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Bedrock Geology of Northern Penobscot Bay Area

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BEDROCK GEOLOGY OF NORTHERN PENOBSCOT BAY AREA

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Introduction

GEOLOGIC DESCRIPTION

An early Paleozoic Continental Collision

This field trip provides an opportunity to observe the evidence for an early Paleozoic continental collision between an ancient North America and an ancient Europe. The trip features a south-southeasterly traverse across major regional structures so that lithologic differences between rocks of equivalent ages can be emphasized and reasons sought for those differences. The traverse starts in Silurian and Devonian marine turbidite sediments of the Merrimack synclinorium in the ancient North American plate, crosses an anticlinorium of older rocks, and ends in a Silurian and Devonian synclinorium called the "coastal volcanic belt" made up of volcanic rocks and shallow-water sediments laid down on the ancient European plate. The differences in regional stratigraphy can be more easily appreciated if we can mentally remove the effects of polymetamorphism, many plutons, and a series of major faults. The lithologic differences are greater than those observed for facies changes and also include a change in the fragmentary fauna from those of North American assemblages on the northwest to those of European or Baltic assemblages on the southeast, and possibly different basement rocks with different metamorphic histories below the Paleozoic rocks. Our discussion will focus on the location and appearance of the suture between these ancient plates as evidenced by some major faults along the traverse.

Stratigraphy and Structural Geology

Basis for Age Assignments of Stratified Rocks

The geologic age assigned to each of the formations in figure 1 was deduced from meager paleontological evidence, from isotopic geochronology of whole rocks or separated minerals from the formations or from the plutonic rocks that intrude them, and from relative deformation or metamorphic styles of the formations. As the predominant contacts are faults, several ambiguities remain unresolved, and field mapping and isotopic studies continue.

Structural Blocks and Intervening Faults

Six regional structural blocks are recognized, and terranes and rocks representative of five of these will be seen on this trip. The sixth, or Islesboro block, is described in Stewart's trip A-6. Major faults bound each structural block. In geographic order, the Vassalboro-Waterville terrane of the northwesternmost block (Stops 1 and 2; fig. 2) is separated by the Norumbega fault from the terrane of Passagassawakeag Gneiss of Bickel (1971) and migmatite (Stops 3-5). The Long Lake fault separates lower grade terrane

Figure 1. TENTATIVE AGE ASSIGNMENTS OF ROCKS SEEN ON TRIP B-7

STRUCTURAL BLOCK	VASSALBORO-WATERVILLE BLOCK	PASSAGASSAWAKEAG BLOCK	BUCKSPORT BLOCK	PENOBSCOT BLOCK	ISLESBORO BLOCK	CASTINE - ELLSWORTH BLOCK
Devonian	Vassalboro Formation 1/					Castine Volcanics 7/
Silurian	Waterville Formation 1/ Mayflower Hill Formation 1/					
Ordovician		"Stubbs" granite 2/ = Stricklen Ridge pluton	? — ? Appleton Formation of Cheney (1967) 3/ Bucksport Formation of Wing (1957) Schist of Rider Bluff ? — ?	Penobscot Formation 4/		
Cambrian		Copeland Formation of Wing (1957) ?= Hogback Schist of Perkins and Smith (1925)			Islesboro Formation 5/	? — ? Ellsworth Schist 8/
Precambrian		Passagassawakeag Gneiss of Bickel (1971)			Rocks of Seven Hundred Acre Island 6/	

Footnotes:

1/ Osberg (1968), J.R. Griffin, oral communication, 1973.
2/ R.E. Zartman, oral communication, 1974.
3/ D.G. Brookins, written communication, 1973.
4/ Boucot, Brookins, Forbes, and Guidotti, 1972; D.G. Brookins, written communication, 1971.
5/ D.G. Brookins, written communication, 1973.
6/ Brookins and Stewart, written communication, 1973.
7/ Brookins, Berdan, and Stewart, 1973.
8/ D.G. Brookins, written communication, 1973.

