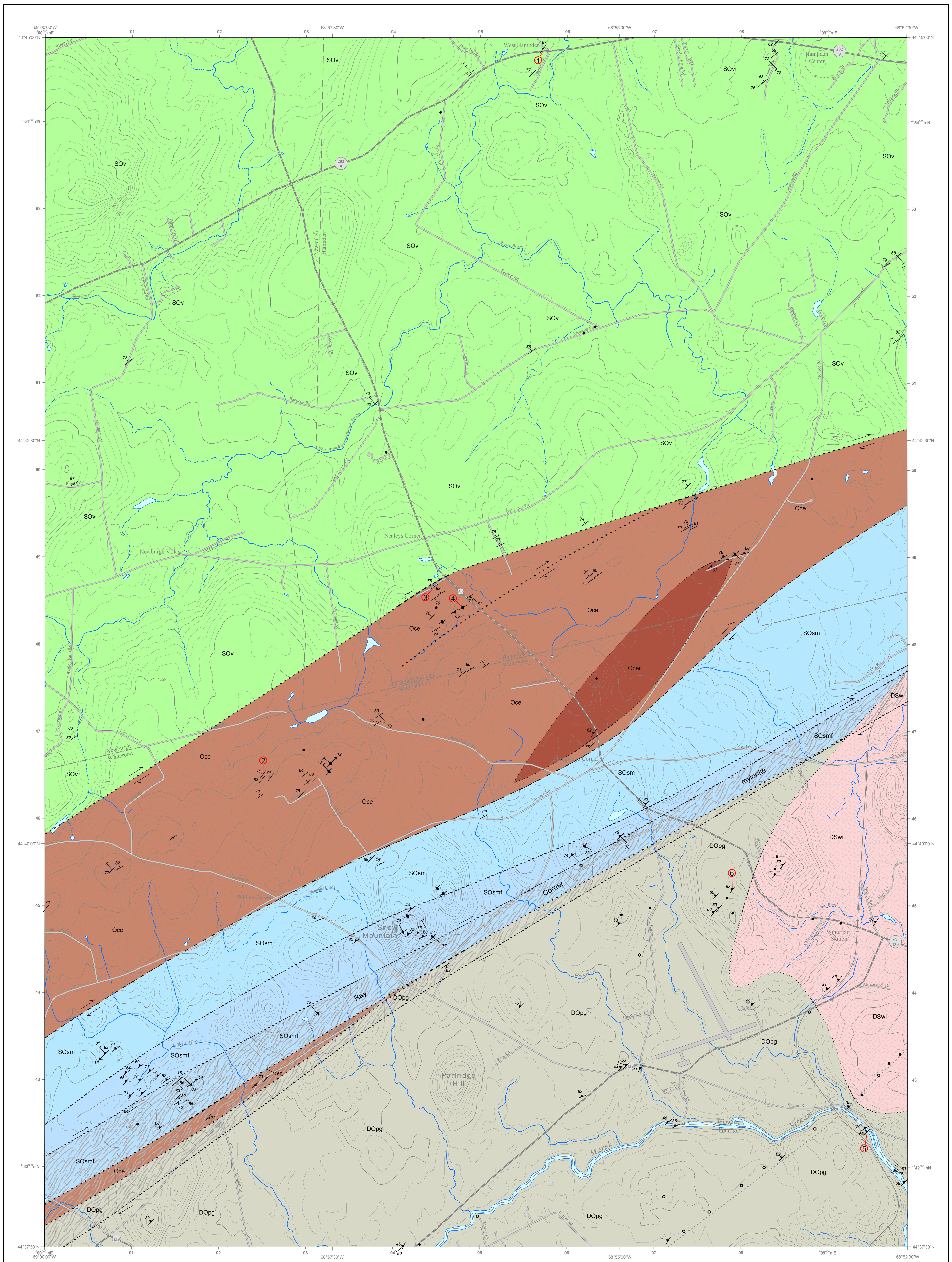
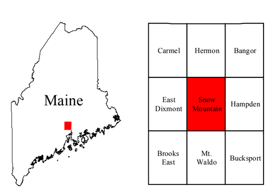


SOURCE OF GEOLOGIC INFORMATION

Field work by David P. West, Jr., 2014.



SCALE 1:24,000

CONTOUR INTERVAL 20 FEET

Approximate Mean Declination, 2016
16° 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. 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.

