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Title: *Bedrock Geology of the Bar Mills Quadrangle, Maine*

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Bedrock Geology of the Bar Mills Quadrangle, Maine

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INTRODUCTION

Detailed mapping in the Bar Mills 1:24,000-scale quadrangle, Maine, was conducted during the summer of 1994 as part of a broader cooperative program with the U.S. Geological Survey to compile the bedrock geology of the Portland 1:100,000-scale quadrangle. This mapping and compilation project is also contributing to the State's efforts to evaluate potential sources of arsenic in ground water (see Marvinney et al., 1994). The field area is located in the section of the Central Maine belt exposed south of the Sebago pluton and just straddling and north of the Nonesuch River fault as mapped by Hussey (1985) (Figure 1). A thick veneer of glacial deposits obscures much of the bedrock of the area, particularly areas underlain by metasedimentary rocks and has frustrated efforts to establish stratigraphic sequences and correlations. The valley of the Saco River presents a fortuitous cross-strike window through these deposits.

Stratified rocks of turbiditic character are punctuated by granitic (Lyman) and gabbroic (Saco) plutons. Structural grain throughout the area is predominantly northeast-southwest although toward the west there is a profound transition, across an inferred thrust, to a northwest-southeast grain. The nature of this transition is the subject of ongoing mapping. The area is generally of amphibolite grade metamorphism (see Guidotti, 1989). Thomson and Guidotti (1989) report on Barrovian type metamorphism indicated by the presence of kyanite closer to the margin of the Sebago pluton to the north and east of the field area.

STRATIGRAPHY

Hutchins Corner Formation

This formation, as defined by Osberg (1988), is presumed to form the base of the exposed section in the field area. The age of this formation as defined by Osberg (1988) is Ordovician or Silurian.

Distribution: The Hutchins Corner Formation underlies the northeastern quarter of the quadrangle and extends southwestward as a narrow belt between the Lyman and Saco plutons. Within the Lyman pluton are several large xenolithic blocks or portions of roof pendants belonging to this formation. Generally the areas underlain by this formation in the area are of low relief and thickly mantled with glacial deposits. Only the larger streams in the northeastern quarter of the quadrangle cut through the overburden to reveal the bedrock.

Lithology: The unit consists of predominantly medium-grained quartz-plagioclase-biotite granofels arranged in beds of generally medium thickness (5-10 cm) although thinner packets and beds up to several meters thick occur. Bedding thickness is unpredictable throughout the area; large outcrops typically contain thinly and thickly bedded packets. Weathered granofels is usually light tan in color while fresh granofels has a distinct salt-and-pepper character. Large outcrops often expose beds which grade from medium-grained granofels upward into thin quartzose biotite schist; bases of these beds are sharp and distinct. In some sections bedding is disrupted, displaying extensive boudinage, pinch-out of beds, and "broken" beds. An excellent exposure of the formation which displays virtually all the lithologic variability is on the east bank of the Saco River just below the dam (Skelton Station) at Union Falls. Disrupted beds are well exposed on the west bank.

Occuring infrequently in the granofels are small greenish-gray calc-silicate-rich lenses and thin beds. The mineralogy includes epidote and often coarse-grained, salmon-colored grossular garnet. Lenses are generally ovals flattened in the bedding plane and often have coarse centers which are easily eroded, imparting a vuggy character to these lenses.