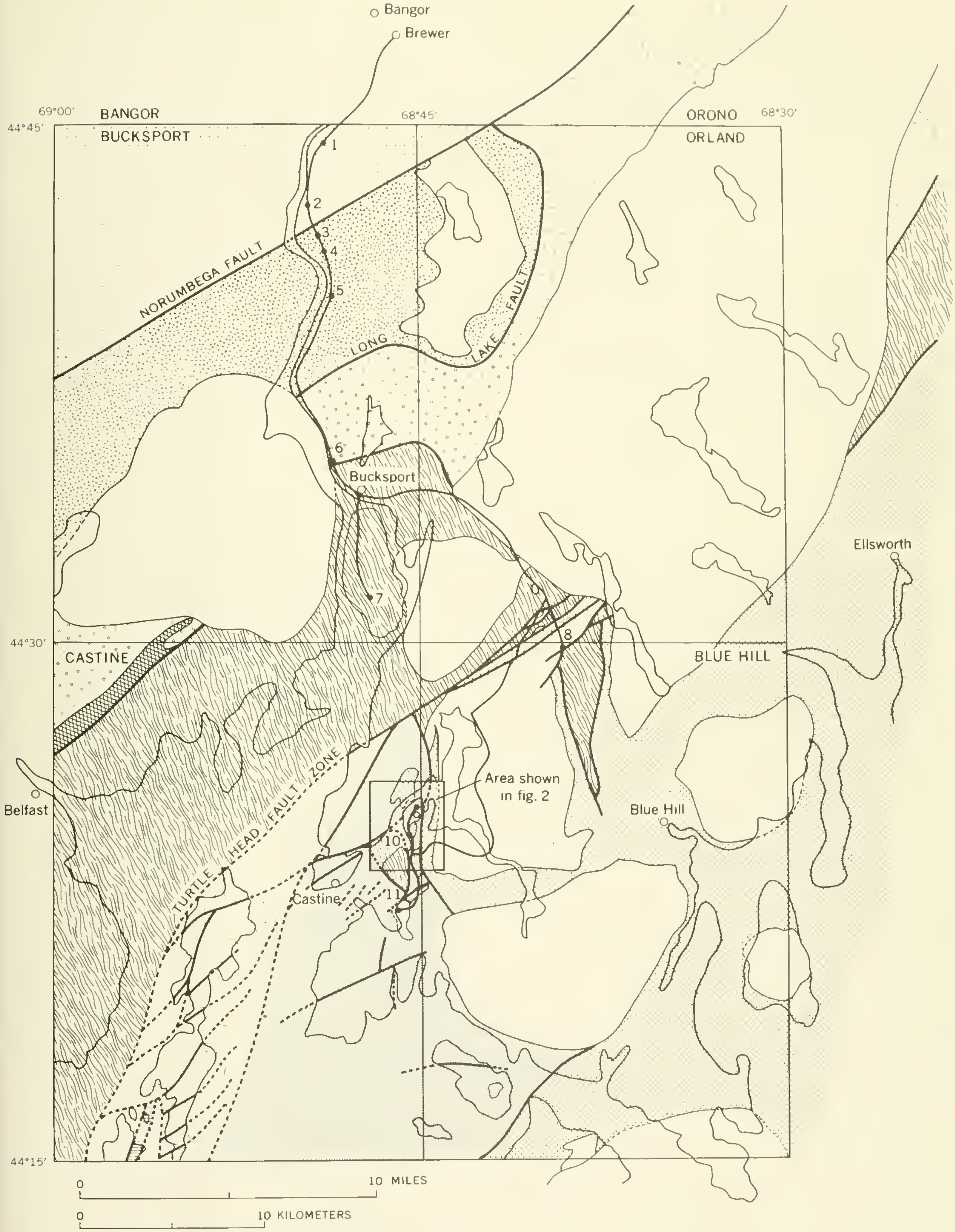
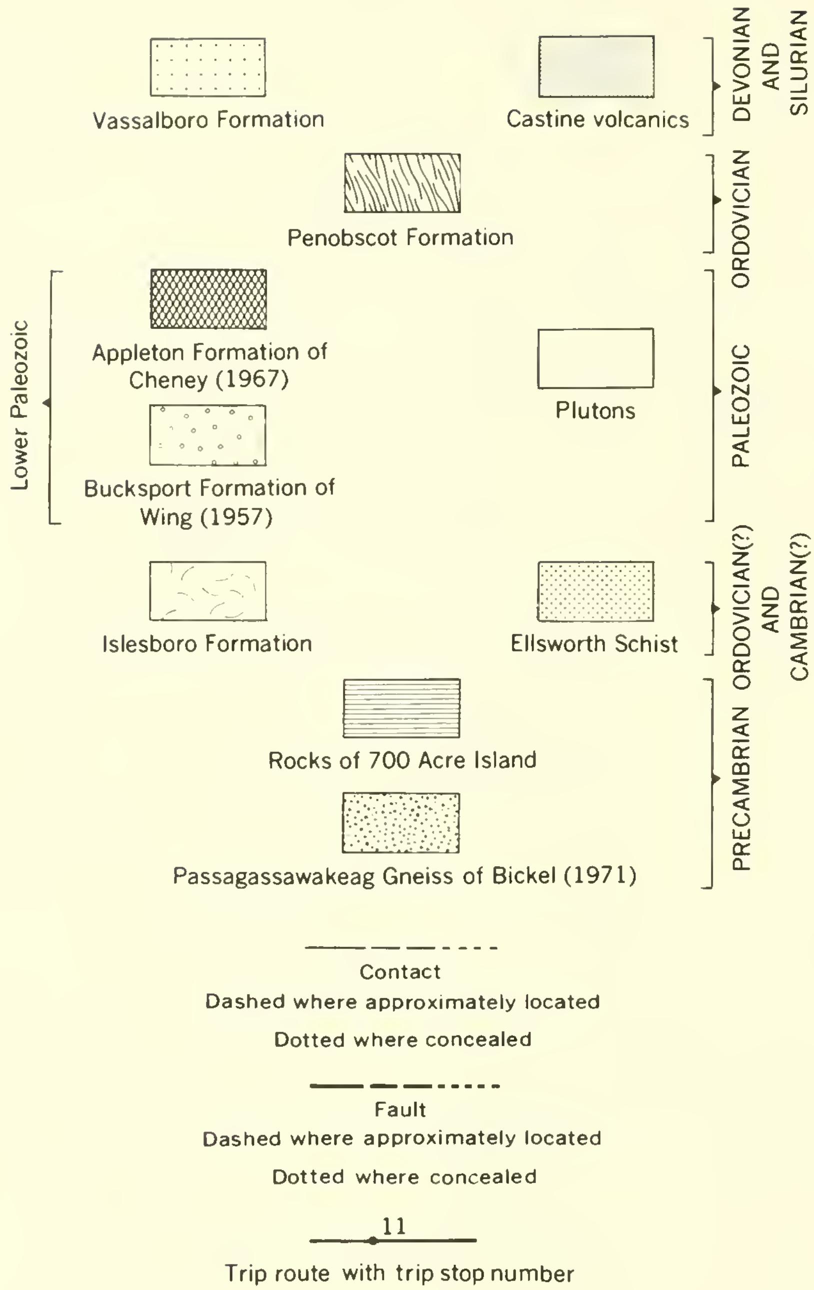


