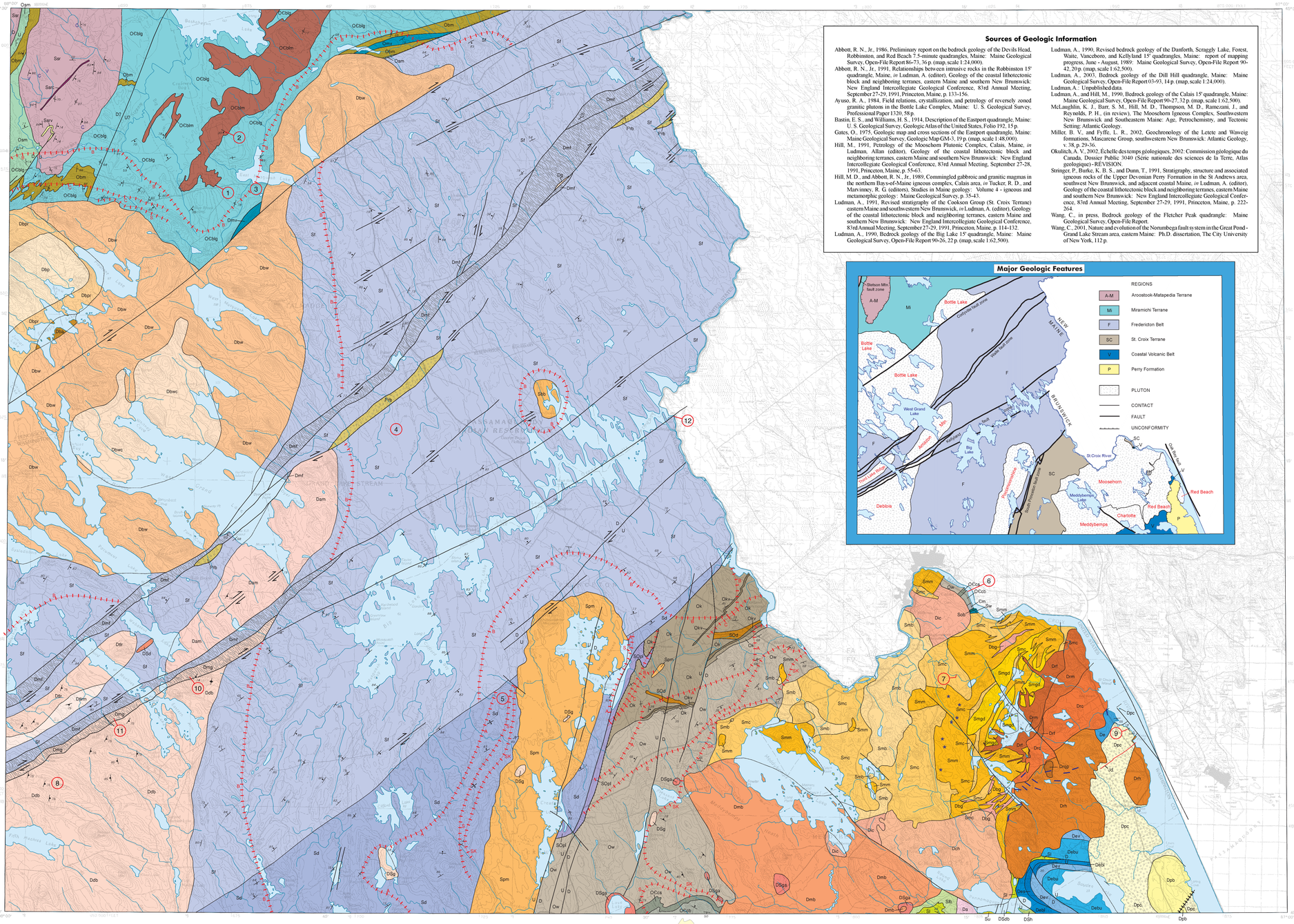
Bedrock Geology of the Calais 1:100,000 Quadrangle, Maine



Topographic base from U.S. Geological Survey Calais, Maine 1:100,000-scale metric topographic map.

