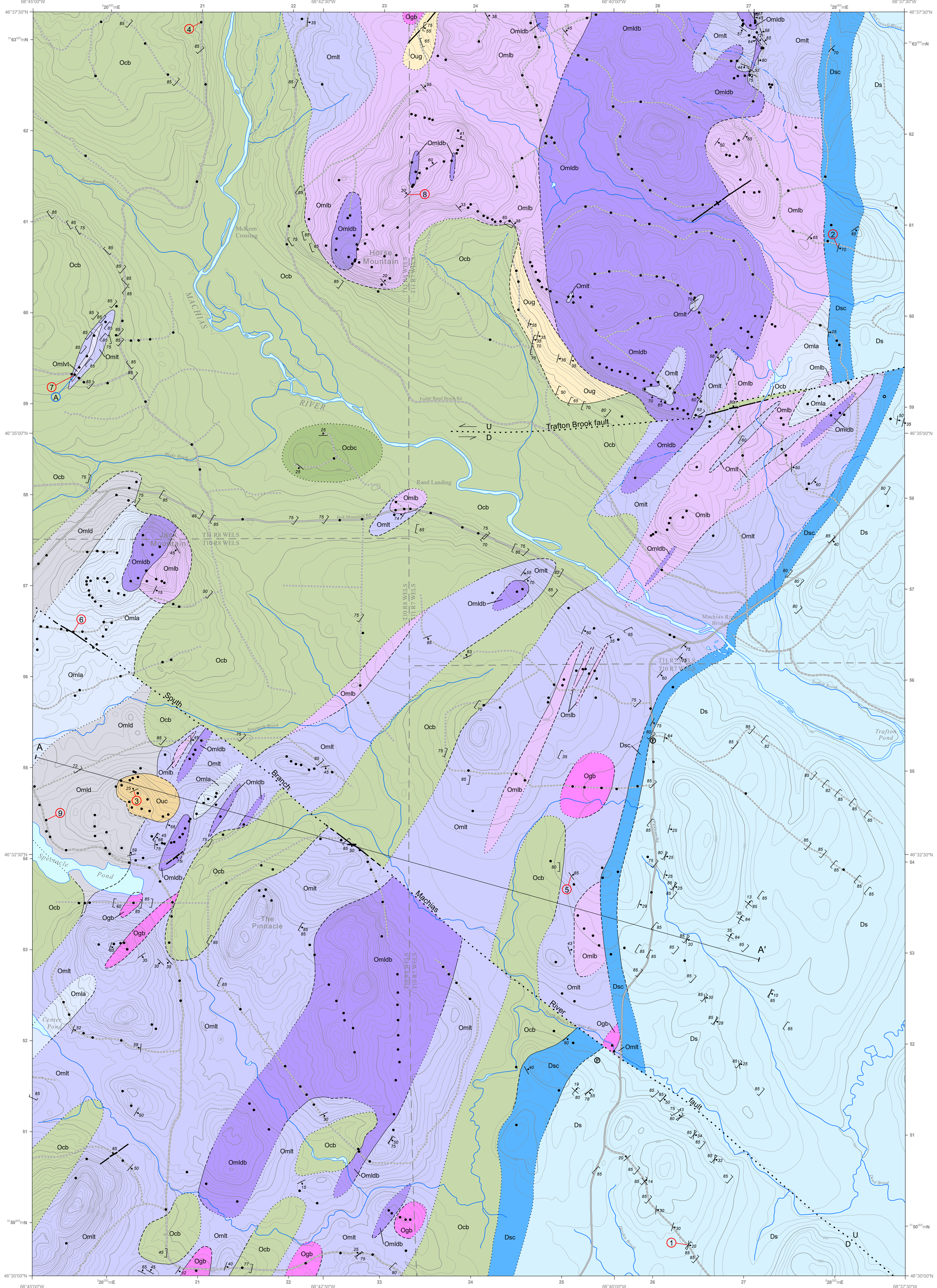
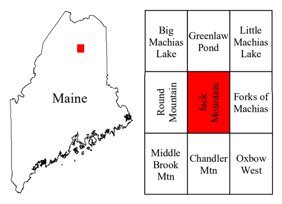


SOURCE OF GEOLOGIC INFORMATION

Field work by Chunzeng Wang (2017, 2018).



