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Geological comparisons across the Norumbega Fault Zone, southwestern Maine

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GEOLOGICAL COMPARISONS ACROSS THE NORUMBEGA FAULT ZONE, SOUTHWESTERN MAINE

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INTRODUCTION

The Norumbega Fault Zone is a genetically related series of faults extending from New Brunswick nearly to Long Island Sound. The zone is widest in southwestern Maine, the area of this field trip (Figure 1). The most significant of the faults within the zone in southwestern Maine appears to be the Flying Point Fault (Fig.1). South of Scarboro, the fault zone is represented by the Nonesuch River Fault with which the Flying Point Fault merges. The Nonesuch River Fault continues into New Hampshire where it apparently is the same break as the Campbell Hill Fault of Lyons, et al. (1982).

In southwestern Maine the Norumbega Fault Zone forms the boundary between the Central Maine sequence and the Merrimack Group, and between the Central Maine sequence and the Casco Bay Group southwest of Portland. To the northeast, in the eastern Maine area, rocks of Late Ordovician to possibly Devonian age (the Vassalboro, Bucksport, and Flume Ridge Formations) have been mapped on either side of the Fault Zone, but have been displaced only a few 10's of kilometers at most. The Fault Zone is essentially locked by plutons of Carboniferous age (Biddeford, Saco, and Lyman; Hussey and Newberg,1978), and may be more significant with respect to basement terranes, as discussed below.

This field trip will focus on geological contrasts and similarities of terranes on either side of the Norumbega - Nonesuch River Fault Zone in southwestern Maine. Stops will be made to examine lithologies and structures of formations of the Merrimack Group, the central Maine sequence, and the Casco Bay Group. Participants will have an opportunity to discuss the significance of radiometric dates which apparently deny correlations of similar rock units on either side of the Fault Zone.

STRATIGRAPHY AND STRUCTURE OF SOUTHWESTERN MAINE

Four terranes comprise the bedrock of southwestern Maine: 1) the Rye Terrane consisting of the Rye Formation, 2) the Central Maine Terrane consisting of the Vassalboro, Windham, and Waterville Formations and formations of the Shapleigh Group; 3) The Casco Bay Terrane consisting of the Cushing, Cape Elizabeth, Spring Point, Diamond Island, Scarboro, Spurwink, Jewell and Macworth Formations; and 4) the Merrimack Terrane consisting of the Kittery, Eliot, and Berwick Formations.

RYE TERRANE. The very southwestern tip of Maine is underlain by the Rye Formation which extends southward in New Hampshire to the Seabrook area where it plunges to the southwest beneath the Kittery Formation of the Merrimack Group. It is restricted to the southeast side of the Norumbega Fault. The Rye Formation consists principally of regionally mylonitized metasedimentary rocks (mostly metashales and metasiltstones, in part calcareous) which have been migmatized and pegmatite-injected to varying degrees (Hussey, 1980; Carrigan, 1984a, b, and c). The most heavily migmatized rocks were originally interpreted to be a sequence of felsic metavolcanic rocks, but detailed studies have shown that 1) some of the migmatized rocks have abundant sillimanite and relic staurolite and andalusite, and 2) the felsic stringers occasionally transect compositional layering interpreted to be bedding in the metasediments. Minor lithologies include amphibolite, rusty schist, and impure marble. At the north edge of its outcrop belt the Rye Formation is in contact with the Kittery Formation across an ultramylonite zone 75m or so wide representing deep ductile strike-slip or thrust faulting. Swanson (personal communication, 1986) regards this to be right-lateral strike-slip motion. The Rye Formation is correlated with the Nashoba Formation, and pelitic parts of the Massabesic Gneiss (Hussey, 1985) and is probably late Precambrian in age.

MERRIMACK TERRANE. The Merrimack Terrane is underlain by the Kittery, Eliot, and Berwick Formations, an apparently conformable sequence of calcareous and feldspathic metaturbidites. These formations are restricted to the southeast side of the Norumbega Fault.

The Kittery Formation consists of thin to thick, variably bedded calcareous and feldspathic metawacke, occasionally with coarse sand sized clasts of quartz, feldspar,and dark rock fragments in the bases of thick graded beds. Minor sedimentary structures in addition to graded bedding include cross-bedding, flame structures, minor channel cut and fill, and parallel laminae (Rickerich, 1983). Rickerich (1983) interprets the environment of deposition of the Kittery Formation to be that of a deep-sea fan. He shows from analysis of direction of inclination of the foresets of crossbeds that the beds of the Kittery Formation were deposited primarily by currents flowing

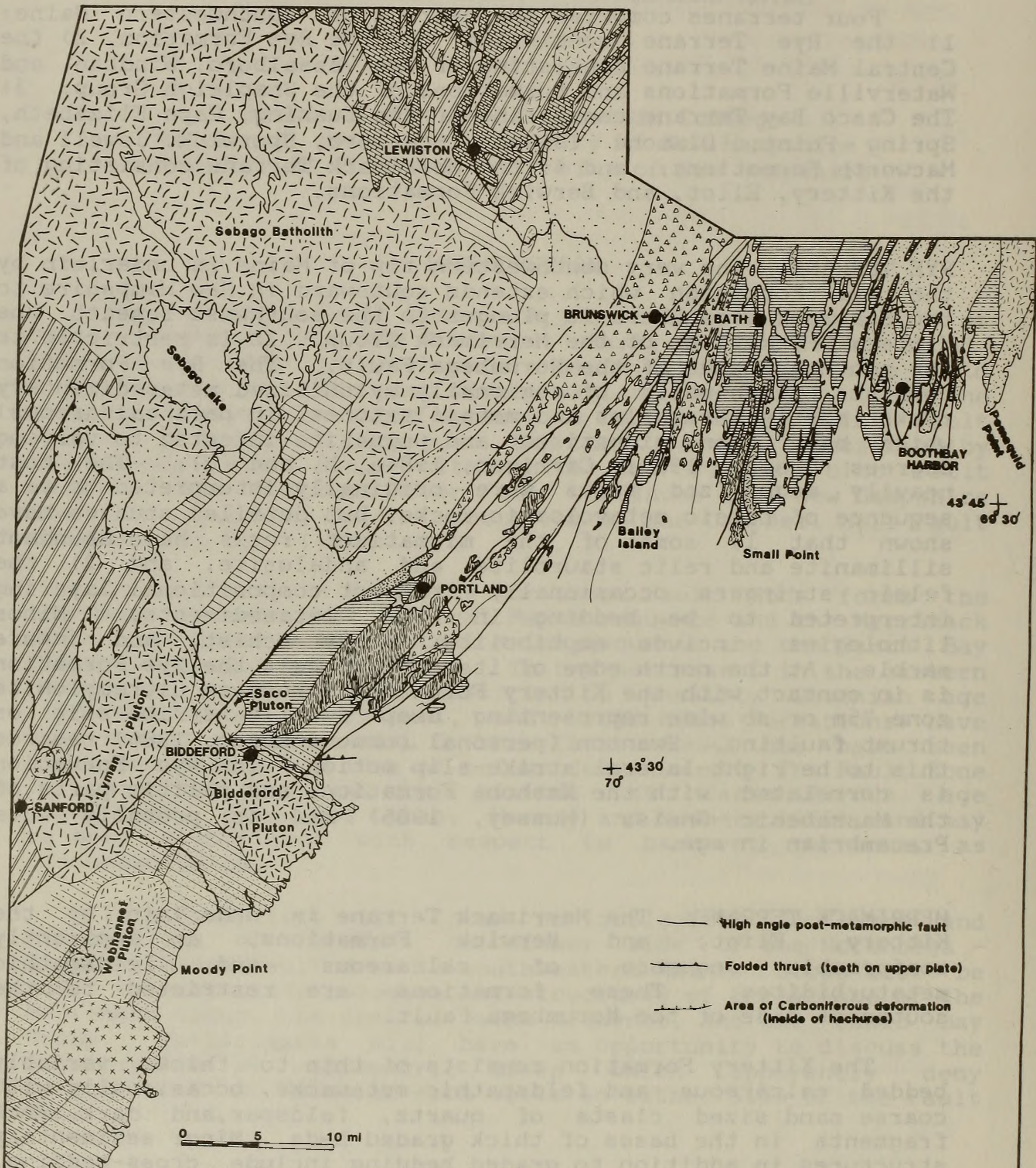
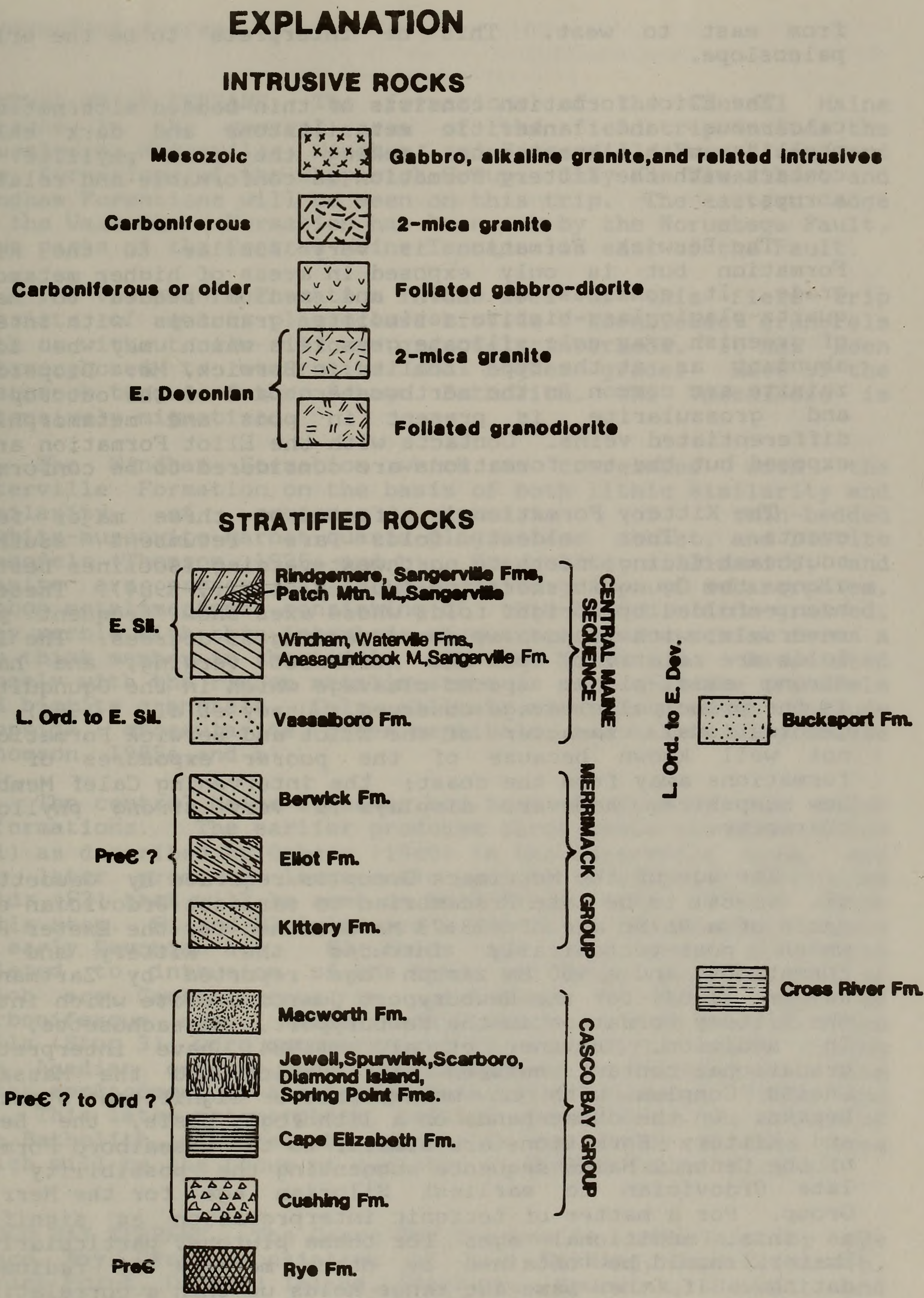


