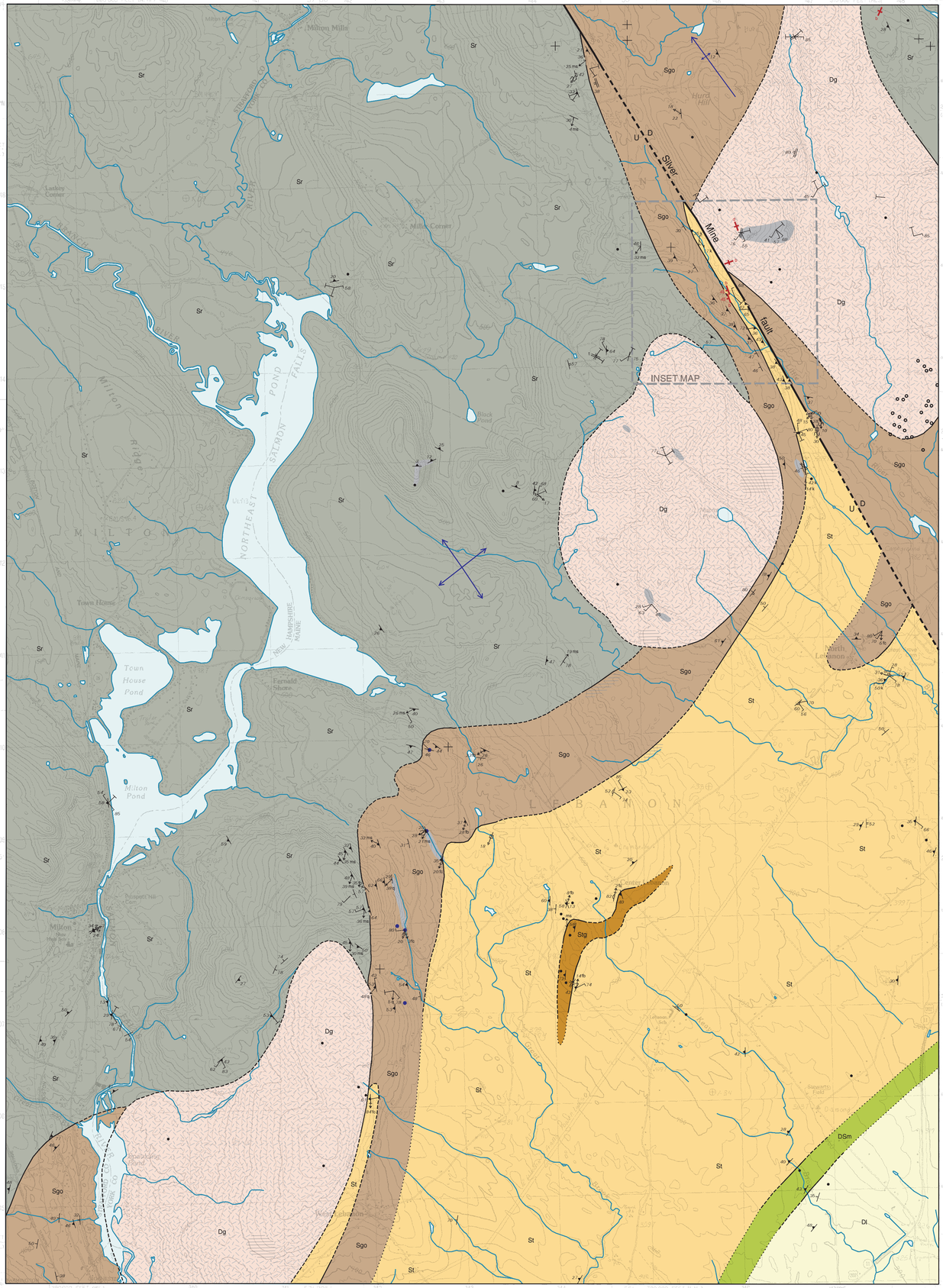

Explanation of Units

Intrusive Rocks

Devonian(?)