Figure 2. Geologic map of northern Penobscot Bay area.

EXPLANATION



of the Bucksport Formation of Wing (1957) from the Passagassawakeag. The Bucksport terrane is in turn probably separated from terrane underlain by the Penobscot Formation by a fault (Stop 6). The Penobscot block (Stop 7) is cut off on the southeast by a major strike-slip fault zone, the Turtle Head fault zone, which also removes all but a small sliver of the Islesboro Formation from along our traverse. The Castine Volcanics rest unconformably on Ellsworth Schist in the "coastal volcanic" block (Stops 9-11). The southeasterly limit of the "coastal volcanic" block is unknown. Several large faults in the Gulf of Maine involve Triassic and possibly Carboniferous rocks as well as lower Paleozoic rocks; all are unconformably overlain by Cretaceous and younger rocks of the Coastal Plain.

Not all of the faults are of the same age, and some have been active for long periods or were reactivated after earlier movements. On the trip, emphasis will be placed on evidence for the faults, about the nature of their movements, and about their effects on the rocks involved. Minor structures such as styles and sense of motion on minor folds, zones of shear and cataclasis, or cleaved, foliated, lineated, and polydeformed rocks all afford useful clues. Breccia zones, map patterns, and strong contrasts in metamorphic grade also provide evidence.

Regional Metamorphism

All rocks in the region are at chlorite grade of regional metamorphism or higher. A few Triassic dike rocks may be exceptions. Rocks of second sillimanite grade are found in the Passagassawakeag block, but, in general, the rocks outside the Passagassawakeag block and the zones of contact metamorphism associated with plutons do not exceed biotite grade. Within the contact aureoles, andalusite and cordierite are abundant, and sillimanite is relatively rare.

Several metamorphic episodes have been established within the region, but the exact number still is unknown. The youngest is not evident in the field in our map area. It is a Permian overprint of argon-bearing minerals reported by Zartman, Hurley, Krueger, and Giletti (1970), and its northeastern limit in New England probably reaches the southwestern part of our map area. Osberg (1968) attributed a Permian age to high-grade metamorphism in the Waterville area to the west, and probably the effects of this metamorphic event reach to the west shore of Penobscot Bay.

One of the attractive features of our mapped area is the opportunity to observe sedimentary rocks at low metamorphic grades and to unravel metamorphic events that have been obliterated by subsequent high-grade metamorphism. The northeastern limits of the high- and medium-grade Devonian Acadian regional metamorphism in New England must be west of Penobscot Bay. The high- and medium-grade metamorphism of the Penobscot Formation (Ordovician) south of Belfast and west of Islesboro in Penobscot Bay could be Acadian but possibly is older. The higher grade metamorphism of the Penobscot Formation is older than the Turtle Head fault zone, which places andalusite-grade Penobscot

Formation against chlorite-grade Islesboro Formation. There is a long history of Devonian movement on the Turtle Head fault zone; this movement began after the Castine Volcanics (Upper Silurian and Lower Devonian) were deposited, and stopped after the emplacement of the South Penobscot pluton (Lower Devonian) but before the emplacement of the Lucerne pluton (Middle Devonian). If Acadian metamorphism took place in Early to Middle Devonian time, Acadian metamorphic rock in the Penobscot Formation could be broken by the Turtle Head fault zone.