SCALE 1:24,000

1 Mile | 7000 Feet | 1 Kilometer

CONTOUR INTERVAL 20 FEET

Approximate Mean Declination, 2016 17° W

Base map features from Maine Office of GIS - 1:24,000 USGS contour lines, E911 roads, 1:24,000 National Hydrography Dataset, USGS GNIS placenames and 1:24,000 political boundaries. Additional unpaved roads digitized from aerial imagery by Chunzeng Wang, 2018. Map projection Universal Transverse Mercator, North American Datum, 1927.

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.

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TABLE 1. GEOCHRONOLOGY

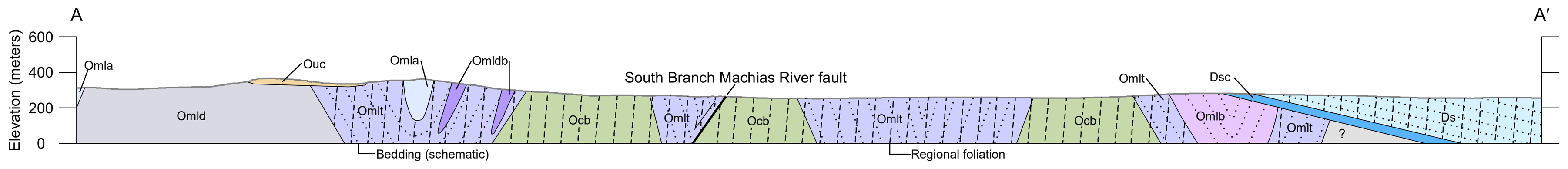
Location	Unit	Mineral	Method	Age±2σ (Ma)	Analytical Laboratory
A	Omlvt	Zircon	LA-ICP-MS U-Pb	**471.2 ± 4.2**	University of New Brunswick, Canada

Location is shown on the map by a letter in a blue circle. Concordia age shown.

ACKNOWLEDGEMENTS

This project is funded by the U. S. Geological Survey STATEMAP Program through Maine Geological Survey. Robert Marvinney and Stephen Pollock are thanked for their support, guidance, and team work. Special thanks to David Putnam for his mentoring and partnership in the North Maine Woods, to Amanda Barker for her leading early trips to the area, to Christopher McFarlane and Brandon Boucher for providing assistance in U-Pb dating, and to Caleb Ward for his three years of loyalty in field assistance. Other UMPI students Adam Weyeneth, Dylan Damboise, and Sarah Swain are also thanked for serving as field assistants. Gary Boone is thanked for his constructive discussion and suggestions over the years. Land owners and managers Tall Timber Trust, LandVest, Seven Islands, and North Maine Woods Inc, in particular Al Cowperthwaite, are much thanked for providing me permissions and convenience to work in the woods.

INTERPRETIVE CROSS SECTION



CROSS SECTION NOTES

Contact lines are solid where projected below ground, and dashed above the ground surface. Dotted lines represent bedding orientation. Dashed lines represent the regional prevailing foliation that overprints bedding. No vertical exaggeration.

EXPLANATION OF UNITS

STRATIFIED ROCKS

Devonian [D]

Ds — **Seboomook Group, undifferentiated.** The Seboomook Group (Seboomook slate of Perkins, 1925) occurs as cover strata overlying the Ordovician basement rocks along flanks of the Munsungun inlier. In the quadrangle, it crops out in lowland areas on the east-southeast side of the inlier. The Group is composed predominantly of medium- to thin-layered, gray quartzose siltstone and argillaceous mudstone/slate (**Photo 1**), with minor sandstone, of largely turbiditic successions, in addition to its basal conglomerate discovered in this project. The basal conglomerate is immediately overlain by fossil-rich calcareous mudstone and siltstone, limestone, and locally maroon slaty mudstone and siltstone of less than 50 meters (m) in thickness. From the basal conglomerate at the bottom up to the turbidites that are distributed miles away to the east-southeast, the beds consistently strike north-northeast and dip toward east-southeast at a shallow angle (average 15°), forming an east-southeast-inclining homocline. The unit is pervasively cleaved by the regional prevailing Acadian foliation (with average strike at 225° and dip angle 75-85°). Pencil cleavage is commonly developed within the argillaceous mudstone and silty mudstone layers.

