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DUCTILE AND BRITTLE STRUCTURES WITHIN THE RYE FORMATION OF SOUTHERN COASTAL MAINE AND NEW HAMPSHIRE

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INTRODUCTION:

The Late Precambrian (?) Rye Formation of Southern Maine and New Hampshire was originally named and described by Katz (1917) and Wandke (1922). The formation was further subdivided by Billings (1956) into an upper metavolcanic and a lower metasedimentary unit (Figure 1). Detailed mapping was carried out by Hussey (1962) and Novotny (1969) to determine the extent and structure of the Rye Formation in southern Maine and southeastern New Hampshire, respectively. These studies verified the overall structural configuration of the Rye Formation as a SW plunging antiform overturned to the SE. Mapping at Gerrish Island by Hussey & Pankiwskyj (1976) located minor NE-plunging antiformal structures suggesting a doubly-plunging antiformal structure for the Rye Anticline. Continued detailed mapping by Hussey (1980) has led to a major reinterpretation of the Rye Formation as a variably sheared and injected metasedimentary sequence. Studies by Carrigan (1984a;b) have resulted in a re-evaluation of the Rye Formation in terms of poly-phase metamorphic events and in the along-strike correlation of two major ductile shear zones and several zones of distinctive lithologic units from Gerrish Island, Maine to Newcastle Island, New Hampshire. The basic lithologic and structural complexities within the Rye Formation have also been superimposed by a mutually complex array of brittle structures that includes brittle faulting and fracturing of Late Paleozoic to Mesozoic age (Swanson, 1982). The Mesozoic structures were coupled with the emplacement of dikes and intrusions related to the development of a rifted continental margin. It is possible, therefore, to examine, within a single formation, ductile structures related to Precambrian-Paleozoic compressional tectonics and brittle structures related to Mesozoic extensional tectonics in the geologic evolution of eastern North America.

LITHOLOGY:

The original sedimentary sequence is hypothesized (Hussey, 1980) to be a series of sandstones, siltstones, carbonaceous shales and limestones. These are now preserved as metamorphic equivalents of the pre-existing lithologies where they have

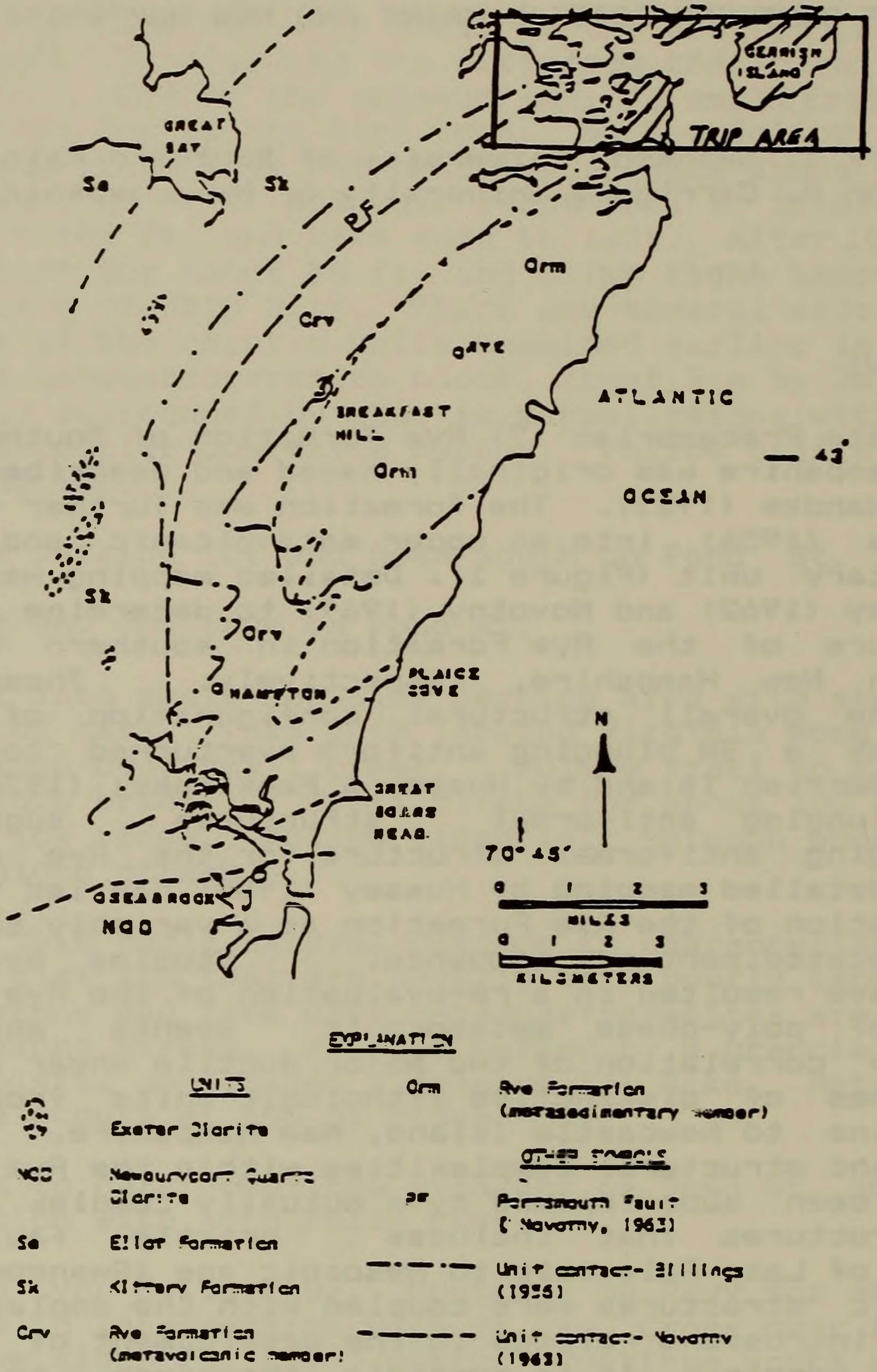


Figure 1. Generalized Geologic Map of southeastern New Hampshire (after Novotny, 1969 and Billings, 1956)