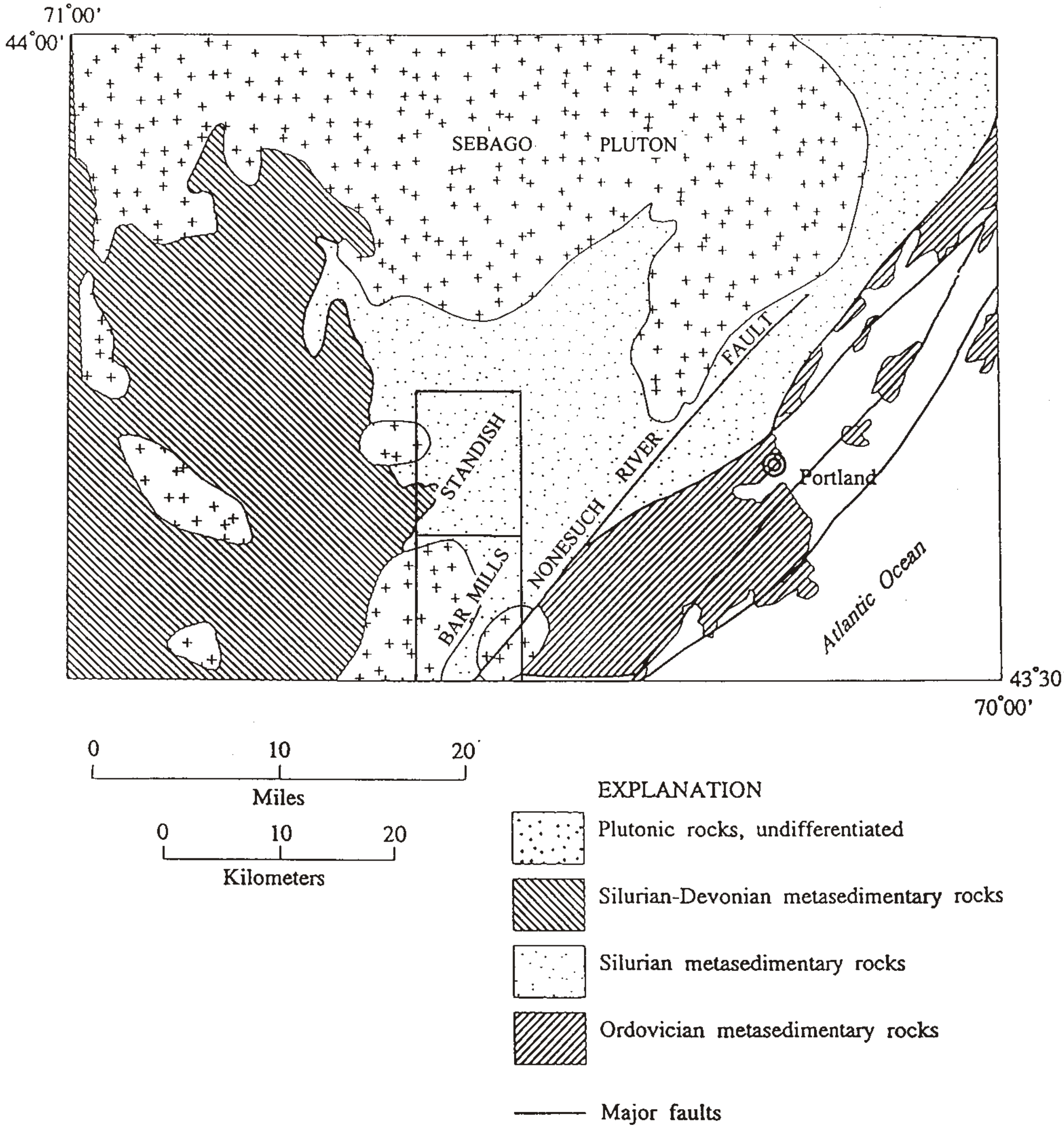

Figure 1. Generalized bedrock geology of the Portland 1:100,000-scale quadrangle showing the location of the Bar Mills 1:24,000-scale quadrangle. Modified from Osberg et al. (1985).

Perhaps 10% of the unit consists of generally massive, rusty-weathering quartzose, sulfidic biotite schist arranged in sequences to a meter in thickness. At several localities but particularly below the dam at Union Falls, the incompetency of this lithology relative to the main part of the formation can be seen. There the rusty schist thickens dramatically in the hinges of minor folds while the thick granofels beds remain generally unchanged from limb to hinge.

The characteristics of the formation are indicative of deposition through turbidity currents.

Contacts: The contacts of the formation with the various plutonic rocks will be discussed in later sections. The lower contact of the formation is not exposed in the field area. The upper contact is presumed to be with the Windham Formation, described to be conformable by Hussey (1985). As this contact is not exposed in the field area and is in an area of scant exposure, there is no new information bearing on the nature of this contact.

Windham Formation

This unit was defined by Hussey (1971, 1985) and correlated by him on the basis of lithology and stratigraphic position with the Waterville Formation exposed northeast of the Sebago pluton. The age of the unit (Silurian) is based on its correlation with the Waterville Formation (Hussey, 1985).

Distribution: This unit underlies two areas in the quadrangle: a narrow northeast-southwest trending belt in the north-central section of the quadrangle; and a large xenolithic block or roof pendant in the Lyman pluton in the vicinity of Union Falls. Hussey (1985) originally interpreted this belt as a synform which plunges northeastward, but more detailed work on the stratigraphy is leading to some reconsideration of this interpretation.