Dg — **Two-mica granite.** Typically with feldspar phenocrysts up to 3 cm long, and coarse pegmatite. Commonly foliated; phenocrysts and foliation form a swirly pattern rather than a preferred orientation. Pegmatite is common in the stratified units, especially in the Rindgemere Formation, as migmatite or isolated bodies.

The best places to observe the granite are along Milton Mills Road ½ mile northwest of Nisbitt Pond, and in the pavement outcrop on Sam Wentworth Road 1 ¼ mile north-northwest of West Lebanon.

Stratified Rocks

Devonian (?)

Dl — **Littleton Formation.** Gray-weathering quartz-muscovite-biotite ± garnet ± staurolite ± sillimanite schist, with sparse light gray to white micaceous quartzite beds. Graded beds are common. Equivalent to upper part of the Rindgemere Formation of Katz (1917) and Hussey (1962, 1987). Exposed along Keay Brook in the southeast corner of the quadrangle. In the next quadrangle to the east, tops toward the southeast provide one basis for determining the topping direction of the stratigraphic sequence.

Devonian-Silurian (?)

DSm — **Madrid Formation.** Well bedded, pale gray calc-silicate granofels and darker gray biotite-quartz-feldspar granofels. Exposed along Keay Brook in the southeast corner of the quadrangle.

Silurian(?)

St — **Towow Formation.** Rusty-weathering phyllite or fine-grained schist dominated by muscovite, quartz, pyrite and/or pyrrhotite, locally with graphite, biotite, and aluminous index minerals. Contains rusty-weathering beds of sulfidic quartzite and granofels in some places.

The Towow Formation is best exposed in brooks, particularly Bog Brook downstream from Depot Road in North Lebanon and in Little River parallel to Goding Road near the Acton-Lebanon town line. Outcrops along Goding Road are also recommended. Several contractors and homeowners report high iron content in water wells drilled in the Towow Formation.

Stg — **Grit member.** Rusty to white-weathering, sulfidic quartzites with granule-sized clasts of quartz, quartzite, and rare phyllite chips. Some quartz clasts are bluish. Grits of the Towow Formation are best exposed along Merchants Row, ¾ mile southwest of Center Lebanon. Because Towow phyllites are exposed both west and east of the grits, the grits are interpreted as a layer within the Towow Formation. A possible alternative is that they represent a horizon at the contact with the Littleton Formation, preserved in a downward-facing antiform.

Sgo — **Gully Oven formation** (new name, informal). Well-bedded, gray to somewhat rusty-weathering schist and gray to white quartzite beds with sharp bedding contacts; graded beds not convincing anywhere in Milton quadrangle. Schist typically contains andalusite, or sillimanite after andalusite, or pseudomorphic lumps composed of muscovite, quartz, etc. Pink coticule lenses are quite common locally; biotitic granofels and calc-silicate rocks are more rare. Colored dots on the map indicate coticule localities. Lower contact, with the Rindgemere Formation, is gradational.

The Gully Oven formation is well exposed at the type locality, a deep bedrock ravine along a branch of Great Brook, west of Gully Oven Road, 2 miles north of West Lebanon (Stop 9 of Gilman, 1986). A more complete exposure across strike is afforded by the next branch of Great Brook to the northeast of Gully Oven. Another good place to see this unit is in a big ledge behind the Burke house west of Goding Road, just south of the Lebanon-Acton town line. The Burkes report black manganese stains on plumbing fixtures, presumably from well water in this unit.

Sr — **Rindgemere Formation.** Variable unit dominated by massive, coarse-grained gray or rusty feldspathic sillimanite schist, locally with biotitic granofels and quartzite beds, and calc-silicate beds and lenses. Rustiness tends to be reddish.

Rindgemere schist and granofels can be observed in the south part of Acton in a pavement outcrop near the junction of Lebanon Road and Blueberry Hill, and along Blueberry Hill Road ¾ mile northeast of Black Pond. Schist containing dark gray calc-silicate lenses is well exposed in a ledge south of County Road 1 mile west of Hurd Hill. Coarse-grained, migmatitic Rindgemere Formation can be seen along the Salmon Falls River below the dam ½ mile south of Milton.

