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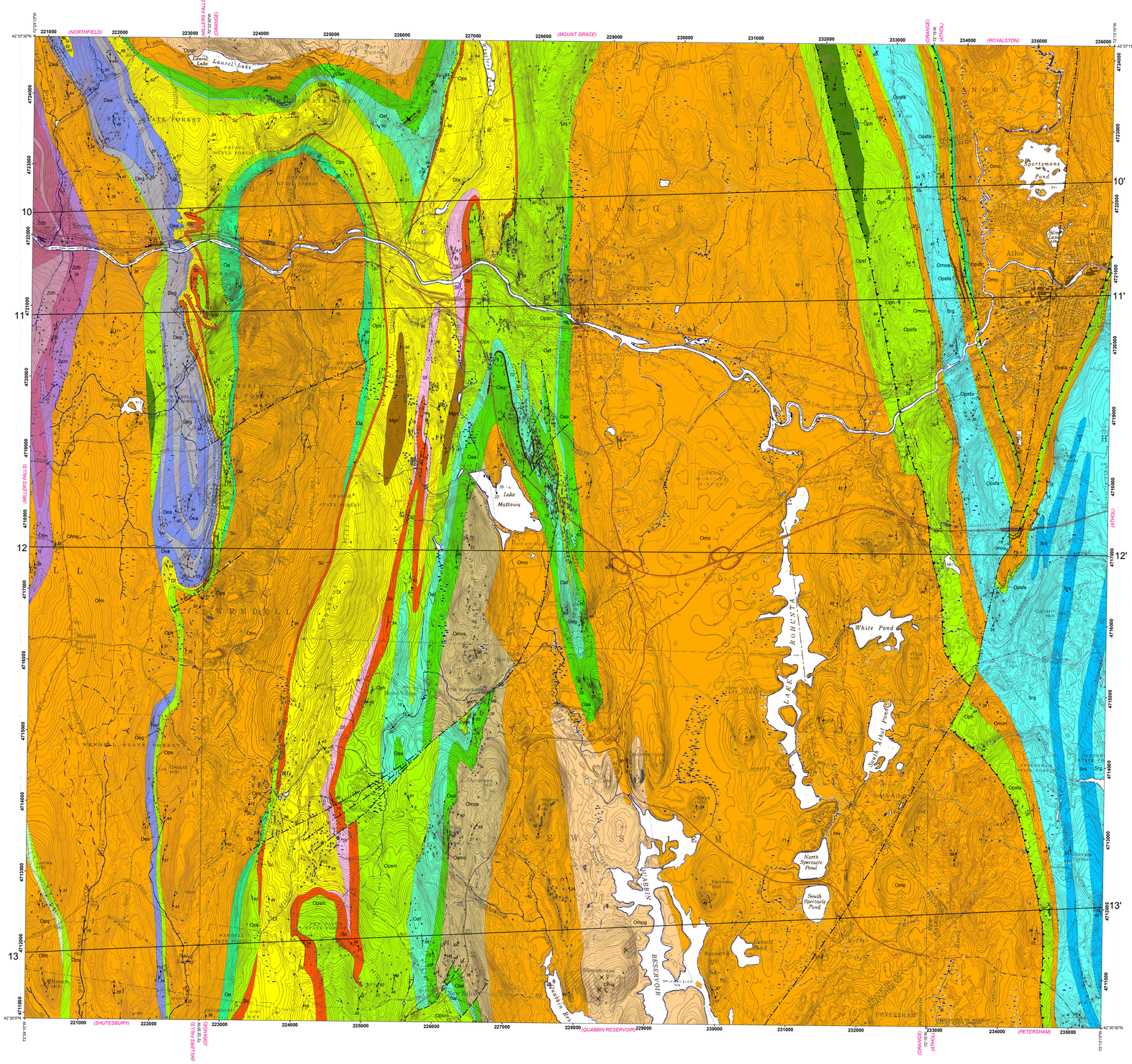
OMSG Open File Report No. 08 -04
Bedrock Geologic Map of the Orange Area
Sheet 1 of 5
2008



Topographic Base Information:

Topographic base modified from U.S. Geological Survey, 1969. Digitally re-projected into 1983 North American Datum.

