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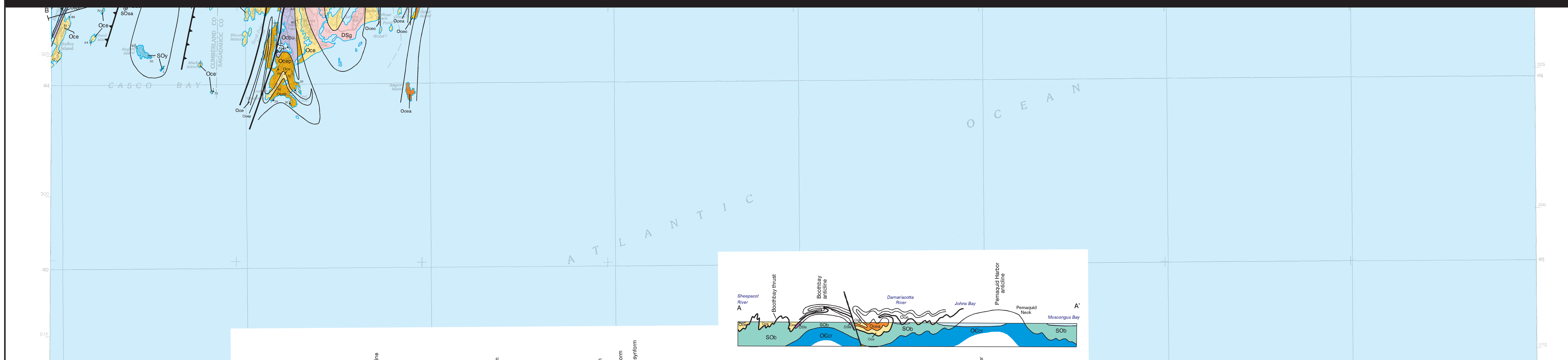

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Bath Quadrangle, Maine

Bedrock geologic mapping by
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Geologic Map No. 02-152
2002

For additional information, see Bulletin 42.

THE BEDROCK MAP

The geologic map at left shows the features of the bedrock, the solid rock that makes up the earth's crust. Although in many areas the bedrock is not exposed due to thick overlying sediments, this map depicts the geologists' interpretation of the bedrock, even in places where it cannot be seen. Symbols on the map show locations where bedrock is exposed at the land surface. Closely related or distinctive rock types are grouped together into formations and other rock units (see map explanation). At this scale of mapping many thin units must be grouped into formations (see, for example, the Cape Elizabeth Formation in the map explanation). Several different types of boundaries are shown on the map (see map explanation). The cross sections illustrate the inferred relationship among rock units that would be seen along vertical slices through the earth.

STRATIFIED ROCKS

The stratified, or layered, rocks of the Bath quadrangle are metamorphic rocks, primarily schist and granofels, although gneiss and phyllite are also important. Schist is a rock composed of small, flat minerals such as mica that are aligned to give the rock a sheet-like structure so that it splits easily. Granofels is a more uniform rock made of equant minerals such as quartz and feldspar, which are not elongated in any particular direction so that the rock breaks into chunks. A gneiss is similar to a granofels, except that it contains more mica which promotes the development of broad banding in the rock. A phyllite represents a lower grade of metamorphism than a schist, so it is finer grained and has more pronounced sheet-like structure. Most of the units are described in the map explanation in terms of the important minerals that make up the rock from most abundant to least abundant, for example, the plagioclase-quartz-biotite granofels of the Nehumkeag Pond Formation.

The stratified rocks were originally sediments that accumulated in an ocean basin during the late Ordovician to Silurian Periods (see Geologic Time Scale below). Geologic processes gradually turned these sediments into rock so that sedimentary characteristics such as layering are preserved, but in a modified form. Each of the photographs is located on the map with a red number.

Structure of the stratified rocks. During the Devonian Period, northern New England was a zone of major continental collision that formed high mountains, long since eroded to the Appalachians that we know today. Rocks now at the earth's surface in central coastal Maine were then at depth and subjected to intense heat and pressure. At this time the original sedimentary materials were metamorphosed to the rocks we see today. In response to the great pressure of continental collision, rocks were folded and faulted, some several times. Deformation is apparent in the folded shapes in the rocks, and layering which is inclined from the horizontal. This deformation occurred on a regional scale, as indicated by the inclined layering throughout the map area and by the structure shown on the interpretive cross sections.

