0.663 | 2.72 | 0.404 | 3.04 | 0.482 | 6.96 |
| 40 | C228015 | 9BS6.11.02 | 15.4 | 6.01 | 9.29 | 39.4 | 94.9 | 175 | 107 | 7.13 | 491 | 22.1 | 44.9 | 19.7 | 3.96 | 0.689 | 0.459 | 1.47 | 0.211 | 3.24 | 0.8 | 9.72 |
| 41 | C228016 | 11BS6.11.02 | 30.3 | 13 | 17.2 | 70.1 | 89.3 | 179 | 88.8 | 2.72 | 474 | 8.08 | 18 | 11.3 | 3.7 | 0.859 | 0.615 | 2.72 | 0.388 | 2.34 | 0.383 | 4.98 |
| 42 | C228017 | 12BS7.11.02 | 8.84 | 1.33 | 4.25 | 46 | 49.6 | 138 | 72.1 | 1.95 | 144 | 8.74 | 18.2 | 8.77 | 1.96 | 0.558 | 0.224 | 1.27 | 0.191 | 2.24 | 0.207 | 2.66 |
| 43 | C228018 | 13BS7.11.02 | 7.51 | 2.01 | 4.11 | 37.4 | 50.5 | 130 | 63.6 | 1.69 | 352 | 18.5 | 36.5 | 16.3 | 2.82 | 0.565 | 0.203 | 0.431 | 0.0665 | 1.8 | 0.211 | 5.77 |
| 44 | C228019 | 14BS7.11.02 | 7.82 | 2.33 | 4.15 | 42.8 | 33 | 149 | 70 | 0.892 | 205 | 4.84 | 20.8 | 5.81 | 1.56 | 0.564 | 0.215 | 0.735 | 0.115 | 2.06 | 0.127 | 3.72 |
| 45 | C228020 | 15BS7.11.02 | 10.9 | 0.926 | 3.62 | 40.5 | 62.4 | 153 | 86.2 | 2.08 | 166 | 11.8 | 24.3 | 11.1 | 2.07 | 0.496 | 0.376 | 6.17 | 0.967 | 2.39 | 0.466 | 3.03 |
| 46 | C228021 | 16BS7.11.02 | 6.38 | 1.78 | 4.27 | 30.1 | 147 | 89.3 | 131 | 3.14 | 584 | 21 | 62.3 | 10.5 | 1.72 | 0.395 | 0.227 | 1.81 | 0.345 | 4.36 | 0.463 | 20.2 |
| 47 | C228022 | 19BS7.11.02 | 8.53 | 10.1 | 7.91 | 85.8 | 98.1 | 379 | 166 | 3.11 | 626 | 93.9 | 193 | 69.8 | 9.71 | 1.22 | 0.526 | 0.744 | 0.109 | 4.15 | 0.386 | 26.8 |
| 48 | C228023 | 2BS8.11.02 | 7.91 | 0.521 | 2.1 | 50 | 50.5 | 84 | 98.8 | 1.89 | 301 | 9.07 | 22.5 | 10 | 2.38 | 0.611 | 0.322 | 4.13 | 0.631 | 3.23 | 0.399 | 3.87 |
| 49 | C228024 | 3BS8.11.02 | 11 | 1.65 | 3.35 | 41.9 | 44.9 | 133 | 106 | 1.99 | 166 | 8.86 | 10.4 | 8.24 | 1.72 | 0.502 | 0.29 | 3.44 | 0.539 | 3.2 | 1.44 | 4.52 |
| 50 | C228025 | 7BS8.11.02 | 28.8 | 4.82 | 23.5 | 57.5 | 37.7 | 163 | 37.9 | 0.595 | 455 | 6.83 | 14.7 | 8.42 | 2.45 | 0.598 | 0.428 | 2.05 | 0.321 | 1.14 | 0.109 | 1.43 |
| 51 | C228026 | 14BS8.11.02 | 18.3 | 1.49 | 4.78 | 43.2 | 45.9 | 110 | 71.6 | 6.88 | 294 | 8.76 | 23.6 | 9.59 | 2.67 | 0.6 | 0.514 | 3.26 | 0.501 | 2.15 | 0.489 | 3.76 |
