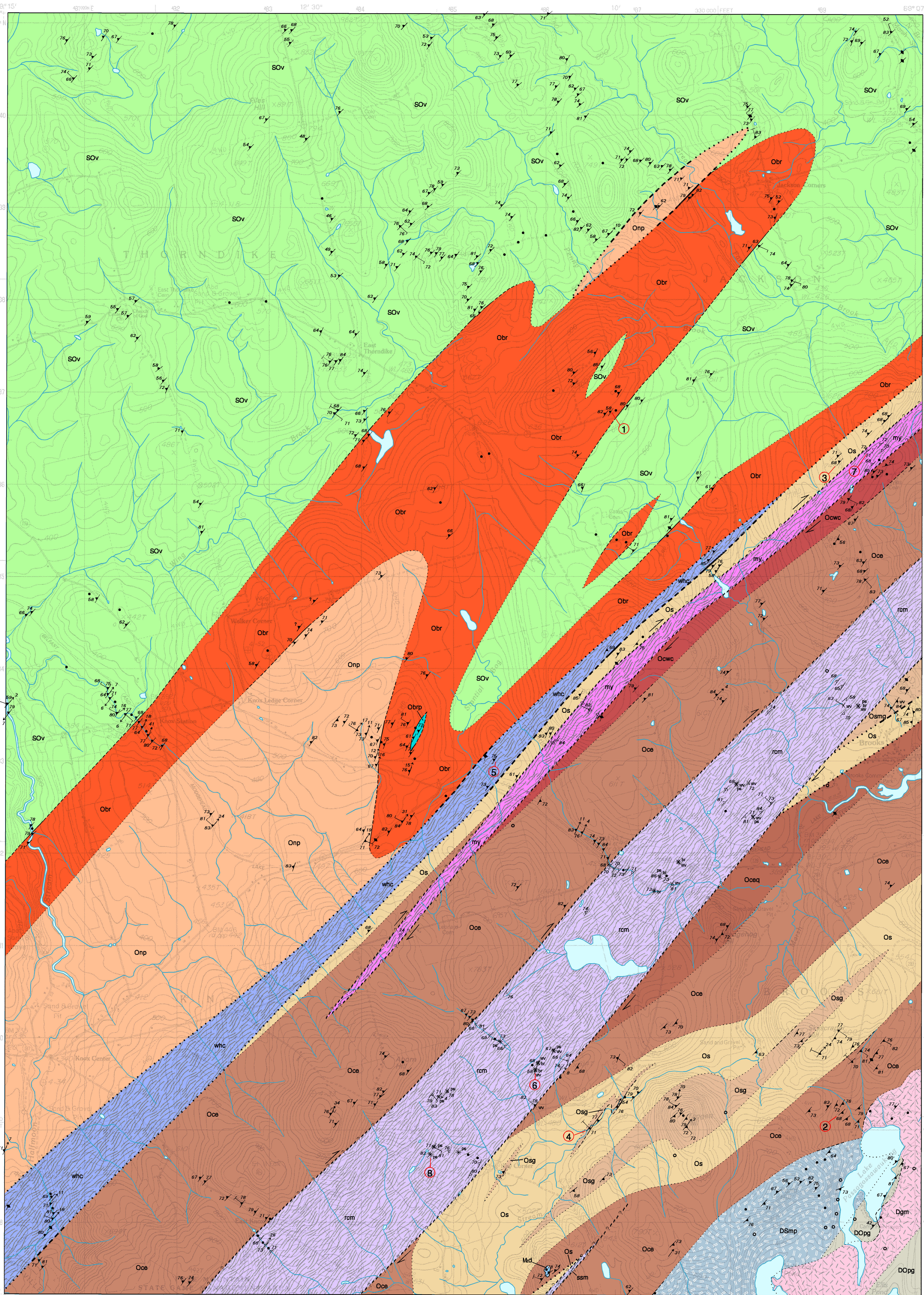

Quadrangle Location

SCALE 1 : 24,000

1 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 0 1 KILOMETER

CONTOUR INTERVAL 20 FEET

TRUE NORTH

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

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

Bedrock Geology of the Brooks West Quadrangle, Maine

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Funding for the preparation of this map was provided in part by the U.S. Geological Survey STATEMAP Program, Cooperative Agreements No. G12AC20185 and G13AC00117.

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Open-File Map 14-4
2014

This map supersedes Progress Map 13-15.

