U.S. Department of the Interior
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STATE OF VERMONT, VERMONT AGENCY OF NATURAL RESOURCES, VERMONT GEOLOGICAL SURVEY,
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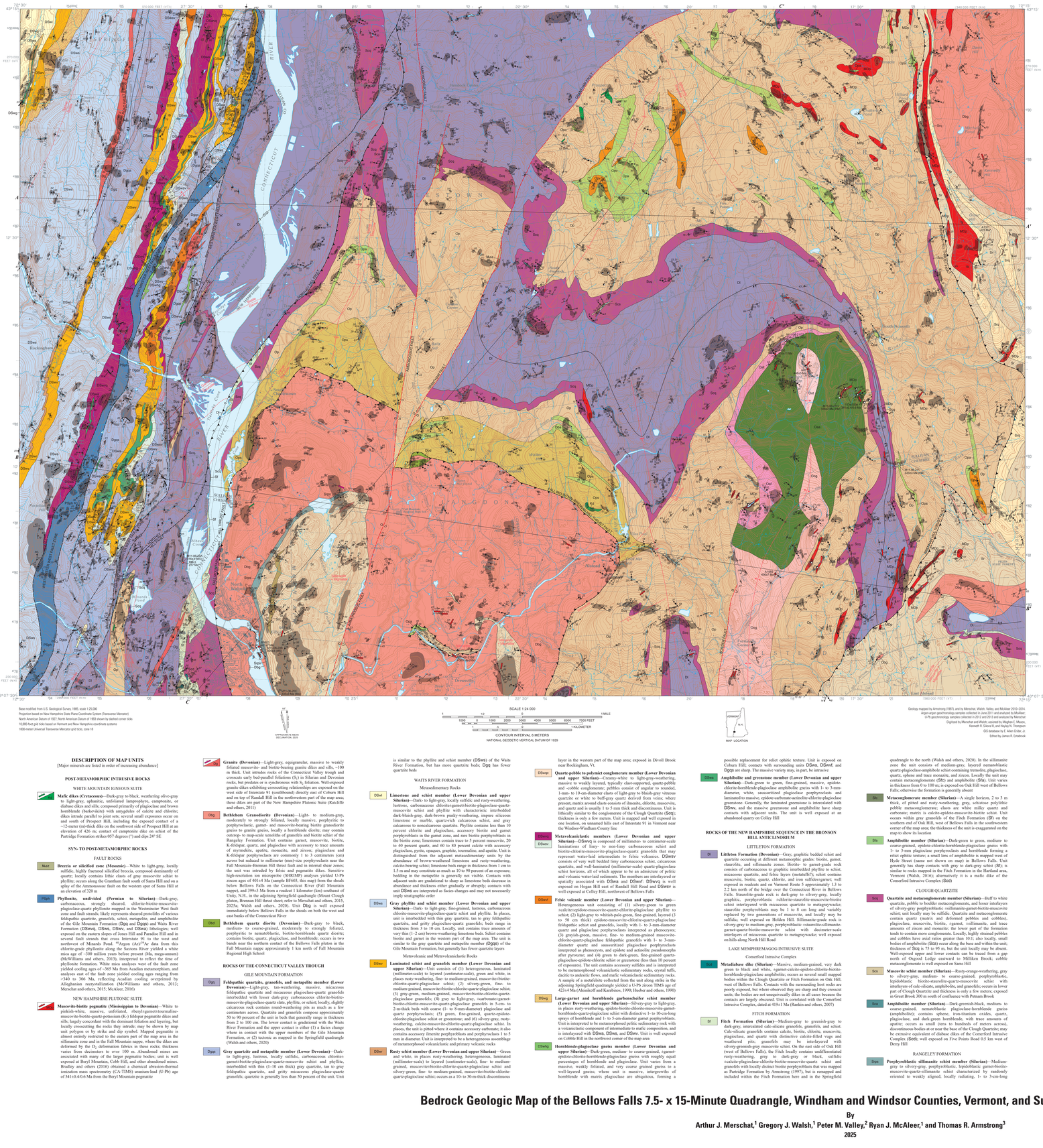
Scientific Investigations Map 3535
Sheet 1 of 2




## DESCRIPTION OF MAP UNITS

[Major minerals are listed in order of increasing abundance]

### POST-METAMORPHIC INTRUSIVE ROCKS

WHITE MOUNTAIN IGNEOUS SUITE

**Mafic dikes (Cretaceous)**—Dark-gray to black, weathering olive-gray to light-gray, aphanitic, unfoliated lamprophyre, camptonite, or diabase dikes and sills; composed primarily of plagioclase and brown hornblende (barkevikite) with amygdules of calcite and chlorite; dikes intrude parallel to joint sets; several small exposures occur on and south of Prospect Hill, including the exposed contact of a ~12-meter (m)-thick dike on the southwest side of Prospect Hill at an elevation of 426 m; contact of camptonite dike on schist of the Partridge Formation strikes 057 degrees (°) and dips 24° SE.