Bedrock Geology of the Snow Mountain Quadrangle, Maine

Bedrock geologic mapping by
David P. West, Jr.

Digital cartography by
Amber T. H. Whittaker
Susan S. Tolman

Geologic editing by
Henry N. Berry IV

Cartographic design by
Christian H. Halsted

Robert G. Marvinney
State Geologist

Funding for the preparation of this map was provided in part by the U.S. Geological Survey STATEMAP Program, Cooperative Agreement No. G14AC00163.

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. 16-26
2016

This map supersedes Open-File Map 15-26.

GEOLOGY OF THE SNOW MOUNTAIN QUADRANGLE

THE BEDROCK MAP

On the geologic map, different bedrock units are indicated by colors and identified by letter abbreviations that represent their assigned 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. Small bedrock outcrops are scattered through most of the area, but they are by no means continuous and thus do not provide a complete view of the complex bedrock geologic relationships. The following description summarizes the major rock types of each unit and gives a simplified geologic history by which they formed.

GEOGRAPHY

Physiographically, the Snow Mountain quadrangle is characterized by low, rolling hills with a total relief of 640 feet. Meandering streams with low gradients form a poorly organized dendritic drainage pattern with streams flowing both north and south from the quadrangle. Hilltops in the quadrangle trend in two general directions: (1) northeasterly, parallel to the predominant strike direction of the bedrock units, such as the line of hills north of Whites Corner, and (2) south-southeasterly, parallel to the late Pleistocene glacial ice flow direction, such as Partridge Hill.

MAJOR ROCK TYPES

Bedrock in the Snow Mountain quadrangle is dominated by well-layered (stratified) metamorphosed sedimentary rock with lesser amounts of intrusive igneous rock. The intrusive rocks, restricted to the southeastern portion of the quadrangle, consist of a single rather poorly exposed granite body, the Winterport Granite (**DSwi**). 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 half of the quadrangle is underlain by a monotonous sequence of Late Ordovician(?) to Early Silurian weakly metamorphosed sandstones, siltstones, and minor shales of the Vassalboro Group (**SOv**). As a result of metamorphism, the sandstones and siltstones are a greenish gray color with a fine-grained granular texture composed mostly of the minerals quartz, plagioclase feldspar, chlorite, and calcite (Photo 1). The metamorphosed shales are darker gray in color and have a fine-grained platy texture (phyllitic) due to a high proportion of parallel-aligned fine-grained micas. Outcrops of these rocks are generally low and weathered surfaces are light gray in color and often appear ribbed.

(2) Immediately southeast of the Vassalboro Group rocks in a belt extending across the quadrangle are metamorphosed sedimentary rocks of the Ordovician Cape Elizabeth Formation (**Oce**). This unit is composed of well-bedded **quartzite** (metamorphosed sandstone) and **phyllite** (metamorphosed shale). The contacts between the two rock types are generally sharp and abrupt (Photos 2 and 3). A unit within the Cape Elizabeth Formation (**Ocer**) contains deeply rusty-weathering phyllite that contains dispersed very fine-grained iron sulfide minerals.

(3) Southeast of the Cape Elizabeth Formation in the central portion of the quadrangle is a thin belt (approximately 500 meters wide) of the Snow Mountain Formation (**SOsm**). Owing to a slightly higher intensity of metamorphism, these rocks appear darker in color than the Vassalboro Group rocks exposed in the northern half of the quadrangle. This darker color is due to the presence of fine-grained biotite (black mica). The Vassalboro Group rocks in the northwestern half of the quadrangle contain an abundance of the green mineral chlorite and lack biotite.

(4) Along the southeastern margin of the Snow Mountain Formation is a narrow belt of highly deformed, fine-grained, dark colored rocks of the Ray Corner mylonite. The mylonite zone is superimposed on different rock units, producing a variety of mylonitic rock types. **Mylonite** is interpreted to have formed by intense deformation of rock at depth in the earth during shearing along fault zones that were active, in this case, hundreds of millions of years ago. This particular ancient fault zone can be traced continuously to the southwest for over 14 miles (West, 2016) and to the northeast for over 9 miles (West and Pollock, 2016; Pollock and West, 2016). Other contacts between rock units in the quadrangle, for example between the Vassalboro Group and Cape Elizabeth Formation, are also interpreted to represent ancient faults (Photo 4), but in these cases mylonite is not so extensive. All of these faults are part of the Norumbega fault system, an ancient fault system similar in some ways to the modern San Andreas fault system in California.

