

# REFERENCES

Bradley, D.C., and O'Sullivan, P., 2016, Detrital Zircon Geochronology of Pre- and Syncollisional Strata, Acadian Orogen, Maine Appalachians: Basin Gibson, D., Osthoff, D., and Rerrick, C., 2017, Field relations, petrography and provenance of mafic dikes, western Maine: in Johnson, B. and Eusden, J.D. (editors), Guidebook for field trips in western Maine and northern New Hampshire: New England Intercollegiate Geological Conference, p. 273-286. Bradley, D.C., and Tucker, R., 2002, Emsian Synorogenic Paleogeography of the Maine Appalachians: Journal of Geology, 110, 10/8/2013-483-492. Hatch, N.L., Jr., Moench, R.H., and Lyons, J.B., 1983, Silurian-Lower Devonian stratigraphy of eastern and south-central New Hampshire; extensions from Bradley, D.C., Shea, E., Buchwaldt, R., Bowring, S., Benowitz, J., O'Sullivan, P.B., and Mccauley, A., 2016, Geochronology and tectonic context of lithiumwestern Maine: American Journal of Science, v. 283, no. 7, p. 739-761. cesium-tantalum pegmatites in the Appalachians: The Canadian Mineralogist, v. 54, p. 945-969. Moench, R.H., and Boudette, E.L., 1987, Stratigraphy of the Rangeley area, western Maine: in Roy, D.C. (editor), Northeastern section of the Geological Brady, J.J., 1991, The bedrock geology of the Bethel, Maine area: M.S. thesis, University of Maine, Orono, Maine, 150 p. Society of America: Geological Society of America, Centennial Field Guide, v. 5, p. 273-278. Choe, S.C., 2014, Petrographic Analysis and Tectonic Implications of the Plutons in the Gilead 7.5' Quadrangle: Connections to the Piscataguis Volcanic Arc

Moench, R.H., Boudette, E.L., and Bothner, W.A., 1999, Tectonic lithofacies, geophysical, and mineral-resource appraisal maps of the Sherbrooke-Lewiston area, Maine, New Hampshire, and Vermont, United States, and Quebec, Canada: U.S. Geological Survey, Miscellaneous Investigations Series Map, and Sebago Batholith: Department of Geology, Bates College, Lewiston, Maine, Standard Theses 18. https://scarab.bates.edu/geology\_theses/18 I-1898-E, 114 p., 3 sheets. Divan, E.J., 2017, Salinic to Neoacadian Deformation within the Migmatite Zone of the Central Maine Belt in Western Maine: Department of Geology, Bates

New England Intercollegiate Geological Conference, p. 287-304.

Solar, G.S., and Tomascak, P.B., 2016, The Migmatite-Granite Complex of southern Maine: Its structure, petrology, geochemistry, geochronology, and College, Lewiston, Maine, Standard Theses 32. https://scarab.bates.edu/geology\_theses/32 Eusden, J.D., 2013, Bedrock geology of part of the Bethel quadrangle, Maine: Maine Geological Survey, Draft map, June, 2013, scale 1:24,000. relation to the Sebago Pluton: in Berry, H.N., IV, and West, D.P., Jr. (editors), Guidebook for field trips along the Maine coast from Maquoit Bay to Eusden, J.D., Jr., Garesche, J., Johnson, A., Maconochie, J., Peters, S. C., Rosbrook, J., and Widmann, B., 1996, Stratigraphy and ductile structure of the Muscongus Bay: New England Intercollegiate Geological Conference, p. 19-42. Presidential Range, N. H.: Tectonic implications for the Acadian orogeny: Geological Society of America Bulletin, v. 108, p. 417-436. Solar, G.S., Tomascak, P.B., and Brown, M., 2017, Relations between deformation, metamorphism, melting and pluton emplacement at the migmatite front: in Eusden, J.D., Baker, S., Cargill, J., Divan, E., Hillenbrand, I., O'Sullivan, P., and Wheatcroft, A., 2017, Transect from the migmatized Central Maine Belt to

Johnson, B. and Eusden, J.D. (editors), Guidebook for field trips in western Maine and northern New Hampshire: New England Intercollegiate the Bronson Hill Anticlinorium: in Johnson, B. and Eusden, J.D. (editors), Guidebook for field trips in western Maine and northern New Hampshire: Geological Conference, p. 217-246. Gibson, D., and Lux, D.R., 1989, Petrographic and geochemical variations within the Songo pluton, western Maine: in Tucker, R.D., and Marvinney, R.G. Region: Department of Geology, Bates College, Lewiston, Maine, Standard Theses 17. https://scarab.bates.edu/geology\_theses/17 (editors), Studies in Maine geology: Volume 4 - igneous and metamorphic geology: Maine Geological Survey, p. 87-100.