Lithology: The primary lithology of the unit is thin bedded to massive muscovite-biotite-garnet-quartz schist with variable rusty weathering. Interbedded with this lithology are thin beds of quartz-biotite+muscovite granofels, and local calc-silicate gneiss. In uncertain stratigraphic position is a metalimestone member consisting of gray, thin ribbon-bedded metalimestone and calc-silicate marble interbedded with quartz-plagioclase-biotite schistose granofels. This lithology comprises the xenolithic block in the Lyman pluton.

Contacts: Nowhere in the field area is the contact of the metalimestone member with the main part of the formation exposed. Given the interbedded nature of the metalimestone and schistose granofels, it is likely that the contact with the main part of the formation is gradational. The contact with the underlying Hutchins Corner Formation is not exposed, but for the xenolithic block it is constrained within several hundred meters. At first blush, topping directions in the Windham and Hutchins Corner Formations suggest that the Hutchins Corner is above the Windham here. This is contrary to data from other well-exposed sections reviewed by Hussey (1985). Minor folding is augmented around the margin of the Lyman pluton and likely causes frequent topping reversals in the outcrops closest to the contact zone.

Unnamed stratified rocks

Several small bodies of unnamed stratified rocks occur within the Saco pluton as xenolithic rafts, roof pendants, down-faulted blocks, or a combination of these. Hussey (1985) originally assigned these, on the basis of lithology, to the Kittery Formation, but in the compilation of Osberg et al. (1985) the rocks are assigned to the Hutchins Corner Formation (then the Vassalboro). The stratigraphic assignment of this unit, and its age, are open to debate.

Lithology: While sections are similar to the quartz-plagioclase-biotite granofels and mica schist of the Hutchins Corner Formation, most are brown-weathering, carbonate-rich, massive schist. The outcrops often have an angular, blocky appearance due to complex fabrics.

Contacts: The contacts of these rocks with the Saco pluton will be discussed in a later section.

INTRUSIVE ROCKS

Lyman pluton

Distribution: This two-mica granite forms a body, elongated along structural grain, about 24 km long and 8 km wide. It underlies nearly the entire western half of the quadrangle. Topographically the pluton in this area is expressed as a series of rounded hills, generally in the contact areas of the pluton, surrounding broad gentle basins now occupied by swamp and representing the more easily erodable core of the pluton.

Lithology: Fine- to medium-grained, light gray, generally unfoliated biotite-muscovite granite is well exposed in the field area. While pegmatite dikes occur throughout the pluton, they are particularly abundant in the northern section and complicate identification of the pluton margin there. An important characteristic of the granite is its jointing. There are several sets of vertical joints and one sheeting set; details are provided in a following section.

Contacts: The pluton's contact with the metasedimentary units is sharp and well exposed in several localities. The best exposure in the field area is below the dam at Union Falls on the west bank of the Saco River. The uniformly smooth contact surface of the granite exposed directly at the base of the dam strikes N-S and dips around 70o eastward. There is no noticeable chilling of the granite. In the metasedimentary rocks of the Hutchins Corner Formation the contact is a brittle zone approximately 1m wide and is accompanied by a late foliation which extends up to a kilometer away from the contact. The distribution of this foliation and the observed dip of the contact form the basis for Hussey's (1985) suggestion that the pluton is a thin lenticular sheet which dips moderately eastward.

The northern boundary of the Lyman pluton is poorly exposed and complicated by extensive pegmatite dike intrusion, these being preferentially exposed. The contact is drawn between the pegmatite and the first metasedimentary rock outcrop. This condition applies to the straight segment of the southeastern boundary of the pluton as well; the actual contact there falls anywhere within a 1 km-wide zone. Other contact zones are well constrained by outcrop.

Age: Rb/Sr whole rock analysis by Gaudette et al. (1982) is the basis for the Mississippian age (322+12 Ma) of the pluton.

Pegmatite dikes

Pegmatite varies from very thin to meters-thick dikes which abound within and in the vicinity of the two granitic plutons. The mineralogy of these is commonly very coarse-grained feldspars, quartz, muscovite, biotite, garnet, and schorlite. Their orientations are quite variable and their distribution is greatest in the vicinity of the margin of the Lyman pluton.