Fossils found within the basal conglomerate and the overlying calcareous mudstone and siltstone and limestone include brachiopods (e.g. *Leptaena rhoboidalis*, *Howellella sp.*, *Meristella sp.*, *Acropsirifer sp.*, and *Strophonella sp.*), bryozoans (e.g. *Fenestella sp.*), coral (e.g. *Favosites helderbergiae* and *Streptelasma strictum*), crinoids, and stromatoporoids – a Helderberg fauna which indicates an Early Devonian age for the Group.

Dsc — **Basal conglomerate member.** Massive, matrix-supported, poorly sorted, polymictic pebble and cobble conglomerate. Minor coarse granule or pebble-bearing sandstone is intercalated within the conglomerate. The granule and pebble clasts are derived from all types of rocks found within units of the Munsungun inlier, such as cherty tuff, basalt, diabase, and gabbro. It is generally characterized by the presence of red or maroon cherty tuff clasts (**Photo 2**), making it different from any other conglomerate mapped within the inlier. The basal conglomerate layer swells and pinches along its strike with a thickness ranging from less than 50 m to near 150 m. The existence of the basal conglomerate indicates an angular unconformity with the underlying units of the Munsungun inlier. The unconformity is largely displaced by post-Acadian faults at two locations in the quadrangle (with a horizontal offset distance at about 600 m), one in the southeast by a southeast-striking fault (referred to as South Branch Machias River fault in this map; it is at least 12 kilometers [km] long) and the other in the northeast by a west-southwest-striking fault (referred to as Trafton Brook fault in this map; it is at least 6 km long).

Ordovician(?) [O]

Ouc — **Unnamed conglomerate.** This unit consists predominantly of non-pyritic pebble and granule conglomerate and some graywacke. It occurs on top of a hill on the northeast side of Spectacle Pond, with an exposed area of about 0.26 square kilometers (km^2). The conglomerates are generally massive, thickly layered, and clast supported. The clasts are generally poorly sorted except at a couple of locations where the granule conglomerate and graywacke show graded bedding. The clasts are predominantly gray and dark-gray cherty tuff with minor basalt (**Photo 3**) that were probably derived from the Middle Ordovician volcanics and subvolcanics. However, no red/maroon cherty tuff clasts have been observed in the conglomerate. Lithologically, it resembles Rowe Lake Formation conglomerate that crops out in the neighboring Round Mountain quadrangle (Wang, 2018). The conglomerate is underlain by Munsungun Lake Formation dacite and tuff, showing an angular unconformity. The provenance of the clasts and the unconformity are suggestive of a Late Ordovician age for this conglomerate formation.

Oug — **Unnamed graywacke and pelite.** This unit consists predominantly of well-bedded, thick- to medium-layered, gray and dark-gray graywacke, pelite, and minor granule conglomerate with immature ingredients and textures. It is exposed in two locations in the quadrangle. One is located on the northeast side of Foster-Rand Brook and on a southwest-facing steep slope with an exposed area of about 0.62 km^2, where the beds generally dip 35° to 105°. Its northeast side is overlain by basalt and diabase of the Munsungun Lake Formation, suggesting an angular unconformity (if the latter is younger) or a fault contact (if the former is younger) between both units. The other is located 2.5 km north of Horse Mountain with an estimated exposed area of only about 0.25 km^2, where it is best exposed in a borrow pit. In the pit, the graywacke and pelite dip 55° to 140°, and a reverse fault (dipping 50° to 130°) occurs within the graywacke and pelite. This exposure is surrounded by Munsungun Lake Formation basalt at higher elevations, suggesting a thrust fault window for the unit if it is younger than the Munsungun Lake Formation.

This well-bedded unit is lithologically and structurally different from Chase Brook Formation mélange. It is likely unconformably overlying the Chase Brook mélange and it is younger than the Munsungun Lake Formation volcanics. If so, its age is probably Late Ordovician.