SUPERSEDED

EXPLANATION OF UNITS

INTRUSIVE ROCKS

Mesozoic (?)

Mzd — **Diabase.** Contacts with surrounding country rocks are not exposed. The only outcrops of this rock type are near the southern quadrangle boundary on the small hill approximately 1.3 kilometers southeast of Ray Corner.

Devonian (?)

Dgm — **Muscovite granite.** Light gray, fine-grained to medium-grained, foliated, garnet-bearing, muscovite ± biotite granite. Small outcrops of this unit can be found along the east-west road located just north of Lake Passagassawaukeag.

METAMORPHOSED INTRUSIVE ROCKS

Devonian-Silurian (?)

DSmp — **Mixer Pond Gneiss.** Medium gray, medium-grained to coarse-grained, strongly foliated, biotite granite. Locally, dikes and sills of light gray, medium-grained muscovite granite may be present. There are good exposures of this unit on the southeastern side of Pond Hill, west of Lake Passagassawaukeag.

STRATIFIED ROCKS

Vassalboro Group

Silurian-Ordovician (?)

SOv — **Undifferentiated.** Gray-weathering, medium gray, fine-grained plagioclase-quartz-biotite granofels interlayered with greenish gray, fine-grained, calc-silicate granofels and occasional layers of light gray, medium-grained, mica schist. Layers range in thickness from 2 to 10 cm. Calc-silicate granofels and mica schist are generally subordinate to the biotite granofels. Locally the granofels contains small amounts of free calcite. There are easily accessible exposures of this unit along Route 7 in small road cuts approximately 500 meters north of, and 1 kilometer south of Jackson Corners.

Falmouth-Brunswick Sequence

Ordovician

Obr — **Beaver Ridge Formation.** Moderately to deeply rusty-weathering, medium gray, medium-grained, sulfidic and locally graphitic and/or garnet-bearing, quartz-muscovite-plagioclase schist and granofels. Subordinate rock types include light gray, fine-grained, quartz-plagioclase-biotite granofels and gneiss, and rare impure marble. Accessible exposures are found in small road cuts west of Route 7 approximately 300 meters south of Jackson Corners.

Obrp — **Phyllite member.** Gray-weathering to moderately rusty-weathering, dark gray, fine-grained phyllite. Locally, thin layers (1-3 cm) of lighter colored, fine-grained, quartz-rich ± carbonate granofels are present. A well-developed crenulation cleavage is prominent in the phyllite.

Onp — **Nehumkeag Pond Formation.** Gray-weathering, medium gray, fine-grained to medium-grained plagioclase-quartz-biotite ± muscovite ± garnet gneiss. Subordinate rock types include dark gray amphibolite, and moderately rusty-weathering, quartz-plagioclase-biotite ± garnet schist and gneiss. The best exposures in the quadrangle are located along the powerline right-of-way, approximately 1.5 kilometers east of Knox Ledge Corner.

Casco Bay Group

Ordovician

Os — **Scarboro Formation.** Slightly to moderately rusty-weathering, medium gray, medium-grained, graphitic quartz-plagioclase-muscovite-biotite ± garnet schist. Discontinuous quartz segregations (2-8 cm thick) are common. Compositional layering is generally thin and discontinuous. An easily accessible exposure is a low road cut west of Route 7 in Jackson, 1.1 kilometers north of the Brooks town line.

Osg — **Granofels member.** Gray-weathering, medium gray, fine-grained plagioclase-quartz-biotite granofels interlayered with subordinate amounts of greenish gray, fine-grained, calc-silicate granofels and occasional layers of light gray, medium-grained, mica schist. Layering (2-8 cm thick) is prominent, and weathered exposures break into slabs. There are good exposures of this unit on Taggett Hill in the southeast portion of the quadrangle.

Osmg — **Mylonitic granofels member.** Medium gray to dark gray, fine-grained mylonitic to ultramylonitic gneiss that commonly is interlayered with medium gray, fine-grained biotite granofels with subordinate amounts of calc-silicate granofels and rusty-weathering phyllite. Thin (< 2 cm) discordant pseudotachylyte veins and/or zones of light gray lithified fault breccia and cataclasite are present locally. This unit is exposed in large road cuts on Route 7, approximately 800 meters north of Brooks village (Route 139 intersection).

