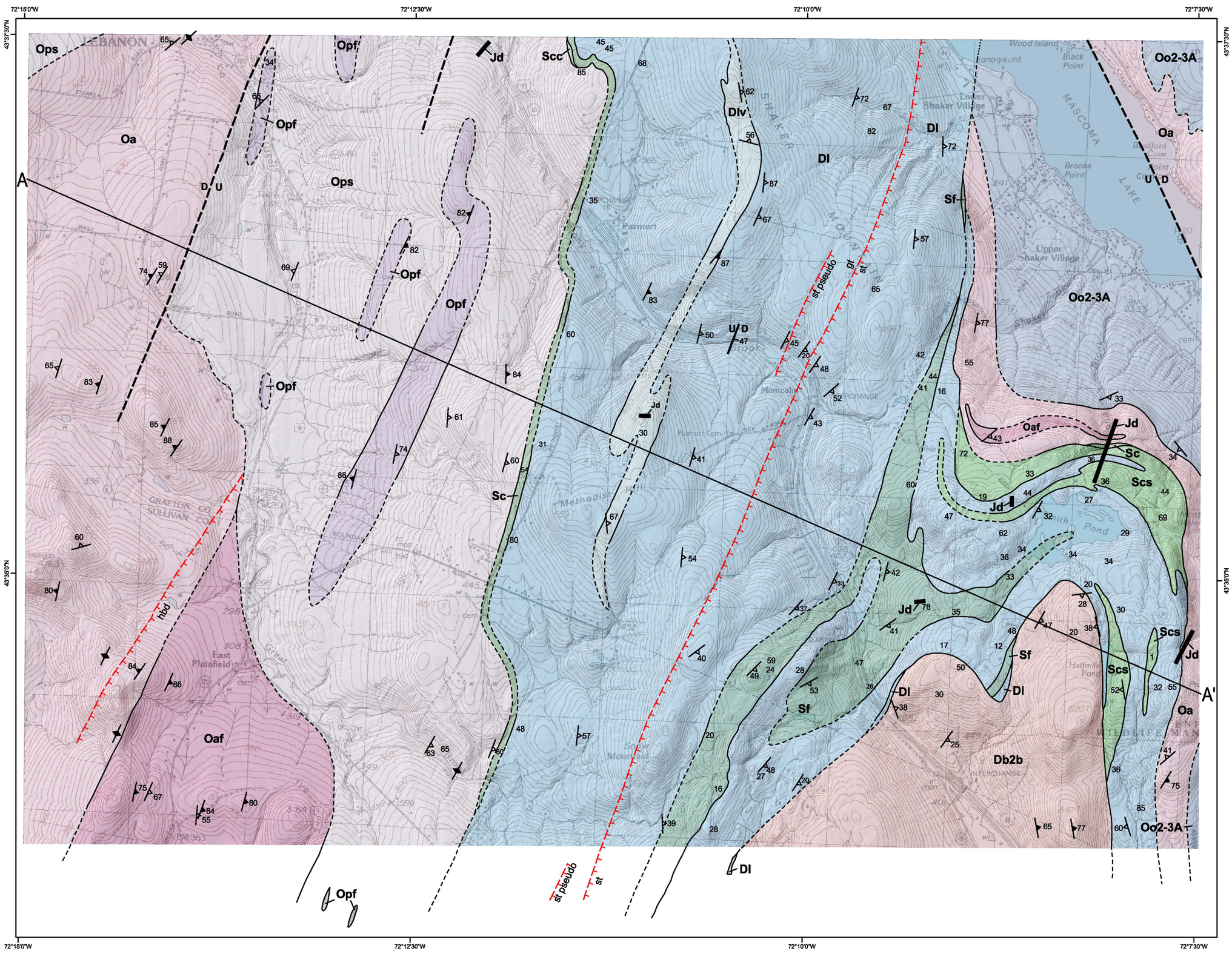
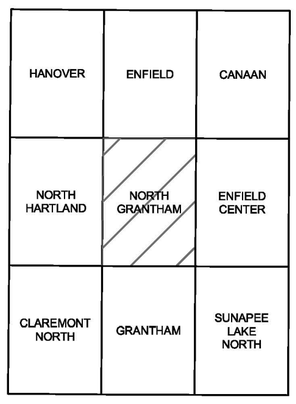
Bedrock Geologic Map of the Northern Half of the North Grantham 7.5' Quadrangle, New Hampshire, 2016