Watermulder, S.Q., 2014, Depositional Setting and Deformation History of Central-Western Maine: Silurian Stratigraphic Revisions for the Newry-Gilead Wheatcroft, A., 2017, Bedrock Geology, Stratigraphy and Geochronology in the Migmatite Terrain of the Southern Gilead 7.5' Quadrangle, Western Maine: Department of Geology, Bates College, Lewiston, Maine, Honors Theses 196. https://scarab.bates.edu/honorstheses/196

# **INTERPRETIVE CROSS SECTION** Mountain Pine Mountain ANDROSCOGGIN RIVER Ssqa + Ssqb + Ssg = Ssrc + Ssqc Ssrc + Ssqa = Ssqa + Ssqb + Ssg (north) PDgm

## **EXPLANATION OF UNITS**

#### **INTRUSIVE ROCKS**

Early Permian(?) [P]

**Pegmatite.** Coarse to very coarse-grained equigranular pegmatite. Minerals include quartz, feldspar, muscovite, and biotite. Observed mineral grain size is typically less than 5 centimeters (cm) (2 inches [in]) in length and width, with extreme cases up to 30 cm (12 in) in length. Sizes of the distinct mineral types varied at each pegmatite outcrop.

Permian-Devonian(?) [PD] Muscovite-biotite granite and pegmatite, undifferentiated. Medium-grained to fine-grained granite, locally containing garnet±tourmaline. Pogm Pegmatite of the same mineralogy occurs with the granite, in various proportions. This granite and pegmatite unit occurs in several mostly small, mappable plutons. Dikes and sills of the same granite and pegmatite are also present throughout the migmatite regions. Blocks or schlieren of metasedimentary rocks within the unit may have measured bedding or schistosity. This granite may be related to granites of the Sebago pluton in southern Maine.

Carboniferous-Devonian [CD] Muscovite-biotite granite. Medium-grained equigranular granite. Mottled appearance due to the combination of minerals including quartz, potassium and plagioclase feldspars, muscovite, biotite, and accessory minerals. The plutons were injected as sills following strike of the netasedimentary units, and present as oblong ellipses in map view. A minor porphyritic phase of the muscovite-biotite granite exists at several outcrops. The porphyritic granite has a medium-grained matrix and phenocrysts of potassium feldspar, approximately 0.25 to 1.5 cm

(0.1 to 0.6 in) in length. Blocks or schlieren of metasedimentary rocks within the unit may have measured bedding or schistosity.

Diorite, quartz diorite, and biotite granite, undifferentiated. Fine-grained to medium-grained, equigranular, "salt-and-pepper" diorite, quartz diorite, and/or biotite granite. Plutons are heterogeneous, containing thin dikes of diorite and biotite granite 1 to 10 meters across, as well as less abundant and smaller dikes of muscovite-biotite granite and pegmatite. Blocks or schlieren of metasedimentary rocks within the unit may have measured bedding or schistosity. Most plutons follow the strike of surrounding metasedimentary units and are undeformed by folding events. These rocks may be related to those of the Songo Pluton, mapped south of the Androscoggin River (Gibson and Lux, 1989).

### STRATIFIED ROCKS

Note: References to named formations are those described by Moench and Boudette, 1987,

Silurian(?) [S] Biotite granofels. Dark gray plagioclase-quartz-biotite granofels interlayered with rare purplish-gray to green calc-silicate granofels and gray schist. Layers of gray mica schist in places. (Possibly correlates with the Madrid Formation.)

Rusty-weathering schist and quartzite. Red-brown rusty-weathering, locally pyrrhotitic mica schist, interbedded with gray quartzite. Calcsilicate pods are rare or absent. (Possibly correlates with the Smalls Falls Formation.) **Rusty-weathering granofels.** Discontinuous rusty-weathering granofels in the southernmost belt of the unit **Ssqr**.

Quartzite with minor gray schist, undifferentiated (Sqs). Light gray quartzite, in beds of variable thickness; well bedded and poorly graded. Contains thin interbeds of gray schist, 1 to 5 cm in thickness. Some sections have abundant calcsilicate pods, while in other sections they are rare or absent. (Possibly correlates with the Perry Mountain Formation.) Quartzite with minor gray schist (Sqsa). Light gray quartzite, in medium to thick beds (10-50 cm); well bedded and poorly graded. Contains sparse, thin interbeds of gray schist, 1 to 5 cm in thickness. Calc-silicate pods are rare or absent. Quartzite and schist with calc-silicate pods (Sqsb). Light gray quartzite in beds 5 to 25 cm thick, somewhat thinner than those in unit **Sqsa**; well bedded and poorly graded. Contains interbedded gray schist in beds, 5 to 15 cm in thickness, and calc-silicate pods. Some calc-silicate pods are zoned, with cores richer in grossular+diopside and rims richer in biotite+plagioclase. In a region northeast of Campbell Mountain, the schist contains coarse-grained aggregates of

muscovite and quartz interpreted to be pseudomorphed and alusite porphyroblasts.