### SYN- TO POST-METAMORPHIC ROCKS

FAULT ROCKS

**Breccia or silicified zone (Mesozoic)**—White to light-gray, locally saffron, highly fractured silicified breccia, composed dominantly of quartz; locally contains lithic clasts of gray muscovite schist to phyllite; occurs along the Grantham fault south of Sams Hill and on a splay of the Ammonoosuc fault on the western spur of Sams Hill at an elevation of 320 m.

**Phyllonite, undivided (Permian to Silurian)**—Dark-gray, carbonaceous, strongly sheared, chlorite-biotite-muscovite-plagioclase-quartz phyllonite mapped in the Westminster West fault zone and fault strands; likely represents sheared protoliths of various feldspathic quartzite, granofels, schist, metapelite, and amphibolite of the Gile Mountain Formation (Dgs and Dgqs) and Waits River Formation (DSwvq, DSwv, DSwsv, and DSwsc) lithologies; well exposed on the eastern slopes of Jones Hill and Paradise Hill and in several fault strands that cross Interstate 91 to the west and northwest of Minards Pond. $^{40}Argon$ ($Ar/^{39}Ar$ data from this chlorite-grade phyllonite along the Saxtons River yielded a white mica age of ~300 million years before present (Ma, mega-annum) (McWilliams and others, 2013), interpreted to reflect the time of phyllonite formation. White mica analyses west of the fault zone yielded cooling ages of ~365 Ma from Arsadan metamorphism, and analyses east of the fault zone yielded cooling ages ranging from >340 to 306 Ma, reflecting Acadian cooling overprinted by Alleghanian recrystallization (McWilliams and others, 2013; Merschat and others, 2015; McAleer, 2016)

NEW HAMPSHIRE PLUTONIC SUITE

**Muscovite-biotite pegmatite (Mississippian to Devonian)**—White to pinkish-white, massive, unfoliated, (beryl)garnet(spessartine)-muscovite-biotite-quartz-potassium (K-) feldspar pegmatite dikes and sills; largely concordant with the dominant foliation and layering, but locally crosscutting the rocks they intrude; may be shown by map unit polygon or by strike and dip symbol. Mapped pegmatite is almost entirely restricted to the eastern part of the map area in the sillimanite zone and in the Fall Mountain nappe, where the dikes are deformed by the $D_2$ deformation fabrics in these rocks; thickness varies from decimeters to over 100 m. Abandoned mines are associated with many of the larger pegmatite bodies; unit is well exposed at Beryl Mountain, Cobb Hill, and other abandoned mines. Bradley and others (2016) obtained a chemical abrasion-thermal ionization mass spectrometry (CA-TIMS) uranium-lead (U-Pb) age of 341±0.4/0.6 Ma from the Beryl Mountain pegmatite

**Granite (Devonian)**—Light-gray, equigranular, massive to weakly foliated muscovite- and biotite-bearing granite dikes and sills, ~100 m thick. Unit intrudes rocks of the Connecticut Valley trough and crosscuts early bed-parallel foliations ($S_1$) in Silurian and Devonian rocks, but predates or is synchronous with $S_2$ foliation. Well-exposed granite dikes exhibiting crosscutting relationships are present on the west side of Interstate 91 (southbound) directly east of Coburn Hill and on top of Randall Hill in the northwestern part of the map area; these dikes are part of the New Hampshire Plutonic Suite (Ratcliffe and others, 2011)

**Bethlehem Granodiorite (Devonian)**—Light- to medium-gray, moderately to strongly foliated, locally massive, porphyritic to porphyroclastic, garnet- and muscovite-bearing biotite granodiorite gneiss to granite gneiss, locally a hornblende diorite; may contain outcrops to map-scale xenoliths of granofels and biotite schist of the Rangeley Formation. Unit contains garnet, muscovite, biotite, K-feldspar, quartz, and plagioclase with accessory to trace amounts of myrmekite, apatite, monazite, and zircon; plagioclase and K-feldspar porphyroclasts are commonly 1 to 3 centimeters (cm) across but reduced to millimeter (mm)-size porphyroclasts near the Fall Mountain–Brennan Hill thrust fault and in internal shear zones; the unit was intruded by felsic and pegmatite dikes. Sensitive high-resolution ion microprobe (SHRIMP) analyses yielded U-Pb zircon ages of 401±4 Ma (sample BF603, this map) from the shoals below Bellows Falls on the Connecticut River (Fall Mountain nappe), and 399±3 Ma from a roadcut 1 kilometer (km) southeast of Unity, N.H., in the adjoining Springfield quadrangle (Mount Clough pluton, Brennan Hill thrust sheet; refer to Merschat and others, 2015, 2025a; Walsh and others, 2020). Unit Dbg is well exposed immediately below Bellows Falls in the shoals on both the west and east banks of the Connecticut River