Saco pluton

Distribution: The Saco pluton underlies the southeastern corner of the quadrangle, straddling the Saco River where it controls a distinct topography consisting of small knobs of 50-100 ft relief. This oval pluton extends into neighboring quadrangles with the long dimension of approximately 6 km parallel to regional structural grain.

Lithology: The primary lithology is a coarse-grained, medium dark gray to slightly greenish gray metadiorite/gabbro in which almost all primary silicate minerals are altered to secondary assemblages. According to Hussey (1985), plagioclase is extremely saussuritized and hornblende and augite are almost entirely altered to fibrous amphibole. These observations are confirmed in the study area.

Some sections of the pluton are non-foliated; others are extremely foliated and sheared. With the exception of the northwestern margin of the pluton which is controlled by a thrust fault, this foliation and shearing is quite variable. Two possibilities exist for the origin of shearing: (1) Shearing is the product of internal adjustments made as the magma was intruded in a semi-solid state; (2) Shearing is the product of post-intrusion tectonics. The latter implies an older age for the pluton.

A previously unmapped phase of this pluton, occurring as several small bodies within the main outline of the pluton, is granitic to granodioritic in composition. The mineralogy of this light-colored medium-grained rock includes plagioclase, biotite, and hornblende with minor quartz in some areas. Along the northwestern margin of the pluton this phase also is sheared.

Contacts: The only exposed contacts of the pluton with the metasedimetary rocks are along the pluton's northwestern margin. This is a fault contact described in a later section.

Age: The age of the Saco pluton as determined through Rb/Sr whole-rock analysis is 307+20 Ma (Gaudette et al., 1982).

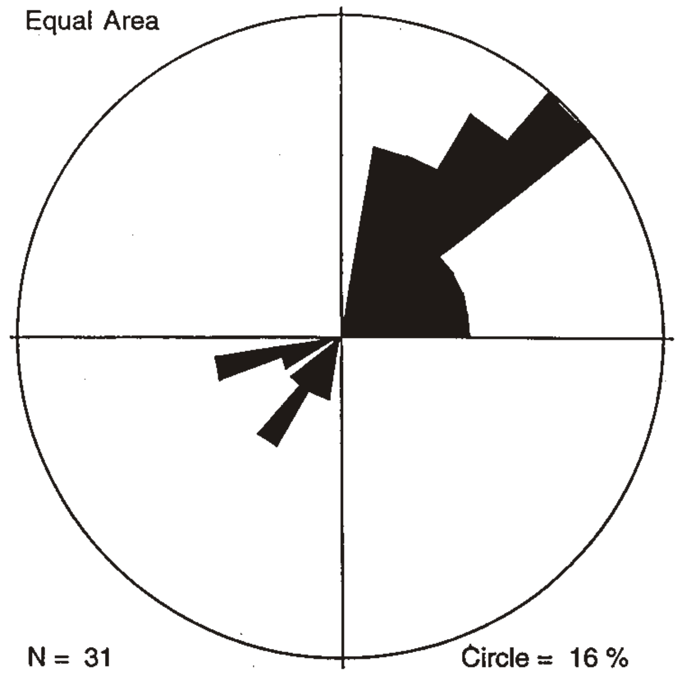

Figure 2. Rose diagrams of strikes of mafic dikes of probable Mesozoic age. Most dikes strike northeastward.

Given the degree of alteration and deformation experienced by this pluton, I concur with Hussey's (1985) suggestion that it could be older.

Mafic dikes

Distribution: Intruding all rock types in the area are unaltered basaltic dikes of presumed Mesozoic age. Swarms of dikes occur in some areas.

Lithology: Dark gray dikes range from a few cm to several meters in thickness. They contain abundant 1-2 mm plagioclase phenocrysts and have lighter gray, narrow chill margins generally devoid of phenocrysts. Dikes typically have planar contacts and impart very little alteration to the host rocks. Columnar jointing is usually developed perpendicular to dike walls. With few exceptions these dikes are steeply dipping and strike NE-SW, generally parallel to bedding/foliation in the metasedimentary rocks. Figure 2 is a rose diagram of the strikes of dikes.