Interbedded gray schist and quartzite, undifferentiated (Ssq). Heterogeneous unit consisting of gray mica schist with thin (1-5 cm) quartzite interbeds. Subordinate rusty-weathering schist, biotite granofels, and calc-silicate granofels. Calcsilicate pods are common throughout the unit. (Possibly part of the Rangeley Formation.) Interbedded gray schist and quartzite (Ssqa). Dominantly gray mica schist with thin (1-5 cm) quartzite interbeds. Subordinate rusty-weathering schist, biotite granofels, and calc-silicate granofels. Calc-silicate pods are common throughout the unit. Rare quartz-pebble conglomerate. Pseudomorphed andalusite porphyroblasts are interpreted to be present in the schist in a region south of Merrill Hill, Newry, near the east edge of the map.

Biotite granofels (Ssqg). Medium-grained, granoblastic quartz-plagioclase-biotite granofels, with rare calcsilicate granofels layers and minor gray schist. Interbedded gray schist and quartzite (Ssqb). Gray mica schist with thin (1-5 cm) quartzite interbeds. Calc-silicate pods are common throughout the unit. Pseudomorphed and alusite porphyroblasts are interpreted to be present in the schist in one

very small region southeast of Campbell Mountain. **Gray schist.** Gray mica schist with rare interbedded thin (1-5 cm) quartzite. Calc-silicate pods rare or absent. (Possibly part of the Rangeley

**Rusty-weathering schist.** Red-brown rusty-weathering mica schist with thin (1-5 cm) quartzite interbeds. Minor discontinuous layers 1-3 Ssrc meters thick of quartz-plagioclase-biotite granofels and calc-silicate granofels. Some calc-silicate layers contain calcite. Calc-silicate pods are or absent. (Possibly equivalent to part of the Rangeley or the Smalls Falls Formation.) **Gray schist and quartzite with calc-silicate pods.** Heterogeneous unit of variably interbedded gray schist and quartzite (1-5 cm), with rare, discontinous layers 1-3 meters in thickness of quartz-plagioclase-biotite granofels, and blocks of bedded, slightly rusty-weathering granofels n migmatite. Calc-silicate pods are common throughout the unit. (Possibly part of the Rangeley Formation.)

Rusty-weathering schist. Red-brown rusty-weathering mica schist with rare interbedded quartzite, and minor, discontinuous layers 1-3 meters thick of quartz-plagioclase-biotite granofels. Calc-silicate pods are common throughout the unit. (Possibly part of the Rangeley

## **EXPLANATION OF PATTERNS**

Region in which aggregates of muscovite+quartz are widespread in schists. The aggregates are interpreted to be pseudomorphs in which andalusite porphyroblasts of an earlier metamorphic event have been completely replaced by muscovite+quartz in a later metamorphic event. No relict andalusite is known from these regions.

Early  $(F_1?)$  hinge zone. Structural region in which schistosity  $(S_1)$  is not parallel to bedding  $(S_0)$ . In most of the map area, schistosity is parallel to bedding, which implies position on the limbs of schistosity-related folds. Area within stratified rocks with abundant small injections of granite and pegmatite (PDgm).

# **EXPLANATION OF LINES**

Contact between rock units, of stratigraphic or intrusive origin (well located, approximately located, poorly located, existence inferred).

Approximate stratigraphic limit where an undifferentiated unit can be divided into distinct stratigraphic units.

Boundary of migmatite area. May be a sharp or gradational boundary. Hachures point toward migmatitic rocks (well located, approximately located, poorly located).

Trace of the axial surface of a regional syncline and anticline (with an overturned section) that formed early in the deformational sequence (F<sub>1</sub>?) or local antiforms and synforms that formed late in the deformational sequence (F<sub>2</sub>). Locations interpreted from map pattern of curved unit contacts.

# **EXPLANATION OF SYMBOLS**

Note: Structural symbols are drawn parallel to strike or trend of measured structural feature. Barb or tick indicates direction of dip, if known. Annotation gives dip or plunge angle, if known. For most planar features, symbol is centered at observation point; for joints, observation point is at end of strike line opposite dip tick. For linear features, tail of symbol is at observation point. Multiple measurements at a site are represented by combined symbols. Symbols on the map are graphical representations of information stored in a bedrock database at the Maine Geological Survey. The database contains additional information that is not displayed on this map.