Figure 1. Generalized geologic map of southwestern Maine.


EXPLANATION
INTRUSIVE ROCKS
Mesozoic
Gabbro, alkaline granite,and related intrusives
Carboniferous
2-mica granite
Carboniferous or older
Foliated gabbro-diorite
E. Devonian
2-mica granite
Foliated granodiorite
STRATIFIED ROCKS
E. Sil.
Rindgemere, Sangerville Fms, Patch Mtn. M.,Sangerville
Windham, Waterville Fms., Anasagunticook M.,Sangerville Fm.
L. Ord. to E. Sil.
Vassalboro Fm.
CENTRAL MAINE SEQUENCE
L. Ord. to E. Dev.
Bucksport Fm.
PreЄ ?
Berwick Fm.
Eliot Fm.
Kittery Fm.
MERRIMACK GROUP
Cross River Fm.
PreЄ ? to Ord ?
Macworth Fm.
Jewell,Spurwink,Scarboro, Diamond Island, Spring Point Fms.
Cape Elizabeth Fm.
Cushing Fm.
CASCO BAY GROUP
PreЄ
Rye Fm.

from east to west. This he interprets to be the original paleoslope.

The Eliot formation consists of thin-bedded alternations of calcareous and ankeritic metasiltstone and dark chlorite phyllite, with a basal zone lacking the dark phyllite. The contact with the Kittery Formation is conformable and relatively abrupt.

The Berwick Formation is very similar to the Kittery Formation but is only exposed in areas of higher metamorphic grade. It consists of thin and medium bedded to massive quartz-plagioclase-biotite-actinolite granofels with interbeds of greenish gray calc-silicate granofels which may be locally abundant as at the type locality in Berwick, Me. Diopside and zoisite are common in the northwestern part of the outcrop belt and grossularite is present in pods and metamorphically differentiated veins. Contacts with the Eliot Formation are not exposed but the two formations are considered to be conformable.

The Kittery Formation is affected by three major folding events. The oldest folds are recumbent south to southeast-facing, north to northwest-verging isoclines best seen along the Ogunquit shoreline (Hussey et al., 1984). These have been refolded by upright folds whose axes show frequent plunge reversals, with plunges seldom exceeding 25 degrees. The latest folds are relatively open and northwest verging, and have a strong axial-planar spaced cleavage which in the Ogunquit area is the principal cleavage observed (Hussey et al. 1984). The deformational character of the Eliot and Berwick Formations is not well known because of the poorer exposures of these formations away from the coast; the intervening Calef Member in New Hampshire, however, displays a very strong phyllonitic character.

The age of the Merrimack Group is regarded by Gaudette et al. (1984) to be Late Precambrian to earliest Ordovician on the basis of a Rb/Sr age of 473+73 Ma obtained for the Exeter Pluton which post-tectonically intrudes the Kittery and Eliot Formations, and a 450 Ma zircon age reported by Zartman and Naylor (1984) for the Newburyport Quartz Diorite which intrudes the Kittery Formation in the Newburyport, Massachusetts, area. In addition, Bothner et al. (1984) have interpreted a gradational contact between the Berwick and the Massabesic Gneiss Complex with no metamorphic or significant structural breaks. On the other hand, on a lithologic basis, the Berwick and Kittery Formations are similar to the Vassalboro Formation of the Central Maine sequence suggesting the possibility of a late Ordovician to earliest Silurian age for the Merrimack Group. For a matter of tectonic interpretation as significant as this, additional ages for these plutons, particularly the Exeter, should be obtained by other methods of radiometric dating. If the same age range holds up then a correlation of the Merrimack Group with the Vassalboro will be precluded and the Merrimack sequence must then be interpreted as a totally independent terrane.

CENTRAL MAINE TERRANE. The formations of the Central Maine Terrane in the general area of the field trip include the Vassalboro, Waterville, Windham, and Sangerville Formations, and the formations of the Shapleigh Group. Only the Vassalboro and Windham Formations will be seen on this trip. The eastern edge of the Vassalboro Formation has been cut by the Norumbega Fault, thus parts of the Central Maine Terrane lie east of the Fault.

The Vassalboro Formation in the area of this field trip consists of quartz-plagioclase-biotite (-hornblende) granofels with or without calc-silicate granofels interbeds. It has been metamorphosed to staurolite and higher grade. East of the Westbrook tongue of the Sebago Batholith, the Vassalboro is extensively migmatized.

The Windham Formation which is correlated with the Waterville Formation on the basis of both lithic similarity and similarity of sequence consists of thin-bedded biotite-muscovite-garnet-quartz-plagioclase schist, and biotite granofels (Thomson, 1985a and b). Staurolite, sillimanite, and kyanite are present at the respective grades of metamorphism. ribbon metalimestone, consisting of thin-bedded, fine-grained, gray marble with thin interbeds of quartzose mica schist forms a 50m thick member in the middle of the Formation. Associated closely with the ribbon metalimestone is calc-silicate granofels and biotite granofels. Calc- silicate minerals present include diopside, grossularite, green amphibole, and calcic plagioclase (Thomson, 1985a and b).

The central Maine sequence has been affected by two major deformations. The earlier produced large-scale recumbent folds (F1) as described by Osberg (1980) in the Waterville area, and the later produced large-scale upright to slightly overturned folds (F2) that will be seen on this field trip at the Union Falls stop. F1 and F2 folds are a result of the Acadian Orogeny of early Devonian age. F3 folds are very minor structures related to intrusion of the Lyman and Sebago plutons, both of which are Carboniferous in age, hence F3 folds are of Carboniferous age. These rock, which will be seen at Union Falls (Stop 3), were metamorphosed to staurolite grade during the Acadian orogeny, and remetamorphosed in Carboniferous time after emplacement of the Sebago Batholith (Thomson, 1985a and b). This later metamorphism, related spatially to the bottom of the Batholith, produced the kyanite in the South Windham area which will be the focus of our stop at Dundee Falls (Stop 4).

CASCO BAY TERRANE. The Casco Bay Terrane is underlain by the Casco Bay Group consisting of the Cushing, Cape Elizabeth, Spring Point, Diamond Island, Scarboro, Spurwink, Jewell, and Macworth Formations in ascending stratigraphic order. The contacts between formations are conformable 2xcept that between the Cape Elizabeth and Cushing Formations which may be, at least locally, unconformable.

