DEPARTMENT OF CONSERVATION
Maine Geological Survey
Robert G. Marvinney, State Geologist

OPEN-FILE NO. 03-96

Title: *Bedrock Geology of the Old Orchard Beach 7.5' Quadrangle, Cumberland and York Counties, Maine*

Author: *Arthur M. Hussey II*

Date: *2003*

Financial Support: Maine Geological Survey

Contents: 7 p. report and map

Bedrock Geology of the Old Orchard Beach 7.5' Quadrangle, Cumberland and York Counties, Maine

Arthur M. Hussey II
Professor of Geology Emeritus
Bowdoin College

INTRODUCTION

The location of the Old Orchard Beach 7.5' quadrangle is shown in Figure 1. This quadrangle lies within the Coastal Lowlands physiographic section characterized by low relief, with elevations ranging from sea level to about 220 feet above sea level. The highest point is Berry Hill, with an elevation slightly over 220 feet, on the western edge of the map. The Old Orchard Beach quadrangle lies close to the northern end of the Maine coastal zone marked by extensive sand beaches. Old Orchard Beach, a part of the arcuate series of beaches bordering Saco Bay occupies the very southeastern corner of the quadrangle (Figure 2). The land is underlain by late glacial outwash sand, dune sand, and marine clay. Outcrops are not abundant, but bedrock lies close to the surface in many parts of the quadrangle, and is commonly encountered in shallow excavations. Drainage is poorly developed, and is characterized by many nearly right angle bends, suggesting control by bedrock jointing, another indication of the shallow nature of drift in the area. Major streams are the Nonesuch River, Cascade Brook, Goosefare Brook, and Deep Brook. Saco River just grazes the southern end of the quadrangle. A major swamp, The Heath, 1.5 miles long and 1

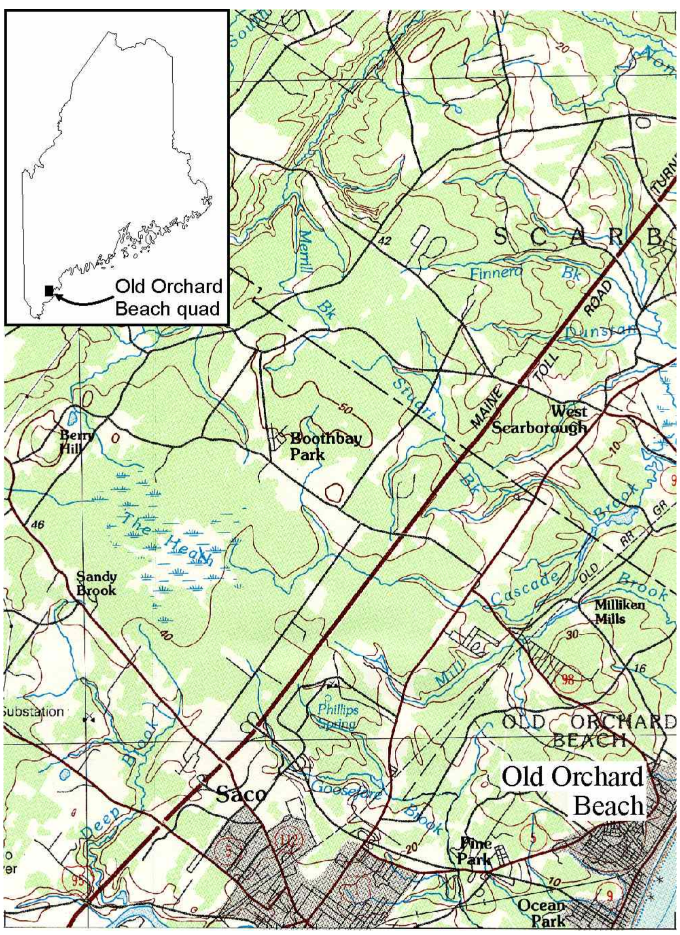


Figure 1. Location of the Old Orchard Beach 7.5-minute quadrangle, southwestern Maine.

Figure 2. Old Orchard Beach, looking south. Dark patch in the middle ground is an outcrop of the Kittery Formation (see Figure 2).

mile wide occupies an area in the southwestern part of the map. It is drained by Cascade and Goosefare Brooks on the southeast, by the Deep Brook drainage system on the southwest, and by a tributary of the Nonesuch River on the northwest.

Major urban areas within the map area are Old Orchard Beach in the southeastern corner, and Saco on the southern edge of the map. The southeastern third of the map, close to the urban areas, U. S. Highway 1, and the Maine Turnpike are becoming heavily developed by suburban settlements and industrial parks. The northwestern two-thirds of the quadrangle is relatively sparsely settled and is an area extensively covered by young-growth forest or cleared for small-scale agricultural use.

Early mapping was carried on by the writer in the late 1960's and 1970's, and was published on a smaller scale as part of the Portland 15' quadrangle (Hussey, 1971). This report is the result of field checking of the earlier work and additional work where warranted. As a result of urbanization and suburbanization in the southeastern part of the quadrangle, many of the outcrops visited during the earlier mapping are no longer available. A particularly good outcrop of the Kittery Formation in Old Orchard Beach village area has been all but completely removed in the excavation for the foundation of a major drug store. Many small "pavement" outcrops along original dirt roads are no longer visible because they have been paved over. Finally, several good exposures have been eliminated in housing developments and commercial lots where developers favored smooth lawns and parking lots uninterrupted by irregular outcrops.

BEDROCK GEOLOGY

The Old Orchard Beach quadrangle is underlain mostly by Late Ordovician to Early Silurian-age metasedimentary rocks of the Merrimack Group, and to a lesser extent by Middle to Late Ordovician metasedimentary rocks and metavolcanic rocks of the Casco Bay Group. The Carboniferous(?) age gabbro of the Saco pluton just grazes the southwestern corner of the quadrangle.