Miles (mi): 0 1 2 3 4 5 6 7 8 9 10 11 12

Map Scale 1:100,000

Quadrangle Location

Kilometers (km): 0 2 4 6 8 10 12 14 16 18 20

Contour interval 10 meters.
National geodetic vertical datum of 1929.
Elevations shown to nearest meter.

Sources of Geologic Information

Abbott, R. N., Jr., 1986. Preliminary report on the bedrock geology of the Devils Head, Robbinston, and Red Beach 7.5-minute quadrangles, Maine: Maine Geological Survey, Open-File Report 86-73, 36 p. (map, scale 1:24,000).

Abbott, R. N., Jr., 1991. Relationships between intrusive rocks in the Robbinston 15' quadrangle, Maine, *in* Ludman, A. (editor), Geology of the coastal lithotectonic block and neighboring terranes, eastern Maine and southern New Brunswick: New England Intercollegiate Geological Conference, 83rd Annual Meeting, September 27-29, 1991, Princeton, Maine, p. 133-156.

Ayuso, R. A., 1984, Field relations, crystallization, and petrology of reversely zoned granitic plutons in the Bottle Lake Complex, Maine: U. S. Geological Survey, Professional Paper 1320, 58 p.

Bastin, E. S., and Williams, H. S., 1914, Description of the Eastport quadrangle, Maine: U. S. Geological Survey, Geologic Atlas of the United States, Folio 192, 15 p.

Gates, O., 1975, Geologic map and cross sections of the Eastport quadrangle, Maine: Maine Geological Survey, Geologic Map GM-3, 19 p. (map, scale 1:48,000).

Hill, M., 1991, Petrology of the Mooschorn Plutonic Complex, Calais, Maine, *in* Ludman, Allan (editor), Geology of the coastal lithotectonic block and neighboring terranes, eastern Maine and southern New Brunswick: New England Intercollegiate Geological Conference, 83rd Annual Meeting, September 27-28, 1991, Princeton, Maine, p. 55-63.

Hill, M. D., and Abbott, R. N., Jr., 1989, Commingled gabbroic and granitic magmas in the northern Bay-of-Maine igneous complex, Calais area, *in* Tucker, R. D., and Marvinney, R. G (editors), Studies in Maine geology: Volume 4 - igneous and metamorphic geology: Maine Geological Survey, p. 35-43.

Ludman, A., 1991, Revised stratigraphy of the Cookson Group (St. Croix Terrane) eastern Maine and southwestern New Brunswick, *in* Ludman, A. (editor), Geology of the coastal lithotectonic block and neighboring terranes, eastern Maine and southern New Brunswick: New England Intercollegiate Geological Conference, 83rd Annual Meeting, September 27-29, 1991, Princeton, Maine, p. 114-132.

Ludman, A., 1990, Bedrock geology of the Big Lake 15' quadrangle, Maine: Maine Geological Survey, Open-File Report 90-26, 22 p. (map, scale 1:62,500).

Ludman, A., 1990, Revised bedrock geology of the Danforth, Scraggly Lake, Forest, Waite, Vanceboro, and Kellyland 15' quadrangles, Maine: report of mapping progress, June - August, 1989: Maine Geological Survey, Open-File Report 90-42, 20 p. (map, scale 1:62,500).

Ludman, A., 2003, Bedrock geology of the Dill Hill quadrangle, Maine: Maine Geological Survey, Open-File Report 03-93, 14 p. (map, scale 1:24,000).

Ludman, A.: Unpublished data.

Ludman, A., and Hill, M., 1990, Bedrock geology of the Calais 15' quadrangle, Maine: Maine Geological Survey, Open-File Report 90-27, 32 p. (map, scale 1:62,500).

McLaughlin, K. J., Barr, S. M., Hill, M. D., Thompson, M. D., Ramezani, J., and Reynolds, P. H., (in review), The Mooschorn Igneous Complex, Southwestern New Brunswick and Southeastern Maine: Age, Petrochemistry, and Tectonic Setting: Atlantic Geology.