| 52 | C228027 | 15BS8.11.02 | 18.4 | 1.25 | 5.99 | 61 | 79.1 | 147 | 91.3 | 4.3 | 123 | 18.6 | 32.7 | 16.2 | 2.97 | 0.524 | 0.356 | 4.1 | 0.621 | 2.47 | 0.762 | 4.56 |
| 53 | C228028 | 2BS9.11.02 | 14.1 | 3.81 | 5.6 | 48.5 | 68.2 | 166 | 130 | 2.54 | 323 | 23.9 | 45.2 | 21.3 | 4.47 | 0.822 | 0.616 | 2.8 | 0.39 | 3.74 | 0.385 | 6.62 |
| 54 | C228029 | 3BS9.11.02 | 36.2 | 39.8 | 22.4 | 97.7 | 68 | 154 | 112 | 3.09 | 238 | 28.9 | 71.5 | 28.8 | 5.74 | 0.936 | 0.678 | 3.22 | 0.489 | 3.18 | 0.439 | 7.49 |
| 55 | C228030 | 5BS9.11.02 | 32 | 16 | 15.5 | 70.8 | 86.9 | 167 | 101 | 3.42 | 203 | 15.8 | 34 | 18.7 | 4.74 | 0.773 | 0.973 | 1.55 | 0.197 | 2.59 | 0.628 | 5.69 |
| 56 | C228031 | 6BS9.11.02 | 55.6 | 61.8 | 50.9 | 85 | 18.2 | 151 | 25.4 | 0.593 | 48.1 | 4.39 | 12.1 | 8.85 | 2.24 | 0.524 | 0.441 | 2.41 | 0.36 | 0.801 | 0.0921 | 0.428 |
| 57 | C228032 | 7BS9.11.02 | 15.8 | 3.03 | 7.82 | 51.2 | 26.3 | 87.6 | 88 | 1.03 | 137 | 8.46 | 18.1 | 9.9 | 2.59 | 0.567 | 0.455 | 2.46 | 0.365 | 1.8 | 0.149 | 2.34 |
| 58 | C228033 | 9BS9.11.02 | 13.6 | 1.18 | 6.23 | 72 | 86.2 | 109 | 94.3 | 3.82 | 168 | 5.99 | 11.3 | 5.39 | 1.27 | 0.47 | 0.195 | 0.469 | 0.0714 | 2.71 | 0.84 | 0.857 |
| 59 | C228034 | 10BS9.11.02 | 9.33 | 5.08 | 6.63 | 59.1 | 72.4 | 319 | 92.4 | 2.73 | 289 | 27.3 | 51.7 | 18.8 | 2.97 | 0.656 | 0.317 | 0.531 | 0.083 | 2.48 | 0.375 | 7.87 |
| 60 | C228035 | 11BS9.11.02 | 15.2 | 36.6 | 9.08 | 107 | 161 | 203 | 299 | 8.35 | 851 | 45.1 | 87.8 | 41.8 | 8.09 | 1.51 | 0.89 | 3.14 | 0.479 | 7.66 | 0.859 | 15.7 |
| 61 | C228036 | 12BS9.11.02 | 20.2 | 6.8 | 11.1 | 69.2 | 110 | 189 | 129 | 5.62 | 404 | 23.7 | 40.7 | 19.6 | 4.07 | 0.785 | 0.657 | 3.13 | 0.475 | 3.12 | 0.529 | 8.59 |
| 62 | C228037 | 16BS9.11.02 | 4.91 | 1.23 | 3.8 | 25.7 | 39.4 | 188 | 80 | 1.67 | 132 | 24.6 | 58.1 | 15.6 | 2.49 | 0.542 | 0.247 | 0.523 | 0.082 | 2.07 | 0.198 | 7.31 |
| 63 | C228037 | 19BS9.11.02 | 26.4 | 16.7 | 12.8 | 69.1 | 78.5 | 135 | 208 | 4.17 | 387 | 19.1 | 40.8 | 23 | 5.75 | 0.928 | 1.07 | 6.04 | 0.892 | 4.79 | 0.752 | 6.19 |