Ocb — **Chase Brook Formation.** The Chase Brook Formation (Hall, 1970) occurs as a slate-rich olistostromal mélange (Neuman and Max, 1989; Pollock, 1993). The matrix-rich olistostromal body consists of crumbly gray slate and locally phyllite. Intraclasts and broken beds of greenish-gray slate occur as small subangular blocks and lens-like bodies (**Photo 4**). Other intraclasts include thin, discontinuous beds and isolated blocks or rounded pieces of light-brown calcareous metasiltstone. Intraclast volume is generally less than 10%, but locally may make up to 25% of the unit. Locally preserved bedded fragments or intraclasts suggest that original bedding was less than 15 centimeters (cm). The slate is mostly pyritic and pyrite concretions (mostly ball-shaped) are nearly ubiquitous and common in the Formation. Due to such, oxidation of pyrite always makes the rock look rusty. The Formation is pervasively and strongly cleaved and the foliation has a dominant 225° strike and northwest dip at 75-85° (it may locally change to southeast dip). Cleavages are mostly irregular and producing biconvex phacoidal fragments, therefore referred to phacoidal cleavage (or "scaly cleavage"). Phacoidal fragments range from approximately 2 by 0.5 cm to more than 10 by 4 cm. Small, isolated fold noses or hinges are locally present and wide spread. The formation is metamorphosed at lower-greenschist facies. Because the Formation is more susceptible to weathering and erosion, it generally forms lowlands and wetlands.

No direct evidence is obtained to establish the age of the Chase Brook Formation. Based on its field relation with the Middle Ordovician Munsungun Lake Formation and Osberg and others (1985), it is considered to be Early Ordovician or as old as Cambrian.

Ocbc — **Conglomerate member.** In general, a predominantly pyritic, polymictic, matrix-supported, pebble and granule conglomerate and occurs as large lenses within Chase Brook Formation mélange. In this quadrangle, only a large lens of it was mapped in an area between Jack Mountain and Machias River. The conglomerate in the lens is rusty weathering due to its highly pyritic nature. Ball-shaped pyrite concretions were observed within the conglomerate. The clasts are moderately to poorly sorted, and are predominantly chert clasts, in addition to other types of rocks such as basalt, quartzite, graywacke, diabase, and marble. The clasts are mostly at pebble size with some up to cobble and even small boulder size. The conglomerate member was first identified and mapped in the Round Mountain quadrangle as part of the Chase Brook Formation (Wang, 2018). Some exposures were mapped as Chase Lake Formation in the past (Hall, 1970; Osberg and others, 1985).

VOLCANIC AND SUBVOLCANIC ROCKS

Ordovician [O]

Munsungun Lake Formation. Munsungun Lake Formation (Hall, 1970) includes voluminous explosive facies of volcaniclastics, effusive facies of basalt, andesite, and dacite flows, and subvolcanic facies of diabase sills/dikes; each of them is mapped as a separate unit. The volcaniclastic rocks mapped in the quadrangle include all type of tephras such as tuff, lapillistone, and volcanic breccia, but are dominated by tuff (i.e. gray and maroon fine tuff and coarse tuff). Only part of it is probably poorly sorted ignimbrite tuff flow as seen in the areas north and southwest of the Machias River bridge. The volcaniclastics and effusive flows generally strike northeast, but abruptly change to northwest in the top part of the map. The Formation is a major part of the northeast-trending Munsungun-Jack Mountain-Bald Mountain Volcanic Belt within the Munsungun inlier. The Belt is part of the Munsungun-Popelogan-Victoria Arc (van Staal and others, 1998, 2016; Wilson, 2003) of the Northern Appalachian Mountains.

Based on major and trace elemental analyses of 13 samples collected in the Center Mountain – Jack Mountain area, the andesite, dacite, tuff, vitric tuff, and most of the diabase of the Munsungun Lake Formation are calc-alkaline, depleted in Ta, Nb, and Ti, and enriched in large-ion lithophile elements (LILE) and light rare earth elements (LREE), with negative Eu anomalies. Basalt and some diabase are tholeiitic and show similar trends but without negative Eu anomalies. Three andesite samples show εNd values of -16.3 ~ - 17.4 and two basalt and diabase samples show εNd values of 3.3-4.5, suggesting different sources of magmas between the calc-alkaline andesite, dacite and the tholeiitic basalt and diabase. Their normalized trace element patterns and tectonic discrimination diagrams suggest intra-oceanic arc or island-arc setting.