Miller, B. V., and Fyffe, L. R., 2002, Geochronology of the Letete and Waweig formations, Mascarene Group, southwestern New Brunswick: Atlantic Geology, v. 38, p. 29-36.

Okulitch, A. V., 2002, Échelle des temps géologiques, 2002: Commission géologique du Canada, Dossier Public 3040 (Série nationale des sciences de la Terre, Atlas géologique)- REVISION.

Stringer, P., Burke, K. B. S., and Dunn, T., 1991, Stratigraphy, structure and associated igneous rocks of the Upper Devonian Perry Formation in the St Andrews area, southwest New Brunswick, and adjacent coastal Maine, *in* Ludman, A. (editor), Geology of the coastal lithotectonic block and neighboring terranes, eastern Maine and southern New Brunswick: New England Intercollegiate Geological Conference, 83rd Annual Meeting, September 27-29, 1991, Princeton, Maine, p. 222-264.

Wang, C., in press, Bedrock geology of the Fletcher Peak quadrangle: Maine Geological Survey, Open-File Report.

Wang, C., 2001, Nature and evolution of the Norumbega fault system in the Great Pond - Grand Lake Stream area, eastern Maine: Ph.D. dissertation, The City University of New York, 112 p.

Major Geologic Features

Intrusive Rocks

Early Jurassic

Jd — **MINISTERS ISLAND DIKE.** Diabase with columnar joints. Age of 189 ± 8 Ma (Stringer and others, 1991).

Late to Middle Devonian

Dch — **CHARLOTTE PLUTON.** Light gray to pink, medium to coarse-grained, biotite ± alkali amphibole granite. Locally has a fine-grained, quenched margin against the Leighton Formation.

Dbg — Small bodies of pink to red biotite granite. Probably contemporaneous with **Dch**, **Drm**, and **Drc**.

RED BEACH GRANITE. Quartz-monzonite, hornblende granophyre, and biotite granite, all cut by granophyre dikes.

Drm — Salmon pink to brick red, medium-grained biotite granite. Alkali feldspar phenocrysts, rarely mantled by plagioclase. Gradational quenched margin up to 300 m wide.

Drc — Salmon pink to brick red, coarse-grained biotite granite. Subhedral to ovoid perthites are commonly mantled by plagioclase.

Drf — White to gray, fine-grained equigranular biotite granite. Single phenocrysts and aggregates of euhedral plagioclase from 0.5 to 1 mm. Quartz and alkali feldspar have poikilitic texture.

Drh — Hornblende granophyre, pinkish gray or gray in the west, brick red or maroon in the east. Plagioclase phenocrysts have mantles of perthite. Quartz and perthite are micrographically intergrown.

Drqp — Quartz-poor granodiorite/granophyre. Texture is essentially same as **Drh**, but with more plagioclase, less perthite, and less quartz (~18%).

Dmb — **MEDDYBEMPS PLUTON.** Light gray to pink, medium-grained biotite ± hornblende granite with abundant myrmekite.

Dic — Commingled intrusive rocks ranging from gabbro to granite, locally containing xenoliths and anatectic migmatite derived from host rock.

BOTTLE LAKE PLUTONIC COMPLEX

PASSADUMKEAG RIVER PLUTON

Dbp — Very coarse-grained white-weathering biotite-hornblende quartz monzonite with subhedral-euhedral potassic feldspar and sodic plagioclase and 15-25% ferromagnesian minerals. Abundant mafic enclaves.

Dbpr — Coarse-grained biotite-hornblende granitic to quartz-monzonitic rim facies, commonly heterogeneous in texture. Quartz forms large mosaic textures. Generally poorer in mafic minerals and mafic xenoliths than rocks in the interior. Locally porphyritic at northern contact.

Dba — Fine-grained, greenish black amphibole-biotite amphibolite with sparse phenocrysts. Most outcrops are intensely sheared.

WHITNEY COVE PLUTON

Dbw — Coarse-grained, gray to white-weathering biotite granite with prominent pink microcline crystals and megacrysts in slightly finer grained anhedral sodic plagioclase and quartz with 10-15% biotite crystals and minor amounts of hornblende. Locally pink weathering.