survived a phase of felsic injection and a later phase of mylonitization. The resulting rock types within the Rye Formation consist of variably-sheared calcareous quartzite, metapelite, amphibolite, calc-silicate-bearing amphibolite, graphitic-sulfidic pelitic schists and impure marble, representing this preserved metasedimentary sequence (Figure 2). The injection of quartzo-feldspathic materials as dominantly concordant sheets and a phase of mylonitization during deformation has resulted in the formation of numerous blastomylonitic schists granitic augen gneisses and ultramylonites from these injected metasedimentary lithologies.

STRUCTURE:

The outcrop pattern and minor fold structures found within the Rye Formation indicate a NE-trending, doubly-plunging antiformal structure (Novotny, 1969; Hussey & Pankiwskyj, 1976). The Rye Formation has been multiply-deformed with the last fold-phase (Carrigan, 1984a; Rickerich, 1983) being synchronous with the NE-trending upright folds in the adjoining Kittery Formation. It is this last NE-trending, tight to isoclinal, fold phase that is responsible for the present-day outcrop pattern and overall regional structural configuration. Both gently- and steeply-plunging isoclinal and asymmetric minor fold structures can be found indicating several phases of folding in the structural evolution of these distinctive lithologies. The deformation and metamorhism of the Rye Formation must also predate the Late Ordivician Newburyport Quartz Diorite suggesting an Early Ordivician or possibly Precambrian age (Zartman & Naylor, 1984; Carrigan, 1984a).

Two phases of ductile faulting have been recognized (Hussey, 1980; Carrigan, 1984a) which are represented by the earlier blastomylonitic fabric of the typical Rye lithologies and the later concentration of strain into discrete zones of ultramylonite. The ductile fault zones are marked by the Portsmouth Fault Zone at the Rye-Kittery contact and the Great Common Fault Zone containing the southern ultramylonite, as well as numerous, smaller, mylonitic zones throughout the Rye (Figure 3). Both phases of ductile deformation may represent a continuum of events in the progressive development of this complex ductile high strain zone. The development of pseudotachylyte within the ultramylonites is interpreted as a later, brittle structural development. The major ductile fault zones and distinctive lithologic assemblages found at Gerrish Island have been traced along strike into New Hampshire (Carrigan, 1984a) where the ultramylonite at the Rye-Kittery contact is found to be folded about the nose of the regional SW-plunging antiformal structure.