IGNEOUS ROCKS

Igneous rocks form by cooling of molten magma to form solid rock, either at the earth's surface (extrusive igneous rocks - also called volcanic rocks) or within the earth's crust (intrusive igneous rocks). Rocks formed by volcanoes or submarine eruptions are examples of extrusive igneous rocks. Granite is an example of an intrusive igneous rock. Intrusive igneous rocks are generally coarser grained because they cool more slowly, allowing crystals more time to grow larger.

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Photo 5. A broad fold in the Yarmouth Island Formation on Yarmouth Island, Harpswell. To the left of geologist Arthur Hussey the layering tilts to the left; to his right the layering tilts steeply to the right. He is standing at the crest of the fold where layering is nearly horizontal. This is a regional-scale fold called the Hen Cove anticline which is responsible for surface exposures of units of the East Harpswell Group.

Photo 6. Upright folds in the Bucksport Formation at Pemaquid Point Lighthouse. The spectacular exposures here reveal many such features to the careful observer. This photograph looks directly along the crest of the fold, with layering on the left tilting to the left and layering on the right tilting to the right. In the middle distance the form of the fold is clearly visible. On the right is a large ridge underlain with pegmatite, a very coarse-grained, resistant rock consisting mostly of quartz and feldspar.

Photo 7. Wildly contorted quartzite and schist layers in the Mosquito Harbor Formation at Marshall Point Lighthouse, Port Clyde. The complicated layering and folding in the thin, light-colored quartzite layers is the result of several events. Probably some of the layers of sand and mud, originally deposited in an ocean basin, slid down the slope and became contorted before they hardened into rock. Some of the folding resulted from the heat and pressure of later mountain building events and the intrusion of nearby igneous rocks between 440 and 360 million years ago.

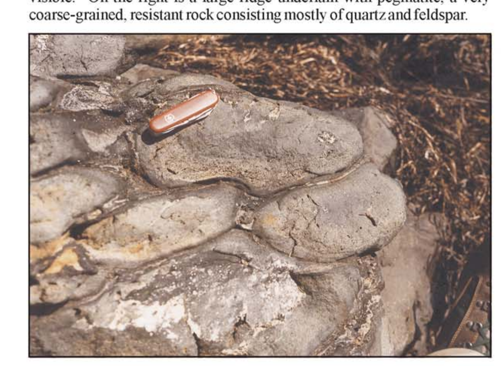

Photo 8. Metamorphosed pillow basalt (a dark volcanic rock) of the unnamed metavolcanic unit, Friendship. The blobby shapes that geologists call pillows develop when molten lava erupts from a fissure on the seafloor. Sea water cools the lava very quickly to form the pillow which breaks away from the fissure as more lava is forced out. These seafloor extrusive igneous rocks are now exposed at the surface because of several continental collision events which closed the ocean basin.

Photo 9. Spruce Head Granite, Rackliff Island, Spruce Head. This is a medium-grained granite that has interlocking, randomly arranged crystals of feldspar (white), quartz (gray), and biotite (black). The ellipsoidal speckled area above the knife is a piece of granofels from the surrounding rock units that fell into the molten magma at the time of intrusion and partially melted. Geologists call these features xenoliths.

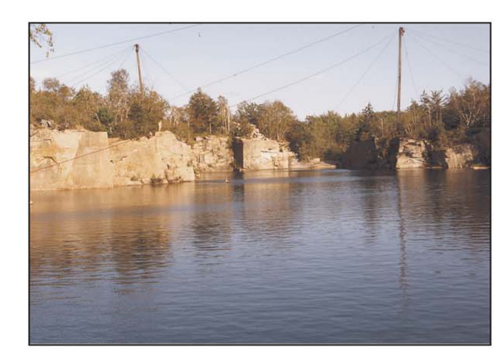

Photo 10. The granite quarry at Long Cove, Tenants Harbor. Quarries like this were an important part of Maine's economic activity around 1900. Durable Maine granite was used in the construction of many important government buildings around the nation. Still standing are two derricks that were used to hoist blocks out of the quarry, now flooded.