Saco pluton

The Saco pluton, an oval stock 5 km by 6 km, is exposed extensively in the Bar Mills 7.5' quadrangle immediately west of the Old Orchard Beach quadrangle. In the Old Orchard Beach quadrangle it occupies a small area in the southwestern part of the map sheet. Here it consists of medium dark gray metagabbro to metadiorite. The primary minerals, plagioclase, brown hornblende, and augite, are occasionally preserved, but are mostly altered to chlorite, epidote, secondary amphibole, sericite, and saussurite. Relict coarse-grained allotriomorphic granular texture (Figure 3) is preserved, but foliation and lineation which is seen extensively in outcrops in the Bar Mills quadrangle to the west (Marvinney, 1995) are not well developed in the Old Orchard Beach quadrangle exposures. In places, the metagabbro/diorite is crisscrossed by fine dark veins (Figure 4) resembling pseudotachylite, although the intervening material does not appear to be mylonitized. Some exposures of the pluton show evidence of multiple injection, with poorly-defined dikelets of fine-grained, dark gray gabbro/diorite cutting through the coarser-grained phase (Figure 5). Gaudette and others (1982) report a 307 ± 20 Ma Rb/Sr age. Given the amount of shearing and the alteration of primary mineralogy, I suspect that the age of this pluton may be significantly older. No other more precise radiometric ages are available.

Berwick Formation

The Berwick Formation is a thick sequence of thin to medium bedded, and also massive, purplish gray fine-grained

Figure 3. Relatively well-preserved primary coarse-grained allotriomorphic granular texture of the Saco gabbo/diorite; road cut on the northeast side of Maine Route 5 (see geologic map for location.)

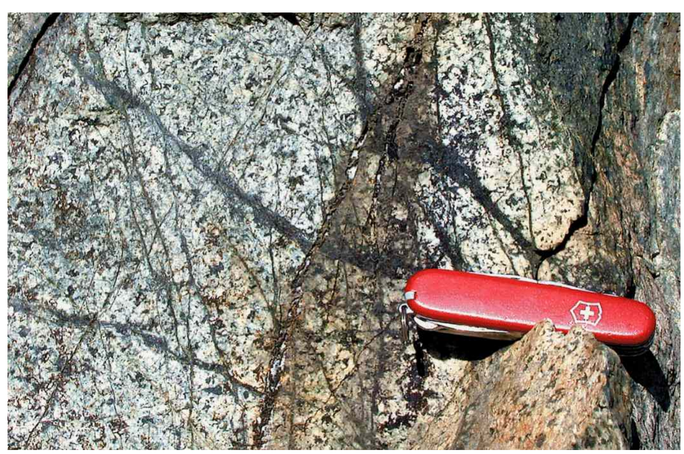


Figure 4. Fine net veining in the metagabbro of the Saco pluton, exposed at the same locality as Figure 3. Medium-grained relict igneous texture between the veinlets does not show noticeable shearing or mylonitization.

Figure 5. Saco pluton. Coarse-grained lighter weathering metagabbro appears to be cut by finer-grained dark gray metagabbro. Same location as Figure 3.

Figure 6. Kittery Formation outcrop on Old Orchard Beach (same as shown in the middle ground on Figure 2). The Kittery Formation is weakly bedded, with bedding striking nearly east and dipping steeply to the south.

quartz-plagioclase-biotite ± actinolite or hornblende granofels, with sparse thin interbeds of greenish gray quartz-plagioclase-epidote-acinolite granofels. Interbeds of quartz-plagioclase-biotite-muscovite-garnet schist are sporadically distributed throughout the formation, but are not abundant. Prior to metamorphism these were calcareous graywackes probably representing deep marine continental rise turbidites. The provenance of these rocks is uncertain. Sedimentary structures such as graded bedding, cross-bedding, and sole markings have not been observed in the Berwick rocks in this quadrangle, and are too rare in exposures of the formation in adjacent areas to be able to draw any conclusions as to direction of sediment transport.

A 200 to 400 meter wide belt of rock, designated by SObf on the map consists of buff-weathering relatively plagioclase-rich, calcareous granofels that in places resembles metamorphosed felsic to intermediate volcanics or very feldspathic sandstone to siltstone. This belt is terminated on the south against the Nonesuch River fault.

The Berwick Formation is lithologically similar to the Hutchins Corner Formation of the Central Maine sequence.

Merrimack Group

The Merrimack Group in the Old Orchard Beach area is represented by the Kittery and Eliot Formations. Both of these units were originally mapped by Katz (1917) as part of the Cape Elizabeth Formation of the Casco Bay Group, but from a consideration of the high calcareous content of the rocks, and their clear similarity to the Merrimack rocks to the south, they have been separated from the Casco Bay Group.

Kittery Formation. Rocks in the southern part of the map sheet around the Old Orchard Beach area are assigned to the Kittery Formation (Figure 6). These are buff-weathering thin to medium bedded quartz-feldspar-chlorite-ankerite-calcite granofels with interbeds of dark gray white-mica - chlorite - quartz phyllite. All are moderately sheared due to strike-slip faulting associated with the development of the Norumbega fault system. Metamorphic grade is low, corresponding to the ankerite zone as recognized by Ferry (1983) for rocks of the Central Maine sequence in the Waterville area to the northeast. Before metamorphism these rocks were deep-marine continental rise graywackes. The extensive shearing of these rocks has obliterated primary sedimentary structures that are well preserved in exposures farther south in Maine (Hussey, 1962). Rickerich (1983) suggested that the turbidites of the Kittery Formation formed a submarine fan on the northwest-facing continental rise of the Avalonian Composite Terrane which was approaching North America during Late Ordovician time. Hussey and others (1999) discuss evidence that the age of the Kittery Formation is probably Late Ordovician or Early Silurian.