(5) Underlying the generally subdued topography of the southeastern quarter of the quadrangle are significantly higher grade metamorphic rocks of the Passagassawakeag Gneiss (**DOpg**). **Gneiss** is a type of rock that is characterized by alternating light and dark layers that, in this case, represents alternating layers of highly metamorphosed sediment and thin discontinuous lenses and layers of granite (Photos 5 and 6). The presence of the fine-grained fibrous mineral sillimanite in some of these gneisses attests to the higher temperatures these rocks experienced.

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 to Devonian time. During this orogeny the rocks were buried several miles beneath the surface and subjected to elevated temperatures and pressures which transformed the sedimentary rocks into the metamorphic rocks we now see at the surface. The Passagassawakeag Gneiss (**DOpg**), currently exposed in the southeastern part of the quadrangle, was heated high enough that the rock began to melt in places. The small amounts of melt collected in layers and patches in the rock and crystallized to form **migmatite**, a rock type prevalent in this unit. Presence of the mineral sillimanite indicates the high grade of metamorphism (upper amphibolite facies). Rocks to the northwest are at significantly lower metamorphic grade (greenschist facies); migmatite and sillimanite are absent. Burial associated with crustal thickening resulted in significant melting at depth, generating large bodies of magma that crystallized to form **granite**, such as the large body that intrudes the Passagassawakeag Gneiss in the southeast corner of the quadrangle (**DSwi**).

During the main stages of deformation, metamorphism, and igneous activity of the Acadian orogeny, regional stress was dominantly compressional, likely a result of head-on convergence of tectonic plates of the earth's crust. During late-Acadian and post-Acadian stages in Late Devonian to Permian time, the movement of land masses became more oblique which generated a major right-lateral strike-slip fault system called the Norumbega fault system (Ludman and West, 1999). By this time, the rocks had been partially exhumed to lower pressure and temperature, so the deformation became more localized into narrow zones such as the Ray Corner mylonite and the numerous faults that juxtapose different stratigraphic units and rocks of different metamorphic grade. The process of faulting and mylonite formation in the roots of a major system undoubtedly was accompanied by countless earthquakes, a situation geologically similar to that of the modern San Andreas fault system, but hundreds of millions of years older and long since extinct.

EVOLUTION OF THE MODERN LANDSCAPE

After strike-slip faulting, the region entered a long period (hundreds of millions of years) of gradual uplift and erosion which eventually exposed at the present surface rocks that once were miles deep. The modern landscape of the Snow Mountain quadrangle is ultimately controlled by the uneven resistance to erosion of the various underlying bedrock types. The most recent significant landscape erosion occurred during the Pleistocene Epoch, when advancing continental ice sheets shaped the surface. The south-southeast movement of the glacier imparted a streamlined form to the landscape. Melting of the ice and subsequent marine flooding left a thin veneer of unconsolidated sediments over much of the bedrock (Kelley and Caron, 2013).

Photo 1. View towards the northeast of steeply inclined beds of greenish gray metamorphosed siltstone of the Vassalboro Group (**SOv**). These rocks originated as fine-grained marine sediments deposited in horizontal layers during Late Ordovician(?) to Silurian time. These sediments were then lithified during burial beneath younger sediments and subsequently folded and metamorphosed during the Late Silurian-Early Devonian Acadian orogeny. *Road cut on the north side of Route 9/202 in West Hampden, 0.5 miles west of the intersection with Canaan Road.*

Photo 2. Oblique view of a horizontal pavement outcrop of of light gray feldspathic quartzite interbedded with reddish brown fine-grained mica schist and phyllite of the Cape Elizabeth Formation (**Oce**). Bedding is nearly vertical. *Approximately 0.9 miles north of Whites Corner, Winterport.*