At least one other early Paleozoic metamorphic episode has been established in this area. Metamorphosed Ellsworth Schist (Cambrian? and Ordovician?) fragments occur on the unconformity below the Castine Volcanics (Stop 9). This unconformity is known to be pre-Middle Silurian at Ames Knob, North Haven Island, just south of the map area. No clasts of unquestioned Penobscot Formation have been observed on the unconformity, and no high-grade metamorphic rocks of any type have been noted, so the age of the metamorphism of the Ellsworth Schist is known only to be post-Cambrian(?) and pre-Middle Silurian. This metamorphic episode is not known in more complete lower Paleozoic sedimentary sections in New Brunswick, although a post-Middle Ordovician pre-Silurian unconformity is known in several places.

On the Islesboro block, the Precambrian foliated rocks of Seven Hundred Acre Island have been regionally metamorphosed to garnet-andalusite grade. They have been approximately dated at 750±150 m.y. by the Rb/Sr whole rock method (Brookins and Stewart, written communication, 1973). The rocks have been extensively retrograded and are cut by less foliated pegmatites that have been dated by two isotopic methods as also of Precambrian age (600±20 m.y. = Avalonian).

Within the Passagassawakeag block, three observed deformations are older than Late Ordovician, but it is difficult to assign a specific age to the high-grade metamorphism observed in these rocks. The age of the oldest rocks is Precambrian (D.G. Brookins, written communication, 1974). Gneiss in the Passagassawakeag block is more complexly deformed than the Precambrian observed in the rocks of Seven Hundred Acre Island and vicinity.

Plutonic Rocks

A variety of plutonic rocks of early Paleozoic age is discussed by Wones in the guide to trip A-7 and will not be reiterated here.

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Itinerary

Mileage	
0	Trip starts at Brewer, Maine, at east end of bridge across Penobscot River, Intersection of Route 15 and Route 1A. Turn south onto Route 15.
4.6	R.R. Crossing. Park cars parallel to R.R. track on south side of highway.
	Stop 1. Exposure of gray-to-green-weathering member of Vassalboro Formation, containing calcareous silts interbedded with rusty-weathering pelites. Pelitic units are more common to the south and east. This outcrop is typical of this formation in the Bucksport and Orono quadrangles. See trip A-3 for a complete discussion of these rocks. Compositional layering was probably sedimentary, but layer boundaries are now slip-cleavage surfaces striking N.55°E., and dipping northwest. Kink bands striking N.20°W. cause "waffling" of surfaces within the pelitic layer. Note the continuity of quartz veins. Rock is chlorite grade, containing white mica, chlorite, calcite, and quartz.
11.5	Outcrop on right (west) side of highway. Be careful of traffic.
	Stop 2. Exposure of Vassalboro Formation. Note that cleavage has further stripped out original bedding and compositional layers compared with those at Stop 1. The average pelitic unit is thinner. Note that quartz veins are stretched and broken. The dominant cleavage is N.55°E. and vertical. The metamorphic grade is chlorite; the rocks contain white mica, chlorite, quartz, and calcite. This outcrop is less than 1 km north of the Norumbega fault which is at the base of the small hills visible to the south. This fault strikes N.55°E., and strains related to that fault motion have affected the rocks at both Stops 1 and 2. (The name Norumbega is taken from the legendary Indian city which was the objective of 16th and 17th century explorers in Penobscot Bay (Morison, 1971).
12.2	R.R. Track. Trace of Norumbega fault crosses Route 15 here.
12.3	Outcrop on left (east) side of highway.
	Stop 3. Exposure of Passagassawakeag Gneiss of Bickel (1971). This material extends about 6-7 km (4 mi) to the northeast and at least 40 km (25 mi) to the southwest where it is exposed in the Belfast quadrangle. Most of this gneiss is a quartz-feldspar-biotite augen gneiss marked by feldspar porphyroblasts that are commonly arranged in thin lenses. The augen gneiss

is intruded by migmatite. A mafic-rich granodiorite (Winterport Granite of Trefethen (1941; 1944) intrudes the gneiss and migmatite and is strongly foliated by the pervasive N.60°E. foliation which is the dominant fabric. This in turn is intruded by another nonfoliated pegmatitic material. The grade of the block is uniformly at sillimanite grade, and evidence of second sillimanite grade is common. At this stop, vertical mylonite streaks strike N.55°E. These mylonites are vitric in appearance because of the exceedingly fine grain size of the crushed fragments.

The Norembega fault is 200 meters to the north and is a zone 300 to 400 meters wide. To the northeast, unmetamorphosed conglomerates with red matrices lie along the fault trace (Stoesser, 1966) and imply a post-Middle Devonian age for the latest motion on this fault. Displacements of metamorphic grade, the antiform to the northeast, and minor drag folds all imply left-lateral motion. Slicken-sides plunge N.55°E. with dips 25°-80° NE. The extension of this fault to the southwest is less certain, but it may connect with faults observed in the Casco Bay area (Hussey, 1968).