Explanation of Lines

Intrusive or stratigraphic contact. Solid where well constrained by outcrops or dense float; dashed where less well constrained, but projected with confidence; dotted where poorly constrained.

Fault. Solid where well constrained by silicified material or unit discontinuities; dashed where conjectural. **U** = upthrown side; **D** = downthrown side.

Anticline axial trace. Arrowhead indicates direction of plunge.

Structural dome in foliation.

Lithologic Symbols

Outcrop of mapped unit. Dot = single outcrop. Shaded area = many outcrops.

Outcrop of Gulley Oven formation containing coticule.

Site of bedrock drill core (Sevee and Maher Engineers, 1986).

Area of float presumed to represent underlying bedrock.

Pegmatite too small to map. Presumably related to granite (**Dg**). (Vertical dike, Isolated outcrop)

Quartz vein (**t** = also contains abundant black tourmaline). Strike and dip indicated. (Inclined, Vertical, Dip unknown)

Basalt dike too small to map. Presumed to be Mesozoic. Dikes are common 1 to 1½ mile south of Hurd Hill, in outcrops along the Little River and along Winchell Orchard Road, Acton. Subsurface dikes at the proposed Hebo-Hybo Road Landfill site, Lebanon, were detected by geophysical surveys and drilling, although one does occur in outcrop (Sevee and Maher Engineering, 1986). Strike and dip indicated. (Inclined, Vertical)

Fine-grained diorite dike. One dike too small to map, about 1 mile south of Hurd Hill, Acton. Strike and dip indicated. (Vertical)

Structural Symbols

Oriented symbols indicate strike and dip of planar features or trend and plunge of linear features.

Bedding, tops unknown, measured on quartzite or granofels bed. (Inclined, Vertical)

Bedding, tops known. (Overturned)

Compositional layering in schist. Color variation interpreted as sedimentary in origin.

Dominant foliation. Pervasive schistosity or phyllitic foliation. (Inclined)

Axial plane of fold with axial plane foliation.

Hinge of fold with axial plane foliation. (Dextral, Sinistral, Rotation sense unknown)

Axial plane of fold which deforms foliation. (Inclined, Vertical)

Hinge of fold which deforms foliation. (Dextral, Neutral, Rotation sense unknown)

Crenulation cleavage.

Mineral lineation (**q** = quartz; **ms** = muscovite or sillimanite). (Plunging, Horizontal)

Boudin neck line.

Intersection lineation (**fb** = foliation-bedding; **fc** = foliation-cleavage).

Kink band.

Kink axis. (Dextral; Sinistral)

Joint or joint set. (Inclined, Vertical)

GEOLOGIC TIME SCALE

Geologic Age		Absolute Age*
Cenozoic Era		0-65
Mesozoic Era	Cretaceous Period	65-145
	Jurassic Period	145-200
	Triassic Period	200-253
Paleozoic Era	Permian Period	253-300
	Carboniferous Period	300-360
	Devonian Period	360-418
	Silurian Period	418-443
	Ordovician Period	443-489
	Cambrian Period	489-544
Precambrian time		Older than 544

*In millions of years before present. (Okulitch, A. V., 2002, Échelle des temps géologiques, 2002: Commission géologique du Canada, Dossier Public 3040 (Série nationale des sciences de la Terre, Atlas geologique) - REVISION.)

Bedrock Geology of the Milton Quadrangle, New Hampshire -Maine

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Digital cartography by: **Susan S. Tolman**

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Stratigraphy

Katz (1917) and Hussey (1962) concluded that the Towow Formation is stratigraphically above the Rindgemere Formation, and assigned rocks both northwest and southeast of the Towow to the Rindgemere. According to their interpretation, the Towow Formation lies within the Lebanon syncline, overturned toward the southeast. Hussey (1968, 1985) divided the Rindgemere Formation into upper and lower members, with the upper, rhythmically-bedded member on both sides of the Towow Formation. The present author, however, thinks that rocks southeast of the Towow Formation in the Milton and adjacent Sanford quadrangles are different from those of the Gully Oven formation, having thicker schist beds and common graded beds, and correlate instead with the Devonian Littleton Formation. Just east of the Milton quadrangle, graded beds top to the southeast, away from the Towow. If assignment to the Littleton Formation is correct, there is no symmetry across the supposed Lebanon syncline in the Milton area.