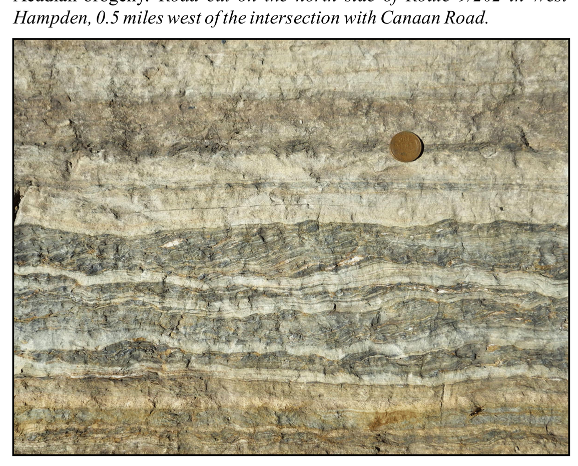


Photo 3. View looking down on a horizontal pavement outcrop of interbedded light gray feldspathic quartzite and darker gray phyllite of the Cape Elizabeth Formation (**Oce**). Bedding is nearly vertical. The wavy pattern prominent in the phyllite is caused by the right-lateral shear bands which formed during deformation of the rock. *Approximately 2000 feet south of Nealeys Corner, Hampden.*

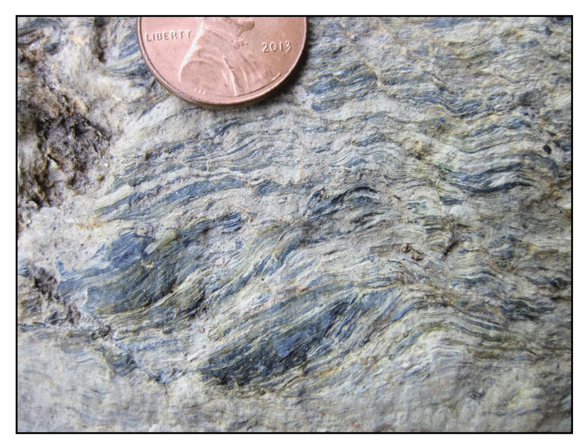


Photo 4. Close up view of nearly vertically dipping mylonitic rocks within the Cape Elizabeth Formation (**Oce**). The dark colored mica-rich segregations in this rock, inclined towards the right, have an asymmetry that is consistent with dextral or right-lateral ductile shear deformation. In contrast to this example, most of the mylonitic rocks in the Snow Mountain quadrangle in the Ray Corner mylonite are very fine-grained and require microscopic investigation to identify the minerals and microstructural features. *Approximately 3000 feet south-southeast of Nealeys Corner, Hampden.*

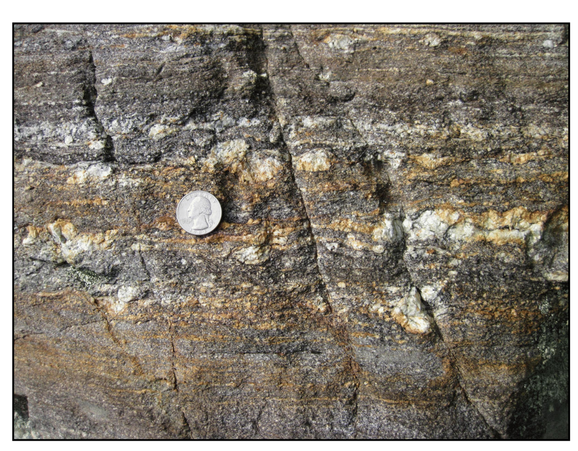


Photo 5. View looking down on a horizontal pavement outcrop of steeply dipping sillimanite-bearing, migmatitic gneiss of the Passagassawakeag Gneiss (**DOpg**). Rocks within this unit have been subjected to metamorphism of a much higher intensity than have rocks to the northwest. *Along Marsh Stream approximately 1200 feet downstream of the powerline crossing in the southeastern portion of the quadrangle, on the Frankfort-Winterport town line.*

Photo 6. Close-up view looking down on a horizontal pavement outcrop of steeply dipping migmatitic gneiss of the Passagassawakeag Gneiss (**DOpg**). Structural features in this rock indicate two episodes of tectonic deformation. An earlier episode of tight folding can be seen on the left side of the photo. These folds are cut by a later dextral shear band, just to the right of the penny and running diagonally down to the right. *Approximately 0.9 miles west-northwest of Winterport Station.*

EXPLANATION OF UNITS

INTRUSIVE ROCKS

Devonian-Silurian(?) [DS]

DSwi — **Winterport Granite.** Light gray, fine-grained to medium-grained, weakly to moderately foliated biotite granite. Locally, layers of biotite felsic gneiss are common, and dikes and sills of coarse-grained, unfoliated, biotite granite are also present in some exposures. Small outcrops of this unit can be found in low outcrops along the south side of Route 69 just west of Winterport Station.