The Munsungun Lake Formation primarily unconformably overlies the Chase Brook Formation mélange and conglomerate. The unconformity may represent the Penobscottian orogeny. Zircon LA-ICP-MS geochronological analysis was performed on a red tuff sample and a vitric tuff sample in 2017. The red tuff sample collected from the same tuff unit on the south side of Center Mountain (which is located in the neighboring Round Mountain quadrangle) yielded a U-Pb concordia age of 468.0±2.0 Ma and a weighted mean $^{207}Pb/^{206}Pb$ age of 467.0±2.2 Ma (Wang, 2018). The vitric tuff sample collected from the vitric tuff unit (at location A, see **Table 1**) yielded a U-Pb concordia age of 471.2±4.2 Ma and a weighted mean $^{207}Pb/^{206}Pb$ age of 469.4±4.2 Ma. The latter ages are reported here for the first time. The ages of both samples are within error range, indicating that the Munsungun Lake Formation was formed in the early Middle Ordovician time, as a result of arc volcanism.

A post-Penobscottian and pre-Acadian orogenic shortening event caused the unconformity and the tight folding of the overlying Munsungun Lake Formation. A number of northeast-southwest-trending, predominantly nonplunging anticlines and synclines are mapped in the quadrangle. They are displaced by the southeast-striking South Branch Machias River fault and the west-southwest-striking Trafton Brook fault, respectively in the central-south and the northeast of the quadrangle.

Omlt — **Tuff.** This unit is predominantly fine tuff, coarse tuff, and lapillistone composed of lithic and crystal volcaniclasts. About 70% of the tuff is gray in color and the rest is maroon or purplish red, with changes between the colors either knife sharp or gradational. Several places in the unit show alternating dark-and-light-gray banded cherty tuff (**Photo 5**). A number of layers of volcanic breccia or tuffaceous breccia (with mostly gray or maroon cherty tuff or jasper as blocks) also occur within the unit. The best example is the jasper-block-bearing breccia in Jack Mountain area where it occurs as a fault sliver within the andesite unit (**Photo 6**). The tuff unit also includes agglomerates with basalt bombs that crop out in several locations, including one located about 1.5 km southwest from the Machias River bridge. Geochemically, the tuffs are calc-alkaline and andesitic or basaltic. Some of the fine-grained tuff are very cherty and toolable. The tuff layers are folded and tilted with a general northeast-striking direction until the strike direction changes to northwest in the tuff that crops out in the upper-northeast corner of the quadrangle (and from there to north beyond the quadrangle). The tuffs are also pervasively foliated with the regional prevailing southwest-striking Acadian foliation; the foliation can be weak in places in tuffs.

Omlvt — **Vitric tuff.** Vitric tuff occurs in a small area between Rowe Lake Rd and Weeks Brook Rd, north of Jack Mountain. It is gray and cherty, and made of nonwelded, microscopic, devitrified glass shards that were derived from pulverization of pumice during eruption. It is characterized by a large volume of spherulites that were produced as a result of devitrification (**Photo 7**). Geochemically it is calc-alkaline and rhyodacitic. The northeast-striking vitric tuff layer is sandwiched by strongly foliated gray cherty fine crystal and lithic tuff on its east and west sides. Measurements of bedding and foliation indicate that both tuff units constitute a northeast-plunging syncline.

Omlb — **Basalt.** Basalt occurs as effusive flows and crops out mostly in central and northern part of the quadrangle. The largest basalt flow(s) occurs around Horse Mountain and north of the Mountain. The basalt flows are predominantly unfoliated, aphyric, and fine grained, and composed of plagioclase and augite with minor olivine and hornblende. Only locally some basalts have porphyritic and/or vitrophyric textures. For example, the basalt around the hilltop area immediately northwest of the Machias River bridge shows typical hyalopilitic or vitrophyric texture with augite, plagioclase, and minor olivine phenocrysts within devitrified glass matrix. Most of the basalt flows are characterized by pillow structure (**Photo 8**), indicating subaqueous eruptive environment. Basalt flows with vesicular and/or amygdaloidal textures (including amygdules of predominantly calcite and minor zeolite and opal) are common as well, also suggesting shallow water environment. Most of the basalts have experienced hydrothermal alteration to become strongly altered with abundant secondary minerals chlorite, calcite, and opaque iron oxides. The basalt flows generally strike to the northeast until they change to northwest in the area northeast of Horse Mountain where there are at least two generations of pillow basalt flows with different strike directions.

