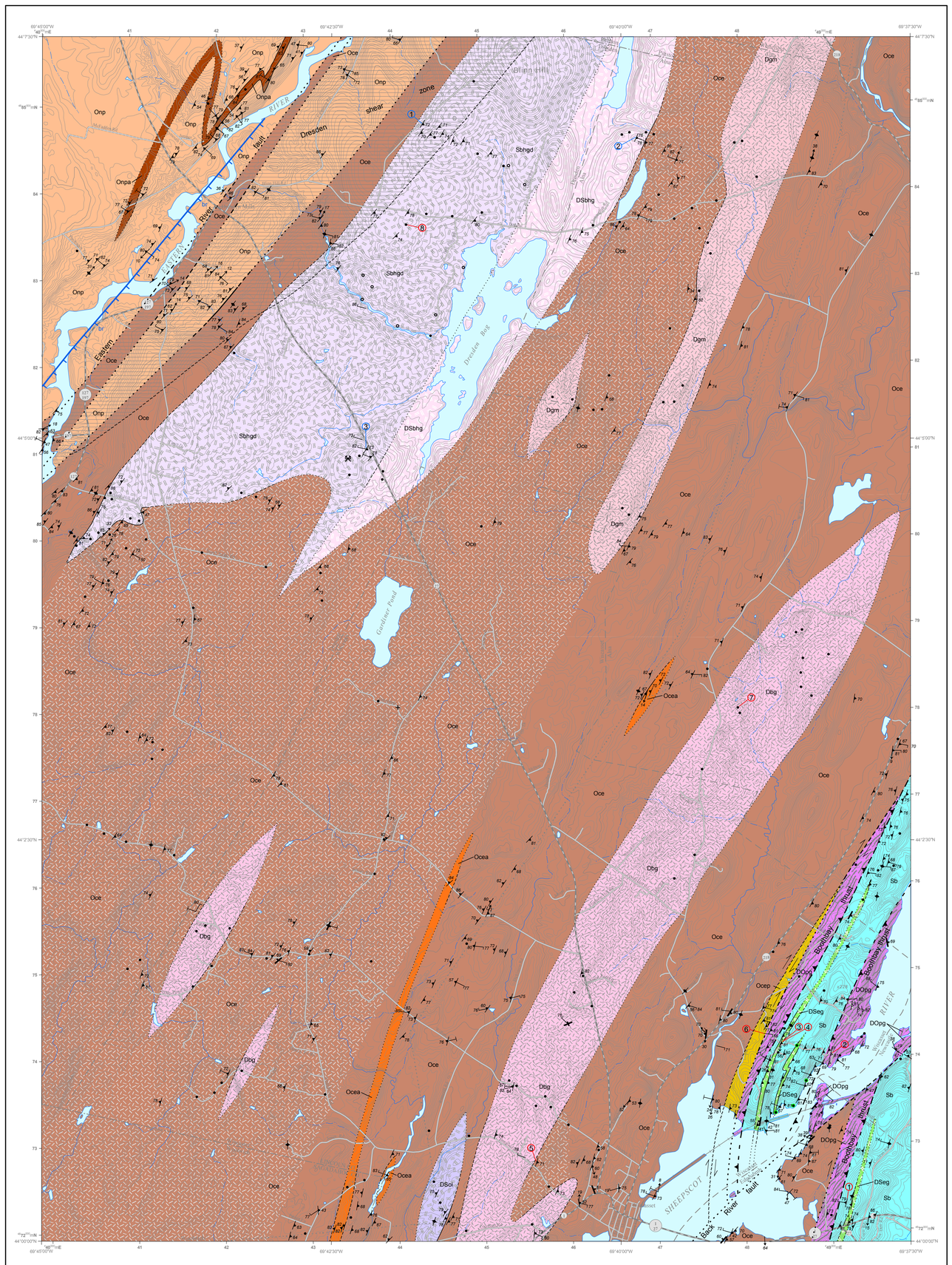

SOURCES OF GEOLOGIC INFORMATION

Field work by David P. West, Jr., 2010 and 2015, and published reconnaissance map by Donald W. Newberg, 1992.

SCALE 1:24,000

1 0.5 0 1 Mile

1000 0 1000 2000 3000 4000 5000 6000 7000 Feet

1 0.5 0 1 Kilometer

CONTOUR INTERVAL 10 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.