12.9 Budweiser sign on left (east). Turn right to Penobscot River boat landing.

13.1 Park cars at boat landing parking area and proceed to outcrop southwest of parking area.

Stop 4. Passagassawakeag Gneiss of Bickel (1971). Augen gneiss is intruded by the Winterport Granite of Trefethen (1941; 1944), which is foliate and intruded by pegmatite. Note that the scale of the rock units is in meters. This scale is observed throughout the area mapped as Passagassawakeag. The sequence of the units is the same as at Stop 3 and in all observed outcrops up to the time of writing, from oldest to youngest: (1) augen gneiss with schist, (2) foliate migmatite, (3) foliate granodiorite (Winterport Granite), (4) nonfoliate migmatite and pegmatite. Although dikes (sills?) of Winterport are most common in the northern section of the Passagassawakeag map area, they occur throughout the area.

13.3 Return to Route 15. Turn right (south).

14.1 Outcrop on left side of road.

Stop 5. Nonfoliate migmatite, "Stubbs" granite. This field is the site of largest mass of nonfoliate granite (migmatitic pegmatite) that has been found in this area. This material may be equivalent to the Stricklen Ridge pluton and part of the same intrusive epoch. Zircons collected from this locality give a preliminary Pb^{206}/Pb^{207} age of 430 ± 10 m.y. (Zartman, oral communication, 1973). This implies that the Passagassawakeag Gneiss is older than Ordovician. Because of the multiple intrusions and deformations observed in that gneiss, it is presumed to be Precambrian. Wones believes that its composition and texture are more similar to gneiss in the Green Mountains than to the Precambrian rocks of Seven Hundred Acre Island (see trip A-6) or eastern Massachusetts. Further mapping combined with detailed isotopic studies is in process.

18.0 Sign "Welcome to Bucksport". You are now crossing the here-unexposed contact between the Passagassawakeag Gneiss of Bickel (1971) and the Bucksport Formation of Wing (1957).

This contact brings biotite-grade rocks adjacent to sillimanite-grade rocks, migmatite, and the Strioklen Ridge pluton, It truncates structures within the higher grade terrane, and a fragment of diorite is found along the contact. It also appears to truncate the contact between the lower grade Rider Bluff and Bucksport rocks. No basal conglomerates or other evidence was found for an unconformity, so a fault seems most likely. Geophysical data by Sweeney (1973) indicates a steep dip, and the map pattern is not compatible with a simple strike-slip fault. It is proposed that it is a normal or reverse fault bringing up the Passagassawakeag on the northwest against the Bucksport-Rider Bluff terrane on the southeast.

21.0 Turn left and park on right side of spur road. Return by foot to Route 15 and examine Bucksport Formation under powerlines. Walk along R.R. tracks to Penobscot outcrops, return to road, and walk along Route 15 to cars.

<u>Stop 6</u>. (1) Bucksport Formation of Wing (1957). The formation is characterized by interlaminated pelite and calcareous pelite, now quartz-biotite and plagioclase-amphibole bands. The compositional layers are related to the original bedding but may not be the original beds (compare with Stop 2). The compositional layers are a cleavage, and it has been folded, especially to the northeast. The overall lithology is grossly similar to that of the gray-to-green-weathering member of the Vassalboro Formation of Silurian and Devonian age. To the southwest, the pelitic members become much less common. Lithologic similarity need not imply chronological equivalence.

(2) Penobscot Formation. Rusty-weathering schist, sulfidic, and marked by bedding and composition lamellae on a centimeter

scale. No fossils have been found in it in northern Penobscot Bay, but similar-appearing rocks at St. John and St. Stephen, New Brunswick, contain Ordovician graptolites. The closer Benner Hill locality (see Osberg and Guidotti, trip A-3) is also Ordovician and may be equivalent to the Penobscot Formation.

(3) Waldo Granite of Trefethen (1941; 1944). The dikes seen crosscutting both the Bucksport and the Penobscot Formation are offshoots of the Mount Waldo pluton to the southwest. The contact of that pluton is beneath the Penobscot River and was drawn close to the eastern shoreline (Trefethen, 1944).

The contact between the Bucksport and Penobscot is disconformable to the southwest, so that it may be either a fault or an unconformity. Penetrative cleavage and regional metamorphic grade are higher within the Bucksport Formation than the Penobscot Formation, suggesting a fault contact.

The metamorphic grade here is high, because of the presence of the Mount Waldo pluton. To the northeast, the grade drops to biotite grade, but to the southwest the regional grade of the Bucksport remains high because of superposed metamorphisms

22.5 Turn right and cross bridge onto Route 1.

23.5 Continue straight (south) at Verona picnic area. (Route 1 bears to the right).

26.1 Turn left into Penobscot Rod and Gun Club. Club members may be shooting, so extreme caution is advised.

Stop 7. Penobscot Formation. (Please be certain to obtain permission from officers of the Rod and Gun Club before examining the outcrops). Note that the graded beds generally indicate tops of beds to the north in this highly contorted area: Sandy layers range from 1-10 mm, with occasional layers 100 mm thick. Pelitic layers are 4 to 400 mm thick. Andalusite, which has been badly retrograded to muscovite, is probably due to the contact aureole of either the Wallamatogus (to the east) or Mount Waldo (to the northwest) plutons, both of which crop out within 2 km of this locality.