- • Outcrop of mapped unit (no structural information available, additional structural information available).
- Outcrop of pegmatite.
- Float, presumed to represent underlying bedrock.
- Occurrence of aggregates of muscovite+quartz, interpreted to be metamorphic pseudomorphs, possibly replacing
- Occurrence of pre-metamorphic fault, indicated by disruption in bedding. Not exposed well enough to determine Bedding (inclined, top direction indicated; inclined, bedding overturned; inclined, top direction unknown; vertical, top
- Schistosity (inclined, vertical).
- Structural elements of folds which have schistosity parallel to their axial plane, and are presumably the same age as the schistosity (fold hinge, plunging; inclined axial plane).
- Structural elements of folds which deform bedding and schistosity, and so are younger than the schistosity (fold hinge, plunging, with unknown asymmetry; fold hinge, plunging, with right-handed asymmetry; inclined axial plane).
- Dike of unusual composition. A brown, medium-grained, biotite-rich rock with granular texture. Straight, sharp contacts.
- Biotite has preferred alignment parallel to contacts. Dike is 1-15 cm wide.

Basalt dike, presumably of Jurassic age (inclined).

- Minor fault, oblique sense of motion, unknown displacement (inclined). Slickenline on fault surface (plunging).
- Joint (inclined, vertical). Inactive rock quarry.
- Location of numbered photograph shown in sidebar. Some photographs are from the Bethel quadrangle to the east (Eusden,
- 2013), or the Old Speck Mountain quadrangle to the north.
- Geochronology sample location (see **Table 1**).

# **Bedrock Geology of the** Gilead Quadrangle, Maine

Bedrock geologic mapping by

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INTRODUCTION TO THE MAP

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Cartographic design by

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### BEDROCK GEOLOGY OF THE GILEAD QUADRANGLE

The bedrock geologic map of the Gilead, Maine, quadrangle shows a geologist's interpretation of the distribution of rock types in the region based upon data collected in the field. The challenging part of this process is that most of the bedrock, up to 80% or more, is covered by vegetation, soil, and/or glacial deposits, making the locational choices of boundaries between rocks at times very difficult to determine. In the Gilead quadrangle, there are regions with excellent outcrop density, such as the Sunday River ski trails, and areas with poor outcrop, such as spruce-dominated forests above 3,000 ft. and lower elevation valley and swampy regions with thick glacial cover. The field data is represented by various symbols or dots giving one a sense of the control for the map. The data in the Gilead quadrangle was collected over three years by Prof. Dykstra Eusden of Bates College with the help of these capable undergraduate students: Riley Eusden (Bowdoin College '12); Saebyul Choe (Bates College '14); Sula Watermulder (Bates College '14); Erik Divan (Bates

College '17); and Audrey Wheatcroft (Bates College '17). To

determine the absolute age of some of the rock types in the

quadrangle a number of samples were radiometrically dated using U-Pb geochronology techniques on the mineral zircon. Dr. Paul O'Sullivan of GeoSeps Services coordinated those efforts. This publication has several parts, the most important of which is the geologic map showing the different rock types uniquely color-coded and symbolized. There is a cross section, along the line labeled A-A' on the map, which shows the interpretation of the subsurface geology based on extending downward the data and interpretations from the Earth's surface. The Explanation of Units is a brief description of each rock type in the quadrangle with intrusive (once molten) rocks followed by stratified, or layered, mostly metamorphic rocks next. These are listed by age with the oldest at the bottom of each section. The Explanations of Patterns, Lines, and Symbols serve to explain the significance of all symbols on the map. The photo gallery shows representative outcrop images of key units and boundaries observed in the field. The map was made and edited in ArcGIS by the

### **GEOLOGIC OVERVIEW**

Maine Geological Survey.

Most of the bedrock that underlies the Gilead quadrangle is stratified, or layered, rock of probable Silurian age (Photos 1-8) that was deposited as sediment on the seafloor in an ancient marine setting. The rocks were subsequently changed into metamorphic rock and deformed into folds by heat and pressure caused by plate collisions during the Salinic, Acadian, Neoacadian, and Alleghanian orogenies, or mountain-building events, as the continents, from west to east, of Laurentia, Ganderia, Avalonia, Meguma, and Gondwana successively collided to form the Appalachian Mountains (see Major Tectonic Events below). A lesser amount of intrusive igneous rock, solidified from molten rock, is also present in several small masses and one medium-sized mass near the center of the map area (Photos 9, 10). There are also thin sheets representing molten rock of several compositions that were injected into the metamorphic rocks (Photos 2, 8, 10, 11). The intrusive rocks likely range in age from as old as Devonian to as young as Permian. Features attributed to the extreme metamorphic conditions

include abundant migmatite (rock that partially melted and solidified nearly in place) (Photos 8, 11), as well as the presence of minerals such as garnet (grossular) and andalusite that form at high temperatures (Photos 1, 7). The map highlights the boundary, shown as a black solid or dashed line with hachures, between areas with abundant migmatite and areas that generally lack migmatite. The migmatization likely occurred in the Late Devonian to Early Carboniferous time period. The map also shows a variety of folds that formed when the rocks were extremely ductile during the Devonian and Carboniferous orogenies. There are two fold axes shown as longer blue lines with symbols on the map representing the earliest folds to form, called F1 folds, with wavelengths on the order of