Dbwc — Medium- to coarse-grained biotite granite core facies; homogeneous, typically porphyritic, and low color index.

Ddb — **DEBLOIS PLUTON.** Coarse-grained to megacrystic hornblende-biotite granite with prominent pink microcline megacrysts, white, subhedral sodic plagioclase, and nearly equal amounts of hornblende and biotite. Northern part of pluton is foliated by shearing in Kelly land fault zone.

Dam — **AMAZON MOUNTAIN PLUTON.** Gray, medium-grained biotite-hornblende granite.

Dtfr — **THIRD LAKE RIDGE PLUTON.** Coarse to megacrystic hornblende-biotite granite with pink microcline. Strongly foliated within Kelly land fault zone.

Dtfrm — Medium-grained variety.

Early Devonian

Da — **MT. TOM ANDESITE.** Hypabyssal porphyritic basaltic andesite stock, with extensive hydrothermal alteration. At south edge of map.

Devonian-Silurian

DSd — Diorite at Wabassus Lake.

DSdb — Diabase and gabbro inferred to intrude the Leighton Formation at the south edge of the map. Projected from Eastport quadrangle to the south (Gates, 1975).

DSg — Unnamed small granitoid plutons. Quartz monzonite near Love Ridge, and biotite granite in the Pocomoonshine pluton.

DSga — Small, mafic plutons of gabbro, diorite, and quartz diorite. May correlate, in part, with **Smm**.

Late Silurian

Sbb — **BERRY BROOK GABBRO.** Small pluton containing norite, gabbro, leucogabbro, and leucodiorite; steeply to moderately dipping layering developed locally.

Spm — **POCOMOONSHINE GABBRO-DIORITE.** Large zoned pluton in which peridotite, troctolite, norite, and gabbro occupy the northwestern and central portions, diorite and quartz-diorite the eastern and southeastern parts. Locally exhibits steeply dipping layering.

MOOSEHORN IGNEOUS COMPLEX

Smb — **BARING GRANITE.** Gray, medium- to coarse-grained (hornblende) biotite granite.

Smc — Commingled intrusive rocks ranging from gabbro to granite. Bulbous mafic pillows and angular blocks are typically engulfed by medium-grained granodiorite to granite. This unit is especially well-developed along the contact between **Smgd** and **Smm**. Xenoliths of anatectic migmatite and restite are abundant near host rock contacts.

Smgd — Light to dark blue-gray to pink-gray, equigranular, medium-grained biotite-hornblende granodiorite. Near contacts with gabbro and diabase, hybridized to diorite and quartz diorite.

Smm — Fine- to coarse-grained gabbro, hornblende gabbro, norite, and quartz gabbro, commonly with ophitic texture. Locally contains plagioclase phenocrysts up to 2 cm long. Rare rhythmic layering has compositions from gabbro to quartz diorite, even in individual layers. Includes Staples Mountain, Woodland Dump, and St. Stephen plutons (Ludman and Hill, 1990).

Silurian-Ordovician(?)

SOd — **BAILEYVILLE DIKE.** Fine-grained metabasalt locally crosscutting and conformable with St. Croix terrane strata in Woodland quadrangle. Actinolite-chlorite pseudomorphs replace original pyroxene phenocrysts.

Highly Deformed Rocks of the Norumbega Fault System

Devonian

Dmf — Phyllonite, mylonite, and ultramylonite derived from the Flume Ridge Formation in the Kelly land and Waite fault zones; typically but not everywhere containing biotite.

Dmg — Mylonite and ultramylonite derived from Deblois granite in the Kelly land fault zone.

Stratified Rocks

AROOSTOOK-MATAPEDIA TERRANE

Silurian

Ssr — **SAM ROWE RIDGE FORMATION.** Chalky weathering, thinly interbedded, fine-grained dark gray sandstone, siltstone, and mudstone. Locally bioturbated, manganiferous.

Ssrc — Polymictic pebble to small cobble conglomerate with rounded clasts of felsic volcanic rock and quartzose sandstone in a silty to sandy matrix. Symbols (**c**) indicate conglomerate occurrences in addition to the mapped unit.