26.2 Return to main road, turn right and return to Bucksport.

28.8 Verona picnic area. Continue straight (north) on Route 1.

29.8 Turn right on Route 1.

33.9 Turn right onto Route 15 towards Blue Hill.

39.0 Turn left at house 100 yards north of Amoco station. Walk 300 yards north through fields to small scarp, 3-4 m high.

Stop 8. Fault between South Penobscot pluton and Penobscot Formation strikes N.70°E. and dips 60° south. It is exposed here for 100 m. Many quartz veins are found within the Penobscot Formation along the fault trace. They contain terminated quartz crystals and have been the target of prospects such as the so-called "Annear Copper mine" which appears on the Orland quadrangle topographic map. The fault breaks the South Penobscot pluton. Near Castine and on northwestern Islesboro, Castine Volcanics are deformed by another fault within this fault zone, called the Turtle Head fault. Stewart postulates large strike-slip motion on the overall fault zone, but only normal fault motions are evident at this locality. The fault is intruded by the Lucerne pluton to the northeast, which indicates no movement since Middle Devonian time.

The South Penobscot pluton is highly variable in composition. Here it is a fine- to medium-grained foliate biotite tonalite with scattered remnants of Ellsworth Schist, mafic inclusions, and mafic intrusions. The age of the South Penobscot pluton is Early Devonian or younger on the basis of Rb-Sr and K-Ar dates and its contact metamorphism of the Castine Volcanics (Upper Silurian and Lower Devonian).

The Penobscot Formation is highly contorted and contains many quartz veins.

39.1 Return to Route 15 and turn right (north).

40.6 North Penobscot. Turn left onto Route 199.

41.6 White quartzite on right is a slice of Islesboro block caught in the fault zone.

45.7 Penobscot village, turn left onto Route 175.

52.4 Turn right on 175 and 176.

53.1 Bagaduce "River" with reversing tidal rip.

53.5 Turn right on Route 176.

56.1 Turn right on Ferry Road.

57.6 Farm yard belonging to Steve Woycke.

Stop 9. South side of Bagaduce Narrows. A lengthy woods walk will be necessary to reach the outcrops. This stop shows the unconformity between the Ellsworth Schist and the Castine Volcanics (fig. 3) and also shows that the Ellsworth Schist underwent a pre-Castine metamorphism (pre-Middle Silurain at Ames Knob, North Haven Island, south of Fig. 2). The unconformity initially had hundreds of feet of local relief