EXPLANATION OF UNITS

INTRUSIVE ROCKS

Devonian(?) [D]

Dgm — **Muscovite granite.** Light gray to white, medium-grained to pegmatitic, non-foliated to moderately foliated, muscovite ± garnet ± biotite granite. In addition to mapped bodies, this rock type also occurs as abundant small, unmapped bodies intruding the Cape Elizabeth Formation (**Oce**) in the patterned area shown on the map as migmatitic rocks.

Dbg — **Biotite granite.** Light gray, medium-grained to pegmatitic, non-foliated biotite ± muscovite granite. In addition to mapped bodies, this rock type also occurs as abundant small, unmapped bodies intruding the Cape Elizabeth Formation (**Oce**) in the patterned area shown on the map as migmatitic rocks.

METAMORPHOSED INTRUSIVE ROCKS

Devonian-Silurian(?) [DS]

DSeg — **Edgecomb Gneiss.** Medium to dark gray, medium-grained to coarse-grained, porphyroblastic, plagioclase-K-feldspar-biotite-quartz-hornblende ± clinopyroxene gneiss (Photo 3). The rock is characterized by large K-feldspar and plagioclase minerals set in a matrix of quartz, plagioclase, biotite and hornblende. Light gray to white layers, up to 15 centimeters (cm) thick, lacking biotite and hornblende are commonly present (Photo 4). In addition to mapped units, the Edgecomb Gneiss occurs in thin layers less than 50 meters (m) thick, indicated on the map by a symbol. This rock unit is interpreted to represent a deformed and metamorphosed intrusion of intermediate composition, such as diorite to granodiorite.

DSoi — **Oak Island Gneiss.** Light to medium gray, medium-grained, strongly foliated and locally lineated, biotite-quartz-plagioclase-K-feldspar gneiss. Weakly foliated to non-foliated granite and granite pegmatite are also present.

Devonian-Silurian [DS] *and Silurian* [S]

Blinn Hill pluton.

DSbhg — **Foliated muscovite-biotite granite.** Light gray, medium-grained, moderately to strongly foliated, biotite-muscovite ± garnet ± tourmaline granite.

Sbhgd — **Biotite granodiorite.** *Outside the Dresden shear zone:* Medium gray, medium-grained to coarse-grained, foliated, porphyritic, biotite ± hornblende granodiorite. Variably foliated pegmatite dikes and sills are locally abundant (Photo 8). *Within the Dresden shear zone:* Medium to dark gray, porphyroclastic, biotite granodiorite containing a steeply dipping mylonitic foliation. Thin sections show a thoroughly recrystallized, very fine-grained matrix of quartz, biotite, and epidote, which anastomoses around strongly aligned feldspar porphyroclasts. Both mesoscopic and microscopic kinematic indicators show a dextral sense of shear.

STRATIFIED ROCKS

Silurian(?) [S]

Kingsclear Group

Sb — **Bucksport Formation.** Light gray, fine-grained to medium-grained, quartz-plagioclase-biotite granofels interlayered with greenish-gray, fine-grained, plagioclase-quartz-actinolite-diopside (calc-silicate) granofels. Layers range in thickness from 3 to 12 cm. Rare layers of rusty-weathering, medium-grained biotite schist are present. The unit is characterized by the distinct and sharp compositional layering of biotite granofels and calc-silicate granofels which when weathered forms distinctive ribbed outcrop surfaces (Photo 1).

Ordovician [O]

Falmouth-Brunswick Group

Onp — **Nehumkeag Pond Formation.** *Outside the Dresden shear zone:* The predominant rock type is light gray, medium-grained to coarse-grained, non-rusty to slightly rusty-weathering, plagioclase-quartz-biotite ± muscovite gneiss. Subordinate rock types include amphibolite, amphibole-rich gneiss with hornblende, cummingtonite, and/or anthophyllite, and quartz-plagioclase-biotite-muscovite ± garnet ± sillimanite schist and gneiss. Some exposures contain calc-silicate gneiss and rusty-weathering schist. Variably deformed muscovite-biotite ± garnet pegmatite dikes, sills, and boudins are locally abundant. *Within the Dresden shear zone:* Medium to light gray, fine-grained, thinly laminated (< 0.5 cm), protomylonitic to mylonitic quartz-feldspar-biotite gneiss. Locally, subordinate amounts of highly sheared, hornblende-bearing gneiss are present.