The Cushing Formation is composed largely of felsic to intermediate metavolcanic rocks, and feldspathic volcanogenic metasedimentary rocks , with lesser mafic metavolcanic rocks, calc-silicate granofels, marble, and sulfidic schist. In the belt from South Portland through the central part of Casco Bay to Harpswell Neck, on the east side of the Norumebega Fault, the Formation shows the most distinctive volcanic character of any part of its outcrop belt. The rocks are very feldspathic, and structures indicate that much of the rock was crystal tuff and volcanic breccia prior to metamorphism. The Formation shows significant facies changes across the strike of the belt, but relatively constant character parallel to strike. Across strike to the east, the upper part of the Formation has a stronger clastic character with abundant calc-silicate granofels and minor sillimanite-bearing feldspathic granofels.

West of the Norumbega Fault, rocks mapped as the Cushing consist predominantly of feldspathic metasedimentary rocks and felsic metavolcanic rocks in part with abundant interbeds of amphibolite 2cm to several meters thick. It also has rusty graphitic and sillimanitic schist, biotite-garnet schist, locally with abundant sillimanite, impure marble, and thin coticule beds. These rocks are sufficiently different from the Cushing east of the Norumbega Fault to warrent consideration that they may not correlate with the Cushing but may be some other, perhaps older, terrane that is a western basement for Cape Elizabeth and higher units of the Casco Bay Group.

The Cape Elizabeth Formation, metamorphosed from chlorite to K-feldspar-sillimanite grade, consists primarily of thin-bedded quartz-plagioclase-biotite (-muscovite) phyllite, schist, or gneiss (depending on metamorphic grade). Interbeds of aluminum-rich metapelite are common and, rusty phyllite and schist form mappable lenses within, and at the base of the Formation. Staurolite and sillimanite are commonly developed at proper grade. Graded bedding is infrequently observed.

The Spring Point Formation is a varied sequence of mafic metavolcanic rocks, feldspathic volcanogenic metasedimentary , and felsic metvolcanic rocks. In the western-most part of its outcrop belt at chlorite grade it is a medium gray chlorite-spessartitic garnet phyllite. Fragmental structures are not present in these rocks. At garnet grade it is a medium to dark greenish gray biotite-actinolite-plagioclase gneiss locally with distinct lineated clots of felsic material interpreted to be felsic volcanic fragments (see description for stop 5 at SMVTI, South Portland). Blue quartz phenocrysts identical to those seen in parts of Cushing are present. In the Harpswell area at the north end of Casco Bay, the Spring Point consists of dark gray garnet amphibolite at the base, and massive to thin and well bedded feldspathic metasandstone with thin interbeds of amphibolite and chloritic medium greenish gray intermediate metavolcanics. Between the mafic and felsic rocks is a zone approximately 15m thick of garnet-rich granofels, some beds of which qualify for the name coticule.

The Diamond Island Formation is the most distinctive unit of the Casco Bay Group. It is a uniform non-bedded sequence of black, rusty-weathering graphite-quartz-muscovite phyllite characteristically with tissue-thin quartz laminae parallel to the foliation.

The Scarboro and Jewell Formations are essentially identical lithologically. They consist of rusty and non-rusty-weathering, light and dark gray phyllites of no systematic distribution within the two units. Both formations have minor medium greenish gray chlorite phyllite representing intermediate ash deposits.

The Spurwink Metalimestone separates the Scarboro and Jewell Formations. It is a 50-75m sequence of thin ribbony-bedded, medium gray fine-grained impure marble and quartz-biotite-plagioclase granofels. Similar ribbon limestone lenses less than 15m thick are present locally near the base of the Scarboro Formation, and within the Diamond Island Formation.

The Macworth Formation consists of fine-grained slightly calcareous and feldspathic medium brownish gray, commonly thinly laminated granofels with sporadic thin beds of light gray metafelsite tuff, and coarse- granule beds. The granules are white, extremely fine grained, and may be metafelsite fragments.

Regional metamorphism of the Casco Bay Group within the area of Fig.2 varies from chlorite to K-feldspar-sillimanite grade in a Buchan-type facies series (andalusite, rather than kyanite, is present in the metapelites). The present prograde assemblage is regarded to be of Acadian age (Hussey, 1985). Retrograde metamorphism, mostly recorded by the alteration of biotite and garnet to chlorite, is developed most strongly in the vicinity of faults of the Norumbega Fault Zone, and is probably genetically related to that faulting.

The Casco Bay Group is currently regarded to be of Precambrian to Ordovician age (Osberg et al., 1985) with a bias toward late Precambrian (Hussey, 1985). Brookins and Hussey (1978) report Rb/Sr ages of 481+40 Ma and 485+30 Ma for the Cushing and Cape Elizabeth Formations respectively but these probably reflect partial resetting of initial ages due to Acadian metamorphism.

The Cape Elizabeth Formation is tentatively correlated with the Rye Formation, with pelitic portions of the Massabesic Gneiss of southeastern New Hampshire, and possibly with the Ellsworth Formation of eastern Maine. The Cushing Formation, in particular the part west of the Norumbega Fault, may correlate with parts of the Massabesic Gneiss and the Cushing east of the Fault may be equivalent to the Ellsworth Formation. Units of the Casco Bay Group above the Cape Elizabeth have no known correlations beyond their own outcrop belt.

The Cape Elizabeth Formation preserves evidence of two major and several minor deformations. The oldest folds (F1) are recumbent folds of unknown facing, vergence, extent, and age. They are known only from minor recumbent parasitic folds seen in outcrop and rare downward-facing F2 folds. F2 folds are major north-northeast-trending upright folds whose axes are gently plunging with frequent plunge reversals. F2 folds control the map distribution of the formations, except locally as at Small Point where thin, mappable units within the upper part of the Casco Bay Group have been affected by intermediate scale recumbent folding as well as later F2 refolding. The nature of multiple deformation of other units of the Casco Bay Group is essentially unknown because of the lack of well-preserved bedding.

BUCKSPORT AND CROSS RIVER FORMATIONS. The Bucksport Formation consists of thin bedded to massive medium gray quartz-plagioclase-biotite-hornblende granofels with thin interbeds of greenish gray calc-silicate granofels. Primary structures other than bedding are rare. Zones of rusty-weathering sulfidic biotite-quartz-plagioclase schist are common. Calc silicate minerals include diopside, hornblende, zoisite, and rarely grossularite. Even though metamorphosed to K-feldspar-sillimanite grade, the Bucksport Formation is not migmatized to agmatitic gneiss as are parts of the Cape Elizabeth at that grade; instead, pegmatite stringers from a few centimeters to several tens of meters cleanly cut the formation either as sills, straight dikes, or contorted lenses. The Bucksport is similar to both the Vassalboro and the Berwick Formations. The Bucksport has been mapped along strike into the outcrop belt of the Flume Ridge Formation for which Ludman (1980) suggests a Siluro-Devonian age. On the recently issued Bedrock Map of Maine, Osberg, et al. (1985) correlate the Bucksport with the Vassalboro Formation as well as the Flume Ridge and give the age as Ordovician to Devonian. If it correlates with the Berwick Formation, then the age range of the Bucksport may have to be extended back to include late Precambrian as well. The Bucksport is overlain by the Cape Elizabeth Formation, but because of inferred discordancy in ages of the two formations, the contact is interpreted to be a premetamorphic folded thrust fault.

The Cross River Formation, exposed in two belts in the Boothbay-Bristol area, consists of two members. The upper member is a medium gray quartz-plagioclase-biotite (-garnet) granofels with, in the lower parts of the member, coarse, irregularly textured amphibolite beds. The lower and most extensive member is a rusty weathering sulfidic quartz-plagioclase-biotite-sillimanite-graphite migmatite locally grading to schist. Rafts of quartz-plagioclase-biotite granofels and amphibolite probably representing non-migmatized metasandstone beds which have been torn apart during plastic mobilization of the migmatite, are common. The contact between the Bucksport and Cross River Formations may be a premetamorphic thrust or possibly an unconformity. It is similar to rusty phases of the Penobscot Formation of Osberg and Guidotti (1974) but also resembles rusty and non rusty schists in the Cushing Formation west of the Norumbega Fault in the Gardiner-Freeport area. Resolution of this critical correlation, which has considerable implications to terrane analysis and tectoncis in southwestern Maine, awaits future field work.

INTRUSIVE HISTORY OF SOUTHWESTERN MAINE

The intrusive rocks of southwestern Maine range in age from Early Devonian to Cretaceous. The oldest rocks are plutons composed of two-mica granite, biotite granite, and granodiorite. An early Devonian age (Table 1) is reported by Gaudette, et al. (1982) for the Webhannet pluton (Figure 1), and similar ages are inferred for the many small plutons in the outcrop belt of the Casco Bay and Shapleigh Groups. The Biddeford Pluton, composed of generally non-foliated biotite granite, is of early Carboniferous age (Table 1). Carboniferous ages are also reported for the Sebago and Saco Plutons (Hayward and Gaudette, 1984; Gaudette et al., 1982; and Aleinikoff, 1984). The age for the Saco Pluton is anomalous. The diorite that makes up the bulk of the pluton is pervasively lineated (strongly) and foliated (weakly), and the original primary igneous mineralogy has been replaced almost completely by secondary minerals either by extensive deuteric alteration, or more likely recrystallization during a metamorphic episode, most likely the Acadian. Younger intrusives include alkaline ring complexes and stocks ranging in age from Permian or Triassic age to Cretaceous. Basalt, diabase, and, to a lesser extent, lamprophyric dikes are abundant in a belt about 5 km wide from the vicinity of the mouth of the Saco River southward along the coast to Kittery and beyond in New Hampshire.