Oce — **Cape Elizabeth Formation.** Light gray, medium-grained, quartz-plagioclase-muscovite-biotite ± garnet schist interlayered with light gray, fine-grained, micaeous quartz-plagioclase granofels. Layering of these rock types, generally 2 to 12 cm in thickness, is prominent in most exposures and contacts between schist and granofels are generally sharp. This unit is exposed in low outcrops along the west side of Route 7 approximately 2 km north of the Route 139 intersection at Brooks village.

Oceq — **Quartzite member.** Gray-weathering to moderately rusty-weathering, light gray, fine-grained to medium-grained, muscovite-biotite quartzite. Locally, layers of moderately rusty-weathering, medium gray, fine-grained phyllite are present. Representative outcrops of this unit are found on Hedgehog Hill in the southeastern part of the quadrangle.

Cushing Formation.

Ocwc — **Wilson Cove member.** Moderately to deeply rusty-weathering, medium to dark gray, fine-grained to medium-grained, sulfidic, quartz-muscovite ± biotite ± garnet schist and granofels. Thin layers (< 2 cm) of fine-grained, garnet-amphibole-rich granofels are present locally. The most accessible exposure in the quadrangle is a low road cut east of Route 7 in Jackson, approximately 600 meters north of the Brooks town line.

ROCKS OF COMPLEX ORIGIN

Devonian-Ordovician(?)

DOpg — **Passagassawaukeag Gneiss.** Interlayered light gray, medium-grained, gray-weathering, quartz-plagioclase-biotite ± muscovite ± sillimanite schist and gneiss and light gray, medium-grained, strongly foliated muscovite ± biotite granite to granite gneiss. Boudinage of the granitic rocks within the schist and gneiss is common, along with a strong degree of shearing within both rock types. The best exposures of this unit are in the southeast corner of the quadrangle, along the southeastern shore of Lake Passagassawaukeag.

HIGHLY DEFORMED ROCKS

whc — **Whitten Hill Complex.** A wide variety of generally fine-grained rock types is present over a relatively short distance across strike in Halfmoon Stream, in the southwest corner of the quadrangle. Rock types include light gray mica-bearing quartzite; light to medium gray calc-silicate granofels interlayered with subordinate amounts of biotite granofels; rusty-weathering, dark gray sulfidic granofels; and rare hornblende gneiss. Outcrop exposure to the northeast of this stream is inadequate to map these various rock types separately along strike. In the central and eastern portion of the quadrangle the unit is thinner and is dominated by deeply rusty-weathering, dark gray, sulfidic, graphitic, quartz-rich granofels and minor schist. The lithologic variability within this unit is displayed in outcrops along Halfmoon Stream. Outcrops of the rusty-weathering granofels in the central portion of the quadrangle are found near the Route 139 crossing of the Belfast and Moosehead Lake Railroad.

rcm — **Ray Corner mylonite.** This bedrock unit is a highly deformed structural complex, characterized by strongly sheared rocks which contain a steeply dipping mylonitic foliation. While there is lithologic variability, the most common rock type is a medium to dark gray, aphanitic to fine-grained, mylonitic gneiss. The very thin layering in the gneiss, defined by alternating shades of gray, typically ranges from 0.2 to 2 cm in thickness. Locally, the mylonite is cut by narrow veins of pseudotachylyte (< 2 cm), some of which are parallel to the mylonitic foliation, and some of which cut across it. In addition, some exposures are cut by complex networks of very thin (mostly < 3 mm) white, chalky-weathering veins that cut across all other structural fabrics. Locally, these veins are much thicker (up to 30 cm across) and represent a lithified fault breccia, containing abundant clasts of mylonite with no obvious preferred orientation. Rocks along the northwestern margin of this unit are protomylonitic and contain abundant muscovite fish that show a dextral or right-lateral sense of shear. Rocks along the southeastern margin of the unit are also protomylonitic, but have a different composition, often containing thin, fine-grained calc-silicate layers. There are accessible exposures of the unit in a series of low outcrops along the south side of County Road, approximately 500 meters west of Ray Corner.

ssm — **Sunny Side mylonite.** Thin zone of mylonite and ultramylonite mapped at the south edge of the quadrangle, inferred from mapping in the Morrill quadrangle (Pollock, 2010).

my — **Mylonite.** Light to medium gray, fine-grained to medium-grained, porphyroclastic mylonite. Porphyroclasts are most commonly feldspar, but carbonate-rich clasts are abundant locally. Layering in the mylonites, where present, is generally on the order of 0.2 to 2 cm in thickness. The mylonitic foliation is steeply dipping. Kinematic indicators consistently show a dextral or right-lateral sense of shear. These mylonites are coincident with the Hill 806 fault originally mapped by Pankiwskyj (1996). There are good exposures of this unit approximately 300 meters north-northwest of Styles Cemetery near the east edge of the map.