Eliot Formation. The Eliot Formation is similar mineralogically to the Kittery Formation. Bedding is generally thinner, more irregular, and the darker phyllite interbeds represent a higher percentage of the rock (Figures 7 and 8). Like the Kittery Formation, the rocks of the Eliot Formation are extensively sheared. The Eliot Formation is lithologically identical to the Mackworth Slate of Katz (1917) in the Portland area. The name "Mackworth" is now abandoned because of assignment of these rocks to the Merrimack Group rather than Casco Bay Group as Katz (1917) had done. Metamorphic grade (ankerite) of these rocks is the same as for the Kittery Formation.

The stratigraphic position of the Kittery Formation relative to the Eliot Formation is uncertain. Billings (1956) considered the Kittery Formation to lie at the base of the Merrimack Group on the basis of position of the two formations in the Rye anticline

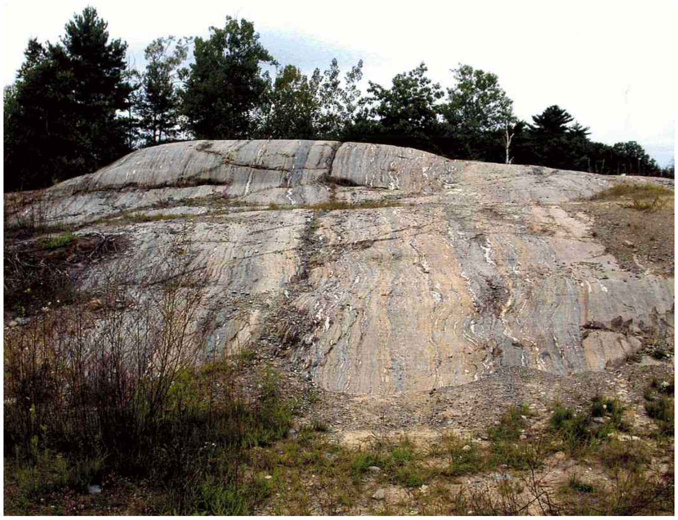


Figure 7. Glaciated outcrop of the Eliot Formation exposed in a large gravel pit off Boom Road near the west edge of the quadrangle. Pinkish-brown weathering of metasiltstone beds reflects the abundance of ankerite. Darker beds are chlorite-white mica phyllite.

Figure 8. Thin alternating beds of buff-weathering ankeritic and calcareous metasiltstone and dark gray crenulated chlorite-muscovite phyllite of the Eliot Formation, exposed along Beach Ridge Road 1 mile north of Holmes Road, Scarborough.

in coastal southwestern Maine and southeastern New Hampshire. Lyons and others (1997) reversed the stratigraphic order of these formations, indicating that the Kittery Formation is stratigraphically the highest. Their interpretation was based on the general map pattern of the formations of the Merrimack Group, along with predominance of north-plunging rather than south-plunging minor folds within the various formations of the Merrimack Group throughout much of the southeastern part of New Hampshire. The Lyons interpretation is followed in the cross section and map explanation.

Casco Bay Group

Two formations of the Casco Bay Group, the Spring Point and Scarboro Formations, crop out in the Old Orchard Beach quadrangle. These formations are separated from the rocks of the Merrimack Group by high-angle faults related to the Norumbega fault system. These two formations are of Middle to Late Ordovician age.

Spring Point Formation. The Spring Point Formation consists uniformly of fine-grained slightly greenish gray chlorite-white-mica-quartz-plagioclase-garnet phyllite. Minor amounts of biotite are seen in thin sections of the exposures in Cascade Brook between U. S. Route 1 and Milliken Mills Road (Figure 9). The greenish color (from chlorite) suggests that these phyllites were mafic to intermediate volcanic rocks, probably volcanic ash, prior to metamorphism. The relatively abundant white-mica content suggests the addition of argillaceous material during sedimentation. Garnet present in these rocks (which is not present in nearby exposures of pelitic phyllites of the Scarboro Formation) may indicate presence of a relatively high MnO content of the green phyllites. High manganese content tends to stabilize garnet at lower temperature (Miyashiro, 1994, p. 144).

Scarboro Formation. The Scarboro Formation consists of dark gray non calcareous, crenulated, slightly to moderately rusty weathering white-mica-chlorite-quartz phyllite (Figure 10). Thin bedding is locally indicated by slight variations in color. Metasiltstone beds are present, but rare. The chlorite, as seen in thin section, is gray in contrast to its green color in the Spring Point Formation. Fine carbonaceous material (probably graphite) is present and is locally abundant enough to leave a mark on paper.

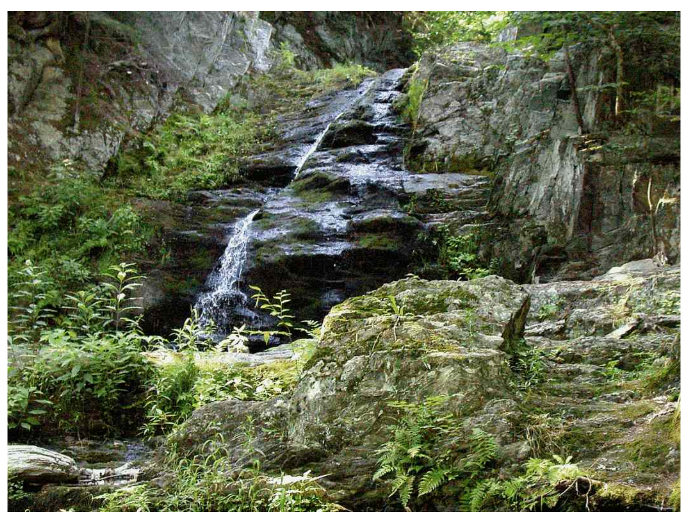


Figure 9. Cascade Falls along Cascade Brook, Saco. Rock is greenish phyllite of the Spring Point Formation.