**Bethlehem quartz diorite (Devonian)**—Dark-gray to black, medium- to coarse-grained, moderately to strongly foliated, porphyritic to nematoblastic, biotite-hornblende quartz diorite; contains biotite, quartz, plagioclase, and hornblende; occurs in two bands near the northern contact of the Bellows Falls pluton in the Fall Mountain nappe approximately 1 km north of Fall Mountain Regional High School

### ROCKS OF THE CONNECTICUT VALLEY TROUGH

GILE MOUNTAIN FORMATION

**Feldspathic quartzite, granofels, and metapelite member (Lower Devonian)**—Light-gray, tan-weathering, massive, micaceous feldspathic quartzite and micaceous plagioclase-quartz granofels interbedded with lesser dark-gray carbonaceous chlorite-biotite-muscovite-plagioclase-quartz slate, phyllite, or schist; locally, slightly calcareous rock contains round-weathering pits as much as a few centimeters across. Quartzite and plagioclase-quartz granofels comprise 50 to 90 percent of the unit in beds that generally range in thickness from 2 to 100 cm. The lower contact is gradational with the Waits River Formation and the upper contact is either (1) a facies change where in contact with the upper members of the Gile Mountain Formation, or (2) tectonic as mapped in the Springfield quadrangle (Walsh and others, 2020)

**Gray quartzite and metapelite member (Lower Devonian)**—Dark- to light-gray, lustrous, locally staurolite, carbonaceous albite-biotite-muscovite-plagioclase-quartz-muscovite schist and phyllite, interbedded with thin (1–10 cm thick) gray quartzite, ten to gray feldspathic quartzite, and gritty micaceous plagioclase-quartz granofels; quartzite is generally less than 50 percent of the unit. Unit is similar to the phyllite and schist member (DSwsv) of the Waits River Formation, but has more quartzite beds; Dgq has fewer quartzite beds

WAITS RIVER FORMATION

Metasedimentary Rocks

**Limestone and schist member (Lower Devonian and upper Silurian)**—Dark- to light-gray, locally sulfidic and rusty-weathering, lustrous, carbonaceous chlorite(garnet)-biotite-plagioclase-quartz-muscovite schist and phyllite with characteristic interbedded dark-blackish-gray, dark-brown rusty-weathering, impure siliceous limestone or marble, quartz-rich calcareous schist, and gray calcareous to noncalcareous quartzite. 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; limestones contain trace to 5 percent muscovite, 20 to 40 percent quartz, and 60 to 80 percent calcite with accessory muscovite, pyrite, opaques, graphite, tourmaline, and apatite. Unit is distinguished from the adjacent metasedimentary units by the abundance of brown-weathering limestone and rusty-weathering, calcite-bearing schist; limestone beds range in thickness from 1 cm to 1.5 m and may constitute as much as 10 to 30 percent of an exposure; bedding in the metapelite is generally not visible. Contacts with adjacent units are gradational to sharp as limestone beds decrease in abundance and thickness either gradually or abruptly; contacts with unit DSwsv are interpreted as facies changes and may not necessarily imply stratigraphic order

**Gray phyllite and schist member (Lower Devonian and upper Silurian)**—Dark- to light-gray, locally sulfidic and carbonaceous chlorite-muscovite-plagioclase-quartz schist and phyllite. In places, unit is interbedded with thin gray quartzite, ten to gray feldspathic quartzite, and gritty plagioclase-quartz granofels; beds range in thickness from 3 to 10 cm. Locally, unit contains trace amounts of very thin (1–2 cm) brown-weathering limestone beds. Schist contains biotite and garnet in the western part of the map area. The unit is similar to the gray quartzite and metapelite member (Dgqs) of the Gile Mountain Formation, but generally has fewer quartzite layers