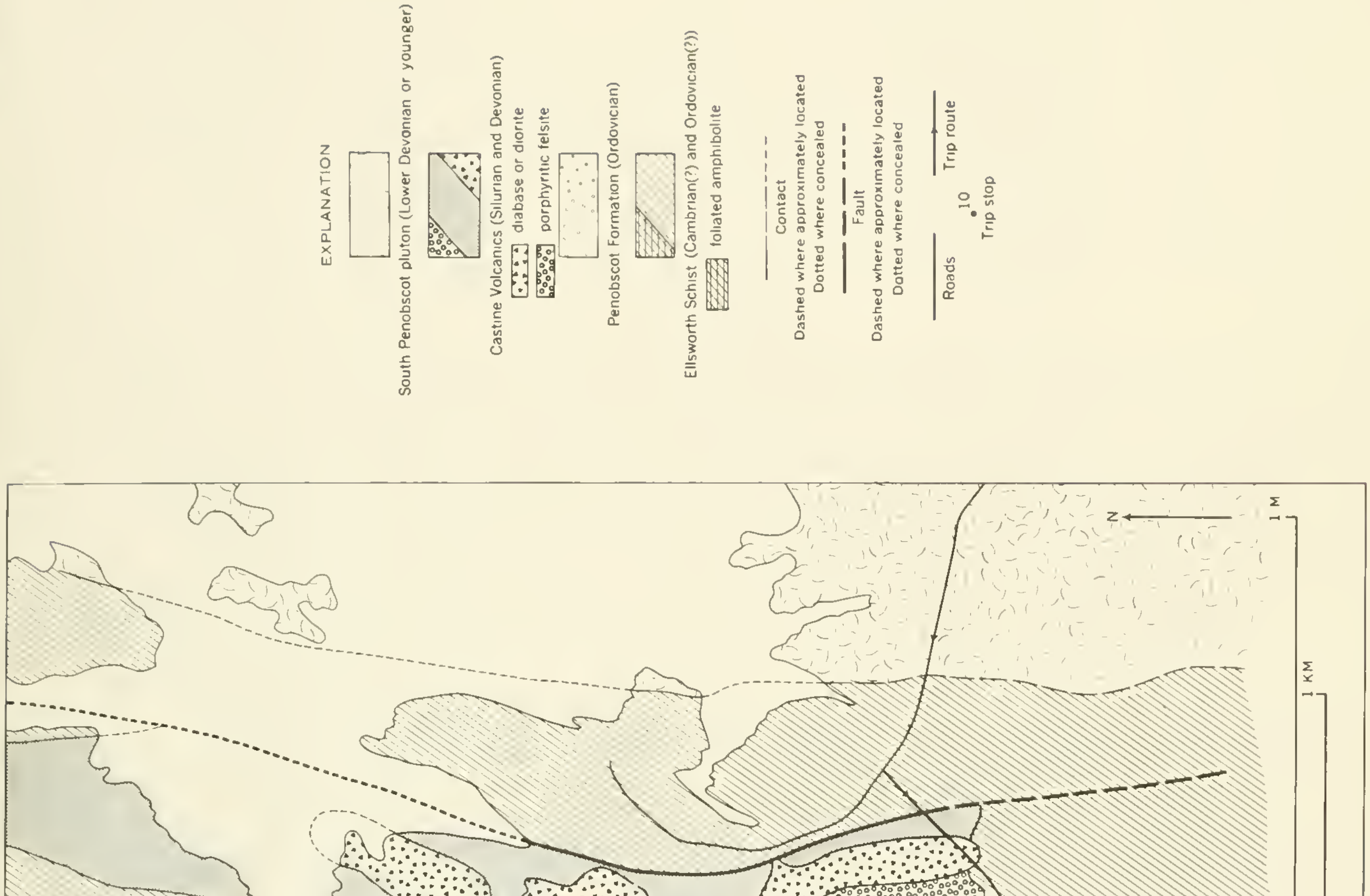

Figure 3. Geologic map in the vicinity of the Bagaduce River.

and has been folded subsequently. All the rocks were contact-metamorphosed to cordierite-andalusite hornfels by the South Penobscot pluton to the east (fig. 2), and metamorphic differences are evident between the Ellsworth and Castine rocks.

This unconformity was first recognized by Wingard (1958). The age of the Ellsworth Schist is not certain; it may possibly be Cambrian on the basis of Rb/Sr whole-rock isochrons by Brookins and Stewart. Typical low-grade Ellsworth Schist contains a quartz-plagioclase-muscovite-chlorite assemblage, and interlayered greenstones contain actinolite. Overall the Ellsworth Schist is notably feldspathic, plagioclase commonly being as abundant or more so than quartz. Bulk compositions are not as aluminous as is common in the Castine Volcanics. The leucogranite found as boulders above the unconformity is rare elsewhere in Ellsworth terrane, but could be a hypabyssal feeder equivalent to many crystal tuffs found within the Ellsworth. The contorted metamorphosed Ellsworth clasts above the unconformity show that extensive greenschist metamorphism had been imposed on the Ellsworth before its erosion. The metamorphic episode is known to be pre-Middle Silurian from the comparable unconformity 25 km southwest at Ames Knob, North Haven Island. A pre-Silurian post-Middle Ordovician orogeny has been identified elsewhere to the northeast in Maine or New Brunswick, but rocks as deformed and metamorphosed as the Ellsworth at this locality have not been noted. Relief on the unconformity is demonstrated by the great variety of immediately overlying basal Castine beds, from silts, sands, grits, to pebble and boulder conglomerates and by their rapid lateral variation. The trace of the unconformity, minor folds, and extensive diamond drilling indicate that the unconformity has folds with amplitudes of 5 to 75 m. The folds plunge gently south and are in the east limb of an anticline to the west.

Contact metamorphism by the South Penobscot pluton 1 km to the east has caused cordierite and andalusite knobs to form, particularly in the more pelitic Castine beds. Reaction of pyrite to pyrrhotite at high grade removed ferrous iron from hornblende in amphibolite beds and yielded anthophyllite near several sulfidic horizons that have been prospected.

Turn around and retrace route 0.9 mile.

58.5 Turn right.

59.0 Park at "I Wunda".

Stop 10. North of Lords Cove, West Brooksville.
A complex structure with strongly cleaved Ellsworth Schist in fault contact with Castine Volcanics and Penobscot Formation, although quite well exposed, is not completely understood because of inadequate knowledge of the third dimension.

The dirt access road roughly parallels the unconformity between Ellsworth Schist and Castine Volcanics. Basal Castine consists of arkosic grit with few quartz pebbles, and strikes approximately north, dipping gently (20°-30°) to the east. The attitude of the unconformity is unknown, but presumably it dips to the east. Typical contorted Ellsworth Schist is found beneath the unconformity. Near the end of the access road (by "Stewart" camp), and along the shore southward from where the road reaches the shore of the Bagaduce, the contorted Ellsworth is extensively sheared by a N.20°-30°E. steep cleavage. The cleavage is parallel to the trace of a major fault that drops diabase in the Castine Volcanics on the northwest side of the fault 50 to 100 m against Ellsworth.