STRATIFIED ROCKS

Silurian-Ordovician(?) [SO]

SOv — **Vassalboro Group, undifferentiated.** Greenish gray, fine-grained, calcareous meta-siltstone or quartz-rich meta-wacke interbedded with subordinate amounts of medium to dark gray phyllite (Photo 1). Bed thickness varies considerably, ranging from 5 to 10 centimeters (cm) in some areas, to nearly 75 cm in others. This unit underlies a wide belt in the northwestern portion of the quadrangle that was not subdivided in the Snow Mountain quadrangle, although it was divided into formations in the Hampden and Bangor quadrangles to the northeast and the East Dixmont quadrangle to the west (Pollock, 2011; West and Pollock, 2016; Pollock, 2016). Large road cuts of this unit can be found in the northeast corner of the quadrangle approximately 0.6 kilometers west of Hampden Center along Johns Way south of its intersection with Route 9/202.

SOsm — **Snow Mountain Formation** (West, 2015). Medium gray, fine-grained to medium-grained, calcareous plagioclase-quartz-biotite granofels interbedded with dark gray phyllite. Beds range from 2 to 12 cm in thickness with phyllite beds typically subordinate to and thinner than granofels beds. There is an accessible exposure of this rock type in a road cut on the east side of Route 69 approximately 700 meters southeast of Ellingwood Corner, Winterport.

Regional correlation of the Snow Mountain Formation is uncertain. Trefethen (1950) included these rocks, among others, in an informal unit he called the Ellingwood shale member of the Bucksport Formation. Osberg and others (1985) showed them as Bucksport Fm. Alternatively, Wones (1991) assigned them to the Vassalboro Fm. In either case, the Snow Mountain Formation would be Silurian and be in fault contact with the Cape Elizabeth. In the East Dixmont quadrangle, Pollock (2016) makes the argument that the Snow Mountain could be a member of the Cape Elizabeth Formation, in which case the Snow Mountain would be Ordovician and in stratigraphic contact with the Cape Elizabeth.

SOsmf — **Fine-grained member.** Dark gray, fine-grained, calcareous plagioclase-quartz-biotite granofels interlayered with subordinate amounts of dark gray phyllite. Granofels layers are typically darker in color, finer-grained, and more flinty than those of the Snow Mountain Formation proper. Foliation surfaces of freshly broken phyllites commonly exhibit a polished appearance. This member is tentatively interpreted to represent a more intensely deformed variety of the Snow Mountain Formation. The northwestern boundary, based on a combination of preliminary field observations, is not well defined. There appears to be a general increase in intensity of deformation from the Snow Mountain Formation (**SOsm**) southeastward into the Ray Corner mylonite. This unit is well exposed on Snow Mountain.

Ordovician [O]

Casco Bay Group

Oce — **Cape Elizabeth Formation.** Medium gray, fine-grained, quartz-plagioclase-muscovite phyllite interbedded with light gray, fine-grained, micaceous, quartz-plagioclase granofels. Layering of these rock types, generally 3 to 15 cm in thickness, is prominent in most exposures and contacts between phyllite and granofels are generally sharp (Photos 2 and 3). Accessible exposures of this unit are found in abundant low outcrops in the blueberry field on the hill about 1.5 kilometers north-northeast of Whites Corner, Winterport.

Ocer — **Rusty-weathering phyllite member.** Deeply rusty-weathering, medium gray, fine-grained, sulfidic, graphitic, quartz-muscovite-plagioclase phyllite and granofels.

ROCKS OF COMPLEX ORIGIN

Devonian-Ordovician(?) [DO]

DOpg — **Passagassawakeag Gneiss.** Light gray, medium-grained, gray-weathering quartz-plagioclase-biotite ± muscovite ± sillimanite gneiss and schist interlayered with light gray, medium-grained, biotite ± muscovite granite gneiss (Photos 5 and 6). Boudinage of the deformed 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 low outcrops along Marsh Stream downstream of the railroad crossing in the extreme southeastern portion of the quadrangle.