**Laminated schist and granofels member (Lower Devonian and upper Silurian)**—Unit consists of (1) heterogeneous, laminated (millimeter-scale) to layered (centimeter-scale), green and white, in places rusty-weathering, fine- to medium-grained, muscovite(biotite-chlorite-garnet)-plagioclase-quartz schist; (2) silvery-green, fine- to medium-grained, muscovite(biotite-chlorite-garnet-plagioclase schist; (3) gray-green, medium-grained, muscovite(chlorite-garnet-plagioclase granofels; (4) gray to light-gray, (carbonate)-garnet-muscovite-plagioclase-quartz granofels; and (5) silvery-gray, rusty-weathering, calcite-muscovite-chlorite-quartz-plagioclase 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. Unit is interpreted to be a heterogeneous assemblage of metamorphosed volcaniclastic and primary volcanic rocks

**Rusty schist member (Lower Devonian and upper Silurian)**—Green and white, in places rusty-weathering, heterogeneous, laminated (millimeter-scale) to layered (centimeter-scale), fine- to medium-grained, muscovite(biotite-chlorite-quartz-plagioclase schist and silvery-green, fine- to medium-grained, muscovite(biotite-chlorite-quartz-plagioclase schist; occurs as a 10- to 30-m-thick discontinuous layer in the western part of the map area; exposed in Divoll Brook near Rockingham, Vt.

**Quartz-pebble to polymict conglomerate member (Lower Devonian and upper Silurian)**—Cream-white to light-gray-weathering, massive to weakly layered, typically clast-supported, quartz-pebble and -cobble conglomerate; pebbles consist of angular to rounded, 1-mm- to 10-cm-diameter clasts of light-gray to bluish-gray vitreous quartzite or white to buff-gray quartz derived from veins; where present, matrix around clasts consists of limestone, chlorite, muscovite, and quartz and is usually 1 to 5 mm thick and discontinuous. Unit is lithically similar to the conglomerate of the Clough Quartzite (Sclq); thickness is only a few meters. Unit is mapped and well exposed in one location, on unnamed hills east of Interstate 91 in Vermont near the Windsor-Windham County line

**Metavolcaniclastic members (Lower Devonian and upper Silurian)**—DSwvq is composed of millimeter- to centimeter-scale laminations of limy- to non-limy carbonaceous schist and biotite-chlorite-muscovite-plagioclase-quartz granofels that may represent water-laid intermediate to felsic volcanics. DSwsv consists of very well bedded limy carbonaceous schist, calcareous quartzite, and well-laminated (millimeter-scale) quartz-plagioclase schist horizons, all of which appear to be an admixture of pelitic and volcanic water-laid sediments. The members are interlayered or spatially associated with DSwsc and DSwsf. DSwsv is well exposed on Hogan Hill east of Randall Hill Road and DSwsv is well exposed at Colley Hill, northwest of Bellows Falls

**Felsic volcanic member (Lower Devonian and upper Silurian)**—Heterogeneous unit consisting of (1) silvery-green to green ±calcite±epidote-muscovite-quartz-chlorite-plagioclase phyllite to schist; (2) light-gray to whitish-pale-green, fine-grained, layered (3 to 50 cm thick) epidote-muscovite-chlorite-quartz-plagioclase 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-chlorite-quartz-plagioclase feldspathic granofels with 1- to 3-mm-diameter quartz and sanassonite plagioclase porphyroclasts interpreted as phenocrysts, and 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 to be metamorphosed volcaniclastic sedimentary rocks, crystal tuffs, dacite to andesite flows, and subaqueous pyroclastic siliceous rocks. A sample of a metafelsite collected from the unit along strike in the adjoining Springfield quadrangle yielded a 1.0 Ga precise TIMS age of 423±4 Ma (Aleinikoff and Karabinos, 1990; Hueber and others, 1990)

**Large-garnet and hornblende garbenschiefer schist member (Lower Devonian and upper Silurian)**—Dark-green-black, medium- to coarse-grained, nematoblastic plagioclase-hornblende gneiss (amphibolite); contains epidote, iron-titanium oxides, quartz, plagioclase, and dark-green hornblende, with trace amounts of apatite; occurs as small (tens to hundreds of meters across), discontinuous bodies at or near the base of the Clough Quartzite; may be extensive equivalent of diabase dikes of the Comerford Intrusive Complex (Sfz); well exposed on Five Points Road 0.5 km west of Derry Hill

RANGELEY FORMATION

**Porphyroblastic sillimanite schist member (Silurian)**—Medium- gray to olive-green-weathering, medium- to coarse-grained, garnet-biotite-muscovite-quartz-sillimanite schist characterized by randomly oriented to weakly aligned, locally bedded, radiating, 1- to 3-cm-long sillimanite pseudomorphs after andalusite (turkey track-like appearance). Unit occurs adjacent to the Bethlehem Granodiorite (Dbg) on Fall Mountain and is interpreted to be a contact aureole. Thickness is ~30 m or less; unit is well exposed immediately below the falls in the Connecticut River underneath the abandoned roadway bridge on the New Hampshire side, across the river from Bellows Falls