Where exposed at the fishing shed at the end of the road, the fault strikes N.60°E. and dips 25°N., but slumping is suspected. Along the strike of the fault to the southwest on the southeast side of the northern Negro Island, the fault trace is strictly parallel with the very strongly developed fracture cleavage. Given the small vertical displacement of the fault, substantial strike-slip components are suspected to be necessary to cause the extensive cleavage observed. Although the fault breaks Castine Volcanics, it does not penetrate the South Penobscot pluton; its age is post-Early Devonian-pre-Middle Devonian.

Proceeding south along the shoreline, a representative, though highly sheared, section of Ellsworth Schist is exposed for several hundred m in front of two summer camps. A small N.70°W. fault dipping 45°-60°N. then separates sheared Ellsworth from 10-20 m of shattered Castine felsites. There are flutes in this fault that strike N.35°E. and plunge 40° NE. This fault traverses shears in the Ellsworth and is younger than the shearing episode. The Castine felsites are silicified and slightly pyritized and weather very whitish. They are distinct from Ellsworth rocks because, though foliated, they lack the lineations of the multiply deformed Ellsworth.

Passing over the plaque of Castine rocks, a N.80°W. fault dipping 45°-65° N. separates the Castine Volcanics from black pyritic phyllite of the Penobscot Formation. The fault plane is well exposed and also has flutes with as much as 2m of relief. These strike N.30°E. and plunge about 50°NE. The flutes are asymmetric and indicate upper plate movement to the east and north over the plastic phyllites. Contorted, highly sulfidic Penobscot Formation is exposed for hundreds of meters south along the shore.

The southernmost of the faults at this stop is exposed about 100 m horizontally and 10 m vertically, about equally above and below the high-tide line. In an easterly direction the fault turns abruptly south and can be traced with some certainty 1.5 km through W. Brooksville and 1 km south. It is apparently dips quite steeply but is not exposed elsewhere. The presence of 2.5 km-long triangular block of Penobscot Formation surrounded by terrane composed of Castine Volcanics has been mind-boggling since its recognition, as the Castine has only been seen on Ellsworth Schist and never on Penobscot Formation. The fault motions observed at this stop are consistent with right-lateral fault motions. Two generations of faulting are clearly involved, and both have been contact metamorphosed by the South Penobscot pluton. A strike-slip fault zone, the Turtle Head fault, parallels the older fault at this locality, breaks the South Penobscot pluton and is cut by the Lucerne pluton (fig. 2). An explanation has been contrived that utilizes a long post-Castine history of north-easterly right-lateral strike-slip motion and the shouldering aside of blocks of Penobscot, Islesboro, and Ellsworth terranes by the diapiric intrusion of the South Penobscot pluton. It will be aired on the field trip if it is still viable and time and weather permit.

Turn around and retrace route.

59.4 Turn right.

60.0 West Brooksville, continue south on Route 176.

61.9 Turn right down steep paved road.

62.3 Park at Brooksville town landing.

Stop 11. Brooksville Town landing on Smith Cove.
The Castine Volcanics is exposed along the northeast shore of Smith Cove. A hornblende-rich diorite intruded into the section along faults has caused local contact-metamorphic effects. The diorite is sill-like locally and is 10 to a 100 m thick. Nonfoliated diorite like this is common the Castine Volcanics and is of late Castine age. Near Stop 9, similar diorite cutting Castine Volcanics was contact metamorphosed by the South Penobscot pluton.

The Castine Volcanics contains a variety of rocks. Igneous rocks include agglomerates, felsites, tuffs, and flows, varying from rhyolite to basaltic composition, most being siliceous. Sedimentary rocks include siltstone and mudstone rich in volcanic debris and some marine beds that contain calcareous or claystone concretions. One of the beds in the traverse along Smith Cove contains calcareous concretions metamorphosed to garnet grade by the diorite. Extensive formation of cleavages has obliterated some primary sedimentary features, but there is little evidence for airfall deposition. Graded beds suggest that the section seen tops to the southeast. Beds 5 to 20 m thick are most typical and are highly variegated. All have attained at least chlorite grade of regional metamorphism. It has not been possible to establish a reliable stratigraphic column for the Castine Volcanics, and the impression gathered is that beds and even sequences of beds are of short lateral extent. This suggests several nearby sources and possibly some topographic influence. Sediments are at least as abundant as igneous rocks, though the igneous rocks dominate the present topography of the areas underlain by Castine Volcanics. The Castine Volcanics are latest Silurian and Early Devonian in age (Brookins, Berdan, and Stewart, 1973) and elsewhere contain fossils of Baltic aspect.

The section at Smith Cove has been broken by many small faults and shears that strike N.50°-70°E. and dip steeply. The strongest cleavage is N.30°-50°E. and steep, and there are at least three sets of kink bands: N.20°E., N.70°E., and N.70°W. Much of the tectonic disturbance of this section was cuased in Early to Middle Devonian time by the major strike-slip fault zone to the northwest and by the diapiric intrusion of the composite South Penobscot pluton to the northeast.

End of trip. Return to Route 1 via Route 176 to North Brooksville, 175 to Route 199 in Penobscot, 199 to Route 15 in North Penobscot, and Route 15 to Route 1.