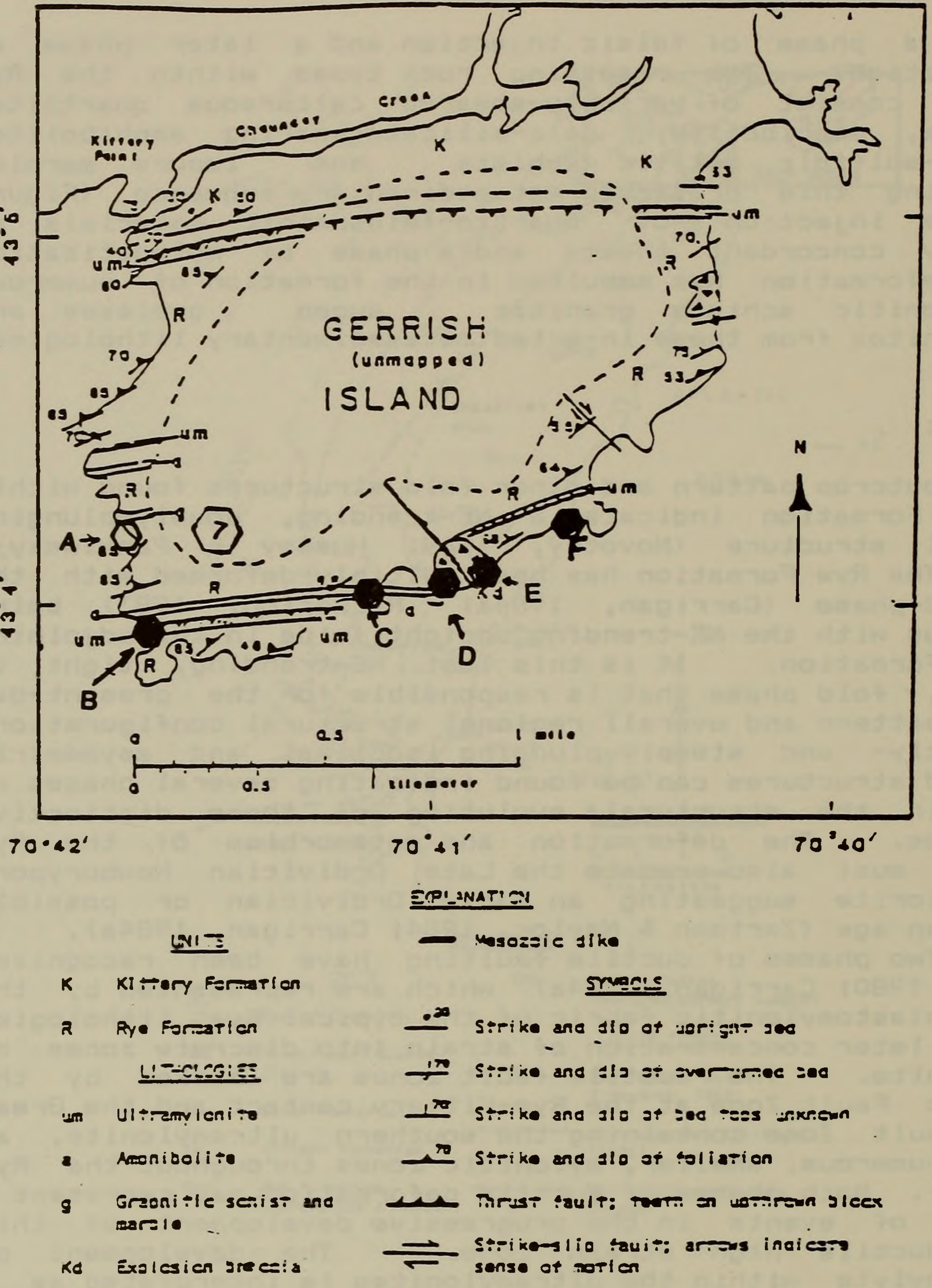
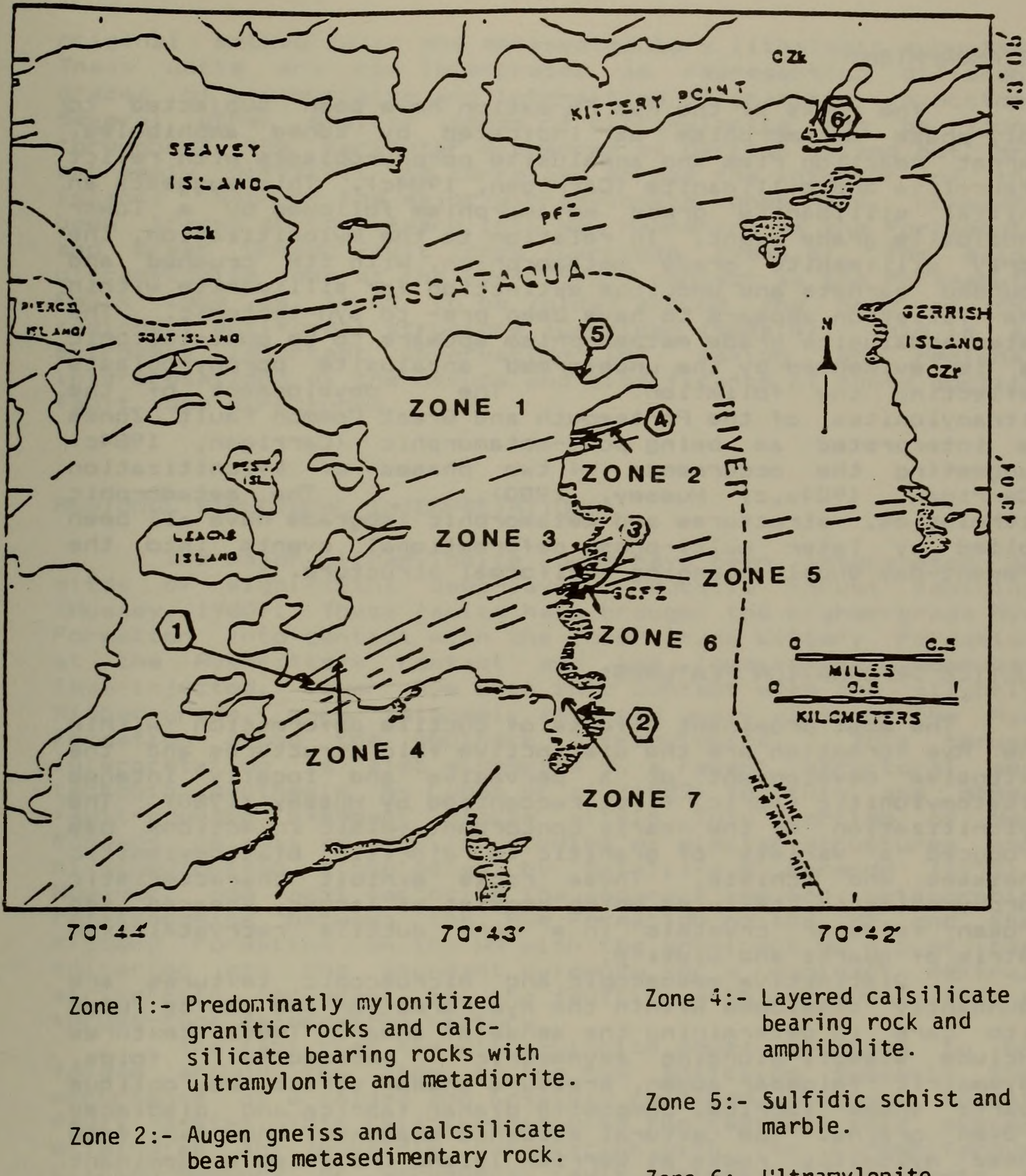


Figure 2. Geologic map of Gerrish Island, Maine (after Hussey, 1980).



Zone 1:- Predominatly mylonitized granitic rocks and calc-silicate bearing rocks with ultramylonite and metadiorite.

Zone 2:- Augen gneiss and calcsilicate bearing metasedimentary rock.

Zone 3:- Predominatly injected pelitic schist and mylonitized granitic rocks .

Zone 4:- Layered calsilicate bearing rock and amphibolite.

Zone 5:- Sulfidic schist and marble.

Zone 6:- Ultramylonite

Zone 7:- Pelitic schist, pegmatite, and quartzite.

Figure 3. Schematic Geologic Map of New Castle Island area New Hampshire.