**Schist and granofels member (Silurian)**—Bright-red- to purplish-red-weathering, medium-gray to silvery-gray, interlayered migmatitic, porphyroblastic, lepidoblastic garnet-plagioclase-sillimanite-biotite-muscovite schist and granofels. Schist contains biotite, muscovite, sillimanite (fibrolite mats), quartz, garnet, plagioclase, K-feldspar, iron-titanium oxides, and trace amounts of tourmaline, monazite, and zircon. Unit locally contains lenses of calc-silicate, quartz-garnet-plagioclase, and coticule layers; migmatite leucosome commonly is parallel to $S_2$ foliation and contains quartz, plagioclase, ±muscovite and ±biotite. Unit is intruded by the Bethlehem Granodiorite (Dbg), felsic dikes, and pegmatites, and is well exposed on Fall Mountain. U-Pb detrital zircon geochronology sample from schist exposed at the southern end of Fall Mountain (in the Walpole quadrangle) yielded a minimum depositional age of 421 Ma (Merschat and others, 2016, 2025a)

**Quartzite, calc-silicate, and schist member (Silurian)**—Light- greenish-gray- to light-gray-weathering, light-greenish-gray to white, strongly foliated quartzite to granofels, calc-silicate, and muscovite schist; contains quartz, clinopyroxene, biotite, plagioclase, zoisite, iron-titanium oxides, and trace amounts of calcite and zircon; calc-silicate contains greenish-black clinopyroxene, zoisite, and biotite that define the dominant foliation. $S_2$ quartz pebbles are 1 to 2 cm across and consist of orthogonal undulose subgrains with serrated edges. Unit is well exposed in the roadbed on Great Hill Road, which also is the location of a detrital zircon geochronology sample that yielded a maximum depositional age of ~423 Ma (Merschat and others, 2016, 2025a)

**Metaconglomerate, granofels, and schist member (Silurian)**—Rusty- to buff-weathering, strongly foliated polymict to polylithic pebble to cobble metaconglomerate and muscovite-biotite-quartz-plagioclase granofels to gneiss; clasts are quartz, quartzite, quartz-pebble conglomerate, and minor granitoid; clasts are round to elongate, with aspect ratios ranging from 2:1 to 20:1; matrix consists of muscovite, biotite, quartz, and plagioclase similar to composition of granofels. Unit is approximately 50 m thick; contacts are not exposed and likely are gradational with the schist and granofels member (Sr); unit is well exposed on the access road to the tower on Mount Kilburn at ~210 m elevation

### ROCKS OF THE BRONSON HILLARC

OLIVERIAN PLUTONIC SUITE

**Trondhjemite gneiss of the Alstead dome (Late Ordovician)**—Buff to white to very light gray, medium- to coarse-grained, equigranular to porphyritic, moderately to strongly foliated garnet- and epidote-bearing, muscovite-biotite trondhjemite gneiss; contains plagioclase, quartz, microcline, and biotite with accessory muscovite, epidote, clinozoisite, garnet, and allanite, and trace amounts of zircon and monazite; trondhjemite gneiss from Milliken Brook yielded a SHRIMP U-Pb zircon age of 448±5 Ma (table 2 [sheet 1], sample A87) (Merschat and others, 2015; Valley and others, 2020)

**Granite gneiss of the Alstead dome (Late Ordovician)**—Gray to white, medium- to coarse-grained, equigranular to porphyritic to porphyroclastic, moderately to strongly foliated, garnet-bearing, biotite-muscovite granite gneiss; contains plagioclase, quartz, microcline, and biotite and muscovite with accessory garnet, clinozoisite, and trace amounts of zircon and monazite; granite gneiss from Forristall Road yielded a SHRIMP U-Pb zircon age of 456±7 Ma (table 2 [sheet 1], sample A1065) (McAleer, 2016; Valley and others, 2020)

PARTRIDGE FORMATION

**Rusty schist and granofels member (Ordovician)**—Rusty- to tan-weathering, silvery-gray to medium-gray porphyroblastic, lepidoblastic ±chlorite±chlorite(±staurolite)±sillimanite-biotite-quartz-muscovite schist with interlayers of dark-gray to black sulfidic quartzite, and bluish-gray to light-gray garnet-biotite-quartz-muscovite-plagioclase granofels; may contain garbenschiefer layers commonly near amphibolite; exposed, unconformable basal section overlying felsic metatuff (Ofsf) of the Ammonoosuc Volcanics in the Alstead dome (location shown in figure 1 on sheet 1 and figure 1 on sheet 2) as a black, magnetite-bearing garnet-biotite schist. Thickness of unit varies from 50 m to more than 100 m due to unconformities at the base and top of the Partridge Formation