Scale 1:24,000

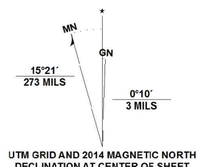
0 1,450 2,900 5,800 Feet

0 0.5 1 2 Miles

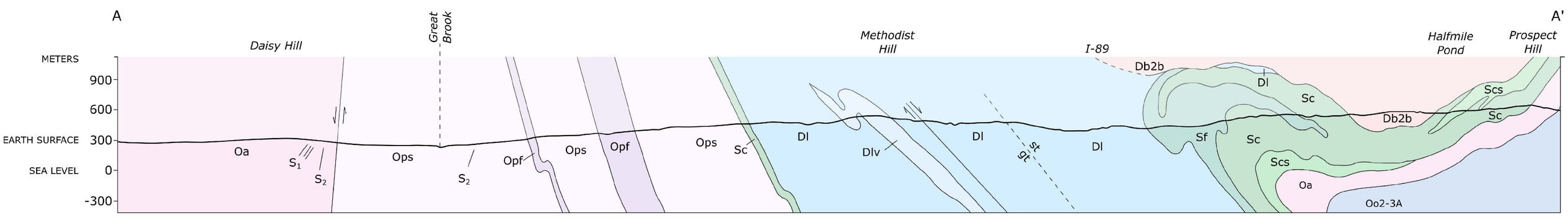
0 1 2 4 Kilometers

Topographic basemap from the USGS 1998 North Grantham 7.5' quadrangle
Projection: North American Datum 1983 New Hampshire State Plane Feet.
1000 meter grid in UTM zone 19 North, Contour Interval 6 m

Hillshade produced from high resolution (1 meter) LiDAR data



NHGS Open-File Disclaimer: This map and the accompanying legend(s) are understood to be open-file products. They are draft versions of an unpublished report and represent mapping progress at the time of completion. Newer information may exist. If you have questions, please contact the New Hampshire Geological Survey (NHGS) at: geology@des.nh.gov or (603) 271-1976



DESCRIPTION OF MAP UNITS

DEVONIAN ROCKS

Db2b — **Bethlehem Gneiss** — Quartz-feldspar-biotite-muscovite granodiorite gneiss, strongly foliated along contacts with older units. Locally contains biotite schist xenoliths parallel to foliation. Well exposed in pavement outcrops on the hilltops south of Smith Pond.

Dl — **Littleton Formation** — Dark gray to silver-gray schist, locally with thin white quartzite layers. Medium-grained with up to 10 cm staurolite porphyroblasts east of a NNE-trending isograd east of Methodist Hill. Medium-fine-grained biotite schist and garnet schist west of the isograd, with local zones of finer-grained schist and phyllite where S2 is well developed. Staurolite is replaced by quartz and muscovite in a retrograde zone about 400 m wide west of the unaltered staurolite isograd. Best exposed along bike path near Montcalm, I-89 Exit 15, although some joint surfaces are unusually rusty there. Typically, natural outcrops are less rusty.

Dlv — **Metavolcanic member of Littleton** — Rusty-tan weathering, light gray, massive quartz-feldspar-biotite fine-grained felsite, locally with up to 5 mm feldspars. Chapman (1939) reported the composition as rhyolite to quartz latite. About 100 m thick, it is well exposed at the Montcalm Golf Course and Whaleback Ski Area, where its thickness is doubled in an F1 S-plunging fold. The metavolcanic pinches out in the Enfield Quadrangle to the north, and its extent to the south is unknown. Age is also unknown. It could conceivably correlate with metavolcanics in the Bernardston nappe, in which case it would be Opv.

SILURIAN ROCKS

Sf — **Fitch Formation** — Heterogeneous unit of rusty-weathering gray schist with brown-weathering, fine-grained biotitic granofels layers, massive gray granofels, thin gray quartzite, and various calc-silicate rocks, the most distinictive of which has a curdled texture of 2 to 6 cm lenses and anastomosing branches of gray and tan calc-silicates. This facies lies near the top of the Fitch and bears some resemblance to the lower member of the Warner Formation (Thompson, 1985). Some of the rusty calc-silicate layers lower in the Fitch resemble Francestown Formation. Easily accessible Fitch can be seen where it crosses Old Shaker Mountain Road. Some rocks that are mapped as Fitch in the area south of Smith Pond were assigned by Thompson (1988) to the Partridge Formation, an interpretation that is not supported by structural data in outcrops north of I-89.

Sc — **Clough Quartzite** — Massive fine-grained gray to white to pink quartzite, quartz-pebble conglomerate and well bedded quartzite with schistose partings up to 20 cm thick, locally with graded beds. Best exposed around Smith Pond and along the bike path south from I-89 Exit 15. Pitted horizons near the top of the Clough contain calc-silicate minerals filling the molds of invertebrate fossils (Boucot and Thompson, 1963; Thompson, 1988).