Omla — **Andesite.** Andesite is less voluminous than the basalt. In the quadrangle, andesite crops out in several areas, with the largest one exposed between Jack Mountain and Spectacle Mountain where it is sandwiched by dacite. Both the andesite and dacite in this area form the Jack Mountain andesite-dacite suite. The andesite is massive and lacks layering, and only locally it may occur as agglomerate. It is generally dark gray to greenish gray and porphyritic or hyalopilitic with mainly euhedral or subhedral plagioclase feldspar and minor quartz phenocrysts (**Photo 9**). Quartz phenocrysts, if present, are generally corroded or embayed due to partial resorption. The matrix is composed of aphanitic feldspar, chlorite, minor quartz, opaque iron oxides, and devitrified glass. Spherulites caused by devitrification are seen in some thin sections. Locally it shows vesicular and amygdaloidal texture.

Omld — **Dacite.** Dacite occurs as part of the Jack Mountain andesite-dacite suite. It is gray to pale gray and porphyritic with mainly quartz phenocrysts and minor feldspar phenocrysts. Quartz phenocrysts are rounded or corroded/embayed due to partial resorption. The matrix is aphanitic microcrystalline and composed of quartz, feldspar, sericite, and devitrified glass. The matrix contains spherulites that were produced by devitrification. Less porphyritic dacite can be very glassy and cherty.

Omldb — **Diabase.** Diabase generally occurs as shallow intrusive, subvolcanic dikes and sills that strike northeast within the volcaniclastics and basalt/andesite flows. Two exposures are greater than 5 km^2, one occurring in the northeast of the quadrangle (which is greater than 12 km^2 and extends into the Greenlaw Pond quadrangle) and the other in the south. Due to their relative higher resistance to weathering, they generally form hilltops such as the summits of Jack Mountain and Horse Mountain. They are texturally and mineralogically quite homogeneous, being massive, holocrystalline, ophitic, and composed predominantly of plagioclase feldspar and augite with accessory minerals magnetite and ilmenite. Locally, as seen at Horse Mountain summit, the diabase can be vesicular, suggesting shallow subvolcanic emplacement. Most of the diabase have experienced hydrothermal alteration to produce chlorite, calcite, and opaque iron oxides. Based on geochemical analysis performed in this project, diabase probably shared the same magma source with the basalts.

Bedrock Geology of the Jack Mountain Quadrangle, Maine

Bedrock geologic mapping by
Chunzeng Wang

Digital cartography by
Amber T. H. Whittaker

Geologic editing by
Robert G. Marvinney

Cartographic design by
Christian H. Halsted

Robert G. Marvinney
State Geologist

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Maine Geological Survey

Address: 93 State House Station, Augusta, Maine 04333
Telephone: 207-287-2801 **E-mail:** mgs@maine.gov
Home page: www.maine.gov/dacf/mgs/

Open-File No. 19-6
2019

Photo 1: Argillaceous mudstone and siltstone of the Seboomook Group (**Ds**). View to the north. Note consistent bedding dipping gently to the east (right).

Photo 2: Gray and maroon cherty tuff and diabase clasts in the basal conglomerate member (**Dsc**) of the Seboomook Group.

Photo 3: Unnamed conglomerate (**Ouc**) with gray cherty tuff and basalt clasts.

Photo 4: Melange with intraclasts and phacoidal cleavage of the Chase Brook Formation (**Ocb**).

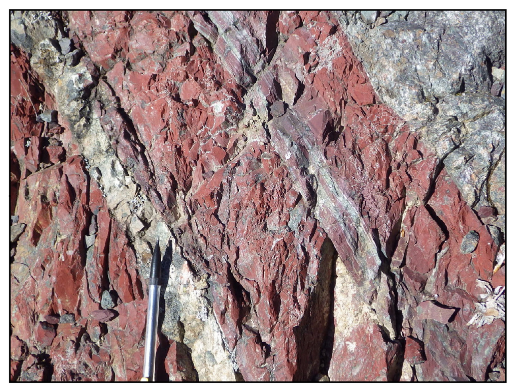

Photo 5: Alternating maroon and gray cherty tuff beds of the tuff member (**Omlt**) of the Munsungun Lake Formation.