Photo 11. Granite dike with mafic enclaves, Marshall Point Lighthouse, Port Clyde. Magmas were forced through a fracture in the surrounding metamorphic rocks to form a dike. Within the dike are blobs or enclaves of dark basalt surrounded by lighter colored granitic rock. The scalloping or cuspate nature of the edges of the basalt indicates that the separate magmas that became the basalt and the granitic rock were both molten at the same time but, like oil and water, did not mix very well. Because basalt solidifies at a higher temperature than granite, it formed the enclaves first and granite filled in all around. Some fantastic shapes form in the process.

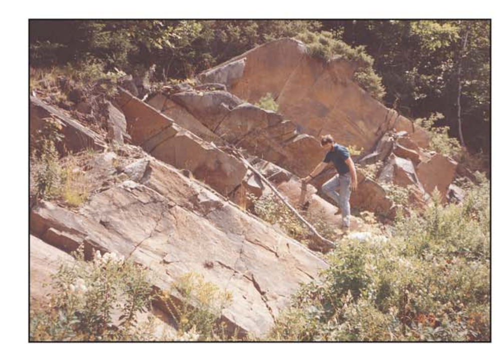

Photo 12. Christmas Cove dike exposed on Mountain Road, Great Island, Harpswell. The youngest of the rock units exposed in the area, the Christmas Cove dike was intruded during the Mesozoic Era and spans the length of the map sheet. Outcrops of this unit are often blocky, as shown in this photograph, because of several orientations of spaced fractures. At this place, the dike dips moderately to the north (left), while the fractures dip to the south.

Intrusive Rocks

Mesozoic

R — Christmas Cove dike. Fine-grained, non-porphyritic diabase (Photo 12). Other smaller and less extensive diabase dikes (not shown) are common throughout the area.

Devonian

*3 *4 *5 Dp — Granitic pegmatite. Only one body is shown. Similar smaller bodies are common throughout much of the map area.

WALDOBORO PLUTON

Dwga, Dwgp, Dwgn, Dwgl

Dwga: Leucocratic, fine sugary to medium-grained, weakly to non-foliated, aplitic, very light gray to pink-gray muscovite granite.

Dwgp: South Pond Porphyry. Feldspathic, sheared porphyroblastic granite porphyry.

Dwgn: Foliated, medium- to coarse-grained, grayish orange-pink to greenish gray two-mica granite with abundant garnet. Ubiquitous metasedimentary schlieren and abundant boudinaged metasedimentary enclaves and pegmatite dikes and irregular bodies.

Dwgl: Leucocratic fine- to medium-grained, weakly to non-foliated, equigranular, gray to pale pink granite.

*2 Dqd — Medium gray foliated quartz diorite and granodiorite.

Silurian - Devonian

R DSls — **LINCOLN SILL.** Dark gray syenite rich in ferromagnesian minerals, with abundant, large phenocrysts of orthoclase. Igneous textures are preserved where body is wide. Where thin, rock is metamorphosed to biotite-hornblende-orthoclase schist.

DSg — Granite.

DSgd — Granodiorite.

DSeg — **EDGECOMB GNEISS.** Dark gray plagioclase-hornblende-biotite-quartz gneiss and schist. (Photo 2)

DSoi — **OAK ISLAND GNEISS.** Light gray, strongly foliated biotite-muscovite-garnet granite gneiss.

DSmdg — Foliated metadiorite and metagabbro. Locally with irregular granite pods and stringers suggesting commingled magmas.

DSgb — Gabbro.

Late Silurian

Sgb — Gabbro and diorite.

SPRUCE HEAD PLUTON

R Ssg — **Ssg**: Granite (Photos 9 and 10).

Ssgd — **Sgd**: Diorite to granodiorite.

*6 Ssgb — **Sgb**: Gabbro and diorite.

RACCOON PLUTON

Srgbh — **Srgbh**: Seriate to equigranular greenish gray, medium- to coarse-grained, slightly foliated hornblende gabbro.

Srgb — **Srgb**: Fine- to medium-grained gray-green noritic gabbro with pyroxene cumulate layers.