Scs — **Schist member of Clough** — Lustrous, fine to medium-grained quartz-muscovite-sillimanite+/-garnet schist locally with thin quartzite layers up to 20 cm thick. Mapped separately where schist is sufficiently thick. May correlate with lower gray schist member of the Rangeley Formation (Thompson, 1985). Best observed NE of Smith Pond.

Scc — **Cobble conglomerate member of Clough** — Quartzite clasts in a quartzite matrix at the base of a 27 m thick exposure of Clough Quartzite, found only west of Eastman Hill Road at the north edge of the quadrangle. Cobbles are flattened in bedding planes and stretched into dagger-shaped ellipsoids up to 30 cm long, which plunge NE parallel to D3 fold axes.

Metadiabase dikes — Medium- to fine-grained hornblende gneiss dikes and sills, abundant in Sc, Scs, and Sf, but not in Dl. Perhaps part of the Comerford Intrusive Suite (Rankin et al., 2007). Especially common in the NE part of the quadrangle.

ORDOVICIAN ROCKS

Ops — **Sulfidic schist member of the Partridge Formation** — Rusty-weathering, black to dark gray carbonaceous, sulfidic, fine- to medium-grained schist, with or without garnet, locally phyllitic where S_2 is strongly developed. Can be difficult to distinguish from Littleton, which is generally more lustrous, less carbonaceous and less rusty. Locally contains thin light gray silty layers and felsite lenses and layers, too thin to map, that may represent ash fall horizons. Local metadiabase dikes, as in Sc and Sf. Best exposed in Great Brook east of East Plainfield and along I-89 at the north edge of the quadrangle.

Opf — **Felsic metavolcanic member of the Partridge Formation** — Rusty tan weathering, light gray to white felsite, indistinguishable from Oaf, but associated with rusty schist. Contains minor mafic layers which may be younger dikes. Best exposed along Great Brook south of Churchill Way/Rt. 120

Oa — **Ammonoosuc Volcanics** — Dominated by pale green chlorite schist in the NW part of the quadrangle and darker green to black hornblende schist and gneiss east of a NE-trending line, west of East Plainfield. This line would correspond to the garnet isograd in pelitic rocks. This isograd presumably loops around north and northwest, barely entering the Enfield Quadrangle, where most mafic rocks contain hornblende and Partridge schists contain garnet. It then heads southwest into the North Hartland Quadrangle (Walsh, 2016). Best exposed at bend on Great Brook Road and at bridge near Daisy Hill Road/Rt. 120 intersection, where pillows may be preserved.

Oaf — **Felsic metavolcanic member of the Ammonoosuc** — Rusty tan weathering, light gray to white felsite, indistinguishable from Opf, but associated with mafic metavolcanics. Well exposed on the hills south of East Plainfield.

Oo2-3A — **Oliverian Gneiss of the Mascoma dome** — Undifferentiated igneous gneisses. Chapman (1939) shows these rocks as quartz diorite and granodiorite, but no thin section work was undertaken for this project. Best exposed in Rt. 4A roadcut in Upper Shaker Village.

EXPLANATION OF MAP SYMBOLS

Contact — Solid where certain; Dashed where approximate; Dotted where concealed

Fault — Dashed where approximate

Mineral isograd — Dashed where approximate, hachures point in direction of higher metamorphic grade.
hbd = hornblende
gt = garnet
st = staurolite

Mesozoic dikes (Jd) — Brown-weathering, black basalt, diabase and (?) camptonite dikes. Two are up to 10 m thick, 500 m long, and contain up to 5 mm feldspar phenocrysts.

Strike and dip of S_0 bedding
- Inclined
- Upright
- Vertical
- Overturned

Strike and dip of foliation
- Inclined S_1 foliation
- Inclined S_2 foliation
- Vertical S_2 foliation

Trend and plunge of linear features
- Axis of F_1 fold
- Axis of F_2 fold

Bedrock Geologic Map of the Northern Half of the North Grantham 7.5' Quadrangle, New Hampshire

Geology by Peter J. Thompson, 2016
Digital Compilation by Sarah W. Baker and Gregory A. Barker, 2016
Field assistant: Thelma Thompson
New Hampshire State Geologist: Frederick H. Chormann

Bedrock Geologic Map Open-File Series GEO-105-024000-BMOF

This geologic map was funded in part by the USGS National Cooperative Geologic Mapping Program under StateMap award number G15AC00504

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Northern Half of NORTH GRANTHAM QUADRANGLE, NH

Summary of Bedrock Geology by Peter J. Thompson

The mapped area lies between the Lebanon dome and Meriden antiform to the west, and the south-plunging Mascoma dome to the northeast. The western third of the quadrangle is underlain by Ordovician rocks of the Ammonoosuc Volcanics and Partridge Formation, which make up the Bronson Hill volcanic arc, here in the Cornish nappe. Bedding and foliation dip northwest toward the south end of the Lebanon dome, where it is overturned toward the south (Thompson, 2015). Prior to that dome-stage overturning the sequence had been inverted, with the older Ammonoosuc above Partridge.