Because the Rindgemere / Gully Oven / Towow sequence so closely resembles the Rangeley / Perry Mountain / Smalls Falls sequence, the present author prefers the correlation with units of the "Rangeley sequence" of the Rochester area, as shown in the accompanying chart. The units generally dip northwest and top to the southeast, meaning that the whole sequence is overturned.

Studies in northern Maine by Hall and others (1976) showed a change in direction of sediment sources between the Silurian units and the Seboomook Formation (correlative with Littleton); in many places along the Bronson Hill anticlinorium in western New Hampshire and Massachusetts the base of the Littleton is marked by an unconformity above Silurian units (Hatch and others, 1983).

Stratigraphic Correlation Chart

Milton, NH/ME (this study)	Rochester, NH (Eusden, 1984)	Berwick 15' quad (Hussey, 1962; 1985)
Littleton Fm.	Littleton Fm.	Upper part of Rindgemere Fm.
Madrid Fm.	Madrid Fm. (discontinuous)	(no equivalent)
Towow Fm.	Smalls Falls Fm.	Towow Fm.
Gully Oven formation	Perry Mountain Fm.	Upper part of Rindgemere Fm.
Rindgemere Fm.	Rangeley Fm.	Lower Rindgemere Fm.

Structural Geology

Milton quadrangle

A northeast-striking, overturned homocline dominates the structure across the Milton quadrangle, with the oldest rocks toward the northwest, according to the present stratigraphic interpretation. Whether or not the corresponding upright limb of an eastward-opening isoclinal syncline is present at depth cannot be determined in this quadrangle. A pervasive foliation is well developed in the more micaceous units. Oddly, the foliation is generally steeper than bedding, which is not what one would expect on the overturned limb of an isoclinal fold. Perhaps the dominant foliation is associated with a younger set of folds that deform an older, unrecognized foliation associated with the isocline.

The bedding and dominant foliation seem to partially wrap around the larger granite plutons, perhaps pushed aside as they intruded. Two of the plutons seem to lie in small structural basins, suggesting the granites are above the schists rather than intruded from below. West of the pluton centered on Nisbitt Pond, foliations in the Rindgemere Formation form a small dome-like shape.

Spaced cleavage, axial planes to folds that deform the dominant foliation, and kink bands do not seem to have any systematic relationship to the wavy map pattern of the Gully Oven formation across the quadrangle. The map pattern suggests late folds with northwest-striking axial planes, but no features with this orientation were noted in outcrop. Fold axes and lineations plunge fairly consistently toward the southwest through much of the quadrangle, except in the Towow Formation where they plunge gently northeast.

The northwest-trending Acton-Lebanon silver mine district follows the Little River across the northeastern part of the quadrangle, mainly in the Towow Formation. Numerous waste piles of bull quartz and prospect pits testify to the mining activity of 1878-1882 (see inset map below; Hussey and others, 1958; King, 2000). A fault has been drawn here along the silver mine trend. Foliation and bedding swing around from a northeast strike to a northwest strike as they near the fault. The Towow / Gully Oven contact appears to be truncated. The Gully Oven formation is apparently repeated across the fault by normal movement down on the northeast side, with an implied offset between 100 and 425 feet to bring it against the Towow Formation. Alternatively, the thin strip of the Towow Formation along the Little River may be in the core of a northwest-trending isocline. Farther north, granite is exposed immediately east of the fault, and toward the north edge of the quadrangle the Gully Oven formation seems to occupy an open antiform plunging gently northwest. On the west flank of Hurd Hill, bedding in the Gully Oven formation dips gently west; to the northeast, in brook exposures just outside the quadrangle boundary, bedding dips northeast.