Onpa — **Amphibolite.** Dark gray, fine-grained to medium-grained amphibolite and amphibole-rich gneiss ± biotite ± garnet. Discontinuous, thin (< 2 cm) layers of greenish gray, fine-grained to medium-grained, calc-silicate rock are locally abundant. Occasional zones of rusty-weathering or non-rusty-weathering felsic gneiss a few meters thick may be present.

Casco Bay Group

Oce — **Cape Elizabeth Formation.** *Outside the Dresden shear zone:* Light gray to medium gray, medium-grained, quartz-plagioclase-muscovite-biotite ± garnet ± sillimanite schist interlayered with light gray, fine-grained, quartz-plagioclase micaceous granofels. Layers are commonly 2 to 12 cm thick. Variably deformed muscovite-biotite ± garnet pegmatite dikes, sills, and boudins are locally abundant. *Within the Dresden shear zone:* Medium to dark gray, fine-grained protomylonite to mylonite characterized by porphyroclasts of feldspar and muscovite set in a dark gray, fine-grained to aphanitic matrix. The muscovite is typically smeared out on moderately rusty-weathering, steeply dipping, mylonitic foliation surfaces. These rocks are interpreted to be highly sheared equivalents of Cape Elizabeth Formation (**Oce**) rocks outside the shear zone.

Oce — **Migmatitic rocks.** In the region south and east of the Blinn Hill pluton, rocks of the Cape Elizabeth Formation (**Oce**) are intruded by variable amounts of non-foliated to weakly foliated muscovite ± biotite ± garnet granite and pegmatite (Photo 5). Generally, intrusive igneous rocks comprise greater than 50% of the outcrop area in this region. Most of the igneous rocks of the migmatite are thought to be related to the nearby plutons of muscovite granite (**Dgm**).

Ocea — **Amphibolite.** Dark gray, medium-grained amphibolite and amphibole-rich gneiss ± biotite ± garnet. Discontinuous layers less than 15 cm thick of greenish gray, fine-grained to medium-grained, calc-silicate rock are locally abundant. Occasional zones of quartz-plagioclase-biotite gneiss a few meters thick are present.

Ocep — **Porphyroclastic schist.** Light gray, medium-grained to coarse-grained, moderately rusty-weathering, sillimanite-garnet-mica schist characterized by abundant sheared feldspar porphyroclasts up to 5 cm across (Photo 6). Dextral kinematic indicators are prominent. Variably sheared muscovite-biotite ± garnet granite and granitic pegmatite dikes, sills, and boudins are locally abundant. Light gray, non-rusty-weathering, quartz-plagioclase-biotite gneiss is locally present.

ROCKS OF COMPLEX ORIGIN

Devonian-Ordovician(?) [DO]

DOpg — **Passagassawakeag Gneiss.** Light gray and locally pinkish gray, medium-grained to very coarse-grained, porphyroclastic, quartz-plagioclase-biotite-K-feldspar gneiss. The rocks are characterized by laterally discontinuous layers of biotite felsic gneiss, commonly containing large feldspar porphyroclasts, interlayered with variably sheared, discontinuous sills of biotite granite and pegmatite (Photo 2). Locally, sillimanite-bearing mica schist or amphibolite may be present.

The name Passagassawakeag Gneiss is used here because of the lithologic similarity to gneissic rocks along strike to the northeast in the Morrill area (Bickel, 1976; Pollock, 2010; Pollock, 2012; West, 2014). Similar gneisses are also present along strike between Wiscasset and Morrill in strongly deformed structural complexes mapped as the Dyer Long Pond Complex (Grover, 2007; Grover and Newberg, 2016) and the Burkettville Complex (West, 2006). The relationship of those complexes to the Passagassawakeag Gneiss is not clear. While they include similar gneisses, the complexes may possibly include rocks from other units as well.

EXPLANATION OF PATTERNS

Strongly deformed rocks of the Dresden shear zone. See unit descriptions for lithologic descriptions of rocks in the shear zone. This shear zone is correlated with the regionally extensive Norumbega fault system, a major north-east trending, right lateral strike-slip fault system that extends through much of southern and eastern Maine (Ludman and West, 1999).