kilometers. Several folds shown with shorter blue lines represent

the younger F2 folds that refolded the earlier F1 folds and have

Mapping in the Gilead quadrangle revealed twelve different

### wavelengths on the order of 100s of meters. STRATIFIED ROCKS

metasedimentary units defining a stratigraphy that best correlates to the Silurian stratigraphy seen in the Rangeley, Maine, region (Moench and Boudette, 1987) and more specifically the Rangeley, Perry Mountain, Smalls Falls, and Madrid Formations. The stratigraphy is poorly controlled by graded beds, which would typically allow one to establish the relative order of the units. Only a few graded beds from the original deposition as marine sediments were found in the region, largely because the prevalent migmatite has obscured these primary sedimentary features. Lithologic correlation of units in Gilead to those of Rangeley, Maine, coupled with the new geochronology results, discussed below, support the conclusion that these rocks are Silurian. The presence of belts of rusty-weathering schists and quartzites, biotite and calc-silicate granofels, ubiquitous calc-silicate blocks, and rare quartz pebble conglomerate in units Ssq, Ssqa, Ssqg, Ssqb, Ssg, Ssrc, Ssqc, and Ssr are hallmarks of the Rangeley Formation in nearby New Hampshire (Eusden and others, 1996). The clean, light gray to white quartzites of the Sqs, Sqsa, and Sqsb units are typical of the Perry Mountain Formation, while deeply rustyweathering schists and granofels of units Ssqrg and Ssqr are typical of the Smalls Falls Formation (Moench and Boudette, 1987). Dark gray, purple to greenish granofels of unit **Sgf** are typical of the Madrid Formation (Moench and Boudette, 1987). In places where there was lack of outcrop it was not possible to further subdivide certain parts of the stratigraphy, but elsewhere it was possible to subdivide when there was better outcrop. For example, units **Sqsa** and **Sqsb** were subdivided based on excellent outcrop on the Sunday River ski trails but on the map's northwest border those units could only be grouped together as **Sqs**. For similar reasons, units Ssqa, Ssqg, and Ssqb were grouped together as Ssq where outcrop control went from good to poor. In the legend and on the map this separation/grouping was shown with a saw-toothed line. We interpret the oldest unit in the stratigraphy to be unit Ssr found as a belt striking east-west across the lower center of the map. The second youngest unit is Ssqr that can be found in two belts along both the north and south borders of the map. The stratigraphy is arranged in somewhat of a mirror-image pattern on either side of the oldest unit, Ssr. We interpret this to be due to an early F1 fold through the middle of **Ssr** that repeats the pattern. Compared to the most recent previous geologic map that included the Gilead region (Moench and others, 1999), the current bedrock geologic map shows no evidence of the Devonian

Gilead. The apparent absence of the Littleton Formation on the new map suggests that more mapping to the west and east of the Gilead quad is needed to verify that no Devonian rocks are The nature of the stratified rocks suggests several things regarding the paleo-environment of the marine depositional basin. Regions of evenly bedded layers record relatively uninterrupted deposition of layer upon layer in a marine basin over perhaps several million years. In contrast, the presence of the blocks, pods, and lenses of bedded fragments of calc-silicate within a finergrained matrix suggest that these units were formed by catastrophic sub-marine debris flows. The blocks were broken up, perhaps triggered by earthquakes in what was a seismically active basin, and then transported to deeper water to ultimately be embedded in a clay matrix. An alternative hypothesis we favor less for these blocks is that the process of migmatization disrupted them after deposition and during the metamorphism. Another feature that also

argues for a tectonically active marine basin were the rare pre-

migmatite faults that juxtaposed two units of the

stratigraphy (Photo 6). The quartz pebble conglomerate (Photo 3)

also suggests active, high-energy deposition, perhaps caused by

localized tectonic uplift. The rusty- and non-rusty-weathering nature

Cretaceous Period (**K**)

Jurassic Period (**J**)

Triassic Period (%)

Permian Period (**P**)

Carboniferous Period (**C**)

Devonian Period (**D**)

Silurian Period (S)

Littleton Formation, which formed the bulk of the previous map of

of the units records times when the basin of deposition was either deprived of oxygen or not. Oxygen-poor basins are considered anoxic and typically lead to the formation of the iron sulfide minerals pyrite and pyrrhotite in the sediments. When these minerals are exposed to the surface by erosion they weather to become rusty brown schists. Non-rusty rocks record times when the basin had better oxygenation and circulation. These variations in ocean circulation and available oxygen were largely due to the construction and removal of sea floor barriers to circulation created during active plate collisions and related deposition of sediment