**Pelitic schist and granofels member (Ordovician)**—Silvery-gray to medium-gray, locally sulfidic and graphitic, thinly layered biotite-garnet-muscovite-plagioclase-quartz schist with thin interlayers of granofels; well exposed in the Cold River below Vilas Pool dam and along the shoulder of Route 123A opposite the dam

**Amphibolite volcanics and granofels member (Ordovician)**—Light-gray, medium-grained, well-foliated porphyroblastic hornblende(garnet)-biotite-quartz-plagioclase gneiss and granofels; locally garnet composes 20 to 30 percent of the rock, with crystals 0.3 to 1 cm across. Unit commonly is associated with amphibolite member (Opa); contacts with adjacent units are not exposed

**Amphibolite member (Ordovician)**—Dark-gray to black, fine- to medium-grained hornblende-plagioclase-quartz-biotite schist to medium- to coarse-grained quartz-garnet-plagioclase-hornblende gneiss to schist; contains accessory iron sulfides, iron-titanium oxides, sphene, epidote, and apatite; locally may be sulfidic. Unit generally occurs as discontinuous layers and lenses throughout the Partridge Formation

AMMONOOSUC VOLCANICS

**Intermediate to felsic metatuff member (Ordovician)**—Buff-weathering, white to light-greenish-gray, garnet-bearing, muscovite-chlorite-quartz-plagioclase gneiss with accessory calcite and iron-titanium oxides; trace amounts of monazite and zircon; sugary, equigranular texture formed by granular recrystallized matrix of quartz and plagioclase crystals 0.05 to 0.2 mm across; quartz and plagioclase porphyroclasts ~1 mm across may be relict phenocrysts; alluvial vein quartz 1- to 10-mm-thick commonly occurs after amphibole; flattened concentric ringed structures may represent relict pyroclastic textures. Unit was mapped for ~5 km along the western flank of the northern part of the Alstead dome (location shown in figure 1 on sheet 1 and figure 1 on sheet 2) and is well exposed at the active quarry on the northern end of Osgood Ledge, where it yielded a SHRIMP U-Pb zircon age of 451±11 Ma (table 2 [sheet 1]) (Merschat and others, 2015; Valley and others, 2020)

**Amphibolite member (Ordovician)**—Black, medium- to coarse-grained, locally migmatitic, nematoblastic plagioclase-hornblende schist to garbenschiefer; amphiboles are randomly oriented and greenish-black, and some have actinolite rims; locally, unit contains gedrite and orthopyroxene. Unit is intruded by decimeter-thick trondhjemite dikes and contains the contact with Oliverian gneisses (Oot); locally may contain sulfidic muscovite schist layers (not mapped). Unit is well exposed along the crest of Osgood Ledge

## EXPLANATION OF MAP SYMBOLS

[The terms "Acadian" and "Alleghanian" refer to orogenic events and not to divisions of geologic time]

**Contact**—Approximately located; dotted where concealed by water. Queried where location is uncertain. In cross sections, dotted where projected above the ground surface

**Outcrops**—Areas of exposed bedrock or closely spaced contiguous bedrock exposures examined in this study

### FAULTS

[Approximately located; dotted where concealed by water. Queried where existance and (or) identity is uncertain. In cross sections, dotted where projected above the ground surface]

**Syn- to post-peak metamorphic thrust fault (Acadian or Alleghanian)**—Parallel to the $S_2$ foliation; sawteeth on upper plate. Includes the Fall Mountain thrust, the Brennan Hill thrust fault, and the Northey Hill fault

**Post-peak metamorphic strike-slip fault or shear zone (Alleghanian)**—Steeply dipping, parallel to the $S_2$ foliation; paired arrows indicate relative motion where known; U, upthrown side; D, downthrown side. Includes faults in the Westminster West fault zone and the Skitchewaug Mountain and Woodbury Road faults

**Brittle fault (Mesozoic)**—Steeply dipping; paired arrows indicate relative motion where known; U, upthrown side; D, downthrown side. Includes the Ammonoosuc, Grantham, and Border faults