STRUCTURAL GEOLOGY

Foliation

Several generations of foliation affect the rocks of the field area. An early foliation of uncertain origin parallels bedding. A later foliation of probable Acadian origin parallels bedding except in the hinge areas of upright folds. These foliations cannot

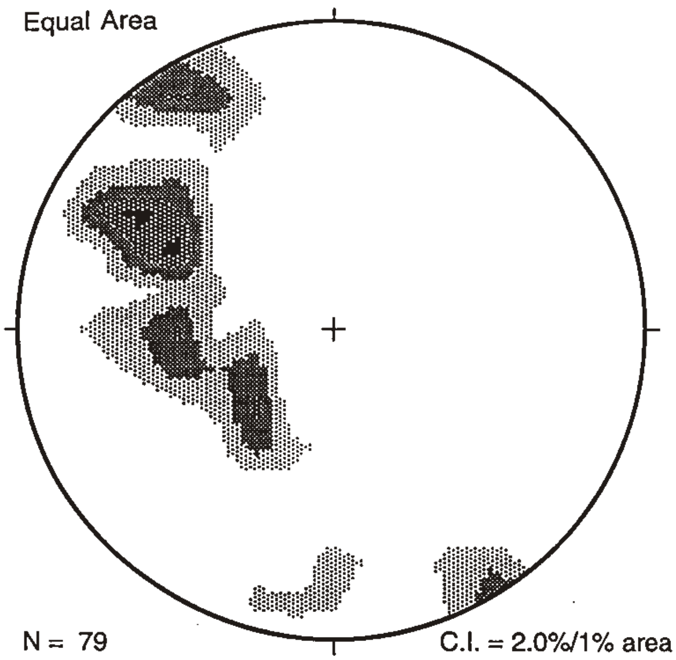

Figure 3. Equal area lower hemisphere stereoplot of poles to bedding planes. The girdling of poles about a great circle indicates that the overall fold structure of the region plunges northeastward.

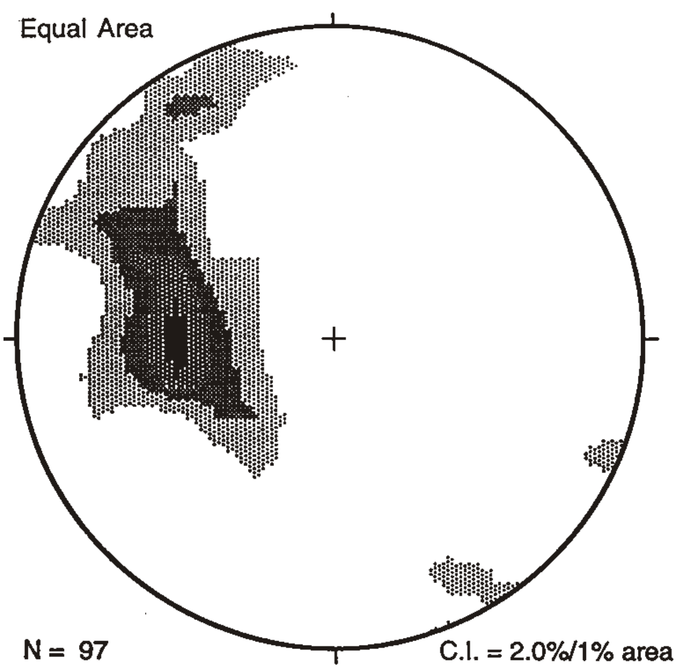

Figure 4. Equal area lower hemisphere stereoplot of poles to planes of early foliation (S_1). The relationships shown here are similar to those for bedding (Fig. 3).

be distinguished outside of hinge areas. A late foliation locally affects metasedimentary rocks intruded by the Lyman pluton.

Bedding (S_0): Bedding is almost universally steeply dipping throughout the area except in the hinge areas of minor folds. Figure 3 is a lower hemisphere stereoplot of poles to bedding which shows the generally steeply dipping nature of bedding. The girdle of poles is indicative of regional-scale folding which plunges moderately northeastward.

Early foliation (S_1): This foliation cannot be distinguished from S_2 except in the hinge areas of upright folds. The coarser grained, well-bedded metasedimentary rocks exhibit a strong bedding-parallel foliation, usually steeply dipping and parallel to the strike of bedding. In granofels, this foliation is manifest as an alternation of light and dark laminae of a few millimeters in thickness. The light laminae are more concentrated in quartz and feldspars; the dark in biotite. In schists, the foliation is a pervasive schistosity.

In the granofels only, this foliation is seen to be folded in several upright folds and may have its origin in early recumbent folding of the type described by Osberg (1988) in areas northeast of the Sebago pluton, and by Eusden et al. (1987) in areas to the west. This foliation is not folded in the schist. Neither recumbent fold noses nor downward-facing sections, which would confirm this interpretation, have been found in the area. Alternatively but less likely, laminae in the granofels may be of sedimentary origin rather than tectonic. If this be the case, then the rocks do not record an early folding episode. Figure 4 is a stereoplot of poles to S_1 foliation.