1000-meter Universal Transverse Mercator grid ticks based on 1983 North American Datum, Zone 19.

15°
MAGNETIC NORTH
TRUE NORTH
APPROXIMATE MEAN DECLINATION, 1999

SCALE 1:24 000
1 1/2 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 .5 0 1 KILOMETER
CONTOUR INTERVAL 10 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

MASS.
QUADRANGLE LOCATION

Geology mapped in 1959, 1960, 1961 by Peter Robinson assisted by Fred Graybeal, Kost Pankiwskyj, John Patrick and Theodore Loder. Revisions 1964-76, 1983, 1986-7 by Peter Robinson assisted in 1973 by Charles Onasch and in 1979 by Charles Shearer. Additional mapping of rock units, outcrops and structure in southwest Orange Quadrangle and eastern Millers Falls Quadrangle in 1972, 1974-76 by David Ashenden, then of Metropolitan District Commission. Revision of map and cross-section contacts and compilation of outcrop map completed in 2007 by Robinson in consultation with Ashenden. Digital conversion and cartography: Maria T. Fernandez, 2008.

Bedrock Geologic Map and Cross Sections of the Orange Area, Massachusetts

Consisting of the Orange 7.5-Minute Quadrangle, the Western Part of the Athol 7.5-Minute Quadrangle and the Eastern Part of the Millers Falls 7.5-Minute Quadrangle

by Peter Robinson[1]

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EXPLANATION OF LITHOLOGIC UNITS

Minor Intrusive Rocks

Jd: Jurassic Diabase Dikes of Pelham-Loudville System

Mgn: Two-Mica Granite Gneiss (Mississippian?)

Metamorphic Rocks

Lower Devonian Erving Formation

Deg: Well bedded fine-grained quartz-plagioclase-biotite granulite with interbedded mica-garnet-staurolite-kyanite schist, thin layers of hornblende-garnet calc-silicate rock, and biotite granulite with 2-3 mm magnetite octahedrons and thin layers of pink, ultra-fine-grained garnet.

Dea: Hornblende-epidote amphibolite. Basal contacts of the Erving Formation with all other units from Littleton down to Fourmile Gneiss suggest a significant basal unconformity.

Lower Devonian Littleton Formation

Dl: Gray-weathering mica-garnet-staurolite schist (kyanite zone), mica-garnet-sillimanite schist with or without staurolite (sillimanite zone) and mica-chlorite-garnet phyllite with pseudomorphs of staurolite (New Salem retrograde zone – see Metamorphic Index Map). Correlative low-grade phyllite in the Littleton and Whitefield areas, northern NH, yielded Late Emsian (latest early Devonian) brachiopods and corals (Boucot and Arndt 1960). Widespread absence of the Fitch Formation along the basal contact indicates a significant unconformity.

Dla: Amphibolite at one locality.

Upper Silurian – Lowest Devonian Fitch Formation

Sf: Fine-grained calc-silicate granulite and minor pyritic and pyrrhotitic schist. Rare quartz-bearing marble. Marble at nearby Bernardston, MA (Elbert et al. 1988) yielded Lochkovian (earliest Devonian) conodonts, but marble at Littleton, NH (Harris et al. 1983) gave Pridoli (latest Silurian) conodonts. Absence of Middle Silurian strata indicates local non-deposition or erosion.

Lower Silurian Clough Quartzite

Sc: Quartzite; quartz-pebble and quartz-cobble conglomerate; quartz-mica, quartz-muscovite-garnet, and quartz-mica-sillimanite-staurolite schist. Thin layers of calc-silicate granulite and layered hornblende amphibolite at top of formation at a few locations. An upper calcareous quartzite at Bernardston, MA (Boucot et al. 1958) yielded a brachiopod of late Llandovery to early Ludlow age. More abundant fossils in similar rocks at Croydon Mtn., NH, gave a more precise late Llandovery age (Boucot and Thompson 1963). The base of the formation is a marked regional unconformity, and the abundance of aluminous matrix minerals and the dominance of vein quartz pebbles and cobbles, including veins with tourmaline, indicates the underlying Ordovician strata underwent severe chemical weathering.