Detrital zircon age population density histograms for two samples of unit Ssqg, informally called the Bog Brook granofels by Eusden and others (2017), yield maximum depositional ages of  $427.6 \pm 3.9$  Ma and  $419.5 \pm 3.9$  Ma, shown on the map as geochronology localities A and B respectively. Taken together, the mean maximum depositional detrital zircon age is circa 422 Ma which places this unit within the traditional age assignment for the Late Silurian Madrid Formation (Hatch and others, 1983). If the Bog Brook granofels was correlated to the Madrid Formation based upon their similar lithologies one would expect it to be directly in contact with rusty-weathering schist equivalent to the Smalls Falls Formation. That is not the case. Instead, the Bog Brook granofels is surrounded by gray schist and quartzite with calc-silicate pods that are all characteristic of the Early Silurian Rangeley Formation to which we have correlated the Bog Brook unit. This new detrital age data is nearly identical to that done by Bradley and O'Sullivan (2016) in the Rangeley, Maine, stratigraphy, and agrees remarkably well with their 1st Acadian Detrital Zircon Cycle for the Greenvale Cove, Rangeley, Perry Mountain, and Smalls Falls Formations composite. This suggests that sediment in both the Rangeley area and in Gilead was derived **Photo 5:** Thinly laminated quartz-plagioclase granofels and biotite-

Carboniferous period but within uncertainty of the Devonian

of the Sebago pluton which have been dated to  $288 \pm 13$  and 297

period. Lithologically these granites are almost identical to granites

± 14 Ma or within the Late Carboniferous to Permian period

(Solar and Tomascak, 2016), as well as granites in the Presidential

Range that have been dated to 363 Ma or within the Late

Devonian (Eusden and others, 2017). Therefore without

geochronologic control, the muscovite-biotite granites are given a

wide range of age from the Permian to Devonian, hence the

symbol **PDgm**. The muscovite-biotite granites cut the diorites, the

migmatitic layering, and the late F2 folds, and are in turn cut by

pegmatites. The granites likely formed from melted continental

Gilead quadrangle and most outcrops have at least some amount of

pegmatite cutting through the older units. Nearly all of these

pegmatites are too small to show as polygons on the map. The

pegmatites cross cut all other units and structures in the Gilead

quadrangle except for the latest brittle joints. These pegmatites also

formed from melted continental crust. The pegmatites in the Gilead

quadrangle have not been dated but are likely as young as

Permian or as old as Devonian based on the pegmatite ages in

New England determined by Bradley and others (2016). The cross

cutting pegmatites at Wheeler Mine must be younger than the

dated muscovite-biotite granites of Carboniferous age and are

shown as Permian on the map. The Wheeler Mine pegmatites have

been mined for feldspar and mica, and crystals of biotite up to 3

The migmatites are found throughout the southern half and

northwest corners of the map. These partially melted rocks formed

when high heat flow from other magmas, or perhaps the mantle,

resulted in the partial melting of the stratified rocks. The lighter

quartz and feldspar-rich portions of the migmatites are thought to

be the now frozen melt fractions while the darker biotite-rich

portions are the residual unmelted fractions. The process of

migmatization happened when the rocks were very ductile and

plastic, hence the once relatively planar layering in the stratified

rocks became more distorted and swirly in orientation. The

migmatites correlate well to the Sebago Migmatite-Granite

Complex dated to  $376 \pm 14$  Ma or the Late Devonian-

There are several phases of deformation that the rocks

experienced during successive plate collisions. The first, mentioned

in the stratified rocks section, was characterized by rare pre-

metamorphic faults that formed in an active tectonic setting

probably just after deposition of the sedimentary rocks. As plate

collisions commenced the first generation of folds formed, called

more often regions where the bedding and foliation are not parallel

(shown by red ovals on the map). The two regional F1 fold axial

traces shown as blue lines on the map represent regions where the

stratigraphy flips over and repeats itself by folding. The northern

bedding and foliation that are not parallel have been observed. The

southern F1 fold within unit Ssr is entirely based upon the

apparent stratigraphic repetition around that unit. The F1 folding

pre-dated the migmatization. The last folding event, F2, is marked

shown as blue lines on the map determined by regional changes in

the bedding and foliation. The geometry of the F2 folds is often

quite variable probably due to the folding of layers that were

already distorted and swirly by the migmatization that predated the

F2 folding. Late brittle fractures or joints, with rare basalt dikes

parallel to them, are the last deformation. These probably

The major geologic and tectonic events in the Gilead region

are: (1) Silurian deposition of the Rangeley, Perry Mountain,

Smalls Falls, and Madrid Formations followed by minor pre-

metamorphic faulting, perhaps during the Salinic orogeny; (2) Early

metamorphism; (3) Middle Devonian widespread migmatization

occurring around 376 Ma; (4) Late Devonian Neoacadian F2

folding: (5) Late Devonian Neoacadian emplacement of the diorites

at 364 Ma; (6) Carboniferous Neoacadian muscovite-biotite granite

emplacement at 350 Ma; (7) Carboniferous to Permian Alleghanian

even younger pegmatites within the region; and (8) Jurassic brittle

fracturing and rare basalt dike intrusion around 200 Ma (?) during

the rifting of Pangea.