S_2 foliation: The foliation which is seen in schist to be axial-planar to upright folds is assigned to the second generation of foliation and is probably Acadian in origin. It is manifest as schistosity in the schist and can only be distinguished from S1 in the hinge zones of minor folds. S_2 is not observed in the granofels.

S_3 foliation: An intrusion-related foliation mapped by Hussey (1985) affects the metasedimentary rocks in areas immediately adjacent to the Lyman pluton. This effect is most clearly seen in the orientation of schistosity in the mica schist sections of the Hutchins Corner Formation near the pluton contact. These effects fade away beyond a kilometer distance of the pluton. This is manifest as a crenulation of the probable Acadian foliation in the schist.

Joints: Joints are the primary avenue for ground-water movement throughout southwestern Maine and elsewhere in the state and affect all rock types in the area. Their characteristics, then, are very significant to studies of ground-water quality and quantity. A summary of brittle fracture orientations by Starer (1995) shows two primary orientations: steeply dipping and striking ~ 030° and steeply dipping and striking ~ 105°. There is an additional sheeting set in the granite. Joint surfaces are clean and fairly uniform. Only about 10% of the brittle fractures are infilled with vein quartz; no other mineralization was observed. Figure 5 is a stereoplot of poles to joint planes that shows the near-vertical, nearly east-west orientation of many joints.

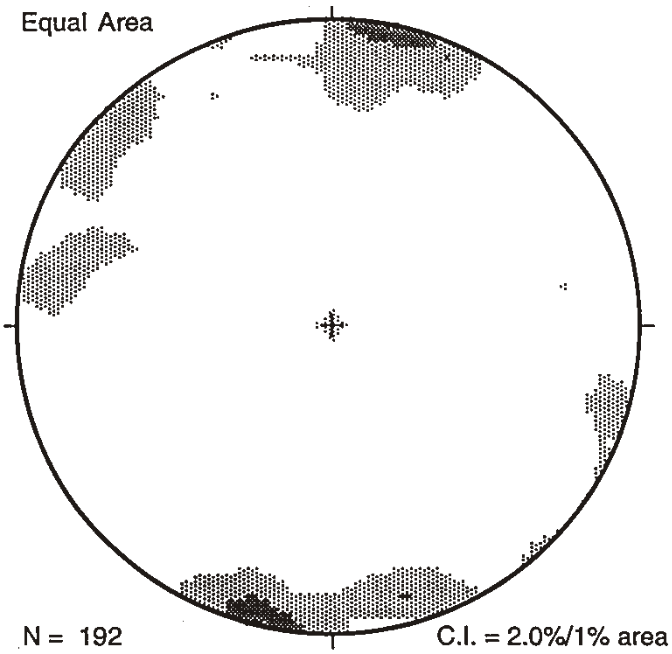

Figure 5. Equal area lower hemisphere stereoplot of poles to joint planes. This shows the generally near-vertical east-west nature of many of the joints.

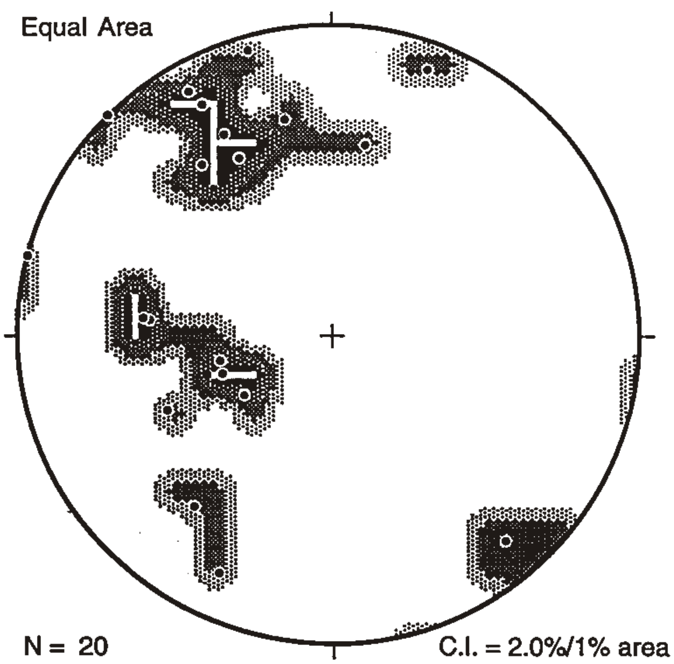

Figure 6. Equal area lower hemisphere stereoplot of poles to shear planes. Although the number of points is low, the plot suggests that shears may have experienced the same folding events as bedding and thus may be fairly old features.