Ssrv — Coarse fragmental volcanic and volcaniclastic rocks. Gray ish-green ashfall tuff. Similar to rocks of the Stetson Mountain Formation. Symbols (**v**) indicate volcanic occurrences in addition to the mapped unit.

MIRAMICHI TERRANE

Ordovician

Osm — **STETSON MOUNTAIN FORMATION.** Dominantly fine-grained rhyolite and rhyodacite with varying amounts of black sulfidic mudstone. Lower portion is mostly cryptocrystalline to fine-grained ashfall tuffs; upper portion contains abundant coarser grained ashflow tuffs and volcaniclastic sedimentary interbeds. Rusty, manganiferous chert and mudstone are intercalated with tuff near the base of the formation.

Obm — **BOWERS MOUNTAIN FORMATION.** Thinly interlaminated, rusty weathering, pyritiferous black carbonaceous mudstone and siltstone. Quartz arenites are abundant near the base of the formation and become sparser near the top.

Omv — Unnamed mafic volcanic rocks. Dark gray to black basaltic metavolcanic rocks including massive basaltic flows, welded ashfall tuffs, and well-bedded coarse-grained ashflow tuffs.

Ordovician-Cambrian

BASKAHEGAN LAKE FORMATION

O€cblg — Gray to chalky-white weathering, gray and green quartzwacke and quartzo-feldspathic wacke interbedded with subordinate red sandstone, siltstone and mudstone.

O€cblm — Light red to chalky-white weathering, light red quartzo-feldspathic wacke interbedded with dark red siltstone and mudstone. Minor granule conglomerate.

FREDERICTON BELT

Pennsylvanian(?)

IPrb — Unnamed redbeds. Massive, pale red polymictic pebble, cobble, and boulder conglomerate; red sandstone, locally cross-bedded; dark red mudstone, locally interlaminated with pale red siltstone.

------ unconformity ------

Silurian

Sf — **FLUME RIDGE FORMATION.** Chalky-white to orange-brown weathering, variably calcareous, light gray wacke interbedded in partial Bouma sequences with medium gray slate. Subhedral to euhedral ferroan carbonate grains are common in the wacke, locally abundant in slate. Wackes are coarsest near contact with Miramichi terrane and fine eastward.

Early Silurian

Sd — **DIGDEGUASH FORMATION.** Medium gray, noncalcareous turbidites composed of granule conglomerate, lithic and feldspathic wacke, and dark gray slate. Pelitic horizons develop large (up to 25 cm) andalusite porphyroblasts in contact aureole of Pocomoonshine gabbro-diorite.

SOpl — **POCOMOONSHINE LAKE FORMATION.** Thinly interbedded rusty-weathering, black, pyritiferous, carbonaceous slate, dark gray to black non-carbonaceous slate, and dark gray siltstone with subordinate thicker beds of quartzo-feldspathic wacke.

ST. CROIX TERRANE

COOKSON GROUP

Ordovician (Caradocian, in part)

Ok — **KENDALL MOUNTAIN FORMATION.** Massive beds of orthoquartzite and slightly feldspathic quartz arenite with horizons of rusty-weathering, black carbonaceous shale.

Okv — Volcanic member. Thin horizon of white to very light gray, cryptocrystalline, felsic ashfall tuff.

Ordovician

Ow — **WOODLAND FORMATION.** Rusty-weathering, pyritiferous quartzo-feldspathic wacke and black shale typically in equal proportions in well-graded beds. Wacke is locally massive and occurs with quartz wacke and quartz arenite. Discoid calcareous lenses occur locally within wacke.

Early Ordovician-Cambrian

CALAIS FORMATION.

O€cs — Shale member. Homogeneous rusty weathering, black pyritiferous carbonaceous slate with very minor sulfidic quartz wacke.

O€cb — Basalt member. Pillowed and massive metabasalt flows locally intercalated with minor carbonaceous slate

Cambrian

€m — **MEGUNTICOOK FORMATION.** Hornfelsed quartzose siltstone and mudstone with coticule (garnet-quartz) layers and lenses. Exposed by St. Croix River southeast of Calais.