**Approximate Time Span of Tectonic Event** 

Pangea rifting/ Atlantic Ocean opening

Alleghanian orogeny

Neoacadian orogeny

Acadian orogeny

Salinic orogeny

**MAJORTECTONIC EVENTS** 

\* In millions of years before present. (Walker, J.D., Geissman, J.W., Bowring, S.A., and Babcock, L.E., compilers,

2012 Geologic Time Scale v. 4.0: Geological Society of America, doi: 10.1130/2012.CTS004R3C.)

emplacement of the Sebago-aged mucsovite-biotite plutons and

Devonian Acadian F1 folding and the onset of regional

developed in the Jurassic during the rifting of Pangea.

y common, cm to m scale, open folds as well as larger folds

of the two F1 folds is somewhat better controlled as regions of

F1. These are recognized in the field by minor isoclinal folds and

Carboniferous period by Solar and Tomascak (2016).

feet in length can be found.

The pegmatites are one of the more common rocks in the

crust and possibly also the melt derived from the migmatites.

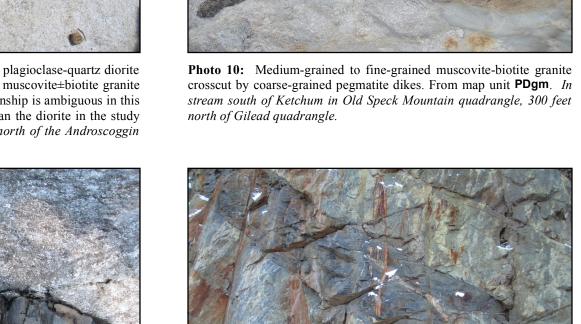
INTRUSIVE ROCKS

#### Three broad types of intrusive igneous rocks were found in the Gilead quadrangle: diorite (**Dgd**), muscovite-biotite granite (CDg and PDgm), and pegmatite (PDgm and Pp). The oldest, based upon cross cutting relationships, is **Ddg**, a suite of diorite, quartz diorite, and biotite granite found in the southwest part of the map as small sheet-like sills typically intruding parallel to the regional foliation in the metamorphic rocks. The age of these rocks is only constrained by correlation to the nearby Songo Pluton, a lithologically similar rock recently dated by Gibson and others (2017) to be $364 \pm 1.3$ Ma, within the Late Devonian. This series of intrusions may be the plutonic part of the Piscataquis Volcanic Arc (Bradley and Tucker, 2002), thought to be a subduction-related arc complex that formed during the Acadian Orogeny. The muscovite-biotite granites are common in the Gilead quadrangle and appear as unfoliated, sill-like bodies, most too small to map as separate polygons on the geologic map. Two samples taken from unit CDg near Wheeler Mine yielded U-Pb zircon ages of $349.2 \pm 2.1$ Ma (geochronology sample C) and $355.3 \pm 2.3$ Ma (geochronology sample C) placing these in the

quartz+muscovite lumps that are possibly pseudomorphs of andalusite. From map unit **Sqsb**. About 0.7 mile south of Whites Notch, Bear



**Photo 9:** Dark gray, salt-and-pepper texture, plagioclase-quartz diorite or tonalite (upper left), in contact with white muscovite±biotite granite or aplite (lower right). Though the age relationship is ambiguous in this image, the granite is consistently younger than the diorite in the study area. From map unit **Ddg**. About 1.2 miles north of the Androscoggin River, east of Peabody Brook.





**Photo 13:** Unit **Sqsb** showing region where beds of coarse schist and fine quartzite extend left to right across the photo and foliation is parallel to the hammer handle indicating the presence of a minor F1



where geochronology sample A yielded a maximum depositional age of  $427.6 \pm 3.9$  Ma. On Bog Brook.



coarse schist and fine quartzite with bedding parallel to foliation. West



West of Pine Mountain.

Location	Unit	Mineral	Method	Age±2σ (Ma)	Reference
A	Ssqg	Detrital zircon	U-Pb	427.6 ± 3.9	Wheatcroft, 2017
В	Ssqg	Detrital zircon	U-Pb	$419.5 \pm 3.9$	Wheatcroft, 2017
C	CDg	Zircon	U-Pb	$349.2 \pm 2.1$	Wheatcroft, 2017
D	CDg	Zircon	U-Pb	$355.3 \pm 2.3$	Wheatcroft, 2017