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.
- Outcrop of granitic pegmatite.
- Outcrop containing dioritic augen gneiss, among other rock types.
- Float, presumed to represent underlying bedrock.
- Bedding, tops unknown (inclined).
- Foliation and/or compositional layering (inclined, vertical).
- Gneissic compositional layering (inclined).
- Mineral lineation on foliation surface (plunging).
- Hinge line of minor fold, plunging (asymmetry unknown, sinistral rotation sense, dextral rotation sense).
- Minor fault with slickensided surface (inclined, vertical).
- Lineation on fault surface (plunging).
- Joint (inclined, vertical).
- Inactive rock quarry.
- (1) Photo location.
- (1) Geochronology sample location (see Table 1).

EXPLANATION OF LINES

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

Boundary between more deformed and less deformed rocks. May be a sharp or gradational boundary. Arrows indicate sense of shear (approximately located).

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

Boothbay thrust. Teeth on original upper plate. Interpreted as a major regional thrust fault because it places older rocks above younger rocks over a wide area (Hussey and Berry, 2002) (well located, approximately located, poorly located).

br

Limit of brittle deformation and retrograde metamorphism. Outcrops between this line and the Eastern River fault contain numerous structural features characteristic of post-metamorphic brittle deformation, such as cataclasite or steeply-dipping small-scale faults with slickensided surfaces. In addition, retrograde metamorphic effects are common, including minerals such as chlorite and epidote, and fine grain size. These features are more extensive to the southwest near the Eastern River fault in the Richmond quadrangle (West and others, 2010). They may reflect a period of post-Devonian, perhaps Mesozoic, brittle faulting with accompanying alteration by hydrothermal fluids.

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 (Ꞓ)	485-541
Precambrian time (pC)		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.)

Bedrock Geology of the Wiscasset Quadrangle, Maine

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2016
This map supersedes Open-File Map 92-58.

Photo 1: Characteristic ribbed outcrop surface in the Bucksport Formation (**Sb**), to the left of the notebook. The ribs reflect a difference in weathering resistance of the steeply dipping layers of biotite granofels and calc-silicate granofels. The calc-silicate rock is more resistant to weathering, so it is left standing higher as ribs. The more uniform white rock to the right of the notebook is granite, which intrudes the Bucksport. *1000 feet northeast of the intersection of Rt. 1 and Rt. 27, Edgecomb, in the southeastern corner of the map.*

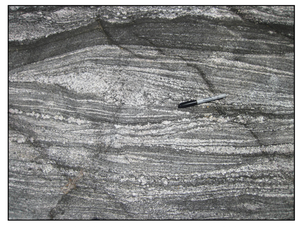

Photo 2: Strongly foliated, light gray, porphyroclastic felsic gneiss of the Passagassawakeag Gneiss (**DOpg**). Note the characteristic thin, discontinuous layers of darker colored biotite gneiss and lighter colored deformed granite which together have been flattened, stretched, and sheared. *Horizontal outcrop surface in Wiscasset 2500 feet south of hill marked by an elevation of 228 feet in the southeastern corner of the map.*

Photo 3: Dark gray, coarse-grained migmatitic hornblende-biotite gneiss of the Edgecomb Gneiss (**DSeg**). *Oblique view of horizontal outcrop surface 3000 feet southwest of hill marked by an elevation of 228 feet in the southeastern corner of the map, Wiscasset.*

Photo 4: Dark gray, coarse-grained hornblende-biotite gneiss with thin layers of light gray, quartz-feldspar gneiss parallel to the foliation. Edgecomb Gneiss (**DSeg**). *Same locality as Photo 3.*

Photo 5: Horizontal outcrop surface of migmatitic Cape Elizabeth Formation (**Oce**). The dark colored layers are mica schist representative of the Cape Elizabeth Formation, and the light colored layers are deformed sills of igneous rock, granite and pegmatite, that intruded the schist. *2500 feet northwest of the intersection of Rt. 1 and Rt. 27, Wiscasset.*