Figure 10. Rusty chlorite-muscovite-graphite phyllite of the Scarboro Formation. Excavation for car dealership parking lot, northwest side of U.S. Route 1, Scarborough, near Slater Hill. At this site, about 25 meters left of the photo, greenish phyllite of the Spring Point Formation was exposed in the flat of the parking lot at the time of excavation, but was covered when the photo was taken. The Diamond Island Formation is not present between the two formations at this locality.

STRUCTURE

Because of the relative infrequency of outcrop, much of the structural synthesis for the Old Orchard Beach quadrangle relies on relations and interpretations from a much broader region around it in southwestern Maine. Most relevant is the interpretation of structure derived for the Prouts Neck quadrangle (Hussey, 2003b).

The Casco Bay Group is exposed in a wedge bounded by the Broad Cove fault on the south and Johns Point fault on the northwest (Figure 11). Two principal anticlinal hinges are defined on the basis of distribution of the outcrops of the Spring Point and Scarboro Formations (see the geologic map). No outcrop-scale structural data are available to indicate whether these are early recumbent folds or late upright folds.

Major faults are the Nonesuch River fault, the Johns Point fault, and the Broad Cove fault (Figure 11). Two other faults, prominent in the adjacent Prouts Neck quadrangle, lie at the very southeastern corner of the map in the vicinity of Old Orchard Beach and Saco Bay. There are no outcrops that help define these faults in the Old Orchard Beach quadrangle.

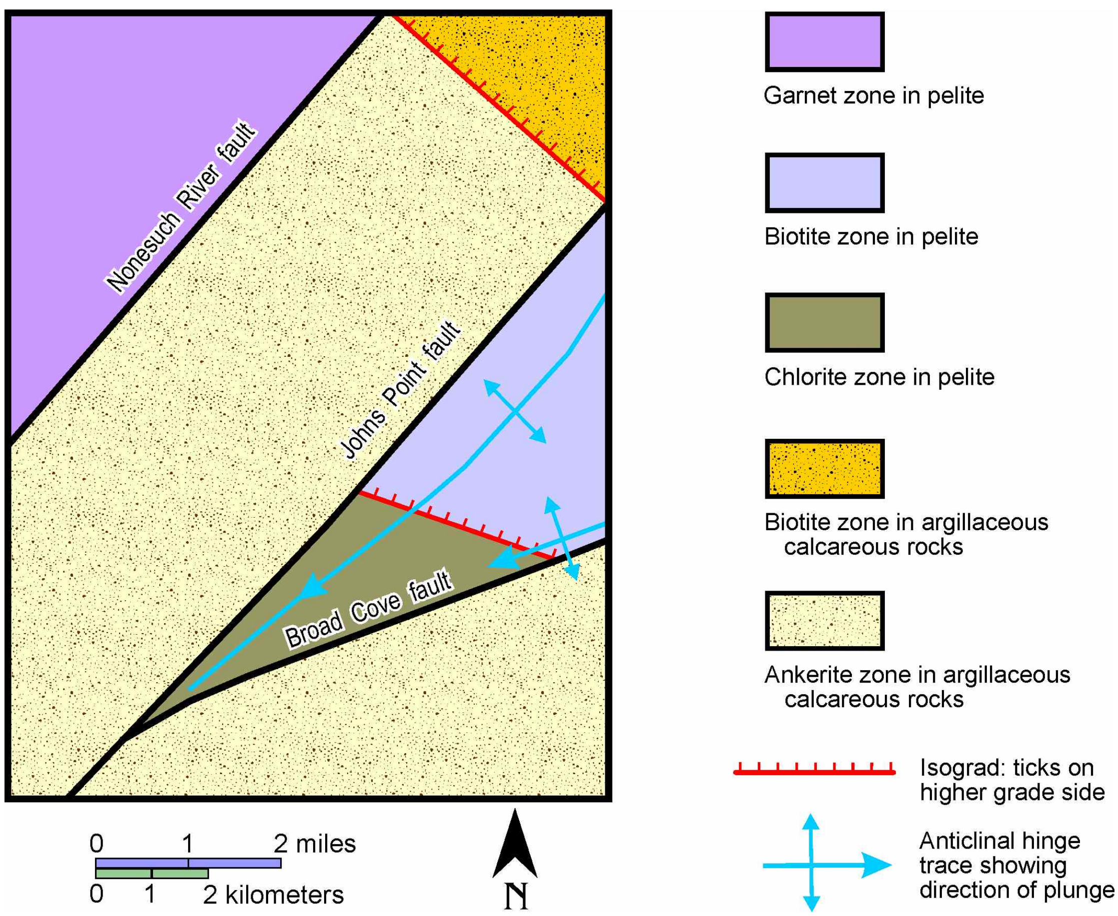


Figure 11. Major faults and approximate distribution of metamorphic zones in Old Orchard Beach 7.5' quadrangle. Also shown are traces of anticlinal hinges within the Casco Bay Group, defined on the basis of the distribution of outcrops of the Spring Point and Scarboro Formations.

Figure 12. Outcrop along Nonesuch River just downstream of Watson Mill Road, Saco, showing contorted cleavage of the Eliot Formation and milky quartz veins that indicate proximity to the Nonesuch River fault. Walter Anderson, for scale.

The Nonesuch River fault is interpreted to be a high-angle fault, downthrown to the southeast, separating garnet or higher grade rocks of the Berwick Formation from ankerite-grade rocks of the Merrimack Group (Figure 11). It controls the very linear northeast trend of the Nonesuch River. Adjacent to the trace of the fault, within the rocks of the Eliot Formation are several zones of breccia with drusy quartz veins; within these zones the schistosity of the Eliot formation is extremely contorted (Figure 12).

The Johns Point fault separates rocks of the Merrimack Group (the Eliot Formation) on the northwest from rocks of the Casco Bay Group (Scarboro Formation) on the southeast. The Johns Point fault is interpreted to be a high angle fault with predominant dip-slip movement, downthrown on the northwest side.