Folds: Small-scale folds are exposed in a few of the larger outcrops along the Saco River; few have been seen elsewhere owing mostly to the poor nature of exposure. Most are tight to isoclinal, upright, and northeast-plunging, mimicking the style interpreted for the regional structure of the area. In the vicinity of the Lyman pluton Hussey (1985) mapped weak contact-parallel small-scale (10s of cm) folds. Elsewhere we are beginning to recognize larger scale (several 10s of meters amplitude) late folds which plunge to the north. They have only been observed in the vicinity of the Lyman pluton and may be a larger-scale version of the contact effects noted by Hussey (1985).

Faults: Hussey (1985) mapped several important faults in the area, including a thrust which separates the Hutchins Corner Formation from units to the west and the Nonesuch River fault. The former is the subject of on-going investigations with no new results at this time. Hussey (1985) mapped the Nonesuch River fault as bisecting the Saco pluton and also resulting in the exposure of metasedimentary rocks in a fault block within the pluton. This particular fault trace has often been noted as a major fault in the continuation of the Norumbega fault zone from the northeast (see, for example, West et al., 1993).

More detailed mapping along this trace leads to the suggestion that this is probably not a major feature of the fault system. Shearing is only localized and not particularly strong within the metasedimentary block in the Saco pluton. Shear fabrics in the bordering Saco pluton are highly variable in strength and predominantly oriented with an E-W strike which is inconsistent with the orientation of the Nonesuch River fault. While there most certainly is a fault along the straight stretch of the Saco River here, it is not a particularly significant one. Figure 6 is a stereoplot of poles to shear planes. The girdle of points here is similar to that for bedding and S1 foliation, giving rise to the suggestion that some of the shearing may have predated folding.

A much more significant fault marks the northwestern boundary of the Saco pluton with the Hutchins Corner Formation and is well exposed in some roadside outcrops and a stream. This feature is marked by an increasing intensity of shear fabric, specifically a strong mineral lineation, in the Saco pluton. This fabric is oriented 020-045o strike with 35-50o dip and dominates the outcrops of the pluton, including the granodioritic phase, along its entire northwestern contact. The lineation falls in a plane parallel to the contact and plunges directly down-dip. I interpret the northwestern contact of the Saco pluton to be a previously unmapped SE -over-NW thrust of significant proportion. The lateral continuation of this fault is uncertain.