Photo 6: Close-up of a horizontal outcrop surface showing porphyroclastic mica schist of the Cape Elizabeth Formation (**Ocep**). The mica grains are oriented parallel to the schistosity, which is vertical. The shape of the light colored feldspar porphyroclasts and their "tails" have an asymmetry that indicates the rock was deformed by ductile shear in a dextral or right-lateral sense. *3300 feet southwest of hill marked by an elevation of 228 feet in the southeastern corner of the quadrangle, Wiscasset.*

Photo 7: Outcrops of light gray granite (**Dbg**) typically have a rounded shape such as this. Straight, parallel fractures (joints) are generally longer and more widely spaced in the intrusive rocks as seen here than in the stratified rocks. *View toward the southeast, 700 feet east of the West Alna Road, 1800 feet south of the powerline right-of-way, Alna, in the east-central portion of the quadrangle.*

Photo 8: Medium-grained granodiorite of the Blinn Hill pluton (**Sbhgd**). Larger grains, relict phenocrysts, of white feldspar have a preferred orientation parallel to the foliation (blue line). Small enclaves of darker, more mafic rock in the granodiorite are elongated in the same direction. A thin, white, granite dike crosses the lower right part of the photo. *500 feet south of Bog Road, 1200 feet east of Blinn Hill Road, Dresden.*

TABLE 1. GEOCHRONOLOGY INFORMATION

Location	Unit	Mineral	Method	Age (Ma)	Interpretation[1]	Reference
1	Sbhgd	Zircon	U-Pb (TIMS)	**424 ± 2**	I	Tucker and others, 2001
2	DSbhg	Zircon	U-Pb (SHRIMP)	**414 ± 7**	I	Condit, 2011
3	Sbhgd	Muscovite	$^{40}Ar/^{39}Ar$	**298 ± 4**	C	West and others, 1993
3	Sbhgd	Biotite	$^{40}Ar/^{39}Ar$	**288 ± 3**	C	West and others, 1993
3	Sbhgd	K-Feldspar	$^{40}Ar/^{39}Ar$	**265 ± 4**	C	West and others, 1993
3	Sbhgd	Apatite	Fission Track	**129 ± 12**	C	West and others, 2008
3	Sbhgd	Apatite	(U-Th)/He	**103 ± 6**	C	West and others, 2008

[1] I = Igneous crystallization age; C = Cooling age after metamorphism.

GEOLOGY OF THE WISCASSET 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 bedrock unit and gives a simplified geologic history by which they formed.

GEOGRAPHY

Physiographically, the Wiscasset quadrangle is characterized by low, rolling hills with a total relief of 447 feet. Two relatively large, tidally influenced, southwesterly flowing rivers skirt the edges of the quadrangle: the Eastern River in the northwestern corner and the Sheepscot River in the southeastern corner. In addition, numerous small streams exhibiting a poorly organized trellis to dendritic drainage pattern are distributed through the quadrangle. The shapes of the small hills and ridges, and the orientations of many of the streams, are strongly influenced by the north-northeasterly strike of the bedrock structure. Most of the bedrock is covered by a thin veneer of unconsolidated glacial and marine sediments including till, gravel, and clay, as shown on the surficial geologic map (Thompson, 2009).

MAJOR ROCK TYPES

Bedrock in the Wiscasset quadrangle is dominated by well-layered (stratified), metamorphosed sedimentary rocks and intrusive igneous rocks. The main mass of intrusive rock (granite and granodiorite), the Blinn Hill pluton of Silurian-Devonian age (**DSbhg, Sbhgd**), is found in the northern portion of the quadrangle, and several smaller granitic plutons are mapped elsewhere (**Dbg, Dgm**). Dikes, sills, and discontinuous layers and pods of granitic rock up to a few feet across are also present in various amounts in many exposures of stratified rock. A distinctive, deformed intrusive rock of intermediate composition, the Edgecomb Gneiss (**DSeg**), is found in long, thin sills of variable width in the southeastern corner of the map. Layering in the stratified rocks dips steeply to vertically and strikes in a north-northeasterly direction. These stratified rocks can be divided into four general groups that are described here in geographic order from northwest to southeast across the map.