METAMORPHISM:

The rocks of the Rye Formation have been subjected to poly-phase metamorphism as indicated by zoned amphiboles, garnet reaction rims and andalusite porphyroblasts with relict staurolite and sillimanite (Carrigan, 1984c). This suggests an initial sillimanite grade metamorphism followed by a lower andalusite grade event. In relation to the mylonitization, the early sillimanite grade metamorphism, with its crushed and rounded garnets and undulose extinction for sillimanite within the foliation appears to have been pre- to syn-tectonic. The later andalusite grade metamorphism appears to be post-tectonic as is evidenced by the undeformed andalusite porphyroblasts deflecting the foliation. The development of the ultramylonites of the Portsmouth and Great Common Fault Zones is interpreted as being post-metamorphic (Carrigan, 1984c) suggesting the occurrence of two phases of mylonitization (Carrigan, 1984a,c; Hussey, 1980). The metamorphic lithologies, structures and metamorphic isograds have all been folded by later multi-phase deformational events into the present-day doubly-plunging antiformal structure.

DUCTILE DEFORMATION FEATURES:

The most prominent effects of ductile deformation within the Rye Formation are the distinctive fold structures and the extensive development of a pervasive and locally intense blastomylonitic fabric, first recognized by Hussey (1980). The mylonitization of the nearly concordant felsic injections has produced a variety of granitic to dioritic blastomylonitic gneisses and schists. These rocks exhibit characteristic porphyroclastic textures which consist of larger, sheared and broken feldspar crystals in a more ductile recrystallized matrix of quartz and biotite.

Distinctive mesoscopic and microscopic textures are abundantly developed within the Rye Formation and can be used with care in determining the sense of shear. These textures include steeply-plunging asymmetric intrafolial folds, asymmetric feldspar augen, pressure shadow structures, oblique quartz shape fabrics, composite planar fabrics and displaced broken grains. The textural evidence examined, thus far, from these mylonitic rocks at Gerrish Island indicates a dominant dextral strike-slip component to this ductile deformation phase.

Two major zones of ductile faulting are developed within the deformed rocks of Gerrish Island (Figure 2) and are marked by the development of ultramylonite (Hussey, 1980). These ultramylonite zones occur at the Rye-Kittery contact and in the southernmost exposures at Gerrish Island and Newcastle Island where the ultramylonite appears to form a contact between the original metavolcanic and metasedimentary lithologic subunits. These units are now interpreted as representing different grades of metamorphism and intensities of granitic injection. Several other smaller zones of ultramylonite can be found throughout the perimeter exposures of Gerrish Island but are extremely difficult to correlate across the interior of the island. Both of the major ultramylonite zones have, however, been traced southwestward into New Hampshire as the Portsmouth and Great Common Fault Zones (Carrigan, 1984a,b). The major ultramylonite zone at the Rye-Kittery contact as the Portsmouth Fault Zone is found to be folded around the nose of the regional antiformal structure (Carrigan 1984a,b). This is an extremely important observation in making any regional interpretations of the nature and significance of these ductile fault zone structures.

REGIONAL STRUCTURAL INTERPRETATIONS:

The major ultramylonite zones have been interpreted as sites of significant deep-level ductile thrust faulting (Hussey, 1980). These faults have brought the higher-grade Rye Formation into contact with the lower-grade Kittery Formation at the Rye-Kittery contact and the lower-grade ,somewhat less-injected, lower Rye unit into contact with the slightly higher-grade, more intensely injected upper parts of the Rye Formation along the southern ultramylonite. This thrust interpretation is also supported by a recent structural and tectonic synthesis by Lyons et al (1982) for this and other fault-bounded basement blocks within this portion of New England as well as detailed studies of similar structures and blastomylonitic lithologies by Ratcliffe & Harwood (1975). However, one must reconcile the apparent age and metamorphic relationships between the Rye Formation on the SE and the Kittery Formation on the NW with the prominent NW dip of the foliation and the abundant evidence for a dominant dextral strike-slip component to the faulting with any model for a thrust-type deformation history.

The fact that the ultramylonite zones are found to be folded around the nose of the Rye anticline suggests the occurrence of a folded and possibly refolded, original thrust fault system. This relationship with the regional fold system eliminates any possible correlation with the Carboniferous Clinton-Newbury or Norumbega fault systems and suggests a pre-Acadian origin. Such a complex folded thrust fault structure could yield apparent strike-slip components for thrusting along the limbs, and dip-slip components on the nose of a regionally-plunging antiformal structure. The exact timing and age relations of the metamorphic events, the mylonitization and ductile thrust faulting, and the later multi-phase refolding are still somewhat speculative at this time. However, these rocks and structures may represent a Late Precambrian or Early Paleozoic compressional deformation expressed in the development of deep ductile fault structures followed by an later phase of refolding to give the structures observed today.

BRITTLE DEFORMATION FEATURES:

Pervasive, and locally intense, brittle deformational structures can be found superimposed on all of the ductile deformation features described in the previous section. These brittle structures can be grouped into an early, possibly Late Paleozoic phase and a later, Mesozoic phase of brittle structural development. The earlier phase of Paleozoic brittle deformation was dominated by dextral layer-parallel strike-slip and a subhorizontal layer-parallel extension accompanied by the production of pseudotachylyte in complex zones of intense brittle shear fracturing and brecciation. The later phase of Mesozoic brittle deformation was dominated by a subhorizontal layer-parallel compression resulting in conjugate shear fracture and kink-band structures associated with a variety of mafic and felsic intrusions.