Stratified Rocks

CENTRAL MAINE SEQUENCE

Late Ordovician - Silurian

SOhc — **HUTCHINS CORNER FORMATION.** Medium gray quartz-plagioclase-biotite-hornblende granofels and gneiss, and calc-silicate gneiss and granofels, with sporadic thin intervals of rusty-weathering biotite schist.

SOrc — **RICHMOND CORNER FORMATION.** Medium gray quartz-plagioclase-biotite-garnet gneiss locally with minor sillimanite-rich zones and thin reddish gray coticule (garnet-quartz granofels) beds.

SOth — **TORREY HILL FORMATION.** Rusty-weathering quartz-biotite-plagioclase gneiss and schist, locally rich in sillimanite, garnet, and graphite.

FALMOUTH-BRUNSWICK SEQUENCE

Ordovician

R Oma — **MOUNT ARARAT FORMATION.** Thinly (1-5 cm) interlayered granofelsic amphibolite and light gray plagioclase-quartz-biotite granofels and gneiss.

R Onp — **NEHUMKEAG POND FORMATION.** Light to medium gray plagioclase-quartz-biotite granofels and gneiss.

Onpr — Rusty-weathering quartz-plagioclase-biotite schist locally with minor sillimanite. Minor rusty calc-silicate granofels, impure marble, and amphibolite.

EAST HARPSWELL GROUP

Late Ordovician - Early Silurian

SOs — **SEBASCODEGAN FORMATION.** Thin-bedded light-gray plagioclase-quartz-biotite granofels (with relict pyroclastic structures in the western edge of the outcrop belt), calc-silicate granofels (with clinozoisite, diopside, hornblende, sphene, and local garnet and scapolite), and quartz-plagioclase-muscovite-biotite-sillimanite granofels. Includes some rusty-weathering zones.

SOsa — Amphibolite, including the following three varieties: (1) Fine-grained hornblende-plagioclase-biotite-sphene amphibolite; (2) Thin-banded association of amphibolite with hornblende, cummingtonite, and anthophyllite; calc-silicate granofels; and magnesian biotite schist; includes 2-meter thick coarse-grained marble bed; (3) Coarse grained hornblende-plagioclase-sphene-biotite amphibolite.

SOsr — Rusty-weathering quartz-plagioclase-biotite gneiss and granofels. Some green chromian mica.

SOspi — Pole Island Member. Calc-silicate gneiss and granofels.

SObp — **BETHEL POINT FORMATION.** Very rusty weathering quartz-biotite-muscovite-plagioclase schist with minor micaceous quartzite interbeds.

*1 SOy — **YARMOUTH ISLAND FORMATION.** Light gray plagioclase-quartz-biotite-garnet granofels and gneiss, locally with gedrite, staurolite, and/or sillimanite; minor calc-silicate gneiss and granofels interbeds and zones. (Photo 5)

SOya — Amphibolite and calc-silicate gneiss.

CASCO BAY GROUP

Ordovician

Ocbu — **UPPER CASCO BAY GROUP**, undifferentiated. Spring Point, Diamond Island, and Scarboro Formations combined.

Oj — **JEWELL FORMATION.** Light gray to dark gray muscovite-biotite-garnet phyllite to schist, locally carbonaceous or rusty weathering.

Osk — **SPURWINK METALIMESTONE.** Fine-grained metamorphosed limestone with thin interbeds of calcareous biotite-quartz phyllite.

Osc — **SCARBORO FORMATION.** Rusty- and non-rusty-weathering, light gray muscovite phyllite, medium gray muscovite-graphite phyllite, light gray muscovite-biotite-garnet schist, and medium gray muscovite-graphite-biotite-garnet schist. Contains sparing andalusite, chloritoid, and staurolite at highest grade in southern part of Harpswell.

SPRING POINT FORMATION

R Ospf — Thin-bedded, light to medium gray plagioclase-quartz-biotite granofels. Metamorphosed felsic volcanics or volcanogenic sediment.

Ospb — Plagioclase-hornblende-biotite amphibolite with 2-6 m thick coticule at top. Metamorphosed basaltic to intermediate volcanics, probably pyroclastics.