| 64 | C228038 | 22BS9.11.02 | 4.39 | 1.24 | 1.98 | 30.2 | 126 | 159 | 123 | 2.01 | 1130 | 36 | 69.1 | 27.2 | 4.94 | 1.02 | 0.455 | 1.81 | 0.832 | 3.58 | 0.752 | 17.4 |
| 65 | C228039 | 3BS10.11.02 | 6.25 | 1.47 | 3.45 | 44.3 | 59.6 | 124 | 48.7 | 2.01 | 135 | 6.48 | 12.1 | 5.84 | 1.54 | 0.611 | 0.433 | 0.492 | 0.283 | 1.79 | 0.351 | 1.3 |
| 66 | C228040 | 7BS10.11.02 | 19.4 | 2.39 | 5.09 | 69.3 | 64.5 | 158 | 139 | 3.3 | 194 | 16 | 50.7 | 15.8 | 3.43 | 0.766 | 0.634 | 3.17 | 0.409 | 3.86 | 0.733 | 7.21 |
| 67 | C228041 C228042 | 2BS11.11.02 | 20 | 5.87 | 12.3 | 84.2 | 133 | 191 | 118 | 6.89 | 523 | 14.4 | 40.7 | 15.9 | 3.43 | 0.706 | 0.034 | 2.66 | 0.403 | 3.49 | 0.733 | 7.21 |
| | C228042 | 7BS11.11.02 | | † | + | 58.4 | | 222 | 137 | 3.31 | 689 | | 47.7 | 23.2 | t | 0.720 | 0.571 | 2.28 | 0.403 | 3.49 | 0.413 | 8.83 |
| 68 | C228043 | 8BS11.11.02 | 22.8 | 8.61 7.73 | 14.4 | | 99.1 | | | | 547 | 30.3 | | † | 4.64 | | | | | | | |
| 69 | + | | 21.4 | - | 13.9 | 60.4 | 83.3 | 222 | 108 | 2.58 | | 16 | 38.3 | 17 | 3.85 | 0.803 | 0.481 | 2.07 | 0.314 | 2.86 | 0.423 | 7.18 |
| 70 | C228045 | 9BS11.11.02 | 8.98 | 2.43 | 5.84 | 40.2 | 100 | 206 | 98.4 | 2.41 | 1080 | 29.1 | 47.4 | 18 | 3.43 | 0.694 | 0.384 | 1.25 | 0.194 | 2.52 | 0.417 | 17.6 |
| 71 | C228046 | 10BS11.11.02 | | 7.74 | 12.8 | 73.4 | 95.6 | 198 | 90.4 | 2.89 | 787 | 5.85 | 22.2 | 8.88 | 2.58 | 0.64 | 0.502 | 1.76 | 0.273 | 2.7 | 0.451 | 11.2 |
| 72 | C228047 | 11BS11.11.02 | | 2.04 | 7.17 | 46.1 | 97.3 | 171 | 109 | 3.44 | 393 | 15.2 | 44.2 | 8.44 | 1.65 | 0.609 | 0.276 | 1.01 | 0.158 | 2.73 | 0.387 | 7.92 |
| 73 | C252974 | 15C | 11.5 | 4.29 | 4.65 | 45 | 50.1 | 111 | 81.3 | 3.07 | 208 | 14.2 | 26.8 | 12.7 | 2.63 | 0.537 | 0.375 | 2.46 | 0.376 | 2.26 | 0.244 | 3.57 |
| 74 | C252975 | 15D | 6.52 | 7.24 | 4.3 | 42 | 41.4 | 124 | 88.4 | 1.7 | 197 | 13.1 | 25 | 11.3 | 2.19 | 0.555 | 0.228 | 0.475 | 0.075 | 2.76 | 0.449 | 3.85 |