LATE PALEOZOIC(?) BRITTLE FRACTURING:

The most conspicuous structures associated with the earlier brittle deformation are pairs of conjugate strike-slip shear fractures. These structures form easily recognizable "horst & graben" structures where cross-cutting the prominent near-vertical mylonitic foliation. Larger shear structures are also prominently developed at a small oblique angle to the foliation with dextral strike-slip offsets of distinctive lithologic layers. These larger displacements (up to approximately 10 meters) are sufficient to sharply truncate the along strike continuation of any mappable unit within these mylonitic gneisses, at least locally at Gerrish Island. Layer-parallel shear structures are also evident in these exposures but are sometimes difficult to recognize in the absence of any cross-cutting pre-existing geologic structures to determine offset relations. However, several complex brittle structural configurations and some offset cross-cutting pseudotachylyte veins suggest the need for significant layer-parallel dextral strike-slip faulting.

PSEUDOTACHYLYTE GENERATION ZONES:

Pseudotachylyte is found to be locally abundant within the brecciated outcrops of the southern ultramylonite zone at

Gerrish Island, Maine and its continuation into Newcastle Island, New Hampshire. The pseudotachylyte is found as rootless veinlets first recognized by Hussey (1980) within the brecciated ultramylonite and along the sheared contacts with the adjacent rock units. Discrete "pseudotachylyte generation zones" can be recognized within the brecciated outcrops at Gerrish Island and Newcastle Island (Swanson,1982). Each generation zone , as originally described by Grocott (1981) for brittle shear zones in Greenland, is defined by a pair of layer-parallel or near-layer-parallel slip surfaces. Individual pseudotachylyte generation zones may vary from a few millimeters or less to over a meter in width. It is along these nearly layer-parallel slip surfaces that pseudotachylyte is generated and subsequently injected into an internal geometric array of shear and extension fractures. All shear fracture surfaces within these Gerrish Island exposures are nearly vertical indicating a subhorizontal compression and a dominance of a strike-slip component to the deformation. These brittle pseudotachylyte-bearing zones are interpreted as characteristic structures related to stick-slip along brittle seismic fault zones (Grocott, 1981;Swanson, 1982). Any regional structural configuration for this early brittle deformation must account for the dominant dextral shear fracturing, both layer-parallel and slightly discordant, as well as the development of the conjugate layer-parallel extensional structures. An EW-trending dextral strike-slip shear couple is hypothesized to be responsible for this brittle structural assemblage. The near-vertical layer-anisotropy within the brittle ultramylonite zones would be in a favorable orientation for reactivated dextral slip and layer-parallel extension within the hypothesized shear couple. This zone of limited dextral strike-slip deformation may continue westward where it appears as a late brittle reactivation of the Rye-Kittery contact, described by Novotny (1969) as the Portsmouth Fault Zone or may correlate with a zone of offset magnetic anomalies described by Birch (1983).

BRITTLE MESOZOIC STRUCTURES:

Structures produced during the later brittle deformation phase consist of a prominent series of NE-trending basaltic dike intrusions. These dike intrusions are also intimately associated with a set of conjugate strike-slip fault and kink-band structures. This assemblage of brittle structures indicates a subhorizontal near layer-parallel compression for this phase of deformation. Similar relationships have been documented at the Seabrook Nuclear Power Plant foundation site by Bellini et al (1982). Cross-cutting relationships in conjunction with K-Ar age determinations for key dikes at this site indicate a Late Triassic age for this later brittle structural phase of deformation.

In addition to the basaltic intrusions developed throughout this region there is a series of explosive igneous breccias (Figure 2) locally developed along the SE shoreline of Gerrish Island, first described by Hussey (1962). These explosion breccias, mapped in detail by Swanson (1982), show a distinct association between the intrusion of rhyolitic melts and the brecciation. The rhyolitic melts often occur as sheath-like structures and peripheral dikes about the virtually matrix-free explosion vent breccias.

These vent breccias are exposed in several discrete structures clustering in northern and southern groups. Within the intervening kilometer or so of outcrop, later-stage hornblende lamprophyre dikes are found to carry an impressive assemblage of plutonic xenoliths that are mafic to felsic in composition. The intrusive rocks represented by these plutonic xenoliths include gabbros, hornblendites, diorites, syenites, alkaline syenites and syenite pegmatites. Quartz-bearing granitic plutonic types are extremely rare.

This has led to the hypothesis of a subsurface White Mountain intrusive complex beneath Gerrish Island which had not intruded through the present level of exposure. This inferred gabbro-syenite intrusion, the Gerrish Island Igneous Complex (Swanson, 1982), can only be seen in outcrop as roof structure breccias, upper-level felsic melts, basaltic intrusions and sampled subsurface plutonic rock types. The occurrence of basaltic xenoliths within the breccias and the development of cross-cutting basaltic dike intrusions suggests a possible Late Triassic age for this subsurface intrusive complex. This phase of crustal extension and intrusion would be more closely related to the Agamenticus intrusive activity. The lamprophyric dikes on the other hand appear to cross-cut most of the basaltic intrusions as well as the felsic melts and vent breccias.This late intrusive phase of hornblende lamprophyric dikes, hornblendite magmas and other associated intrusives would be more closely related to the intrusive activity of the Cape Neddick Gabbroic Complex.

The youngest structures to develop include a set of NNE-trending brittle extensional fractures that may be related to a late phase of dike intrusion. These fractures are associated with a silicic hydrothermal alteration that produces bleached, rusty-weathering alteration haloes about the open fractures. Their intimate association with the last phase of dike intrusion would suggest that these fractures may represent a continuing phase of crustal extension after the cessation of partial melting at depth. Circulating hydrothermal solutions during this waning stage of extension would be responsible for the conspicuous wall-rock alteration.