### 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 inferred $F_1$ overturned syncline (Acadian, nappe-stage)**

**Axial trace of $F_2$ fold (Acadian? early dome-stage)**

Antiform

Synform

**Axial trace of $F_3$ or younger fold (Alleghanian? late dome-stage or Mesozoic near the Ammonoosuc fault)**

Overturned antiform

Synform

### PLANAR FEATURES

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

**Strike and dip of bedding**—Parallel to $S_1$

Inclined

Overturned

Inclined, showing top from graded beds

Overturned, showing top from graded beds

### DIKES

**Strike and dip of Cretaceous inclined mafic dike or sill (Kd)**

**Strike and dip of Mississippian to Devonian inclined pegmatite dike or sill (MZp)**

**Strike and dip of Devonian inclined granitic dike or sill (Dg)**

**Strike and dip of Ordovician inclined granite to tonalitic dike or sill (Oot)**

### FOLIATION

**Strike and dip of layer-parallel schistosity ($S_1$)**—Parallel to bedding or compositional layering; Acadian

Inclined

Inclined, deformed

Horizontal

**Strike and dip of spaced foliation ($S_2$)**—Variable across the map; less penetrative to the west, zonal in the east; Acadian

Inclined cleavage

Schistosity

Inclined

Vertical

**Mylonitic or phyllonitic $S_2$ foliation in local shear zones**

Inclined

Vertical

**Strike and dip of dominant foliation ($S_m$)**—Not age specific, but where $S_1$ or a composite $S_1$-$S_2$ foliation expressed as a schistosity where the $S_2$ is penetrative

Inclined

Vertical

**Strike and dip of inclined crenulation cleavage ($S_3$)**—Associated with open folds and a crenulation lineation that is most apparent in fine-grained metapelites (Alleghanian)

**Kink bands ($S_4$)**—Strike and dip of non-penetrative widely spaced cleavage, locally parallel to broad low-amplitude, high-wavelength folds with variable orientation; locally quartz and carbonate mineralization fills veins parallel to kink surfaces; may be related to brittle faults and Mesozoic extension

Inclined

Vertical

### MINOR FOLDS

**Strike and dip of inclined fold axial surface of $F_2$ fold that is parallel to $S_1$ foliation**—Isoclinal; rootless folds; Acadian nappe-stage

**Strike and dip of axial surface of $F_2$ fold that is parallel to $S_2$ foliation**—Tight to isoclinal, locally rootless folds; Acadian early dome-stage

Inclined

Vertical

**Strike and dip of inclined axial surface of $F_3$ or younger minor fold**—Open folds; Alleghanian late dome-stage or younger

### LINEAR FEATURES

[Symbols may be combined with other linear features; point of intersection shows location of measurement. Fold axis measurements are placed at the center of associated axial surface measurements, even where axial surface measurements are combined with other measurements at a point of intersection]

**Bearing and plunge of $F_1$ minor fold axis**

**Approximate bearing and plunge of folded $F_1$ minor fold axis**

**Bearing and plunge of $L_2$ intersection lineation**—Intersection between the $S_1$ and $S_2$ foliations

**Bearing and plunge of $F_2$ minor fold axis**—Fold axis of tight, isoclinal, or rootless fold associated with $S_2$

**Bearing and plunge of $L_3$ mineral lineation**—Aggregate lineation or grain lineation associated with the $S_3$ foliation; consists of quartz, plagioclase, biotite, muscovite, chlorite, or epidote

**Bearing and plunge of $F_3$ minor fold axis**—Fold axis of late, open fold or crenulation lineation

**Bearing of glacial striation or groove**

### OTHER FEATURES

**Isograd or tectonic metamorphic boundary**—Approximate boundary between diagnostic indicator mineral assemblages in pelitic rocks; mapped at first occurrence of mineral: biotite, garnet, staurolite, and sillimanite; sillimanite+mig. represents rocks with the assemblage sillimanite+muscovite+potassium feldspar+migmatite; isograds may be truncated by faults; metamorphic breaks at tectonic boundaries are not true isograds

**Quarry**—Construction aggregate or dimension stone. Sand and gravel pits are indicated on the base map and are not field checked

Active

Inactive

**Abandoned mine, quarry, prospect, or occurrence**—Number corresponds to list in table 1 on sheet 1

**Geochronology sample location**—Showing sample number and preliminary uranium-lead (U-Pb) zircon crystallization age in millions of years before present (Ma, mega-annum), derived by sensitive high-resolution ion microprobe (SHRIMP), by chemical abrasion-thermal ionization mass spectrometry (CA-TIMS), or by laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS). Asterisk indicates youngest detrital zircon age. Refer to table 2 on sheet 1

**Argon (Ar)/Ar sample location**—Showing sample number and preliminary $^{40}Ar/^{39}Ar$ plateau age in millions of years before present (Ma, mega-annum). Ms, muscovite; Hbl, hornblende (McAleer, 2016; Merschat and others, 2015, 2017)