In southeastern New Hampshire, Gaudette et al. (1984) report a 473 Ma Rb/Sr age for the Exeter Pluton which intrudes the Kittery and Eliot Formations post-tectonically, and after the earliest recognized metamorphism. Zartman and Naylor (1984) report a Zr age of 455 Ma for the Newburyport pluton that intrudes the Kittery Formation in southeastern New Hampshire and northeastern Massachusetts. As noted earlier, these dates appear to pose serious restraints on correlation of lithically similar belts of rock nearly on strike with each other (Berwick and Vassalboro Formations).

TABLE I. RADIOMETRIC AGES REPORTED FOR SOME PLUTONIC ROCKS IN SOUTHWESTERN MAINE

PLUTON	METHOD	AGE MA	REFERENCE
Webhannet	Rb/Sr Whole Rock	390+10	Gaudette et al.(1982)
Webhannet	Zir Pb	403+13	Gaudette et al.(1982)
Lyman	Rb/Sr Whole Rock	322+12	Gaudette et al.(1982)
Biddeford	Rb/Sr Whole Rock	344+12	Gaudette et al.(1982)
Saco	Rb/Sr Whole Rock	307+20	Gaudette et al.(1982)
Sebago	U/Pb zir	325+3	Aleinikoff (1984)
Sebago	Rb/Sr Whole Rock	325+-	Hayward and Gaudette (1984)
Exeter	Rb/Sr Whole Rock	473+37	Gaudette et al.(1984)
Newburyport	Pb-Pb Zir	455+15	Zartman and Naylor (1984)

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ITINERARY (FIGURE 2)

ASSEMBLY POINT: Commuter parking lot at exit 2 (Wells) Maine Turnpike. If there is insufficient space here, park also beside the kiosk opposite the exit to Route 109. Departure time from this lot is 8:30 A.M. We must leave promptly because of the tide at the first stop. We will not return to this point at the end of the trip.

Mileage	
0.0	Turn left from exit of Maine Turnpike onto Route 109.
1.6	Junction, Route 1; turn right on Route 1.
3.6	Turn left onto Eldridge Road.
4.9	Turn left on Webhannet Drive.
5.0	STOP 1. MOODY POINT, WELLS (Figure 3).

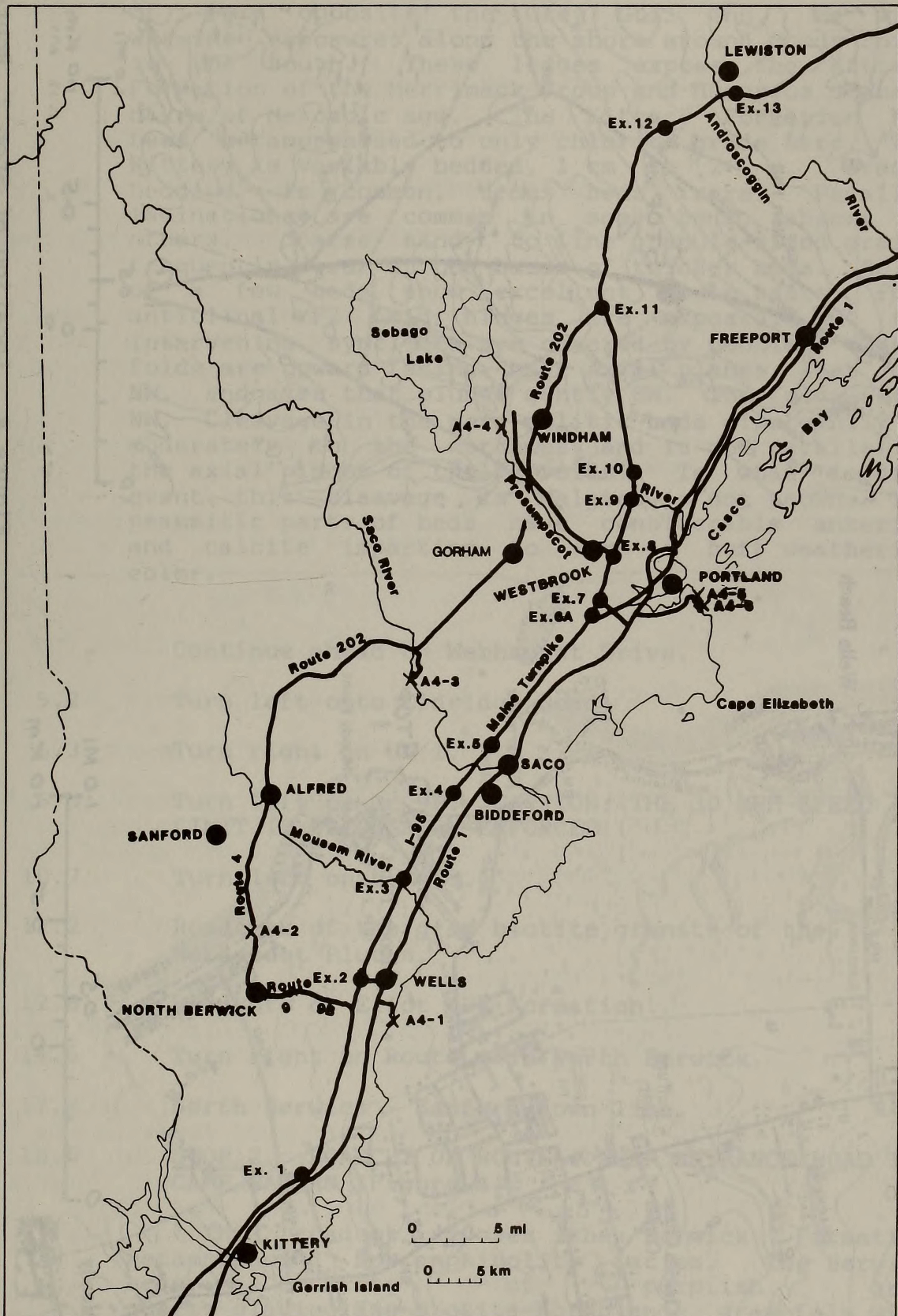


Figure 2. Itinerary and general location of stops, trip A4.

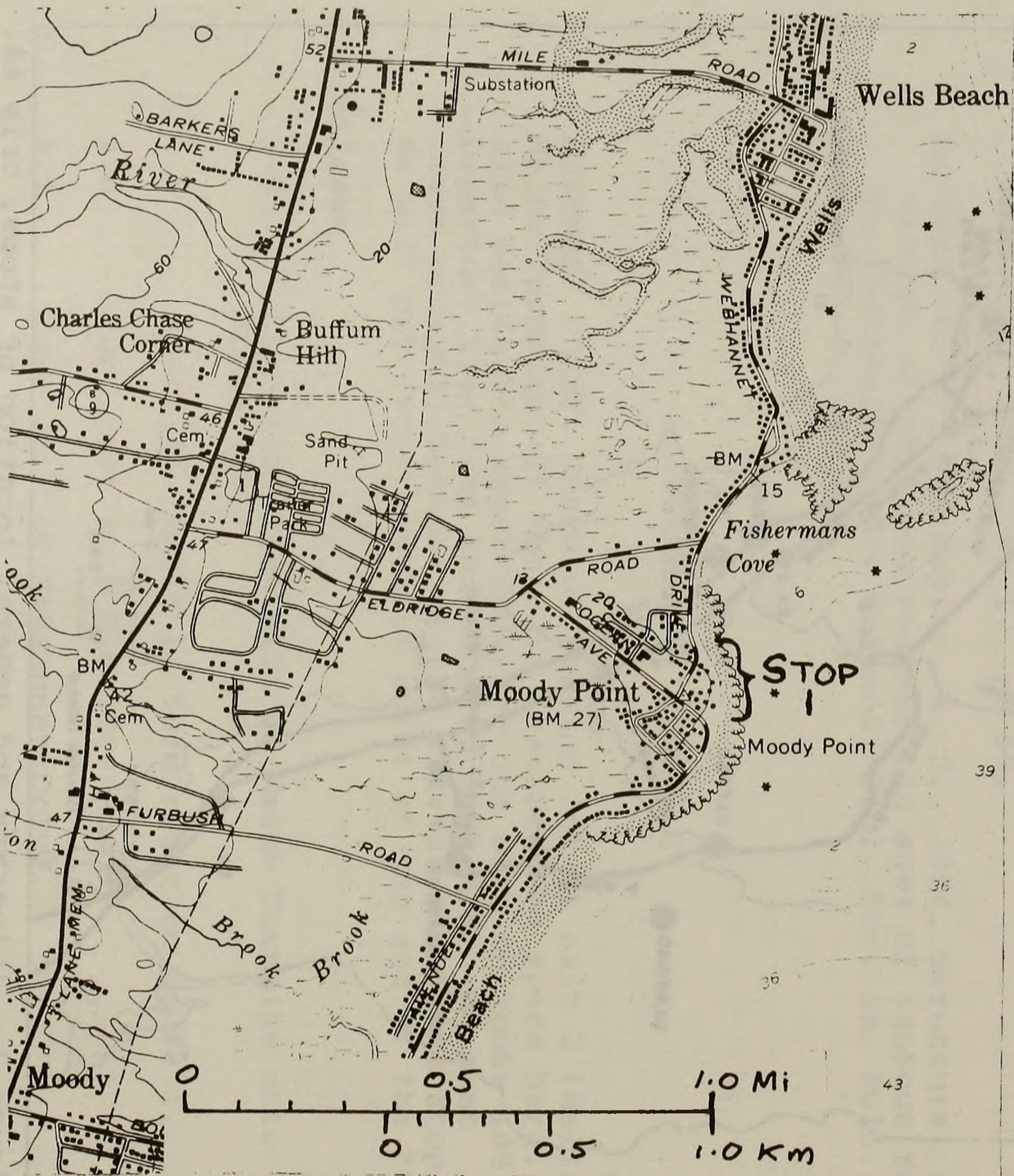


Figure 3. Location of Stop 1, Moody Point, Wells, Maine (Wells 7.5′ quadrangle).