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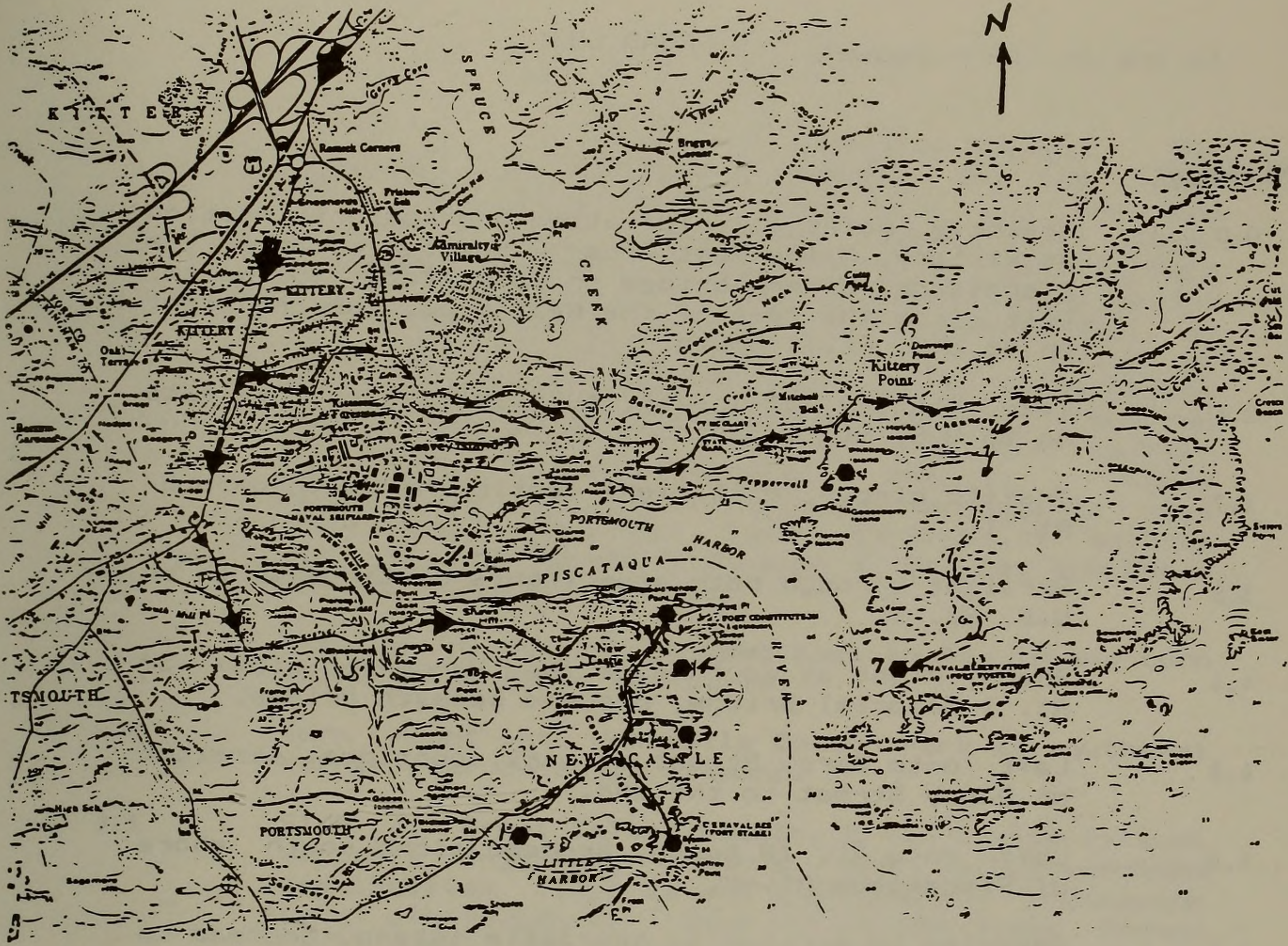

1 ● Stop Location

FIGURE 4: Trip Map

ROAD LOG:

Mileage:	
0.0	Assembly point at information and comfort station at Kittery, Maine Rest Area- 2.9 miles north of the Piscataqua River bridge on interstate 95 North. Exit from the rear of the Rest Area, turning right on to U.S. Rt. 1 South.
2.4	Take Kittery Rt. 1 exit, turn left at end of ramp on to U.S. Rt. 1 South.
2.7	Traffic circle, exit right continuing south on U.S. Rt. 1.
3.8	Straight through both stop lights continue south on U.S. Rt. 1.
4.4	Sharp right at south side (New Hampshire side) of Rt. 1 Memorial Bridge, proceed beneath bridge.
4.5	Left onto Darcy Street at park, continue straight on Darcy Street to the end.
4.8	Left onto Rt. 1B South, proceed along south shore of Piscataqua River.
6.4	Entering NW portion of Newcastle Island, proceed on Rt. 1B around island to the SW side.
8.0	STOP 1: Wentworth-by-the-sea, SW Newcastle Island: Stratigraphy and structure of the upper "metavolcanic" unit of the Rye Formation (Zones III, IV, & V) in approaching the Great Common Fault Zone (SW extension of the southern ultramylonite of Hussey 1980). Rock types and structures from NW to SE include variably injected, sheared & refolded amphibolite with gently NE-plunging fold structures; calc-silicate gneisses; sulfidic schists; marble with steeply SW-plunging dextral asymmetric folds, containing pyroxene and epidote consistent with amphibolite facies metamorphism; variably injected pelitic and quartzo-feldspathic metasediments; and pseudotachylyte-bearing ultramylonite with its characteristic creamy well-foliated texture.
8.0	Reverse direction and proceed north back on Rt. 1B.