Oce — **CAPE ELIZABETH FORMATION.** *Staurolite-andalusite zone:* quartz-plagioclase-biotite ± muscovite ± garnet schist; muscovite-biotite-staurolite-garnet-plagioclase-quartz schist, reddish gray coticule as thin beds associated with typical quartz-mica schist; coarse poikiloblastic andalusite-muscovite-biotite-garnet-staurolite-quartz schist, locally with large muscovite poikiloblasts pseudomorphous after chiastolite; thinly interbedded quartz-plagioclase-biotite granofels and calc-silicate granofels; amphibolite; impure marble; and black quartz-muscovite-graphite schist. *Sillimanite zone:* quartz-plagioclase-biotite schist with or without muscovite and garnet; muscovite-biotite-sillimanite-quartz ± muscovite ± garnet schist, in part rusty-weathering. *Sillimanite+K-spar zone:* Same as sillimanite zone but with sheath-like K-feldspar; slightly to heavily migmatized. (Photo 3)

Ocep — Association of thin units of the following lithologies: dark gray biotite-quartz-plagioclase-garnet-sillimanite schist, very rusty-weathering muscovite-quartz schist, reddish gray coticule as thin beds associated with typical quartz-mica schist; coarse poikiloblastic andalusite-muscovite-biotite-garnet-staurolite-quartz schist, locally with large muscovite poikiloblasts pseudomorphous after chiastolite; thinly interbedded quartz-plagioclase-biotite granofels and calc-silicate granofels; amphibolite; impure marble; and black quartz-muscovite-graphite schist.

Ocea — Amphibolite; in places with associated coarse skarn-like calc-silicate marble. May represent several different horizons within Cape Elizabeth Formation.

Ocer — Rusty-weathering, fine-grained, plagioclase-quartz-muscovite schist.

Ocec — Coticule where extensive enough to be mapped separately from Ocep.

UNCONFORMITY?

CUSHING FORMATION

Ocw — **Wilson Cove Member**. Black garnet-biotite schist, garnet-plagioclase-grunerite(?)-biotite granofels, in part very rusty-weathering. (Photo 4)

Oca — Amphibolite with minor calc-silicate gneiss and impure limestone.

R Ocp — **Peaks Island Member**. Light gray plagioclase-quartz-biotite granofels and gneiss, locally with microcline and muscovite. Locally retains original pyroclastic structures including flamme structure, volcanic breccia blocks, and phenoclasts.

Ocm — **Merepoint Member**. Rusty weathering muscovite-plagioclase-quartz-biotite gneiss and schist.

FREDERICTON SEQUENCE

Ordovician - Silurian

SOb — **BUCKSPORT FORMATION.** Medium gray to purplish gray quartz-plagioclase-biotite-hornblende granofels and gneiss with greenish gray calc-silicate interbeds; some rusty quartz-biotite schist zones. Similar to the Sebascodegan Formation. (Photos 1 and 6)

BENNER HILL SEQUENCE

Late Ordovician (Caradocian)

Obh — **BENNER HILL FORMATION.** Thinly interbedded, rusty-weathering quartz-mica schist and quartzite. Some thin interbeds of metavolcanics and calc-silicate granofels. Distinctive of the formation are thin bedlets of coticule.

Late Ordovician (Caradocian) and older

Ohn — **HART NECK FORMATION.** Heterogeneous unit consisting of biotitic rock types including quartzite, granofels, grits, quartzose metapelite, and quartz-pebble metaconglomerate. Muscovite pseudomorphs up to 2 cm long are common in some metapelites.

Omh — **MOSQUITO HARBOR FORMATION.** 1/4 to 1 cm interbedded, light gray feldspathic quartzite and gray mica schist. Sporadic zones (up to 30 m thick) of flaggy-bedded amphibolite. (Photo 7)

MEGUNTICOOK SEQUENCE

Cambrian - Ordovician

R OЄp — **PENOBSCOT FORMATION.** Moderately to very rusty-weathering, thick-bedded dark biotitic quartzite, schist and granofels. Some thick-bedded, buff-weathering quartzite; some rusty-weathering metapelite with coarse chiastolite porphyroblasts (to 2 cm long). Common sills or dikes of metagabbro and metadiorite.