Lower Silurian Rangeley Formation

Srg: Gray-weathering quartz-plagioclase-mica-garnet-sillimanite schist and gneiss. Local layers of calc-silicate rock. Located only east of the Brennan Hill Thrust. Stratigraphic relations in NH and ME (Robinson et al. 1991) indicate a Lower Silurian age, older than the Clough Quartzite.

Srs: Sulfidic quartz-plagioclase-mica-garnet-sillimanite schist and gneiss. Local layers of calc-silicate rock.

Upper Ordovician Partridge Formation

Ops: Sulfidic mica schist with or without garnet, staurolite, kyanite, sillimanite, chlorite (retrograde zone); sulfidic feldspathic schist; calc-silicate rock, feldspathic gneiss, and amphibolite. At Bernardston, MA, a quartz phyric metamorphosed rhyolite bed 10 m above the base of the formation (Tucker and Robinson 1991) gave a U-Pb zircon age of 449+3/-2Ma (early Ashgill). Different facies are indicated east and west of the Brennan Hill Thrust. The geochemistry of feldspathic gneisses and amphibolites indicates they are metamorphosed arc and back-arc volcanics similar to the Ammonoosuc Volcanics (Hollocher 1993).

Opsm: Predominantly sulfidic mica schist.

Opa: Amphibolite where separately mapped.

Opq: Basal quartzite member (SE Millers Falls Quadrangle only). Gray-weathering, well foliated to glassy, garnet-mica quartzite, and gray-weathering well foliated, kyanite-garnet-mica schist.

Opsf: Predominantly sulfidic feldspathic schist.

Opsfa: Part of Opsf with 50% amphibolite.

Opsfc: Sulfidic feldspathic schist with gray well bedded calc-silicate granulite.

Opau: Augen gneiss member. Sulfidic to gray-weathering mica gneiss with plagioclase augen. Minor amphibolite.

Oph: Separately mapped boudins of hornblendite with or without olivine, orthopyroxene, spinel, chlorite, anthophyllite, talc and ankerite, considered to be metamorphosed komatiite lavas (Wolff, 1978).

Upper Ordovician Ammonoosuc Volcanics

Oa: Undifferentiated irregularly interstratified amphibolite and quartz - feldspar gneiss.

Oaf: Felsic Upper Member. Fine-grained feldspar-quartz gneiss with or without muscovite and garnet, representing metamorphosed peraluminous rhyolite and dacite (Schumacher 1988) believed to have melted from a basaltic source. Minor amphibolite. Local layers contain kyanite, sillimanite, or staurolite indicating metamorphosed hydrothermally altered volcanics. Felsic gneisses with weather-resistant quartz-sillimanite nodules are common in the upper part of the section. A quartz-phyric metamorphosed rhyolite 30 m below the top of this member at Bernardston, MA (Tucker and Robinson 1991) has yielded a U-Pb zircon age of 453+/-2 Ma (late Caradoc). This felsic unit represents a distinct episode when felsic volcanism dominated over the background of continuing mafic volcanism that predominated in the Lower Ammonoosuc and continued through much of the deposition of the Partridge Formation. It may represent a limited number of major felsic eruptions taking place over a limited time span.

Oag: Middle Quartz-Garnet Granulite Member. Discontinuous quartz-garnet-amphibole-magnetite granulite representing metamorphosed volcanic exhalative chemical sediments. This unit is typically only 2-3 m thick, but has been mapped where thinner than 1 m. The unit occurs exactly where the volcanism changed from predominantly mafic to predominantly felsic.

Oaa: Mafic Lower Member. Predominantly amphibolite with subsidiary interbedded quartz-feldspar gneiss. Amphibolites are variably composed of hornblende, garnet, biotite, cummingtonite and/or gedrite. Gneisses composed of plagioclase and brown gedrite with or without garnet and biotite, form a conspicuous component, particularly in the lower part. The geochemistry of these rocks (Schumacher 1988) indicates they are metamorphosed basaltic and andesitic lavas and tuffs of tholeiitic arc affinities, or their hydrothermally altered equivalents. Locally pillows, graded tuffs, agglomerates and other features are preserved even at sillimanite grade. Locally in the upper part are calc-silicate rocks with variable proportions of hornblende, epidote, diopside, and calcite, considered to be a metamorphosed mixture of basalt and calcareous sediments. The age of this member is unknown. Similar rocks in northern New Hampshire (Moench and Aleinikoff 2002, Rankin et al. 2007) are cut by the Joslin Turn pluton with an age of 469 +/- 2 Ma (late Arenig).