Photo 1. Rusty-weathering mica schist of the Beaver Ridge Formation (**Obr**). Hammer handle is about two feet (60 cm) long. *Large road cut in Jackson, approximately 2.8 kilometers east (S80E) of East Thorndike.*

Photo 2. Interlayered quartzite and mica schist of the Cape Elizabeth Formation (**Oce**) that has been folded, probably during the Acadian orogeny in Late Silurian-Devonian time. *Pavement outcrop approximately 300 meters northwest of Lake Passagassawaukeag, Brooks.*

Photo 3. Light gray quartz-mica schist of the Scarboro Formation (**Os**) with characteristic discontinuous quartz pods. The asymmetry of these quartz pods, all inclined toward the right, is consistent with dextral or right-lateral ductile deformation. *West side of Route 7, approximately 600 meters northwest of Styles Cemetery, Jackson.*

Photo 4. Interlayered biotite granofels and calc-silicate granofels of the granofels member of the Scarboro Formation (**Osg**). Natural weathering enhances the layering, typically producing a ribbed surface. *Stream exposure approximately 1.1 kilometer east-northeast (N70E) of Ray Corner.*

Photo 5. Extremely rusty-weathering, sulfidic, graphitic granofels is one of the rock types in the Whitten Hill Complex (**whc**). *Hillside outcrop along the powerline right of way approximately 500 meters south of Stantial Bog, northeast corner of Knox.*

Photo 6. Lithified fault breccia of the Ray Corner mylonite (**rcm**). The white veins formed by mineral deposition along brittle fractures. *Pavement outcrop approximately 1.1 kilometers north-northeast (N25E) of Ray Corner.*

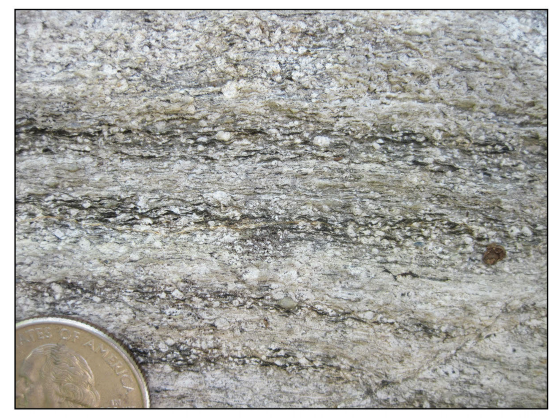

Photo 7. Porphyroclastic mylonite (**my**). The tiny white feldspar grains, called porphyroclasts, are remnants of larger grains that have been partly destroyed by ductile shearing of the rock during intense deformation. Most of the minerals in the rock have been reduced to microscopic bits, entrained in the intense foliation which trends left to right in this photo. Mylonite forms at depth, in rocks that are at elevated temperature and pressure in the earth. *Pavement outcrop approximately 300 meters northwest (N40W) of Styles Cemetery, Jackson.*

Photo 8. Fine-grained mylonitic gneiss of the Ray Corner mylonite (**rcm**) cut by light gray veins of pseudotachylyte. Sudden, brittle failure at depth in the earth can generate intense frictional heating which causes melting along the fault surface. The melt then invades any open fractures and solidifies instantly, producing a rock similar to volcanic glass, called pseudotachylyte. This is an indicator of ancient faulting that probably produced earthquakes. *Pavement outcrop approximately 700 meters west-northwest (N80W) of Ray Corner, Knox.*

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.

- Outcrop of mapped unit.
- Float, presumed to represent underlying bedrock.
- 20 — Foliation or schistosity (inclined, vertical).
- 20 — Mylonitic foliation (inclined, vertical).
- 20 20 — Hinge of fold (unknown rotation sense, clockwise rotation sense).
- 20 — Mineral lineation on foliation surface (plunging).
- 20 — Joint (inclined, vertical).
- wv — Occurrence of vein filled with white, fine-grained, chalky-weathering material; commonly northwest-trending.
- br — Occurrence of breccia or cataclasite.
- ps — Occurrence of pseudotachylyte.
- 4 — Photo location.

EXPLANATION OF LINES

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

? ?