The Broad Cove fault is interpreted to be a splay of the Norumbega fault system (Bothner and Hussey, 1999). It separates rocks of the Casco Bay Group (Scarboro Formation) on the northwest from Merrimack Group rocks (Eliot and Kittery Formations) on the southeast. Swanson (1999) regards this as a predominantly right-lateral strike-slip fault of Late Devonian to Permian age.

Figure 13 is an interpretive cross section running from Old Orchard Beach village north-northwest to South Buxton. This interpretation is based not so much on critical data exposed within the Old Orchard Beach map sheet but mostly on regional synthesis of the geology of the greater Casco Bay area. The writer followed the Lyons and others (1997) interpretation (i.e., the Kittery Formation lies stratigraphically above the Eliot Formation) in constructing the cross section. An important, albeit speculative, interpretation presented in Figure 13 is that the Merrimack Group overlies (conformably?) the Jewell Formation of the Casco Bay Group. This is suggested by relations on the north end of Great Chebeague Island in Casco Bay where rocks similar to the Eliot Formation are in contact with rusty phyllite of the Jewell Formation (Hussey, unpublished mapping). Similarly, rusty phyllite on the east edge of Mackworth Island (Hussey, 2003a) may correlate with the Jewell Formation, returning us very nearly to Katz's original interpretation that the Mackworth Slate (his original name) is the uppermost unit of the Casco Bay Group. By correlating the Mackworth with the Eliot Formation, we now establish a conformable stratigraphic suc-

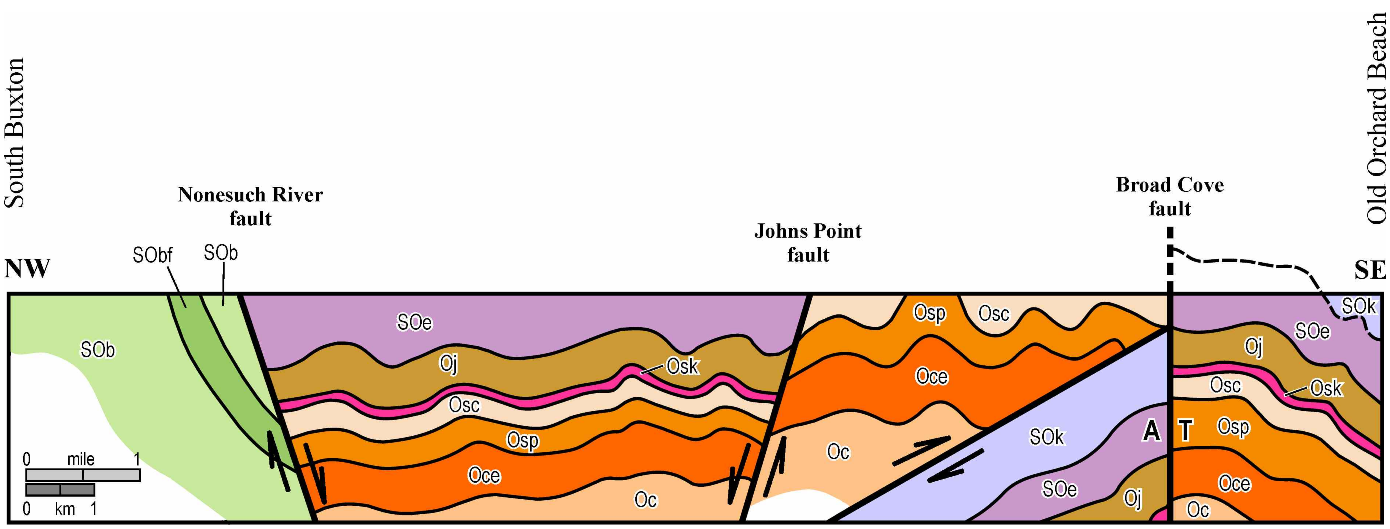


Figure 13. Interpretive cross section sketch across the Old Orchard Beach 7.5' quadrangle between Old Orchard Beach and Buxton (for location of the place names, see geologic map). **SOb**: Berwick Formation; **SObf**: feldspathic granofels member of the Berwick Formation; **SOk**: Kittery Formation; **SOe**: Eliot Formation; **Oj**: Jewell Formation; **Osk**: Spurwink Metalimestone; **Osc**: Scarboro Formation; **Osp**: Spring Point Formation; **Oce**: Cape Elizabeth Formation; **Oc**: Cushing Formation.

cession between the Casco Bay and Merrimack Groups (the latter on top).

The exposure of the Casco Bay Group between the Johns Point and Broad Cove faults may represent the upper plate of a major thrust fault that is not exposed within the quadrangle (Figure 13). Eastward rather than westward thrusting of the Casco Bay rocks over Merrimack rocks is preferred on the basis of a small eastward thrust and associated east-verging minor recumbent folds of the Casco Bay rocks exposed along sea cliff exposures just east of the Nonesuch River in Cape Elizabeth (see Hussey, 2003b).

REFERENCES CITED

Berry, H. S., IV, and Osberg, P. H., 1989, A stratigraphic synthesis of eastern Maine and western New Brunswick, *in* Tucker , R. D., and Marvinney, R. G. (editors), Studies in Maine geology, Volume 2: Structure and stratigraphy: Maine Geological Survey, p 1-32.

Billings, M. P., 1956, Geology of New Hampshire, Pt. 2, Bedrock geology of New Hampshire: New Hampshire State Planning and Development Commission, Concord, N. H., 203 p.

Bothner, W. A., and Hussey, A. M., II, 1999, Norumbega connections: Casco Bay, Maine to Massachusetts, *in* Lucman, A., and West, D. P., Jr. (editors), Norumbega fault system of the Northern Appalachians: Geological Society of America, Special Paper 331, p 59-72.

Ferry, J. M., 1983, Regional metamorphism of the Vassalboro Formation, south-central Maine, USA: as case study of the role of fluid in metamorphic petrogenesis: Journal of the Geological Society, London, v. 140, p. 551-576.