| 75 | C252979 | 3BS8.11.01 | 7.99 | 14.7 | 4.76 | 53.3 | 48 | 133 | 79.5 | 2.05 | 226 | 11.2 | 22.5 | 10.1 | 2.11 | 0.568 | 0.233 | 0.564 | 0.0839 | 2.23 | 0.465 | 3.61 |
| 76 | C252985 | 15B | 14.9 | 5.98 | 6.14 | 30.1 | 6.46 | 103 | 133 | 1.46 | 57.7 | 15.7 | 33.8 | 18 | 4.79 | 0.923 | 0.888 | 4.53 | 0.664 | 3.31 | 0.188 | 4.79 |
| 77 | C252987 | 2BS8.11.01 | 11.4 | 11.8 | 4.83 | 37 | 9.55 | 125 | 102 | 1.48 | 95.6 | 14 | 28.2 | 15.8 | 4 | 0.85 | 0.772 | 4.24 | 0.646 | 2.81 | 0.202 | 4.48 |
| 78 | C252988 | 16BS11.11.02 | | 12.1 | 1.72 | 32 | 2.45 | 134 | 126 | 0.216 | 56.7 | 13.7 | 33.4 | 18.8 | 5.54 | 1.35 | 1.06 | 5.29 | 0.786 | 3.38 | 0.23 | 4.27 |
| 79 | C252990 | 15U | 11 | 6.3 | 5.84 | 46.7 | 55.6 | 122 | 73.6 | 2.25 | 206 | 11.1 | 26.4 | 8.69 | 1.92 | 0.482 | 0.379 | 1.81 | 0.267 | 2.29 | 0.164 | 6.03 |
| 80 | C252992 | 15K | 4.53 | 8.95 | 2.43 | 22.6 | 98.1 | 138 | 152 | 1.62 | 973 | 48.5 | 87.5 | 32.7 | 6.19 | 0.979 | 0.567 | 1.13 | 0.171 | 4.32 | 0.28 | 34.5 |
| 81 | C252996 | 15S | 24.7 | 3.7 | 8.28 | 124 | 7.79 | 294 | 87 | 0.318 | 134 | 6.5 | 22.3 | 11.8 | 3.95 | 1.04 | 0.826 | 4.53 | 0.667 | 1.9 | 0.173 | 2.53 |
| 82 | C252997 | 15T | 22.5 | 7.25 | 12.3 | 41.2 | 67.8 | 180 | 104 | 2.4 | 310 | 30.2 | 56 | 23.4 | 4.76 | 0.926 | 0.629 | 2.4 | 0.356 | 2.67 | 1.03 | 12.2 |
| 83 | C252998 | 4BS8.11.01 | 18.2 | 18.3 | 10.2 | 40.5 | 94.9 | 163 | 125 | 3.66 | 329 | 26.4 | 50.2 | 22.8 | 4.64 | 0.829 | 0.527 | 1.57 | 0.224 | 3.52 | 0.703 | 9.48 |
| 84 | C253006 | 1 5J | 6.01 | 5.94 | 2.75 | 47.8 | 174 | 130 | 263 | 3.31 | 460 | 51.4 | 103 | 42.9 | 8.82 | 1.01 | 1.15 | 3.9 | 0.559 | 7.32 | 1.75 | 17.1 |
| 85 | C253007 | 5BS8.11.01 | 5.67 | 10.9 | 3.03 | 45 | 187 | 160 | 289 | 3.22 | 632 | 59.1 | 116 | 49 | 9.65 | 1.17 | 1.15 | 3.04 | 0.436 | 7.64 | 1.65 | 20.5 |
| 86 | C253008 | 15W | 12.2 | 7.5 | 7.42 | 54.4 | 29.6 | 357 | 295 | 3.68 | 592 | 22.2 | 43.2 | 21.2 | 4.8 | 1.43 | 0.681 | 2.62 | 0.395 | 6.63 | 0.428 | 2.16 |
| 87 | C253016 | OL-290 | 6.92 | 15.2 | 1.72 | 71.6 | 99.9 | 139 | 550 | 0.877 | 2360 | 145 | 305 | 113 | 16.4 | 3.24 | 1.59 | 4.28 | 0.641 | 13.3 | 0.635 | 17.2 |