Oamc: Moosehorn Conglomerate Member. Thin quartz-grit to fine quartz-pebble conglomerate with a matrix of epidote, diopside and calcite. Occurs at the basal contact of the Ammonoosuc with the Monson Gneiss near Fiske Hill.

Upper Ordovician Intrusive Igneous Rocks

This group of rocks, with the exception of 2- 3 outcrops, is interpreted to be intrusive. Strong layering in many locations, once thought to be evidence of some volcanic protoliths (Robinson 1963), is now interpreted to be the result of strong deformation of varied intrusive rocks and xenoliths along with a few mafic dikes (Robinson et al. 1989). The group as a whole is comparable to calc- alkaline plutons in a magmatic arc (Hollocher et al. 2002). U- Pb zircon ages in the range 455 - 442 Ma (late Caradoc to early Llandovery) show that these rocks cannot be a basement beneath the Ammonoosuc Volcanics and Partridge Formation. The ages would permit an intrusive relationship, that is not supported by field relations in Massachusetts and southern New Hampshire. Present interpretation is that a terrane of tholeitic and back- arc volcanics has been implaced against a terrane of calc-alkaline arc- related intrusions along a major extensional detachment of probable early Silurian age.

Pauchaug Gneiss (Exposed in Warwick dome)

Opchb: Poorly defined finer-grained border zone.

Opch: Coarse-grained, non-layered, poorly foliated, microcline-plagioclase - quartz - biotite gneiss. In the adjacent Mount Grace Quadrangle, north of Laurel Lake (Tucker and Robinson 1991), yielded a U - Pb age of 447 +3/-2 Ma (Ashgill) on igneous zircon.

Fourmile Gneiss (Exposed in Pelham dome and Kempfield anticline)

Ofm: Coarse - to fine - grained massive to weakly layered feldspar-quartz gneiss with minor amphibolite. In the adjacent Northfield Quadrangle (Tucker and Robinson 1991) yielded a U- Pb age of 454 +3/- 2 Ma (late Caradoc) on igneous zircon. Based on the occurrence of Ordovician, Silurian and possibly Lower Devonian strata beneath Fourmile Gneiss and above Dry Hill Gneiss in the Shutesbury Quadrangle (Robinson et al. 1992), the base of this unit is considered to be an E- directed thrust fault, probably of late Devonian age.

Ofma: Similar to Ofm with local lenses of gedrite gneiss (near Wendell). Such rocks are extremely rare in the Fourmile Gneiss and may be xenoliths of volcanic rocks.

Monson Gneiss (exposed in main and Tully bodies)

Omo: Coarse-grained, layered to massive feldspar-quartz gneiss and hornblende amphibolite. Amphibolites occur as both xenoliths within felsic intrusions and as cross-cutting dikes, with contact relations obscured by great strain. In the adjacent Quabbin Reservoir area (Tucker and Robinson 1991) yielded U-Pb igneous zircon ages of 454 +3/-2 Ma, 445 +3/-2 Ma, 442 +3/-2 Ma and 442 +3/-2 Ma (late Cardoc to early Llandovery).

Omog: Mapped areas where massive granitoid gneiss predominates.

Omoa: Interlayered amphibolite and feldspar-quartz gneiss where separately mapped.

Omos: Area of rusty-weathering gneiss containing pyrite, muscovite and rare sillimanite, indicating pre-metamorphic hydrothermal alteration (Sioui, 1990).

Omu: Metamorphosed ultramafic lens consisting of hornblende with or without olivine, talc, chlorite, anthophyllite and ankerite.