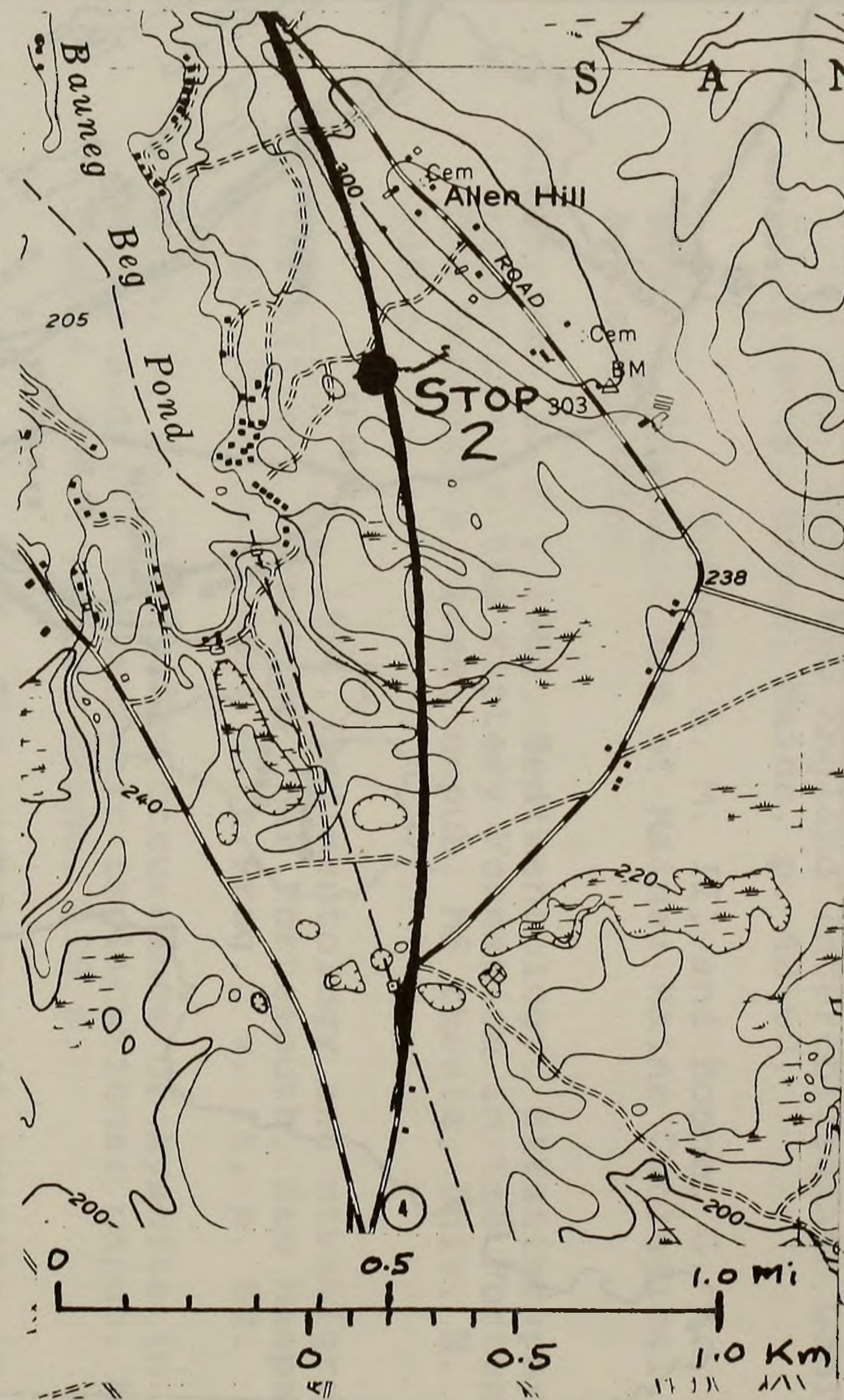


Figure 4. Location of Stop 2, Route 4 at entrance to Camp Wauban (North Berwick 7.5′ quadrangle).

Park opposite the Grey Gull Inn. We will examine exposures along the shore around Moody Point to the south. These ledges expose the Kittery Formation of the Merrimack Group and numerous diabase dikes of Mesozoic age. The Kittery Formation has been metamorphosed to only chlorite grade here. The Kittery is variably bedded, 1 cm to 2+ m. Graded bedding is common, cross beds, rare. Parallel laminations are common in some beds, absent in others. Coarse sand- to fine granule-sized grains frequently occur at the bases of thicker beds. Soles of a few beds show excellent flute casts. Four anticlinal F2 fold hinges are exposed, but the intervening synclines are covered by cobbles. These folds are upward facing, have axial planes that dip NW, and axes that plunge gently SW. The folds verge NW. Cleavage in the more pelitic beds dips gently to moderately to the northwest and is not parallel to the axial planes of the F2 folds. To what folding event this cleavage is related is not known. The psammitic parts of beds have considerable ankerite and calcite imparting to some a buff weathering color.

Continue ahead on Webhannet Drive.

5.2 Turn left onto Eldridge Road.

6.3 Turn right on US 1.

6.5 Turn left on Me 9B. CAUTION: THE 30 MPH SPEED LIMIT IS FREQUENTLY ENFORCED!!

10.7 Turn left onto Me 9.

12.2 Roadcuts of the gray biotite granite of the Webhannet Pluton.

12.8 Roadcuts of Eliot (?) Formation.

14.6 Turn right on Route 4 in North Berwick.

17.7 North Berwick - Sanford town line.

18.5 <u>STOP 2</u>. ROADCUT ON ROUTE 4 NEAR ENTRANCE ROAD TO CAMP WAUBAN (Figure 4).

This roadcut exposes the Berwick Formation metamorphosed to amphibolite facies. The Berwick here consists of purplish gray quartz-plagioclase-biotite-hornblende granofels with light greenish gray hornblende-diopside-grossularite granofels interbeds. Compositional layering shows moderate transposition along planes parallel to the layering.

Continue along on Route 4.

20.7 Roadcut of granite of the Lyman Pluton.

22.4 Stoplight. Continue straight on Route 4A.

26.9 Stoplight at junction with Route 202. Straight on Route 202.

27.5 Village of Alfred, shiretown of York County. Hills on left (west) are underlain by the Alfred Complex (norite, monzodiorite, and granodiorite) of Cretaceous age.

33.9 Blinker light at cutoff leading to Route 5. Continue straight on Route 202.

35.2 Junction with Route 5. Turn right at yield sign, staying on Route 202.

35.3 Outcrop of Vassalboro Formation.

36.9 Route 5 leaves Route 202. Stay on Route 202.

40.5 Junction with Route 35. Stay on Route 202.

41.1 Junction with Route 117. Stay on Route 202.

42.8 Cross the Saco River and make an immediate right turn onto Route 117. Prior to damming, the course of the Saco River here was one of the most scenic river gorges in Maine.

43.2 Turn right onto Simpson Road.

44.1 Turn right onto gravel road opposite gravel pit.

45.0 STOP 3. SKELTON DAM, UNION FALLS ON THE SACO RIVER, BUXTON, MAINE (Figure 5).

Park in the turn around area, walk down the dirt road to the left. The other road leads to the end of the lip of the dam. At the end of the dirt road is a precipitous path down over the cliff. Watch your footing as you descend down over the cliff to the ledges below.