Boundary of mylonitic shear zone. Arrows indicate sense of shear. May represent a fault or a high strain gradient (well located, approximately located).

High-angle fault, interpreted from truncation of units on the map or from disruption of stratigraphic sequence (well located, approximately located, poorly located).

GEOLOGY OF THE BROOKS WEST QUADRANGLE

THE BEDROCK MAP

On the geologic map, different bedrock units are indicated by colors and identified by letter abbreviations that represent their assigned geologic age and unit name, as given in the Explanation of Units. Bedrock exposures visited by the geologist are identified by various symbols plotted on the map (see Explanation of Symbols) and provide the basis for constructing the geologic map. In the Explanation of Units, specific outcrop localities are mentioned for some units; in addition, representative photographs of different rock types and notable features are provided. Note, however, that public access to these locations is not implied and any locations on private property require permission of the landowner before being visited. The following description summarizes the major rock types of each unit and gives a simplified geologic history by which they formed.

GEOGRAPHY

Physiographically, the Brooks West quadrangle is characterized by low, rolling hills with a total relief of 780 feet. Meandering streams with low gradients form a poorly organized dendritic drainage pattern with streams flowing both west and east from the quadrangle. The shapes of hills and ridges reflect two general trend directions: (1) northeasterly, parallel to the predominant strike direction of the bedrock units, such as the line of hills including Aborn Hill, and (2) south-southeasterly, parallel to the late Pleistocene glacial ice flow direction, such as Taggett Hill. Small bedrock outcrops are scattered through most of the area, but they are by no means continuous and thus provide an incomplete view of the complex bedrock geologic relationships. Most of the bedrock is covered by a thin veneer of unconsolidated glacial sediments, including till, gravel, and clay, and the interested reader is referred to the surficial geologic map of the quadrangle for that aspect of the geology (Thompson, 2014).

MAJOR ROCK TYPES

Bedrock in the Brooks West quadrangle is dominated by well-layered (stratified) metamorphosed sedimentary rock with lesser amounts of intrusive igneous rock. The intrusive rocks, restricted to the southeast corner of the quadrangle, consist of older deformed and metamorphosed granites of the Mixer Pond Gneiss (**DSmp**) well exposed on Pond Hill, and a younger granite body (**Dgm**) exposed north and east of Lake Passagassawaukeag. The layering in the stratified rocks strikes in a northeast-southwest direction, with the dip of the layers being near vertical in most locations. The stratified rocks can be divided into five general groups that are described here in geographic order from northwest to southeast across the map.

(1) The northwestern third of the quadrangle is underlain by a monotonous sequence of Late Ordovician to Early Silurian metamorphosed sandstones and minor shales of the Vassalboro Group (**SOv**). As a result of metamorphism, these rocks are now interlayered granofels and schist. Granofels is a hard, crystalline rock with a fine-grained, granular texture composed mostly of the minerals quartz, plagioclase feldspar, and biotite (black mica). Schist has a high proportion of parallel-aligned fine-grained micas and thus the rock typically splits into thin sheets. Outcrops of these rocks are generally low and weathered surfaces often appear ribbed.

(2) Immediately southeast of the Vassalboro Group in the west-central portion of the quadrangle are metamorphosed sedimentary and minor volcanic rocks of the Ordovician Falmouth-Brunswick sequence. The Nehumkeag Pond Formation (**Onp**) is dominated by gneiss, a type of rock that is characterized by alternating light and dark layers which likely represent metamorphosed volcanic ash or volcanically-derived sediment. The Beaver Ridge Formation (**Obr**) is distinctive deeply rusty-weathering schist that contains abundant fine-grained sulfide minerals (**Photo 1**). These formations of the Falmouth-Brunswick sequence are exposed continuously over a distance of nearly 150 kilometers from just north of Portland to the Brooks West quadrangle where their exposure at the surface ends in a series of plunging folds cut by faults.

(3) Rocks of the Casco Bay Group are exposed southeast of the Falmouth-Brunswick sequence and Vassalboro Group. The oldest of these rock units is the thin but distinctive Wilson Cove Member of the Cushing Formation (**Ocwc**). Some of these deeply rusty weathering rocks are very dense due to a concentration of iron- and manganese-bearing minerals. The Cape Elizabeth Formation (**Oce**) underlies much of the central portion of the quadrangle and consists of metamorphosed Ordovician sandstones and shales. These rocks are now interlayered light gray mica schist and quartzite (**Photo 2**). The Scarboro Formation (**Os**) is dominated by metamorphosed shale, now quartz-mica schist, that contains numerous light gray to white quartz pods (**Photo 3**). A subunit of the Scarboro Formation (**Osg**) consists of interlayered gray (biotitic) and light green (calcium-silicate) granofels (**Photo 4**).