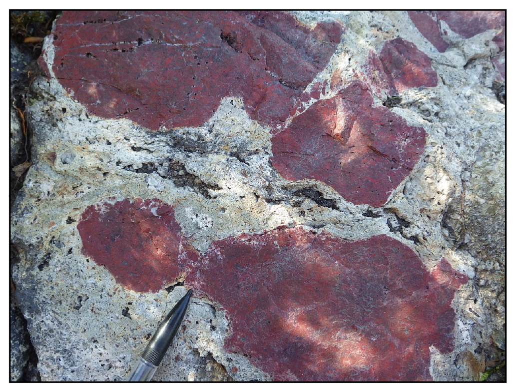

Photo 6: Lapilli breccia with large jasper blocks in the tuff member (**Omlt**) of the Munsungun Lake Formation, found in a fault sliver within the andesite member (**Omla**) of the Munsungun Lake Formation.

Photo 7: Spherulites in the vitric tuff member (**Omlvt**) of the Munsungun Lake Formation.

Photo 8: Basalt with pillow structure (**Omlb**) in the Munsungun Lake Formation.

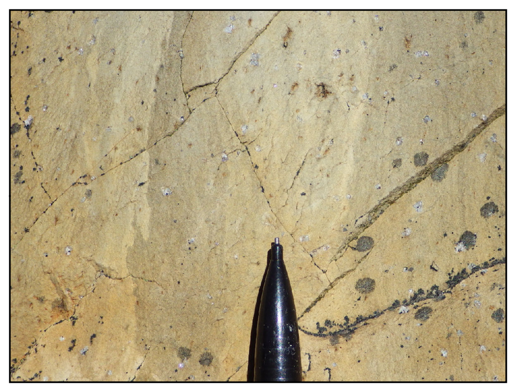

Photo 9: Quartz phenocrysts (white) in the dacite member (**Omld**) of the Munsungun Lake Formation. Gray ovals and streaks are staining on the outcrop surface.

GEOLOGIC TIME SCALE

Geologic Age	Absolute Age*
Cenozoic Era (Cz)	0-66
Mesozoic Era (Mz)	
Cretaceous Period (K)	66-145
Jurassic Period (J)	145-201
Triassic Period (Ꞧ)	201-252
Paleozoic Era (Pz)	
Permian Period (P)	252-299
Carboniferous Period (C)	299-359
Devonian Period (D)	359-419
Silurian Period (S)	419-444
Ordovician Period (O)	444-485
Cambrian Period (Ꞓ)	485-541
Precambrian time (pꞒ)	Older than 541

* 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.)

PLUTONIC ROCKS

Ordovician [O]

Ogb — **Gabbro.** Gabbro occurs as small plutonic intrusions within the volcanics and subvolcanics of the Munsungun Lake Formation. Seven of them were mapped in the quadrangle. The gabbro is dark gray, massive, and medium grained with a typical gabbroic (i.e. allotriomorphic-granular) texture. It consists predominantly of plagioclase and augite with accessory minerals magnetite and ilmenite. Most of the gabbro intrusions are hydrothermally altered, producing abundant chlorite, calcite, sericite, and iron oxides. The exception is the gabbro stock located near the southern border of the map and the headwater of the South Branch Machias River. This gabbro stock forms a hilltop and shows near intact original mineralogical composition of plagioclase and augite with little alteration. Based on its intrusive relation with the early Middle Ordovician Munsungun Lake Formation, its age is considered to be later than the Munsungun Lake but older than the postulated Late Ordovician conglomerate and graywacke units.

EXPLANATION OF LINES

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

D
U

High-angle fault, interpreted from truncation of units on the map or from disruption of stratigraphic sequence. Arrows indicate sense of strike-slip motion. D (down) and U (up) indicate sense of dip-slip motion (well located, approximately located, poorly located).

A A′

Line of cross section.

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.
- Float.
- 20 Bedding or contact between basalt flow and tuff, tops toward ball (inclined).
- 20 Foliation, metamorphic (inclined).
- 20 Fault (inclined, vertical).
- Fossil location.
- 1 Photo location.
- A Geochronology sample location (see **Table 1**).