Ledges at the base of the dam (Figure 6) expose thin- to medium-bedded quartz-plagioclase-biotite (-hornblende) granofels of the Vassalboro formation. Ledges on the opposite side of the River at the base of the dam expose the contact between the Lyman

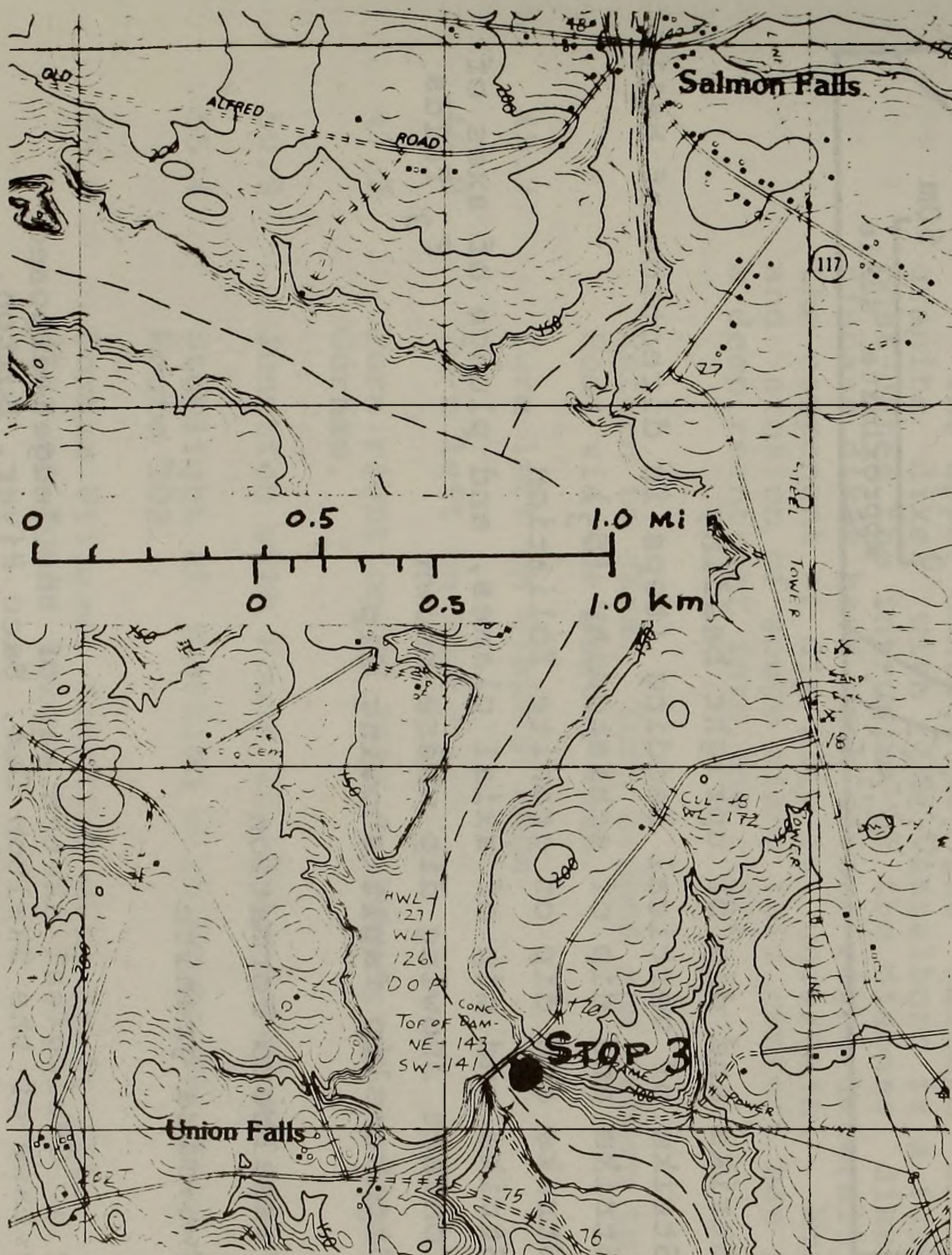


Figure 5. Location of Stop 3, Skelton Hydroelectric Dam, Saco River, Buxton, Maine Bar Mills 7.5′ quadrangle).

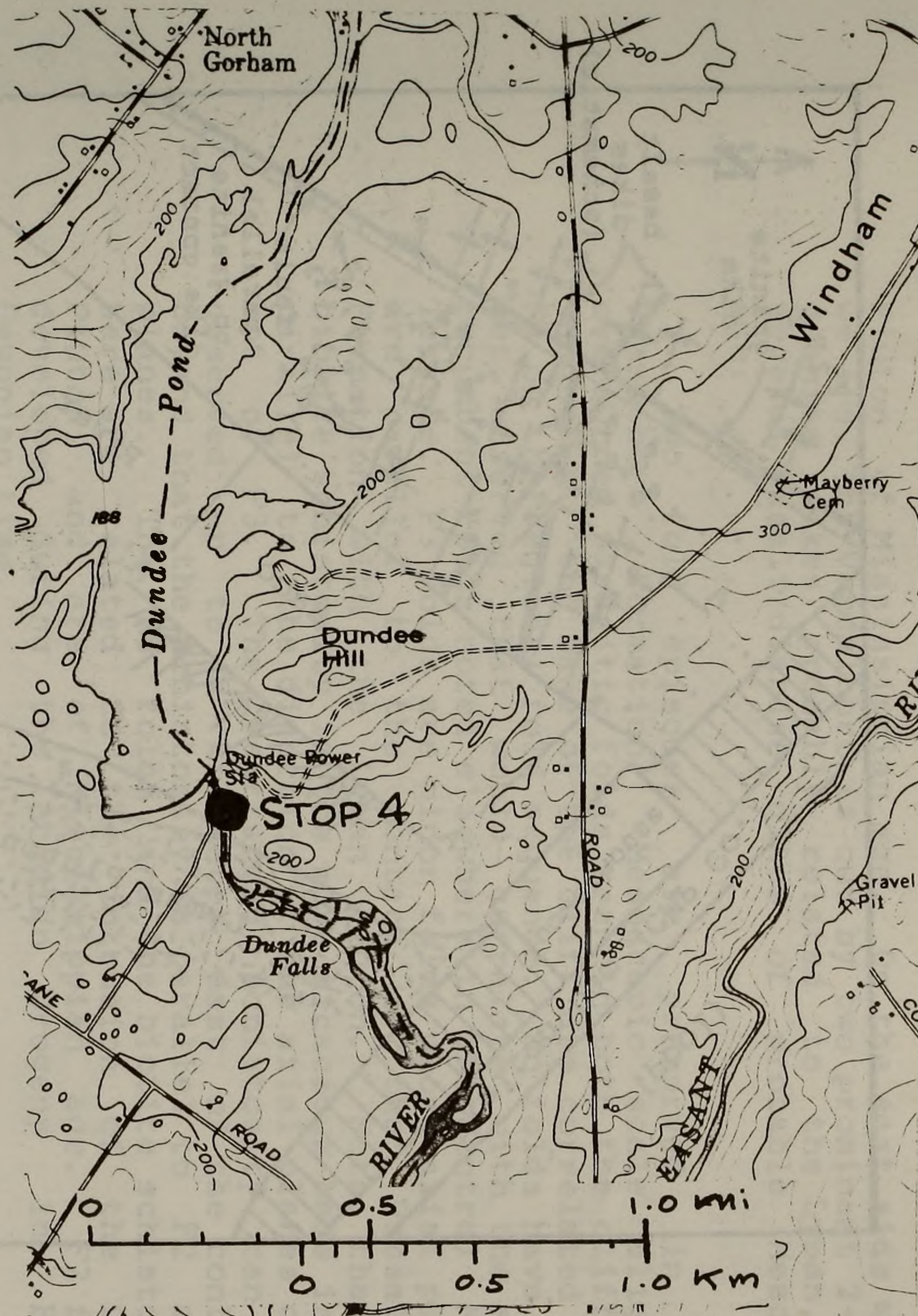
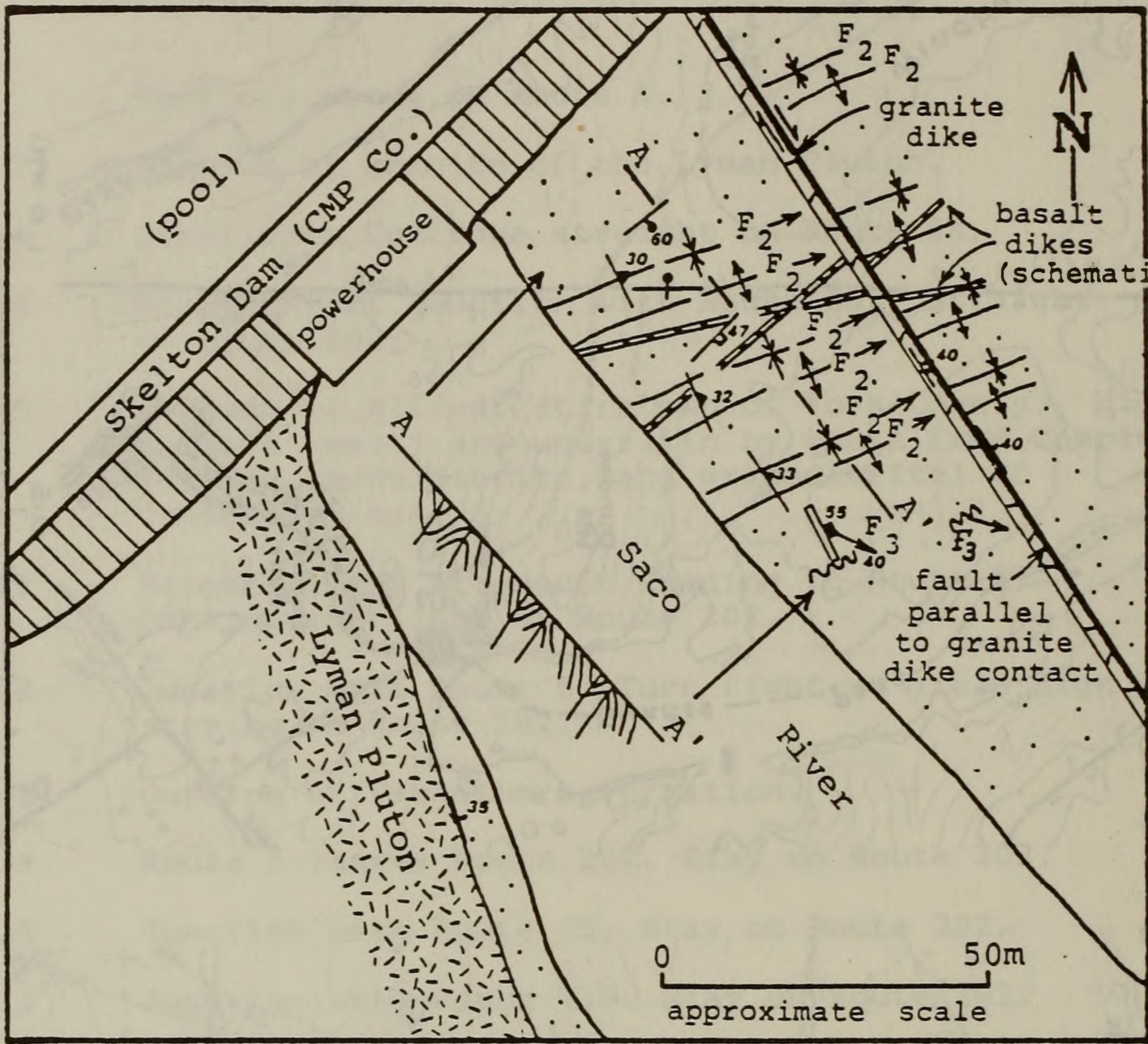