COASTAL VOLCANIC BELT

Upper Devonian

PERRY FORMATION

Dpc — Sandstone and conglomerate member. Red boulder through pebble conglomerate interbedded with subordinate red sandstone, siltstone and mudstone.

Dpb — Basalt member. Fine-grained lava flows, locally vesicular or amygdaloidal.

------ unconformity ------

Lower Devonian

De — **EASTPORT FORMATION.** Undifferentiated shale, mudstone, siltstone, and lavas baked to hornfels by the Red Beach Granite.

Debu — Black to dark green upper basalt flows, locally amygdaloidal. Altered to chlorite, epidote, and albite.

Dev — Red to black devitrified vitrophyre and autobreccia rhyolite. Felsic lapilli tuffs. Lapilli consist of pressed pumice fragments.

Deis — Gray mudstone, shale, and siltstone, commonly calcareous, locally tuffaceous. Calcareous mudstones are variegated, with alternating calcareous and non-calcareous mudstone layers 1 cm thick. Minor buff, cross-bedded, fine-grained sandstones. Essentially indistinguishable from parts of the Leighton Formation.

Dedl — Lower basalt flows, altered to chlorite, albite, and epidote.

Devonian-Silurian

DSh — **HERSEY FORMATION.** Maroon mudstone and very fine-grained siltstone, locally calcareous.

Silurian

Sl — **LEIGHTON FORMATION.** Gray siltstone, mudstone, and shale, locally calcareous or tuffaceous. Minor lithic crystal lapilli tuff and tuff breccia, rhyolite, and dacite.

Slb — Basalt member, primarily fine-grained.

Su — Undifferentiated shale, argillite, and bedded tuff. Silurian graptolites reported by Bastin and Williams (1914) from the Eastport quadrangle.

Sw — **WAWEIG FORMATION.** Hornfelsed quartzo-feldspathic siltstone and fine-grained sandstone with minor volcanic rocks. Small exposures by St. Croix River south of Calais.

Sob — **OAK BAY FORMATION.** Polymictic pebble to cobble conglomerate. Clasts flattened near fault contact. Small exposure by St. Croix River southeast of Calais. In New Brunswick, rests unconformably on Cookson Group.

Symbols

Rhyolite dike in or near the Red Beach Granite (symbol is parallel to strike).

Granite of Magurrewock Lakes. Small stocks of fine- to medium-grained porphyritic biotite granite. Younger than Mooschorn Complex.

Conglomerate locality in the Sam Rowe Ridge Formation.

Volcanic rock locality in the Sam Rowe Ridge Formation.

20 — Strike and dip of inclined bedding (tops unknown, upright, overturned).

20 — Strike and dip of vertical bedding (tops unknown, tops toward ball, tops both ways in the same outcrop).

20 — Strike and dip of cleavage or metamorphic foliation (inclined, vertical).

4 — Photo locality.

Lines

Dip-slip fault younger than Perry Formation. Hachures on downthrown block.

West-northwest-trending fault younger than Devonian plutons; age uncertain.

Strike-slip fault of the Norumbega system; Devonian-Carboniferous. Arrows show sense of motion.

U D — Dip-slip fault younger than Silurian plutons and older than Devonian plutons. U = upthrown block, D = downthrown block where known.

Thrust fault that predates Devonian plutons. Teeth on upper plate.

Stratigraphic or intrusive contact.

Metamorphic isograd. Ticks on higher grade side. B = biotite, C = cordierite, A = andalusite, S = sillimanite, SK = sillimanite and K-feldspar, with anatectic migmatite.

Calais Quadrangle, Maine

Bedrock geology compiled by
Allan Ludman
Henry N. Berry IV

Digital cartography by:
Susan S. Tolman
Robert A. Johnston

Robert G. Marvinney
State Geologist

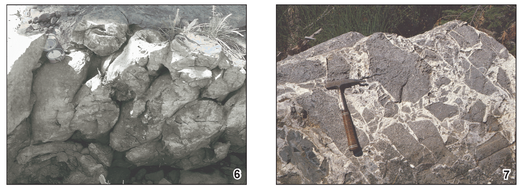
Cartographic design and editing by:
Robert D. Tucker
Henry N. Berry IV

Funding for the preparation of this map was provided in part by the U.S. Geological Survey STATEMAP Program, Cooperative Agreement No. 00HQAG0007.