Regional implications

The author spent several field days looking at the area mapped by Eusden (1984) southwest of the Milton quadrangle, and drew somewhat different conclusions. Using the same schist/quartzite proportion criteria applied on the Maine side of the border for distinguishing the Gully Oven and Littleton Formations, the author concluded that the inclined second-phase folds that deform the overturned sequence in Eusden's area involve the Smalls Falls and Littleton Formations rather than the Smalls Falls and Perry Mountain Formations. Without this reinterpretation, some significant right-lateral offset is required along a fault or faults parallel to the Salmon Falls River along the state border. The Towow Formation mapped by Eusden near Rochester lines up with Towow infolded with Littleton along the Salmon Falls River. Axial traces of these folds (F_2) would extend into the broad area of the Towow Formation in the Milton quadrangle, helping to explain such a broad outcrop width for what is a relatively thin unit elsewhere. Alternatively, the Towow Formation could be thicker due to a local accumulation of reducing muds during deposition.

The grit horizon at Merchants Row might correlate with grits recognized by Eusden near Goose Pond, New Hampshire, at what he interpreted as the Smalls Falls / Littleton contact, and by Hussey near the Salmon Falls River at the Towow / Littleton contact (Eusden and others, 1984, stop 6). If so, the grits (**Stg**) surrounded by the Towow Formation in the Milton quadrangle might be explained as the crest of an antiform underlain by the Littleton Formation. They are more or less on strike with a northeast-plunging antiform cored by the Littleton Formation at the Salmon Falls River.

The extent of the Silver Mine fault in either direction is unknown. Hussey (personal communication, 2004) points out that bedding in the Littleton Formation also swings around to the north and northwest as it approaches what would be the fault's extension near Lebanon, Maine (Hussey, 1962). The fault there has apparently juxtaposed the Littleton to the west against the Rindgemere to the east. Farther south, however, the Gonic / Berwick contact does not seem to be offset where the fault might

Metamorphism

The grade of metamorphism increases toward the northwest across the Milton quadrangle, though not as abruptly as it would seem at first sight. The Towow Formation is finer-grained than the other units and lacks obvious index minerals due to its bulk composition, namely the high sulfide content, not because of lower grade. The staurolite-out isograd apparently lies somewhere within the Towow, but suitable rock types are not present to locate it precisely. Pelitic schists in the Littleton Formation exposed to the southeast of the quadrangle bear garnet and staurolite, whereas pelitic schists in the Gully Oven formation have large andalusite porphyroblasts, locally replaced by sillimanite and/or muscovite, as well as garnet. The Rindgemere Formation contains abundant sillimanite and seems to have andalusite only in the most pelitic layers; it is generally more feldspathic than the Gully Oven or the Littleton Formations. The feldspar content may be responsible for the tendency toward migmatization of the Rindgemere Formation, and the abundant pegmatite and two-mica granite bodies associated with this formation may be derived quite locally.

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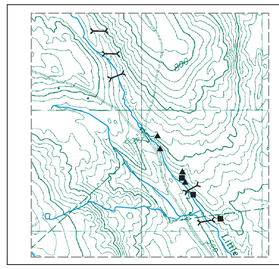
Prospects and tailings still evident in Acton-Lebanon silver mine district



Historical maps (Hussey and others, 1958; King, 2000) indicate that more mines existed in the 1800's, but they were not mapped precisely. Some mine sites visible in the 1950's have undoubtedly filled in or collapsed.

Prospect. Trench with quartz.

Tailings. Pile or ridge of bull quartz rubble.

Pit. Rectangular excavation about 4' x 6', depth unknown.

SOURCES OF INFORMATION

Field work by P. J. Thompson (2003). Additional structural data from Eusden (1984) and subsurface lithologic information from Sevee and Maher Engineers (1986).

Quadrangle Location

SCALE 1 : 24,000

1 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 0 1 KILOMETER

CONTOUR INTERVAL 20 FEET

TRUE NORTH

Topographic base from U.S. Geological Survey Milton quadrangle, scale 1:24,000 using standard U.S. Geological Survey topographic map symbols.

The use of industry, firm, or local government names on this map is for location purposes only and does not impute responsibility for any present or potential effects on the natural resources.