Figure 7. Location of Stop 4, Dundee Falls, North Windham, Maine (North Windham 7.5′ quadrangle.



Strike and dip of upright bedding

Strike of vertical bedding (tops in direction of ball)

Strike and dip of schistosity (S_3)

Strike and dip of granite foliation

Strike and dip of axial planes, and plunge of axes of F_3 folds

Contact showing dip where known

Strike-slip fault showing dip

Vassalboro Formation

Two-mica granite

Figure 6. Geological sketch map of the ledges exposed at the base of the Skelton Dam, Saco River, Buxton.

Pluton of Mississippian age. On the east side where we are, the Vassalboro is cut by two prominant 2-mica granite dikes probably related to the Lyman, and several basalt/diabase dikes of probable Mesozoic age.

Two fold episodes are preserved in the Vassalboro Formation. Mesoscopic scale slightly overturned parasitic folds seen in both the cliff and ledges at the base of the cliff are correlated with F2 of the regional fold sequence. No folds have been yet observed that would correlate with the early recumbent folds noted elsewhere in the Central Maine Terrane. F3 folds are minor folds whose axial planes are parallel to the contact of the Vassalboro Formation with the Lyman Pluton. Note that the biotite schistosity in the more micaceous beds is not parallel to the direction of the axial planes of F2 but of F3. The rearranged schistosity can be observed up to a kilometer east of the contact; beyond that the schistosity is parallel to F2 axial planes. The F3 folds and the biotite schistosity here are related to the intrusion of the Lyman Pluton, and are of Mississippian age. F2 folds developed during the Acadian Orogeny in Early Devonian time.

The upper contact of the eastern of the two granite dikes with the Vassalboro is a fault which post-dates the intrusion of the diabase dikes. The diabase dikes have been offset right laterally 20 cm; the component of dip slip is uncertain. Weathering and erosion of gouge along this contact has produced a deep reentrant into the cliff.

Return to cars. Turn around and return to Simpson Road via the gravel road.

45.7 Turn left on Simpson Road

46.8 Turn left on Route 117.

47.2 Turn right on US 202, following it through Gorham.

50.9 Junction with Route 22. Stay on Route 202.

55.4 Stoplight at junction with Route 4A. Stay on Route 202.

55.6 Gorham Village. Junction with Route 114. Stay on Route 202.

55.9 Stoplight. Stay on Route 202

56.0 Blinker. Bear left on Route 202.

59.3 Junction with Route 237. Stay on Route 202.

59.8 Cross Presumscot River at Gorham/Windham town line.

60.6 Blinker. Turn left on River Road.

62.4 Covered Bridge Road to the left. Stay on River Road.

63.5 Curtis Road to the right. Stay on River Road.

63.7 Park Road to the right. Park and walk down the lane to the left to ledges along the Presumpscot River at the base of the hydroelectric dam at Dundee Falls.

STOP 4. DUNDEE FALLS KYANITE LOCALITY (Figure 7).

All three units of the Windham Formation are exposed in approximately 700 feet of pavement outcrop below the dam at this locality. Near the base of the dam, the unit consists of thin-bedded two-mica + garnet + quartz + plagioclase schist. Downstream, the unit grades into a more aluminous schist with abundant staurolite, garnet, and sillimanite. Kyanite is also present but is generally associated with quartz pods. The lithology changes abruptly further downstream (Figure 8) to interbedded calc-silicate and biotite granofels (medium- to thick-bedded), and then, finally to thin bedded ribbon limestone (fine-grained gray marble layers interbedded with thinly layered micaceous quartz schist).

The rocks crop out just north of the kyanite-sillimanite isograd and therefore are interpreted to occur within the lower sillimanite zone of metamorphism. Both pre- and post-tectonic staurolite porphyroblasts have been observed in thin sections from this locality and suggest two periods of mineral growth. The first (M1) occurred during the Acadian Orogeny which metamorphosed much of the Windham-Gorham area to staurolite grade. The second (M2), a direct result of the intrusion of the Sebago Batholith at 325 Ma, caused prograde metamorphism of the M1 assemblages to sillimanite grade. M2 metamorphism recorded here is interpreted to have occurred on the underside of the Sebago Batholith at pressures of 6 to 7.5 kb (20-25 km).

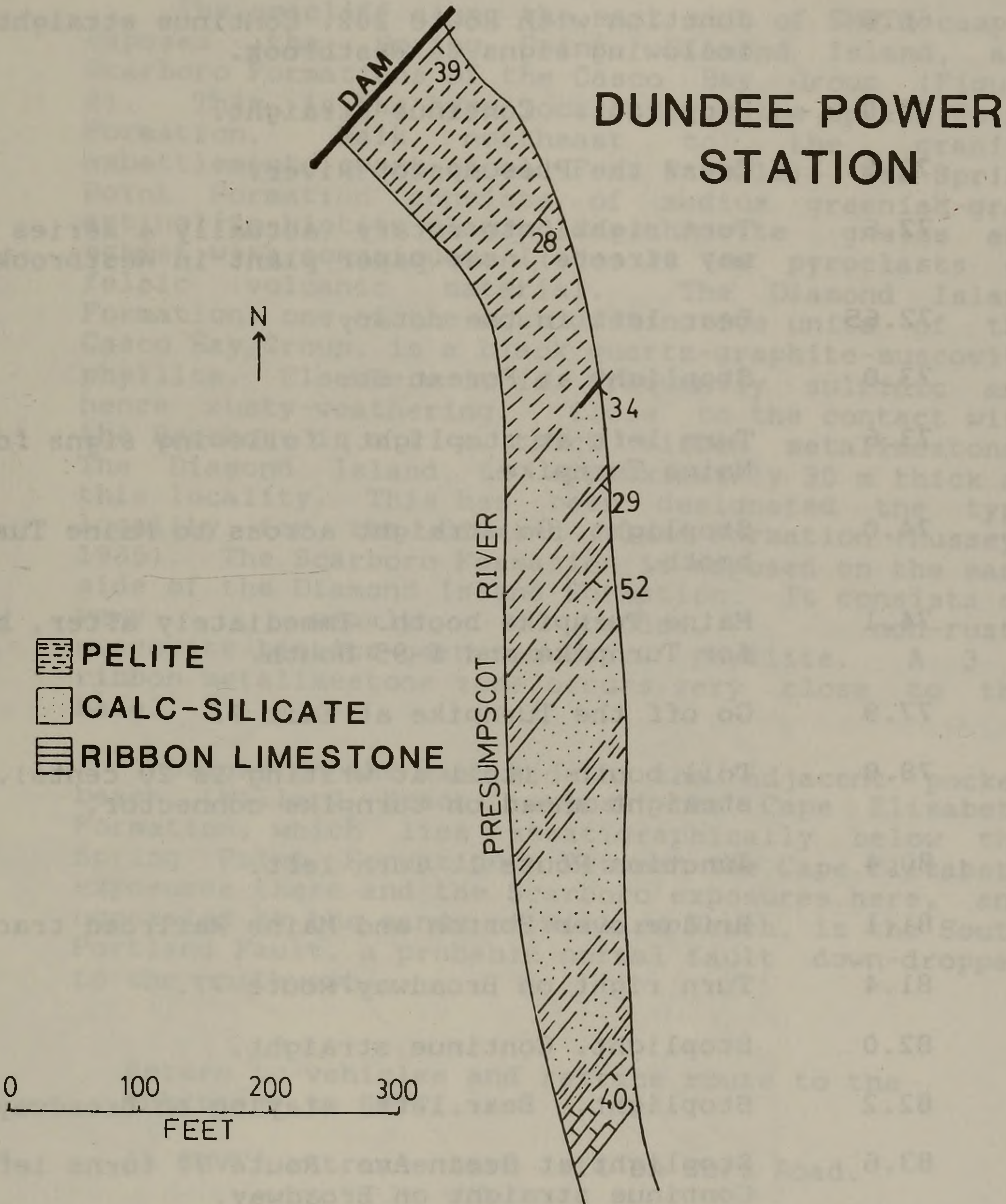


Figure 8. Stratigraphic succession at Dundee Power Station (North Windham 7.5' quadrangle), showing lithologic layers within the Windham Formation.