Omon, Omoc: North Orange and Creamery Hill bands of Monson Gneiss. These are strongly layered feldspar-quartz gneiss and amphibolite considered to lie along the axial region of an early recumbent fold nappe. The North Orange band lies east of the main body of Monson Gneiss, the Creamery Hill band encircles the south end of the Tully body.

Late Neoproterozoic Stratified Rocks

Poplar Mountain Gneiss

Zpm: Coarse gray microcline-plagioclase gneiss with conspicuous white microcline porphyroclasts, red-brown biotite, and muscovite; and with rare layers of quartzite. Interpreted as metamorphosed arkosic sediments (Ashenden 1973, Hodgkins 1985). Contains local interlayers similar to Dry Hill Gneiss. Single grain analyses of 10 zircons (Robinson et al. 1992) yielded 7 grains with a high degree of discordance in two groups with suggested inheritance 2150-1850, and 1510-1000 Ma. A single concordant igneous grain at 585 Ma was likely derived from the underlying Dry Hill Gneiss. Another grain at 370 Ma was probably derived from a sheared relic of a late Devonian pegmatite. The final Th-depleted grain appears to have grown during high-grade Late Pennsylvanian regional metamorphism.

Dry Hill Gneiss

Zdb: Biotite member. Coarse pale-pink to buff-weathering microcline-plagioclase gneiss with green biotite and with rare layers of quartzite. Interpreted as rhyolitic volcanics.

Zdh: Hornblende member. Coarse pale-pink- to buff-weathering microcline-plagioclase- gneiss with conspicuous black hornblende porphyroblasts and green biotite, and rare layers of quartzite, amphibolite and calc-silicate. Field relations and chemistry suggest the Dry Hill Gneiss is a series of lavas and/or pyroclastics with the composition of alkalic A-type granite (Hodgkins 1985). In the adjacent Northfield Quadrangle yielded a U-Pb age of 613 +/-3 Ma on igneous zircon (Tucker and Robinson 1991), as well as U-Pb ages on titanite indicating Late Pennsylvanian regional metamorphism.

EXPLANATION OF MAP SYMBOLS

Lithologic Contacts

Location Accurate — Location Approximate — Location Inferred

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Thrust Fault (teeth on original upper plate)

Normal fault (hatchures on downthrown side)

Exposure

Bedrock outcrops

Area of abundant small outcrops or shallow bedrock

Structural Symbols

80 Strike and dip of inclined or overturned bedding or compositional layering

34 Strike and dip of inclined foliation, generally parallel to bedding

Strike of vertical foliation

9 Trend and plunge of lineation or minor fold axis

Comments to the Map User

A geologic map displays information on the distribution, nature, orientation and age relationships of rock and deposits and the occurrence of structural features. Geologic and fault contacts are irregular surfaces that form boundaries between different types or ages of units. Data depicted on this geologic quadrangle map are based on reconnaissance field geologic mapping, compilation of published and unpublished work, and photogeologic interpretation. Locations of contacts are not surveyed, but are plotted by interpretation of the position of a given contact onto a topographic base map; therefore, the accuracy of contact locations depends on the scale of mapping and the interpretation of the geologist(s). Any enlargement of this map could cause misunderstanding in the detail of mapping and may result in erroneous interpretations. Site-specific conditions should be verified by detailed surface mapping or subsurface exploration. Topographic and cultural changes associated with recent development may not be shown.

We recommend reading Reading Maps with a Critical Eye: Becoming an Informed Map Reader by the Maine Geologic Survey to make the best use of a geologic map (*http://www.maine.gov/doc/nrimc/mgs/mapuse/informed/informed.htm*).

This research was supported by U.S. Geological Survey, National Cooperative Geologic Mapping Program, under assistance Award Nos. 07HQAG0061.

Citation:
Robinson P., 2008, Bedrock geologic map and cross sections of the Orange area, Massachusetts: Office of the Massachusetts State Geologist Open File Report 09-01. Scale 1:24,000. 5 sheets and digital product: Adobe PDF files.

This map was produced on request directly from digital files (PDF format) on an electronic plotter.

A digital copy of this map (PDF format), including GIS datalayers, is available at *http://www.geo.umass.edu/stategeologist*