Wintsch, R.P. (1985) Bedrock geology of the Deep River area, Connecticut, in Tracy, R.J., ed., Guidebook for field trips in Connecticut: State Geological and Natural History Survey of Connecticut, Wintsch, R.P., and Aleinikoff, J.N. (1987) U-Pb isotopic evidence for late Paleozoic anatexis, deformation

and possible accretion of the Avalon terrane, south central Connecticut: American Journal of Wintsch, R.P., and Andrews, M.S. (1988) Deformation induced growth of sillimanite: "Stress" minerals revisited: Journal of Geology 96, 143-161. Wintsch, R.P., Andrews, M.S., and Ambers, C.P. (1990a) The case for thrust napping and against fold

napping in the Avalon terrane of southeastern Connecticut, in Socci, A.O., Skehan, S.J., J.W., and Smith, G.W., eds., Geology of the composite Avalon terrane of southern New England: Geologi cal Society of America, Special. Paper 245, 209-233. Wintsch, R.P., Webster, J.R., Bernitz, J.A., and Fout, J.S. (1990b) Geochemical and geological criteria for in Socci, A.O., Skehan, S.J., J. W., and Smith, G.W., eds., Geology of the composite Avalor

Structural Geology 69, 428-448.

terrane of southern New England: Geological Society of America, Special Paper 245, 187-208. Wintsch, R.P., Sutter, J.F., Kunk, M.J., Aleinikoff, J.N., Dorais, M.J. (1992) Contrasting P-T t paths: Thermochronologic evidence for a Late Paleozoic final accretion of the Avalon composite terrane in the New England Appalachians: Tectonics 11, 672-689. Wintsch, R.P., Kunk, M.J., Boyd, J.L., and Aleinikoff, J.N., (2003) P-T-t paths and differential Allegha nian loading and uplift of the Bronson Hill terrane, south-central New England: American Journal of Science 303, 410-446.

Wintsch, R.P., Aleinikoff, J.N., Webster, J.R., and Unruh, D.M., (2005) The Killingworth Complex: A middle and late Paleozoic magmatic and structural dome: Guidebook for Field Trips in Connecti cut: State Geological and Natural History Survey of Connecticut, Guidebook 8, p. 305-324. Wintsch, R.P., Aleinikoff, J.N., Walsh, G.J., Bothner, W.A., Hussey, A.M., II., and Fanning, C. M., (2007) SHRIMP U-Pb evidence for a Late Silurian age of metasedimentary rocks in the Merrimack and Putnam-Nashoba Terranes, eastern New England: American Journal of Science 307, pp.119-167. Wintsch, R.P., Yi, K., and Dorais, M. J., (2014) Crustal Thickening by Tectonic Wedging in Southern New England, USA: Evidence from Cataclastic Zircon Microstructures and U-Pb ages: Journal of

This geologic map was funded in part by the USGS National Cooperative Geologic Mapping Program under StateMap award number G19AC00144, 0002., 2019.

State Component of the National Cooperative Geologic Mapping Program.

INSTITUTIONAL RELATIONSHIPS The geologic mapping activities under this project were conducted under subcontract from the Connecticut Geological Survey, in conjunction with the University of Connecticut, to Robert Wintsch and Ryan Deasy. An Interagency Project Agreement between the Connecticut Geological Survey, Department of

Energy and Environmental Protection, and the University of Connecticut Center for Integrative Geosci-

¹ Connecticut Dept. of Energy & Environmental Protection, Connecticut Geological Survey ² Indiana University Dept. of Earth & Atmospheric Sciences
³ Wesleyan University Dept. of Earth & Environmental Sciences