The northwestern portion of the quadrangle is underlain by metamorphosed sedimentary and minor volcanic rocks of the Ordovician Nehumkeag Pond Formation (**Onp**) of the Falmouth-Brunswick Group. The Nehumkeag Pond Formation is dominated by gneiss, a type of rock that is characterized by alternating light and dark layers which in this case likely represent countless layers of volcanically-derived sediment or volcanic ash. A minor unit within the Nehumkeag Pond Formation (**Onpa**) consists of amphibolite, a dark gray to black rock dominated by amphibole minerals. This rock type likely represents a metamorphosed thin mafic igneous rock.

Immediately southeast of the Nehumkeag Pond Formation, and underlying the majority of the quadrangle, are highly metamorphosed sedimentary rocks of the Ordovician Cape Elizabeth Formation (**Oce**) of the Casco Bay Group. The Cape Elizabeth Formation is composed of well-bedded, metamorphosed sandstones and shales that due to the effects of metamorphism are now interbedded light gray quartzite and mica-rich schist. Throughout much of the quadrangle, metamorphic rocks of the Cape Elizabeth Formation are intruded by various amounts of igneous rock, granite and pegmatite, in bodies too small to be portrayed on the geologic map. Such an intricate mixture of igneous and metamorphic rock is called migmatite (Photo 5), which is indicated on the geologic map by an overprint pattern. Amphibolite (**Ocea**) is mapped as units within the Cape Elizabeth Formation. A unit of schist with porphyroclasts (**Ocep**) is mapped in the southeast part of the map. The porphyroclasts are large remnant grains of white feldspar preserved in a strongly deformed rock in which the other minerals have been reduced to a much finer grain size by shearing. This distinctive porphyroclastic texture characterizes the unit (Photo 6).

Southeast of the Cape Elizabeth Formation, in the Sheepscot River region, are two more bedrock units, the Passagassawakeag Gneiss (**DOpg**), and the Bucksport Formation (**Sb**) of the Kingsclear Group. The relationship between these two units is complicated by faulting. The Passagassawakeag Gneiss is dominated by highly sheared layers of light gray biotite gneiss alternating with layers of variably deformed biotite granite and pegmatite (Photo 2). The Bucksport Formation originated as bedded sandstone and siltstone which has been metamorphosed to become interlayered gray and light green granofels. The minerals of these layers weather differently to produce a conspicuous ribbed outcrop surface which reflects its internal layering (Photo 1).

DEFORMATION, METAMORPHISM, AND FAULTING

Although the stratified rock units were originally deposited in horizontal layers parallel to the earth's surface in Ordovician to Silurian time, they were subsequently compressed into folds during a period of major Appalachian mountain building known as the Acadian orogeny that occurred during the Late Silurian to Devonian. 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. Particular combinations of minerals found in the metamorphic rocks, as well as the presence of migmatite produced by partial melting, together indicate a moderately high intensity of metamorphism (amphibolite facies). Deep burial and crustal thickening during the Acadian orogeny caused melting at depth, generating large bodies of magma that rose through the crust, invaded the stratified rocks and crystallized to form the relatively large granite and granodiorite plutons found in the quadrangle. Some of the magma was emplaced into the stratified rocks immediately prior to the dominant phase of deformation in the Late Silurian (**Sbhgd, DSbhg, DSoi, DSeg**) and some was emplaced in the Devonian, following most of the deformation (**Dgm, Dbg**), resulting in igneous rocks with a variety of textures and intrusive relationships (Photos 7 and 8).

During the main stages of deformation, metamorphism, and igneous activity of the Acadian orogeny regional stress was dominantly compressional, likely a result of the head-on convergence of tectonic plates, and rocks throughout the region were folded and thrust together. The Boothbay thrust is interpreted as one of these compressional features (Hussey and Berry, 2002). During late-Acadian and post-Acadian stages of tectonic deformation in the Middle and Late Devonian, the stresses 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 mylonitic ductile shear zones (Dresden shear zone) and brittle faults (Eastern River fault). The process of faulting and mylonite formation in the roots of a major fault 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 were once miles below ground. The modern landscape of the Wiscasset quadrangle is ultimately controlled by the uneven resistance to erosion of the various underlying bedrock types, reflected in the strong north-northeasterly trends of many hills and streams. 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 some parts of the landscape, with an excellent example being Blinn Hill in the north-central part of the quadrangle which is elongate in a south-southeast direction. As the ice melted, the ocean inundated lower elevations leaving deposits of unconsolidated glacial and marine sediments over much of the bedrock (Thompson, 2009).

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