The intensely folded rocks south of Mascoma Lake have puzzled geologists for years. A stratigraphic sequence of Ammonoosuc Volcanics, Clough Quartzite, Fitch Formation and Littleton Formation overlie Oliverian Gneiss of the Mascoma dome. The map pattern is the result of several interfering sets of folds: F1 isoclines between the autochthon and the overlying Bethlehem Gneiss, a large overturned F2 fold trending NE and plunging SE, and open upright cross folds that plunge south. A weaker set of approximately E-W cross folds can be seen in some outcrops, and locally kink folds with gently dipping axial planes also deform older fabrics. The kink folds are likely associated with the Grantham normal fault, which lies within 2 km east of the quadrangle.

Overall, bedding and S1 foliation in the area south of Mascoma Lake dip towards the Bethlehem Gneiss, which occupies a sulcus between the south-plunging Mascoma dome and the north-plunging Croydon dome (see Lyons et al., 1997). Chapman (1939) mapped the interlayered quartzites, conglomerates and schists between the Ammonoosuc and the Bethlehem all as Clough Quartzite. Thompson (1988) reinterpreted the major schist layers as three F_1 infolds: from north to south, Littleton in a syncline and two anticlines of Partridge, separated by attenuated Clough Quartzite layers. The present mapping does not support the latter interpretation. Littleton, Fitch and Clough strike south and dip east all along the west side of the area, precluding a connection between Littleton and the lowermost Scs. The lower contact of the Fitch with the Clough curves around to the SE, passing through the vertical to dip south toward the overlying Bethlehem Gneiss. Numerous outcrops of schist and granofels (here interpreted as Fitch) occupy the area south of this contact, shown by Thompson (1988) as Partridge Formation. Although somewhat rusty, the rocks do not resemble Partridge, even at sillimanite grade. More field work is needed to confirm the continuation of Fitch-like rocks in the center of the dome-stage antiform, south of I-89. The Clough immediately below the Bethlehem occupies a large isoclinal anticline that closes westward. It is the same isocline as the long finger of Clough in the map pattern farther west.

The Ordovician rocks of the Cornish nappe are separated from Devonian Littleton Formation to the east by a thin quartzite, which is continuous with the so-called Hardy Hill Quartzite in the Enfield quadrangle, now correlated with Clough Quartzite (Lyons et al., 1997; Thompson, 2014). Open folds plunge NE, with a sinistral sense related either to the dome-stage Meriden antiform or the Northey Hill shear zone, or both (Thompson, 2016). An isoclinal fold in the Littleton metavolcanic member is also sinistral, but it plunges south. In cross-section view this fold can be seen to lie on the west limb of a major F_1 syncline within the Littleton. Map-scale F_1 folds in the Clough Quartzite above the autochthon, by contrast, are dextral, and lie on what was originally the upright limb of that syncline, which is cored by Littleton Formation and which opened westward. To see this properly in cross-section, one must mentally undo the large overturned F_2 dome-stage fold cored by Oliverian Gneiss. All the rocks from here west to Great Brook, in fact, were overturned during the dome stage of deformation. The major F_1

syncline continues in quadrangles to the north as the Garnet Hill syncline (Thompson, 2016), where it is intruded by Bethlehem Gneiss in the Indian Pond pluton (Thompson, 2008). The overturned limb of this syncline reappears to the west, where Ordovician rocks lie above the Clough in the Cornish nappe. If this interpretation is correct, it implies two important conclusions: (1) the Bethlehem Gneiss cuts downward across the Skitchewaug nappe from its usual tectonic position above the Skitchewaug (i.e. Fall Mountain nappe/Brennan Hill thrust) into the underlying syncline, and (2) the Skitchewaug and Cornish nappes are one and the same. See Robinson et al. (1993) and Thompson et al. (1968) for details of the nappe theory in New Hampshire.

In the very NE corner of the quadrangle, north of Mascoma Lake, the Ammonoosuc/Oliverian contact is apparently repeated, which Chapman (1939) explained by extending a branch of the Grantham fault NW across the lake. More field work is needed to confirm these relationships.

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