SEQUENCE UNCERTAIN

Ordovician(?)

Ouss — Unnamed sulfidic schist. Rusty-weathering biotite-muscovite-sillimanite schist and feldspathic quartzite. Amphibolite layers 1-6 m thick are locally common and may represent premetamorphic intrusive sills.

Ouv — Unnamed metavolcanic. Amphibolite, locally with well-preserved pillow structures (Photo 8), indicating volcanic protolith. Contains calc-silicate rocks and impure marble.

Cambrian(?) - Ordovician(?)

OЄcr — **CROSS RIVER FORMATION.** Exposed in the Boothbay and Pemaquid Harbor anticlines. Highly migmatized, very rusty-weathering to slightly rusty-weathering gneiss with relict zones of rusty-weathering biotite-muscovite-sillimanite-graphite schist; unmigmatized rafts of non-rusty quartz-plagioclase-biotite granofels, calc-silicate granofels, and amphibolite. In the Pemaquid Harbor anticline, grades downward into non-rusty, moderately migmatized quartz-plagioclase-biotite-muscovite schist with interbeds of more quartzose granofels.

OЄcrg — Granofels member. Exposed at top of formation in the Boothbay anticline. Fine-grained, salt and pepper textured, medium gray quartz-biotite-plagioclase-garnet granofels; medium to coarse-grained feldspathic amphibolite with large anhedral to poikiloblastic garnet.

MAP SYMBOLS

- Compositional layering (Includes bedding and gneissic layering in metasedimentary and metavolcanic rocks). Inclined and vertical.
- Schistosity in metamorphic rocks; layering and foliation in igneous rocks. Inclined and vertical.
- Contact
- High-angle fault
- Thrust fault
- Photo locality
- *5 Location of radiometric age listed below.

RADIOMETRIC AGE DETERMINATIONS. Localities in the Bath 1:100,000 quadrangle are numbered in this list and in the Explanation. Units dated outside the map area are indicated by an R.

Igneous rock ages

- R Penobscot Fm: 503 ± 5 Ma (U-Pb zircon)[5]
- R Cushing Fm, Peaks Island Member: 471 ± 3 Ma (U-Pb zircon)[2]
- R Spring Point Fm: 469 ± 3 Ma (U-Pb zircon)[5]
- R Carrs Corner (=Nehumkeag Pond) Fm: 460 ± 2 Ma (U-Pb zircon)[5]
- R Sill cutting Mount Ararat Fm: 458 ± 3 Ma (U-Pb zircon)[1]
- *1 Yarmouth Island Fm: 445 ± 2 Ma (U-Pb zircon)[4]
- R Granite, Spruce Head pluton: 421 ± 1 Ma (U-Pb zircon)[5]
- R Lincoln Sill: 418 ± 1 Ma (U-Pb zircon)[5]
- *2 Quartz diorite, Georgetown Island: 376 ± 3 Ma (U-Pb zircon)[1]
- R Waldoboro granite: 368 ± 2 Ma (U-Pb zircon)[5]
- R Biotite-muscovite granite at Brunswick: 278 ± 1.5 Ma (U-Pb monazite)[3]
- *3 Pegmatites, Standpipe Hill pits: 271-275 Ma (U-Pb monazite)[3]
- *4 Pegmatite, Trebilcock Pit: 272 ± 4 Ma (U-Pb monazite)[3]
- *5 Pegmatite, Square Pit: 270 ± 2.5 Ma (U-Pb monazite)[3]
- R Christmas Cove dike: 196 to 205 Ma (Ar-Ar whole rock)[7]

Cooling age

- *6 Gabbro, Spruce Head pluton: 430 +/- 5 Ma (Ar-Ar hornblende)[6]

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GEOLOGIC TIME SCALE

Geologic Age	Absolute Age*
Cenozoic Era	0-66
Mesozoic Era	66-245
Paleozoic Era	245-545
Permian Period	245-286
Carboniferous Period	286-360
Devonian Period	360-418
Silurian Period	418-443
Ordovician Period	443-495
Cambrian Period	495-545
Precambrian time	Older than 545

* In millions of years before present.