EXPLANATION OF PATTERNS

Ray Corner mylonite. A zone of intense deformation, characterized by strongly sheared, fine-grained rocks that contain a steeply dipping mylonitic foliation. This structural zone overprints the southeastern portion of the Snow Mountain Formation, and adjacent parts of the Cape Elizabeth Formation, Passagassawakeag Gneiss, and Winterport Granite. The deformation has different character depending on the type of rock affected. The most common rock type, probably derived from the Snow Mountain Formation, is a medium to dark gray, fine-grained to aphanitic, weakly to moderately calcareous, flinty mylonite to ultramylonite. Layering, where visible, is defined by alternating shades of gray and typically ranges from 0.2 to 5 cm thick. Locally, the mylonite is cut by thin pseudotachylyte veins less than 1 cm thick, or zones of lithified fault breccia up to 10 cm thick. Sheared schist of the Cape Elizabeth Formation and foliated gneiss of the Passagassawakeag are also included in this zone. Toward the east, in the neighboring Hampden quadrangle, this mylonite zone is hosted mainly along the northwest margin of the Winterport Granite (West and Pollock, 2016). Except for a series of outcrops southwest of Littlefield Brook, this mylonite zone is poorly exposed in the Snow Mountain quadrangle, and the overgrown woods exposures make mapping of these dark colored, fine-grained rocks difficult in this quadrangle. More accessible exposures are present along strike to the southwest in the Brooks East (Pollock, in press) and Brooks West (West, 2014) quadrangles.

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 may contain additional information that is not displayed on this map.

- Outcrop of mapped unit.
- Float, presumed to represent underlying bedrock.
- 20 — Bedding, tops undetermined (inclined, vertical).
- 20 — Metamorphic foliation (inclined, vertical).
- 20 — Lineation (plunging).
- 20 — Mylonitic foliation (inclined, vertical).
- 20 — Joint (inclined, vertical).
- 1 — Photo location.

EXPLANATION OF LINES

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

Contact of uncertain origin. May represent a stratigraphic contact or a fault. Arrows indicate sense of shear.

Structural boundary between more deformed and less deformed rocks. Arrows indicate sense of shear. May be a sharp or gradational boundary.

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

GEOLOGIC TIME SCALE

Geologic Age		Absolute Age*
Cenozoic Era (Cz)		0-66
Mesozoic Era (Mz)		66-252
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 (Є)	485-541
Precambrian time (pЄ)		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.)

REFERENCES

Kelley, Alice R., and Caron, Lynn, 2013, Surficial geology of the Snow Mountain quadrangle, Maine: Maine Geological Survey, Open-File Map 13-3, scale 1:24,000.

Ludman, Allan, and West, David P., Jr. (editors), 1999, The Norumbega Fault System of the Northern Appalachians: Geological Society of America, Special Paper 331, 202 p.

Osberg, Philip H., Hussey, Arthur M., II, and Boone, Gary M. (editors), 1985, Bedrock geologic map of Maine: Maine Geological Survey, scale 1:500,000.

Pollock, Stephen G., 2016, Bedrock geology of the southeastern half of the East Dixmont quadrangle, Maine: Maine Geological Survey, Open-File Map 16-11, scale 1:24,000.

Pollock, Stephen G., in press, Bedrock geology of the Brooks East quadrangle, Maine: Maine Geological Survey, scale 1:24,000.

Pollock, Stephen G., 2011, Bedrock geology of the Bangor quadrangle, Maine: Maine Geological Survey, Open-File Map 11-57, scale 1:24,000.

Pollock, Stephen G., and West, David P., Jr., 2016, Bedrock geology of the Brewer Lake quadrangle, Maine: Maine Geological Survey, Open-File Map 16-9, scale 1:24,000.

Trefethen, Joseph M., 1950, Bucksport - Orland map area: New England Intercollegiate Geological Conference, 42nd Annual Meeting, Bangor, Maine, 3p., schematic cross-section, geologic map, scale 1:62,500.

West, David P., Jr., 2014, Bedrock geology of the Brooks West quadrangle, Maine: Maine Geological Survey, Open-File Map 14-4, scale 1:24,000.

West, David P., Jr., 2015, Bedrock geology of the Snow Mountain quadrangle, Maine: Maine Geological Survey, Open-File Map 15-26, scale 1:24,000.

West, David P., Jr., and Pollock, Stephen G., 2016, Bedrock geology of the Hampden quadrangle, Maine: Maine Geological Survey, Open-File Map 16-10, scale 1:24,000.

Wones, David R., 1991, Bedrock geologic map of the Bucksport [15-minute] quadrangle, Waldo, Hancock, and Penobscot Counties, Maine: U. S. Geological Survey, Geologic Quadrangle Map GQ-1692, scale 1:62,500.