(4) Along the northwestern margin of the Casco Bay Group (**whc**), and in two belts within the Casco Bay Group (**rcm, my**) are three northeast-trending belts of highly deformed rocks. The Whitten Hill Complex (**whc**) contains a wide range of fine-grained rock types in the southwestern corner of the quadrangle, and is dominated by very rusty-weathering granofels and minor schist in the central and eastern portions of the map (**Photo 5**). The Ray Corner mylonite (**rcm**) and unnamed mylonite (**my**) are dominated by fine-grained rocks called mylonite (**Photos 6** and **7**). Mylonite is interpreted to have formed by intense deformation of rock during shearing along fault zones at depth that were active, in this case, hundreds of millions of years ago. In addition to mylonites, the Ray Corner mylonite zone locally contains thin veins of a very fine-grained rock called pseudotachylyte (**Photo 8**) that is interpreted to represent solidified veins of melt produced by frictional heating during sudden motion along fault surfaces. The two mylonite zones within the Casco Bay Group (**rcm**, **my**) are part of the Norumbega fault system, a likely ancient analog to the presently active San Andreas fault system in California.

(5) In the southeastern portion of the quadrangle along the eastern shores of Lake Passagassawaukeag are several small exposures of higher grade metamorphic rocks of the Passagassawaukeag Gneiss (**DOpg**). These rocks are exposed more extensively in neighboring quadrangles to the east (Brooks East), south (Morrill), and southeast (Belfast); those interested in this rock unit should refer to those areas for more details (Pollock, 2010; 2012).

DEFORMATION, METAMORPHISM, AND FAULTING

While the stratified rock units described above were originally deposited in horizontal layers parallel to the Earth's surface in Ordovician to Early Silurian time, they were subsequently compressed into nearly vertical folds during a period of major Appalachian mountain-building known as the Acadian orogeny in Late Silurian-Devonian time. During this orogeny the rocks were buried several miles beneath the surface and heated to pressures and temperatures which transformed the sedimentary and igneous rocks into the metamorphic rocks we now see at the surface. Sandstones were transformed into granofels and quartzite, shales into schist and phyllite, and volcanic ashes and volcanically-derived sediments into gneiss. The deep burial and associated crustal thickening associated with the Acadian orogeny also resulted in the melting of rock and production of magma at depth. This magma invaded the stratified rocks both immediately prior to the dominant phase of deformation (**DSmp**) and after it (**Dgm**), producing rocks now found in the southeastern portion of the quadrangle.

The early stages of the Acadian orogeny likely involved dominantly head-on collision of crustal plates that resulted in the compressional rock deformation, metamorphism, and igneous activity described above. During later stages of this mountain-building, the movement of land masses transitioned into more longitudinal motion and a major strike-slip fault system called the Norumbega fault system developed. Because the presently exposed rocks had been partially exhumed due to uplift and erosion, the deformation became more localized and is now represented by the relatively narrow belts of highly deformed rock found in the mylonites zones (**rcm**, **my**). The extreme deformation and range of fault rock types found in these zones reflect countless numbers of earthquakes that occurred hundreds of millions of years ago within the roots of a major San Andreas-like fault system.

Following the localized strike-slip faulting, the region entered a long period (hundreds of millions of years) of slow, but steady uplift and erosion. This eventually exposed at the present day surface rocks that were once several miles beneath the surface. The modern landscape of the Brooks West quadrangle is ultimately controlled by the uneven erosion of the various rock types that underlie the region. The most recent significant landscape erosion occurred during the Pleistocene Epoch, when advancing continental ice sheets sculpted the surface. The last glacial advance was in a south-southeast direction, imparting a streamlined shape to much of the area and depositing the thin veneer of unconsolidated sediments that covers most of the bedrock in the quadrangle.

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GEOLOGIC TIME SCALE

Geologic Age		Absolute Age*
Cenozoic Era		0-66
Mesozoic Era		66-252
Paleozoic Era	Permian Period	252-299
	Carboniferous Period	299-359
	Devonian Period	359-419
	Silurian Period	419-444
	Ordovician Period	444-485
	Cambrian Period	485-541
Precambrian time		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.)