Gaudette, H. E., Kovach, A., and Hussey, A. M., II, 1982, Ages of some intrusive rocks of southwestern Maine, U.S.A.: Canadian Journal of Earth Sciences, v. 19, no. 7, p. 1350-1357.

Hussey, A. M., II, 1962, The geology of southern York County, Maine: Maine Geological Survey, Bulletin 14, 67 p.

Hussey, A. M., II, 1971, Geologic map of the Portland 15' quadrangle, Maine: Maine Geological Survey, Geologic Map GM-1.

Hussey, A. M., II, 1988, The lithotectonic stratigraphy, deformation, plutonism, and metamorphism, Greater Casco Bay region, southwestern Maine, *in* Tucker, R. D., and Marvinney, R. G. (editors), Studies in Maine geology, Volume 1, Structure and stratigraphy: Maine Geological Survey, p. 17-34.

Hussey, A. M. II, 2003a, Bedrock geology of the Portland East 7.5' quadrangle, Cumberland County, Maine: Maine Geological Survey, Open-File Report 03-90, 12 p. (map, scale 1:24,000).

Hussey, A. M., II, 2003b, Bedrock geology of the Prouts Neck 7.5' quadrangle, Cumberland and York Counties, Maine: Maine Geological Survey, Open-File Report 03-95, 8 p. (map, scale 1:24,000).

Hussey, A. M., II, Ludman, A., Bothner, W. A., and West, D. P., Jr., 1999, Fredericton and Merrimack Troughs: Once one or always two?: Geological Society of America, Abstracts with Programs, v. 31 no. 2, p. A-25.

Katz, F. J., 1917, Stratigraphy in southwestern Maine and southeastern New Hampshire: U. S. Geological Survey, Professional Paper 108, p. 165-177.

Lyons, J. B., Bothner, W. A., Moench, R. H., and Thompson, J. B., Jr., 1997, Bedrock geologic map of New Hampshire: U. S. Geological Survey, Washington, D. C.

Marvinney, R. G., 1995, Bedrock geology of the Bar Mills quadrangle, Maine: Maine Geological Survey, Open-File Report 95-75, 7 p. (map, scale 1:24,000).

Miyashiro, A., 1994, Metamorphic petrology: Oxford University Press, New York, 404 p.

Newberg, D. S., 1981a, Bedrock geology and structure of the Gardiner 15' quadrangle: Maine Geological Survey, New England Seismotectonic Activities in Maine during FY 1981, p. 57-66.

Newberg, D. S., 1981b, Bedrock geology and structure of parts of the Vassalboro and Wiscasset 15' quadrangles: Maine Geological Survey, New England Seismotectonic Activities in Maine during FY 1981, p. 67-69.

Newberg, D. S., 1985, Bedrock geology of the Palermo 7.5' quadrangle, Maine: Maine Geological Survey, Open-File Report 85-84, 14 p. (map, scale 1:24,000).

Pankiwskyj, K. A., 1996, Structure and stratigraphy across the Hackmatack Pond fault, Kennebec and Waldo Counties, Maine: Maine Geological Survey, Open File Report 96-2, 15 p. (2 maps, scale 1:24,000).

Rickerich, S. F., 1983, Sedimentology, stratigraphy, and structure of the Kittery Formation in the Portsmouth, N.H., area: Masters thesis, University of New Hampshire, 115 p.

Swanson, M. T., 1999, Kinematic indicators for regional dextral shear along the Norumbega fault system in the Casco Bay area, coastal Maine, *in* Lucman, A., and West, D. P., Jr. (editors), Norumbega fault system of the Northern Appalachians: Geological Society of America, Special Paper 331, p. 1-23.

Old Orchard Beach Quadrangle, Maine

Bedrock geologic mapping by
Arthur M. Hussey II

Digital cartography by:
Susan S. Tolman

Robert G. Marvinney
State Geologist

Cartographic design and editing by:
Robert D. Tucker

Funding for the preparation of this map was provided by the Maine Geological Survey.