8.6 Right on to Wild Rose Lane, proceed south to end of lane.

9.0 STOP 2: Fort Stark, SE Newcastle Island: The lithology and structure typical of the lower "metasedimentary" unit (Zone VII) of the Rye Formation SE of the Great Common Fault Zone. Variably injected schists of this zone contain abundant andalusite porphyroblasts with inclusions of staurolite, sillimanite and garnet as well as the foliation suggesting a second phase of metamorphism. Discrete pegmatite injection bodies have been intensely- sheared and preserve fractured tourmaline crystals floating in a more ductile pegmatitic quartzo-feldspathic matrix. These lithologies and ductile deformation features have been overprinted by later EW-trending oblique dextral shear zones, kink-band structures and Early Mesozoic dike injections.

9.2 Reverse direction, proceed back to Rt. 1B and turn right going north on Rt. 1B.

9.3 Turn right into Newcastle Common Park at southeast corner near baseball diamond.

9.3 STOP 3: Great Island Common, E New Castle Island: Variably injected, sheared and multiply-folded amphibolites (Zone V) and a gradual(?) transition into ultramylonite (Zone VI) of the Great Common Fault Zone (southern ultramylonite of Hussey, 1980). Both lithologies have been complexly folded with gently-plunging structures being the most prominent feature. within the ductile fault zone with The ultramylonite also exhibits the characteristic creamy, well foliated texture typical of these zones and style of brittle deformation that is associated with the development of pseudotachylyte generation zones. Near-layer-parallel slip surfaces can be observed some filled with dark fine-grained pseudotachylyte. These slip zones may develop an internal brecciation as well. The center of the ultramylonite within this fault zone develops a chaotic internal texture in contrast to the well foliated nature of most of the ultramylonites. The later development of altered joint systems can also be observed.

10.0 Leave New Castle Common turning right on to Rt. 1B North.

10.4 At right-angle bend in Rt. 1B proceed straight on to Main Street and turn right on to Ocean Street. Proceed to end of street.

10.4 STOP 4: Ocean Street Beach, E Newcastle Island: Augen gneisses (Zones II& III) of the upper "metavolcanic" unit of the Rye Formation can be seen as intensely injected and sheared amphibolitic metasediments. The feldspar augen are preserved as porphyroclasts of an originally coarse-grained pegmatitic injection. Numerous lenses of amphibolite are preserved within the augen gneisses as remnants of the original injected lithology. Late oblique dextral shears are also abundantly developed.

10.5 Proceed back to Main Street and turn right continue to right angle bend in Main Street.

10.5 STOP 5: Coast Guard Station Pier, NE Newcastle Island: This outcrop exhibits the lithologic and ductile-brittle deformational complexity characteristic of the Rye Formation in general. Rock types include variably injected amphibolites, sheared augen gneisses and mylonitized granitic gneiss with its irregular aplitic injections as well as basalt dikes of Mesozoic age. The multi-phase fold structures are complex. The overprinted brittle structures include a prominent and well developed EW-trending dextral shear structure with its own assemblage of minor fractures and sigmoidal en echelon gash veins. These structures are clearly cross-cut, and locally intruded by a Mesozoic basalt dike.

10.8 Proceed south back on Main Street and turn right on to Rt. 1B North.

11.7 Leaving Newcastle Island.

12.4 Take right off of Rt. 1B on to Darcy Street and proceed straight to end of Darcy Street.

13.2 Turn right at end of Darcy Street proceed under bridge.

13.3 Left at stop sign and proceed North on Rt. 1 across Memorial Bridge.

14.1 Take right at second stop light on to Rt. 103 East.

14.9 Right at intersection of Rt. 263 and Rt. 103.

14.9 Continue East on Rt. 103.

17.1 Right onto hidden drive marked by "Rutelidge" sign on tree. Continue to end of road parking on southeast corner of Philips Island. Please note we are on private property and here only at the courtesy of the owner. Please stay with the group leaders.

17.1 STOP 6: Philips Island, Maine, Midway between Newcastle and Gerrish Islands: These outcrops exhibit Kittery-type lithology as a purplish weathering, actinolite-bearing calcareous quartzite. These Kittery-type litholgies grade southeastward into the ultramylonites of the Rye-Kittery contact exposed at Gooseberry Island. These Kittery litholgies also develop their own internal ultramylonite zones toward the northwest suggesting that the Portsmouth Fault Zone developed within rock types of both the Rye and Kittery Formations generating a tectonic Rye-Kittery transition zone. The Rye-Kittery Contact, NW Gerrish Island, as originally described by Hussey (1980), can be seen from this point. The tectonic contact between the Rye and the Kittery Formations is marked by a 100' wide zone of ultramylonite. The transitional character of this contact zone is due to mylonitization of both lithologies resulting in a gradational change southeastward from the Kittery lithologies into the mylonitic and metasedimentary lithologies of the typical Rye Formation.

17.6 Proceed back to Rt. 103 and turn right on to Rt. 103 East.

17.9 At left curve in Rt. 103 continue straight off of Rt. 103 on to Chauncey Creek Road.

18.4 Turn right off of Chauncey Creek Road and cross bridge to Gerrish Island. Turn right at south end of bridge on to Pocahontas Road and continue to Fort Foster and Stops 7A-F.

19.6 Enter gate at Fort Foster and proceed to parking lot, if gate is open. Otherwise we will park at gate and walk into the Park.

STOP 7A: Pre-cataclastic metasedimentary lithologies, W Gerrish Island: Remnant metasedimentary lithologies include graphitic-sulfidic schists, marble, and amphibolite preserved in gently plunging antiformal structures. Also included in these exposures are examples of the injected felsic lithologies exhibiting their characteristic porphyroclastic textures as mylonitic augen gneisses and minor ultramylonite zones.