**Table 1.** List of abandoned mines, quarries, prospects, and occurrences in the Bellows Falls 7.5- x 15-minute quadrangle.
Number corresponds to location on map.
[Locations with an asterisk (*) were visited and confirmed during mapping; other locations are "approximate" from the Mineral Resource Data System (MRDS). Abbreviation: -, not applicable.]

| Number | Name | Primary commodity | Secondary commodity | Ore |
|---|---|---|---|---|
| 1 | Allen Mine | Niobium (columbium), tantalum, feldspar | - | Columbite, tantalite |
| 2 | George Parker Mine* | Feldspar | Mica | Pegmatite |
| 3 | Unnamed | Feldspar | Copper, lead, silver | Chalcopyrite, galena, silver |
| 4 | Beryl Mountain Mine | Feldspar | Beryllium | Pegmatite |
| 5 | Colony Feldspar Mine* | Feldspar | Mica | Pegmatite |
| 6 | Allen Feldspar Quarry | Feldspar | - | Pegmatite |
| 7 | Beryl Mountain Pegmatite* | Feldspar | Beryllium, silica | Pegmatite |
| 8 | Ringleton Mica Mine* | Feldspar | Gemstone, mica | Pegmatite |
| 9 | Yuhas No. 1 Feldspar Mine | Feldspar | - | Pegmatite |
| 10 | Lyman Mine* | Feldspar | Gemstone, mica | Pegmatite |
| 11 | Yuhas No. 2 Mica Mine | Feldspar | - | Pegmatite |
| 12 | Provencher Mica Prospect | Mica | Feldspar | Pegmatite |
| 13 | Langdon Quarry | Silica | - | Quartz vein |

**Table 2.** Summary of reported U-Pb zircon ages from rocks in the Bellows Falls 7.5- x 15-minute quadrangle.
[Abbreviations: U-Pb, uranium-lead; Ma, mega-annum (million years before present); CA-TIMS, chemical abrasion-thermal ionization mass spectrometry; SHRIMP, sensitive high-resolution ion microprobe]

| Sample number | Map unit and rock type | Age (Ma) | Method | References |
|---|---|---|---|---|
| 110ed09b | Pegmatite (MZp) | 341±0.4/0.6 | CA-TIMS | Bradley and others (2016) |
| BF603 | Bethlehem Granodiorite (Dbg) | 401±4 | SHRIMP | Merschat and others (2015, 2025a) |
| A87 | Trondhjemite gneiss of the Alstead dome (Oot) | 448±5 | SHRIMP | Merschat and others (2015); Valley and others (2020) |
| A1065 | Granite gneiss of the Alstead dome (Dog) | 456±7 | SHRIMP | McAleer (2016); Valley and others (2020) |
| A400 | Ammonoosuc Volcanics, intermediate to felsic metatuff (Oaf) | 455±11 | SHRIMP | Merschat and others (2015); Valley and others (2020) |
| RM-3 (detrital) | Littleton Formation (Dl) | 417* | SHRIMP | Merschat and others (2016, 2025a); McAleer (2016) |
| A1011 (detrital) | Rangeley Formation (Dsrg) | 422* | SHRIMP | Merschat and others (2016, 2025a) |
| A1661 (detrital) | Partridge Formation (Op) | 541* | SHRIMP | Merschat and others (2016, 2025a) |
| A1757 (detrital) | Partridge Formation (Opa) | 482* | SHRIMP | Merschat and others (2016, 2025a) |

* Maximum depositional age based on youngest detrital zircon.

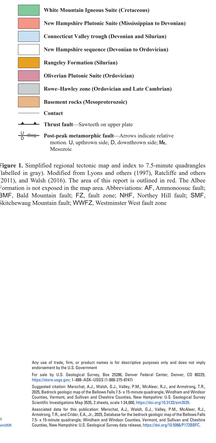



**Figure 1.** Simplified regional tectonic map and index to 7.5-minute quadrangles (labelled in gray). Modified from Lyons and others (1997), Ratcliffe and others (2011), and Walsh (2016). The area of this report is outlined in red. The Albany Formation is not exposed in the map area. Abbreviations: AF, Ammonoosuc fault; BMF, Bald Mountain fault; FZ, fault zone; NHF, Northey Hill fault; SMF, Skitchewaug Mountain fault; WWFZ, Westminster West fault zone

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# Bedrock Geologic Map of the Bellows Falls 7.5- x 15-Minute Quadrangle, Windham and Windsor Counties, Vermont, and Sullivan and Cheshire Counties, New Hampshire

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2025

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