Maine Geological Survey
Address: 22 State House Station, Augusta, Maine 04333
Telephone: 207-287-2801 **E-mail:** mgs@maine.gov
Home page: http://www.maine.gov/doc/nrimc/nrimc.htm

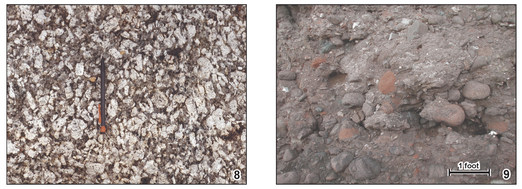
Open-File No. 03-97
2003

Examples of Stratified Rocks. **1.** These sandstone beds in the Baskahegan Lake Formation (**O€blg**) grade downward from white to gray, indicating they were overturned before being folded. **2.** Maroon mudstone interbedded with pink sandstone, Baskahegan Lake Formation (**O€blm**). **3.** Sandstone with fine sedimentary lamination is cut by a dark, anastomosing cleavage (**O€blg**). **4.** Beds of sandstone grade upward into darker siltstone, Flume Ridge Formation (**Sf**). Iron carbonate grains weather orange-brown. **5.** Sharply bedded white sandstone and dark slate, Digdeguash Formation (**Sd**). Heat from nearby intrusion caused small andalusite crystals to grow in the slate.



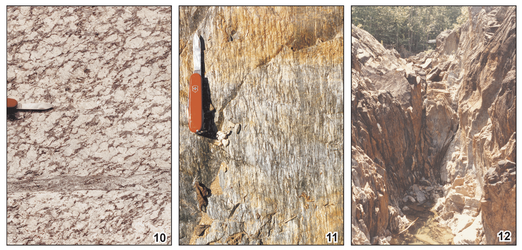
6. Pillow basalts in the Calais Formation (**O€c**) formed when lava erupted onto an ocean floor.

7. Mixed mafic (dark) and felsic (light) rocks of the Mooschorn Igneous Complex (**Smc**) were part of the same igneous event.



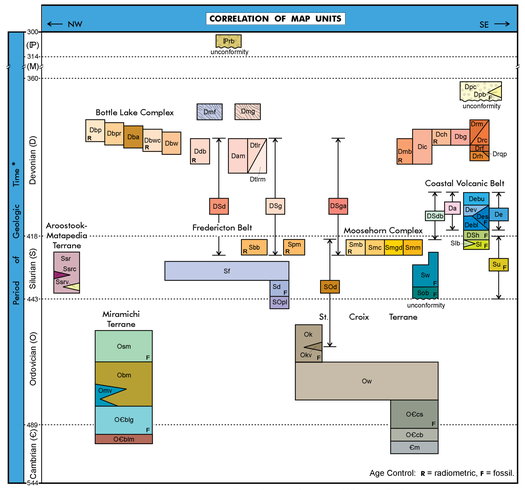
8. Coarse-grained granite of the Deblois pluton (**Ddb**). The large, white feldspar crystals have rectangular shapes typical of growth in magma.

9. Conglomerate near the base of the Perry Formation (**Dpc**) contains boulders eroded from the underlying Red Beach Granite.



Examples of Deformed Rocks from the Kellyland Fault Zone. **10.** Shearing has converted Deblois granite into this coarse-grained s-c mylonite, in which feldspar crystals have been rounded and distended (unit **Dmg**). **11.** Under more intense shearing, feldspar grains are stretched into thin ribbons, barely recognizable. **12.** Small fault zone in the Flume Ridge Formation (**Sf**). In this "tulip structure," a block of sandstone and shale is isolated between two curving fault planes. Grooved surfaces show the rocks moved horizontally along the faults.

All photos by A. Ludman except: Photo 7 by W. B. Thompson, Photo 9 by H. N. Berry IV. Photo locations are indicated on the map.



* Age of boundaries given in millions of years before present (Okulitch, 2002)