STOP 7B: Southern Ultramylonite zone, S Gerrish Island: The southern ultramylonite zone forms a complex structural boundary between the upper, more heavily-injected, "metavolcanic' unit and the lower, less-injected, metasedimentary unit. The lithologies present include amphibolite, pelitic-schists, mylonitic granitic gneisses and abundant ultramylonite that demonstrate the progressive although complex mylonitization of these rocks.

The ultramylonite exhibits internal fold structures of a gently plunging isoclinal nature. A localized high strain zone within the adjacent biotite schist unit contains a sheared lens of exotic, ductilly-deformed marble as a remant lithology similar to the marble observed in the last outcrop. The internal structure of this zone consists of moderately plunging Z-shaped asymmetric intrafolial folds.

Both the ultramylonite and adjacent cataclastic lithologies of this zone are cross-cut by assemblages of brittle structures representing subhorizontal layer-parallel extension and layer-parallel-compression. The layer-parallel extensional structures consist of conjugate near-vertical strike-slip faults which combine to form conspicuous "horst & graben" structures where cross-cutting the prominent lithologic layering in these rocks. Near layer-parallel dextral shear structures are also prominantly developed representing an intense brittle deformation phase that has resulted in the formation of pseudotachylyte. The pseudotachylyte is produced in distinctive generation zones defined by two near layer-parallel principal shear surfaces as the sites of generation, bounding an injected internal, geometric fracture array. Numerous pseudotachylyte generation zones are developed in these outcrops and range from a few centimeters to over a meter in width.

Early Mesozoic dominantly NE-trending structures related to a second phase of brittle layer-parallel compression have been superimposed on all previous structures and lithologies. These structures include conjugate strike-slip faults, kink-band structures and the injection of basaltic dikes.

The remaining outcrops are on private property. Please stay with the group leaders.

STOP 7C: Cedar Point, SE Gerrish Island: This outcrop represents an isolated block of unmylonitized calcsilicate laminated amphibolite preserved within ductile shear zone lithologies. This block essentially forms a "mega-porphyroclast" whose internal structure can indicate sense-of-shear within the zone as well as the nature of the pre-mylonitic geologic processes. The internal structure of the amphibolite exhibits components of an early phase of layer-parallel flattening in the form of discordant highly-contorted ptygmatic granitic veins and small-scale boudinage structures within the foliation. Thicker, nearly-concordant granitic injection layers remain virtually undeformed except where crosscut by sets of conjugate ductile-brittle fault zones and zones of en echelon vein arrays. The granitic injections are mylonitized where they are crosscut by these faults, particularly along the dominant NNE-trending sinistral shear structures of this conjugate set. The dominance of these internal, sinistral shear structures produces an effective clockwise rotation of the segmented amphibolite blocks as would be expected of thin section scale displaced broken grains in a more ductile recrystalling matrix within a ductile shear zone.

This amphibolite block is bounded by the mylonitic ductile shear zone lithologies that include augen gneisses and thinner but more intense zones of mylonitization. Both of these rock types exhibit textural characcteristics in the form of asymmetric feldspar augen structures which indicate a dominant component of dextral strike slip.

This outcrop is also located at the outer fringe of the roof-structure assemblage which represents the near-surface expression of a subsurface Mesozoic White Mountain intrusion. This roof-structure assemblage is represented by the beginning of rhyolitic dike intrusion as the outcrop is approached from the SW and by the development of the southernmost vent breccia at the NE end of the outcrop. Vent breccias are characteristically chaotic, virtually matrix-less and are often bordered by a sheath of rhyolitic melt. Abundant NNE-trending basaltic intrusions are also present within these outcrops, many of which appear to be reactivating the dominant sinistral shear structures within the host amphibolite block.

STOP 7D: Yellow Rocks, SE Gerrish Island: Excellent vent breccia exposure exhibiting the chaotic ,matrix-free characteristics, as well as, the nature of, and variation in the xenolith compositions. The metamorphic xenolith composition changes within the vent breccias, reflecting the abrupt change in lithology that is apparent within this complex ductile high strain zone. Basaltic dike rocks occur as fragments within the breccia and as cross-cutting intrusions. A sheath of rhyolitic melt can also be seen along the NE contact of this vent breccia exposure.

STOP 7E: Dike Point, SE Gerrish Island: This outcrop represents the largest, and one of the youngest, basalt dike intrusions in the area and exhibits an anomalous NW trend. This intrusion crosscuts all lithologies, structures and intrusions . Excellent vent breccia exposures on the NE margin of the dike contain abundant basaltic xenoliths and rhyolite is present on the SW margin.

STOP 7F: Robbins Rocks, E Gerrish Island: These exposures contain abundant ductile shear zone lithologies which range from mylonitic biotite schists and coarse-grained porphyroclastic augen gneisses to finer grained blastomylonites and thinner zones of ultramylonite toward the NE along this coastal section. The ductile shear zone rocks are cross-cut in these exposures by numerous NW-trending dextral shear zones that are correlated with the pseudotachylyte-bearing structures within the southern ultramylonite exposures.

These rocks and structures are, in turn, cross-cut by a series of intrusions representing, at least in part, the roof assemblage for the hypothesized subsurface intrusive complex. These intrusions begin with several NE-trending quartz-breccia veins that are crosscut by numerous NNE-trending basaltic dike intrusions. The basalts are then crosscut by several hornblende lamprophyre dikes that carry a complete assemblage of sampled plutonic xenoliths from this subsurface complex. The plutonic xenoliths range in composition from gabbro to syenite similar to the White Mountain Magma Series.

0.0 Return to Fort Foster and vehicles.

1.7 Retrace route from Fort Foster Gate back to Rt. 103 and proceed west.

4.4 Intersection of Rt. 103 and Rt. 263; continue on Rt. 103 to Rt. 1 or continue on Rt. 263 back to Interstate 95.