Return to cars, and turn around.
Return to Route 202

66.6 Junction with Route 202. Continue straight, following signs to Westbrook.

71.0 Stoplight. Continue straight.

72.5 Cross the Presumpscot River.

72.6 Turn right onto rotary (actually a series of one way streets) near paper plant in Westbrook.

72.65 Bear left in the rotary.

73.0 Stoplight at Forest St.

73.6 Turn left at stoplight, following signs for the Maine Turnpike.

74.0 Stoplight. Go straight across to Maine Turnpike booth.

74.1 Maine Turnpike booth. Immediately after, bear right for Turnpike and I-95 South.

77.9 Go off the Turnpike at Exit 7.

78.9 Toll booth (toll at writing is 20 cents). Continue straight ahead on turnpike connector.

80.4 Junction Route 1. Turn left.

81.1 Bridge over Boston and Maine Railroad tracks.

81.4 Turn right on Broadway/Route 77.

82.0 Stoplight. Continue straight.

82.2 Stoplight. Bear left, staying on Broadway.

83.6 Stoplight at Ocean Ave. Route 77 turns left. Continue straight on Broadway.

83.8 Stoplight at Cottage Road. Continue straight on Broadway.

85.0 Stopsign at junction with Pickett Street. Turn right.

85.1 Stopsign at Fort Street. Cross and enter SMVTI campus, Proceed to parking lot opposite Hildreth Hall. Walk to shoreline exposures in front of and northeast of the Hall.

STOP 5. SPRING POINT-SMVTI CAMPUS, SOUTH PORTLAND (Figure 9).

The seacliff along the east side of SMVTI campus exposes the Spring Point, Diamond Island, and Scarboro Formations of the Casco Bay Group (Figure 8). This is the type locality for the Spring Point Formation. Walk northeast to the granite embattlement (part of old Fort Prebble). The Spring Point Formation consists of medium greenish-gray actinolite-biotite-plagioclase-chlorite gneiss and schist with conspicuous 1 to 10 cm pyroclasts of felsic volcanic material. The Diamond Island Formation, one of the most distinctive units of the Casco Bay Group, is a black quartz-graphite-muscovite phyllite. Elsewhere it is frequently sulfidic and hence rusty-weathering. Close to the contact with the Scarboro is a 1 m thick ribbon metalimestone. The Diamond Island is approximately 30 m thick at this locality. This has been designated the type locality for the Diamond Island Formation (Hussey, 1985). The Scarboro Formation is exposed on the east side of the Diamond Island Formation. It consists of very weakly bedded, non-rusty muscovite-biotite-garnet-quartz phyllite. A 3 m ribbon metalimestone zone occurs very close to the base.

Ledges on the east side of the adjacent pocket beach (Willard Beach) expose the Cape Elizabeth Formation, which lies stratigraphically below the Spring Point Formation. Between the Cape Elizabeth exposures there and the Scarboro exposures here, and concealed by the sands of Willard Beach, is the South Portland Fault, a probable normal fault down-dropped to the northwest.

Return to vehicles and retrace route to the entrtance to SMVTI.

85.4	At SMVTI entrance turn left on Fort Road.
85.7	Stopsign. Bear left on Prebble Street.
86.0	Stopsign at Willard Square. Bear left, staying on Prebble.
86.6	Stopsign. Turn left on Cottage Road.
86.7	Park on Cottage Road opposite Sea View Avenue. Walk down Sea View Avenue to concrete stairs and descend to the base of the seacliff.

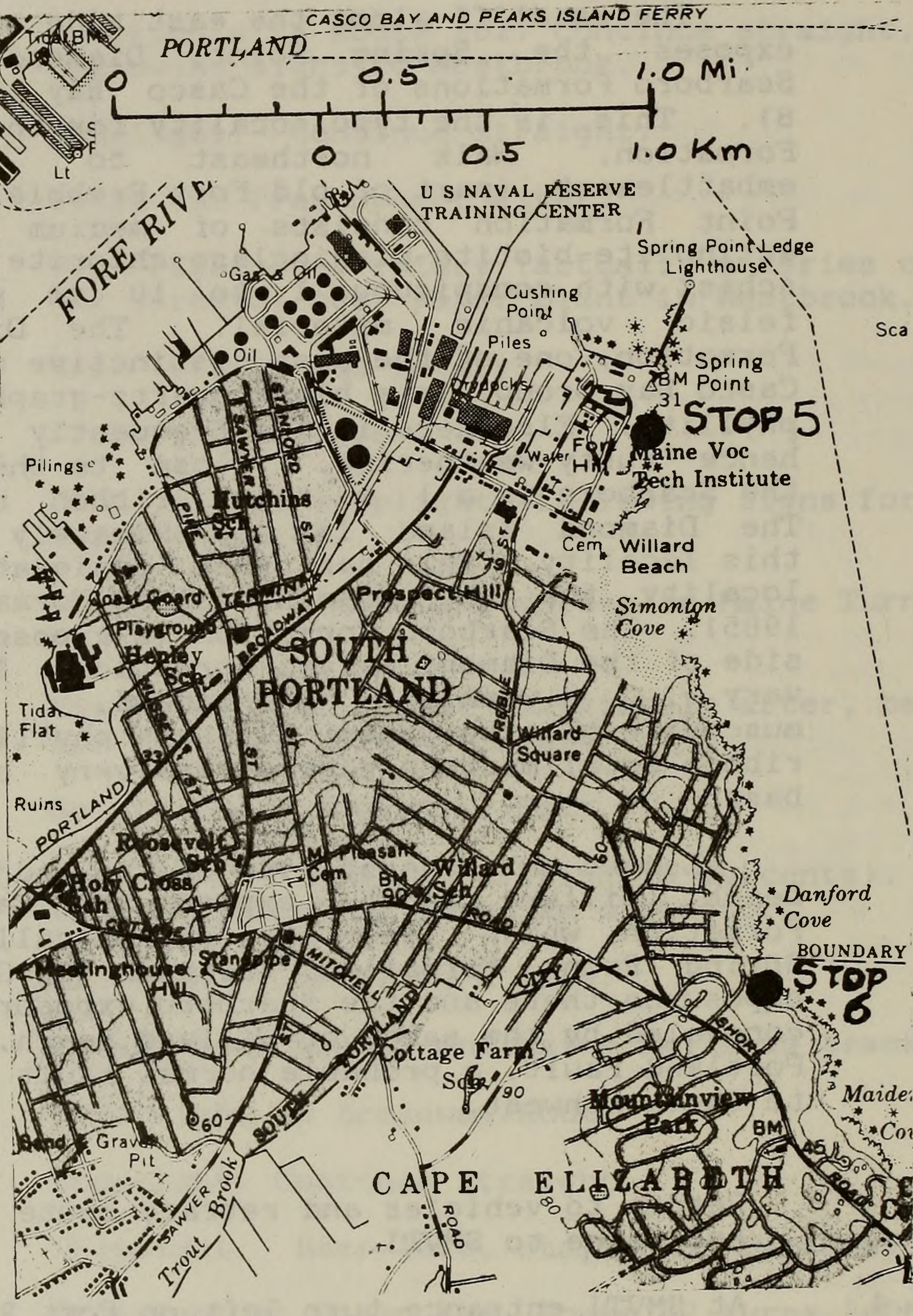


Figure 9. Location of Stops 5 and 6, South Portland and Cape Elizabeth, Maine (Portland East 7.5 quadrangle).

STOP 6. DANFORD COVE, SOUTH PORTLAND AND CAPE ELIZABETH (Figure 9).

Rocks of the Cushing Formation display original pyroclastic structures indicating that these rocks were originally felsic to intermediate volcanic breccia, and crystal tuff. These rocks are massive with only a minor suggestion of bedding locally. Grains of spectacular blue quartz and white plagioclase up to 3 mm in diameter are interpreted to be relict crystal fragments of an original crystal tuff. These rocks preserve weak foliation, but are strongly lineated (elongation of biotite clots parallel to the regional F2 fold hinges). Seventy five meters south of the concrete stairs the Cushing preserves distinctively recognizable breccia structure. Breccia fragments are mostly felsic and intermediate metavolcanic clasts.

Walk approximately 200 meters north from the stairs. The Cape Elizabeth-Cushing contact is exposed in the wavecut bench. The Cape Elizabeth Formation here is a biotite-chlorite-muscovite-garnet phyllite with thin interbeds of micaceous quartzite. Feeble graded bedding near the contact suggests that these beds are upright, and that the Cape Elizabeth Formation is stratigraphically above the Cushing. At this locality, the contact appears to be conformable.

This is the end of the trip. To get to Lewiston, retrace route to exit 7 of the Maine Turnpike. Travel north on the Turnpike to the Lewiston exit. Take the exit ramp for the City of Lewiston. Follow the signs for Bates College.