DEPARTMENT OF CONSERVATION MAINE

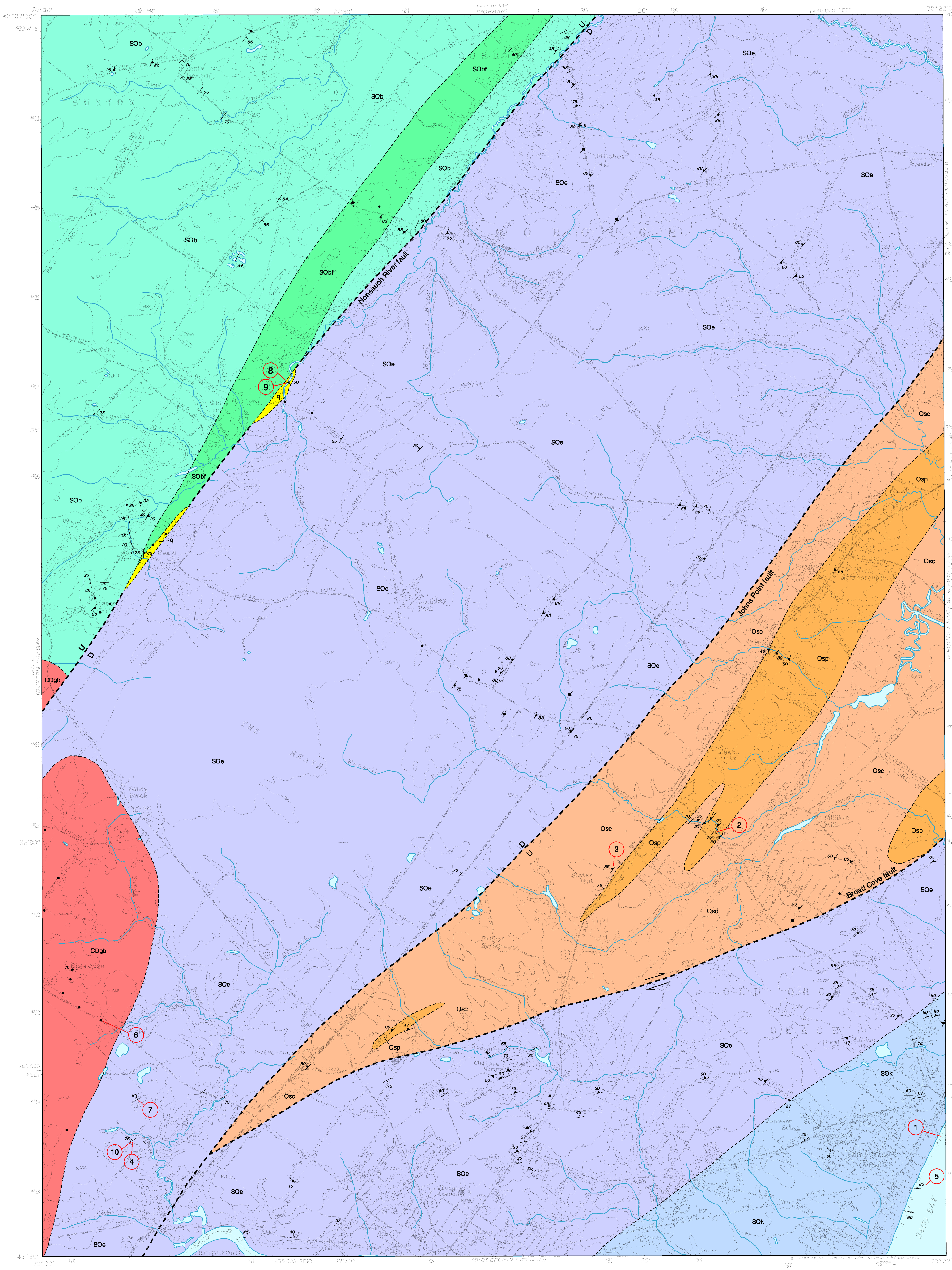
Maine Geological Survey

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. 03-96
2003

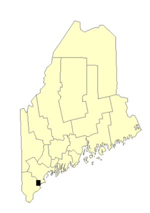
This map accompanied by a 7 p. report.

Bedrock Geology



SOURCES OF INFORMATION

Geologic mapping by A. M. Hussey II, 1970 - 2003.



Quadrangle Location

SCALE 1 : 24,000

1 MILE / 7000 FEET / 1 KILOMETER

CONTOUR INTERVAL 20 FEET

TRUE NORTH

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

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

On the geologic map, different bedrock units are indicated by colors and identified by letter symbols that represent their assigned age and unit name. The following description summarizes the major rock types of each unit and gives a simplified geologic history by which they formed.

GEOGRAPHY

The Old Orchard Beach quadrangle lies close to the northern end of the Maine coastal zone marked by extensive sand beaches. Old Orchard Beach, a part of the arcuate series of beaches bordering Saco Bay, occupies the very southeastern corner of the quadrangle (Photo 1). The land is underlain by late-glacial outwash sand, dune sand, and marine clay. Outcrops are not abundant, but bedrock lies close to the surface in many parts of the quadrangle and is commonly encountered in shallow excavations. Drainage is poorly developed and is characterized by many nearly right angle bends, suggesting control by bedrock jointing, another indication of the shallow nature of drift in the area.

MAJOR ROCK TYPES

The stratified, or layered, rocks of the Old Orchard Beach quadrangle are all metamorphic rocks, including schist, phyllite, and granofels. Schist consists mostly of thin, flat flakes of mica which are arranged parallel to each other such that the rock splits into thin sheets. Phyllite has a similar mineral texture except the individual grains are very small and not readily seen without a microscope. Granofels, made up primarily of the minerals quartz and feldspar, has a grainy texure somewhat like sugar. In contrast with schist and phyllite, granofels tends to break into angular blocks or chunks. Varieties of schist and granofels may be further distinguished by their particular mineral content, grain size, color, or other characteristics.

ORIGIN OF THE STRATIFIED ROCKS

The oldest rocks of the Old Orchard Beach quadrangle belong to the Casco Bay Group, a diverse assortment of metamorphosed volcanic rocks, shales, and limestone, deposited during Ordovician time (see Geologic Time Scale, below). Within this quadrangle the oldest rock of the Casco Bay Group exposed at the surface is the Spring Point Formation consisting of crudely layered basaltic volcanic ash (Photo 2). These rocks formed as hot lava erupted on an ancient ocean floor and became fragmented on contact with the cold ocean water. As volcanic activity ended, sulfidic shale of the Scarboro Formation (Photo 3) accumulated in thin beds conformably on top of the volcanic pile.

The Merrimack Group is represented in the Old Orchard Beach quadrangle by the Eliot Formation, a sequence of slightly metamorphosed calcareous siltstone and shale (Photo 4); and the Kittery Formation, consisting of thin to medium-bedded metamorphosed feldspathic sandstone and shale (Photo 5). These rocks are interpreted to be deep ocean sediments deposited during Late Ordovician to Early Silurian time. Similar rocks northwest of the Nonesuch River fault, the Berwick Formation, accumulated in a deep ocean environment during the same time interval.

DEFORMATION, METAMORPHISM, FAULTING AND IGNEOUS INTRUSION

Early in the Devonian Period, in an episode of crustal compression referred to as the Acadian orogeny, the sedimentary rocks of the quadrangle were extensively folded and broken by a major thrust fault. The rocks that were pushed down into the Earth's crust during this compressional event were metamorphosed; shale was transformed into phyllite and schist, siltstones and sandstones into granofels, and fine basaltic ash into green phyllite. At about the same time gabbro magma intruded into these metamorphosed sedimentary rocks, forming the Saco pluton (Photo 6). Shortly after the Acadian orogeny, the sedimentary rocks and the metagabbro/diorite of the Saco pluton were extensively sheared during a period of right-lateral faulting that formed the Norumbega fault zone of which the Broad Cove fault is interpreted to be a branch. Most prominently affected by this shearing were the phyllites of the Eliot and Scarboro Formations (Photo 7). Later, during the Mesozoic Era, the rocks were broken by high-angle faults (Nonesuch River and Johns Point). The Nonesuch River fault is well expressed as a linear depression occupied by the Nonesuch River (Photo 8), along which rocks of the Eliot Formation are contorted and extensively injected by milky quartz veins (Photo 9).