**Photo 1:** Thinly interbedded (1-10 cm) rusty-weathering sulfidic schist

and quartzite with a rectangular calc-silicate pod. The bedded calc-

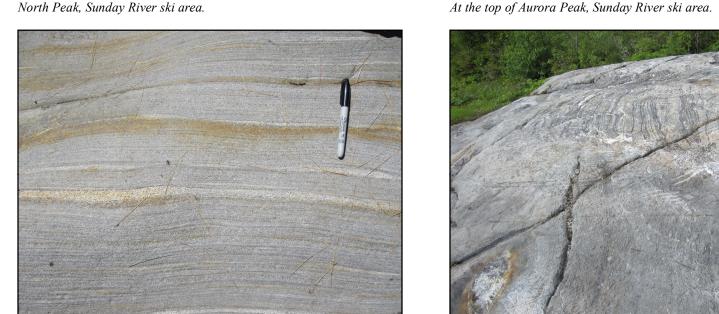
silicate granofels contains coarse grains of diopside, grossular, and

minor calcite, and may represent a relict sedimentary clast. From map

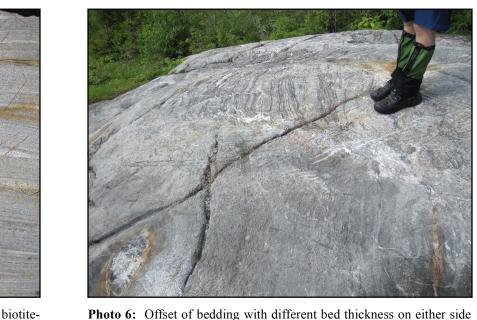
unit **Ssrc**. *Photo from Bethel quadrangle*.



**Photo 3:** The only outcrop of a quartz-pebble conglomerate with a schist matrix found in the entire study area. From map unit **Ssqb**.



near Frenchman's Hole, Old Speck Mountain quadrangle.



**Photo 2:** Matrix of dark gray biotite-quartz-plagioclase granofels with

a series of calc-silicate pods arranged in an en echelon pattern (arranged

above head shadow L to R across lower center of image). The pods are

mineralogically zoned, richer in grossular+diopside in the core and

richer in quartz+plagioclase+biotite at the rim. All rocks are cut by late

veins and stringers of pegmatite. From map unit **Ssr**. In Whites River, a

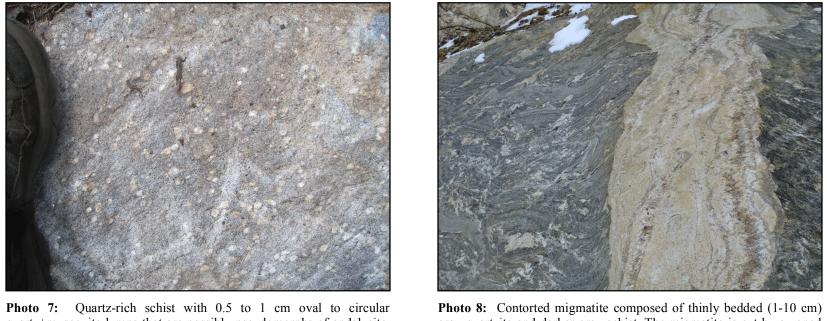
Photo 4: Well-bedded, poorly graded, thick, 2-30 cm, white to light

gray quartzites and thin, 1-5 cm, knobby schists. From map unit **Sqsb**.

mile north of the Androscoggin River.

from the Laurentian (currently west) side of the basin in the quartz-plagioclase granofels. From map unit **Sgf**. Along Sunday River of a boundary in map unit **Ssqg**. The entire outcrop has been metamorphosed and migmatized to the same degree, so presumably the boundary (fault?) is pre-metamorphic in age. It could be a soft sediment slump or a tectonic fault that developed early in the sequence of deformation, perhaps during the Salinic Orogeny. Northwest slope of

North Peak, Sunday River ski area.



gray quartzite and darker gray schist. The migmatite is cut by a zoned pegmatite stringer, 40 cm thick. From map unit **Ssqc**. South side of Route 2, east of Gilead.



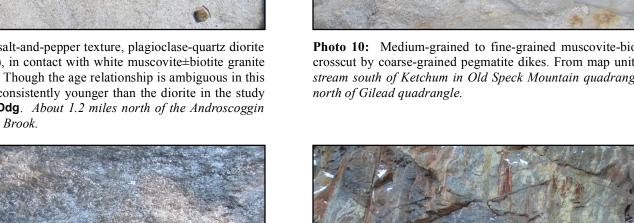


Photo 11: Rare, thin, basalt dike cutting across a block of gray **Photo 12:** An unusual, biotite-rich dike injected along joint surfaces migmatite (Ssqc) in Ddg. From Whites Brook, about 0.8 mile north of



fold. Approximately 3,100 feet south of where Bog Brook crosses Route



**Photo 15:** Unit **Ssrc**, a moderately rusty-weathering, well bedded, flank of Peaked Hill.

**TABLE I: GEOCHRONOLOGY** Method Λσο+2σ (Ma