Photo 1. Old Orchard Beach, looking south. Dark patch in the middle ground is an outcrop of the Kittery Formation.

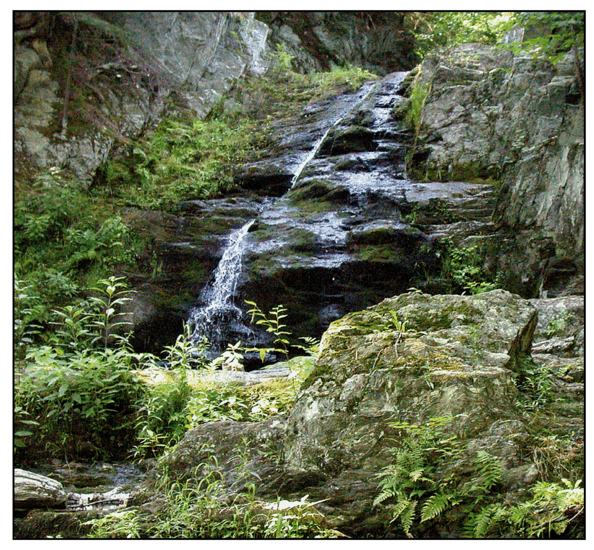


Photo 2. Spring Point Formation exposed at Cascade Falls on the Cascade River, Saco.

Photo 3. Black graphitic phyllite of the Scarboro Formation exposed in excavation near Slater Hill, Saco.

Photo 4. Glacially smoothed exposure of the Eliot Formation in a gravel pit near the Maine Turnpike in Saco.

Photo 5. Close-up of the outcrop of the Kittery Formation on the intertidal zone of Old Orchard Beach, seen in Figure 1.

Photo 6. Metagabbro/diorite of the Saco pluton exposed in road cut along Maine Route 5, Saco. Patches of green epidote may represent digested xenoliths of Eliot Formation.

Photo 7. Sheared bedding of the Eliot Formation exposed in glaciated outcrop in large gravel pit on the west side of Maine Route 5, Saco.

Photo 8. Straight course of the Nonesuch River along the trace of the Nonesuch River fault, 400 feet downstream of Watson Mill Road bridge, Saco.

Photo 9. Milky quartz veins and contorted cleavage of the Eliot Formation along the Nonesuch River at same locality as Photo 8.

Photo 10. Glacial striations on outcrop of the Eliot Formation in a gravel pit near the Maine Turnpike in Saco.

EXPLANATION OF UNITS

INTRUSIVE ROCKS

q — Silicified zones related to the Nonesuch River fault.

Devonian or Carboniferous

CDgb — **Saco pluton.** Coarse-grained, medium dark gray to slightly greenish-gray metadiorite/gabbro; plagioclase is saussuritized, hornblende and augite altered to fibrous amphibole. Some sections of the pluton are non-foliated; others are extremely foliated and sheared.

STRATIFIED ROCKS

Late Ordovician to Early Silurian

SOb — **Berwick Formation.** Medium-bedded medium gray plagioclase biotite granofels, locally with abundant calcite; interbeds of two-mica garnet schist.

SObf — Light-buff gray fine-grained plagioclase-quartz granofels with essentially no mica; represents either feldspathic metasandstone or metafelsite.

MERRIMACK GROUP

SOk — **Kittery Formation.** Very similar to Eliot Formation but thicker bedded. Buff-weathering beds commonly have relict fine-granule detrital quartz grains.

SOe — **Eliot Formation.** Fine-grained medium gray muscovite-chlorite-quartz-plagioclase phyllite with ankerite and calcite; buff-colored and finely limonite-speckled on weathered surface; interbedded with dark gray crenulated muscovite-chlorite phyllite.

Middle to Late Ordovician

CASCO BAY GROUP

Osc — **Scarboro Formation**. Rusty and non-rusty weathering crenulated muscovite-chlorite-garnet phyllite with rare interbeds of quartz-plagioclase muscovite-chlorite granofels.

Osp — **Spring Point Formation**. Medium greenish gray chlorite-white mica-garnet phyllite; probably representing intermediate metavolcanic ash beds.

EXPLANATION OF SYMBOLS

Strike and dip of bedding. (inclined, vertical)

Strike and dip of bedding, tops known. (upright)

Strike and dip of cleavage, schistosity, or foliation. (inclined, vertical)

④ Photo location

EXPLANATION OF MAP LINES

Stratigraphic or intrusive contact between rock units.

High angle mostly dip-slip fault (U - upthrown block; D-downthrown block).

High-angle mostly strike-slip fault (arrows indicate sense of motion).

High angle oblique-slip fault (arrows indicate sense of motion; U - upthrown block; D-downthrown block).

GEOLOGIC TIME SCALE

Geologic Age		Absolute Age*
Cenozoic Era		0-65
Mesozoic Era	Cretaceous Period	65-145
	Jurassic Period	145-200
	Triassic Period	200-253
Paleozoic Era	Permian Period	253-300
	Carboniferous Period	300-360
	Devonian Period	360-418
	Silurian Period	418-443
	Ordovician Period	443-489
	Cambrian Period	489-544
Precambrian time		Older than 544

* In millions of years before present. (Okulitch, A. V., 2002, Échelle des temps géologiques, 2002: Commission géologique du Canada, Dossier Public 3040 (Série nationale des sciences de la Terre, Atlas geologique) - RÉVISION.)