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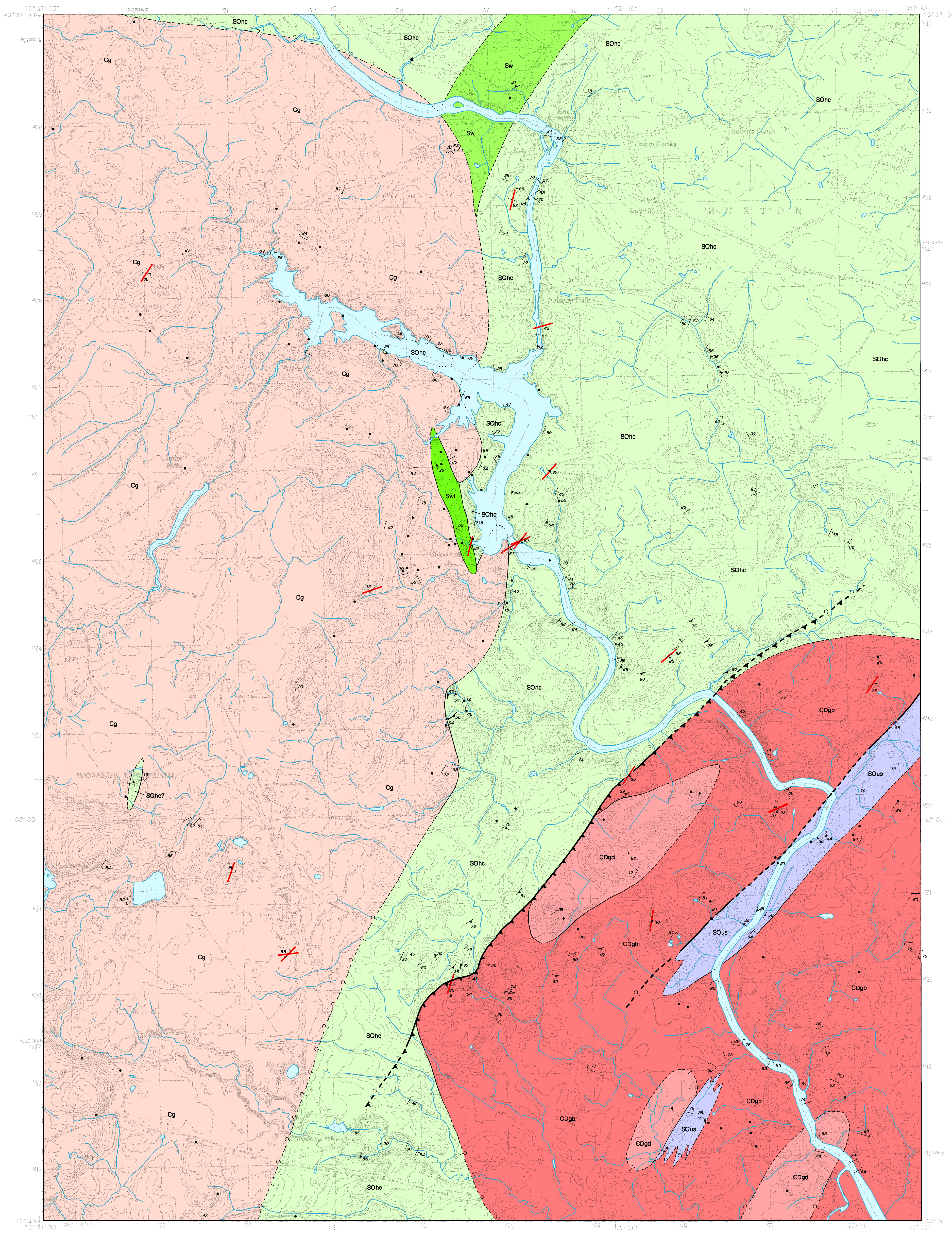

EXPLANATION OF UNITS

Intrusive Rocks

Mesozoic

Mafic dikes. Dark gray, unaltered basaltic and diabasic dikes of presumed Mesozoic age ranging from a few cm to several meters in thickness; plagioclase phenocrysts common; planar contacts with narrow chill zones; columnar jointing common perpendicular to dike walls.

Carboniferous

Cg — **Lyman pluton.** Fine- to medium-grained, light gray, generally unfoliated biotite-muscovite granite. Pegmatite dikes abound within and in the vicinity of the pluton. These are very thin to meters-thick dikes; very coarse-grained quartz, perthitic microcline, muscovite, biotite, garnet, and schorlite.

Devonian or Carboniferous

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

CDgd — **Granodiorite of the Saco pluton.** Light-colored medium-grained granodiorite containing plagioclase, biotite, and hornblende with minor quartz.

Stratified Rocks

Silurian

Sw — **Windham Formation.** Thin bedded to massive muscovite-biotite-garnet-quartz-staurolite or sillimanite schist with variable rusty weathering. Thin interbeds of quartz-biotite ± muscovite granofels, and local calc-silicate gneiss.

Swl — **Metalimestone member.** Gray, thin ribbon-bedded metalimestone and calc-silicate marble with thin interbeds of brownish gray quartz-plagioclase-biotite-calcite granofels.

Ordovician or Silurian

SOhc — **Hutchins Corner Formation.** Light tan-weathering, medium-grained quartz-plagioclase-biotite granofels in beds of 5-10 cm thickness with some thinner packets, some beds to several meters thick. Graded bedding common; bed bases are sharp and distinct. Minor thin quartzose biotite schist. Small greenish gray calc-silicate-rich lenses and thin beds occur infrequently in the granofels. Massive, rusty-weathering quartzose biotite schist comprises 10% of unit.

SOus — **Unnamed stratified rock.** Massive, brown-weathering, carbonate-rich schist in outcrops of angular, blocky character, occurring as several small bodies within the Saco pluton. Minor quartz-plagioclase-biotite granofels and mica schist.

EXPLANATION OF SYMBOLS

20 — Bedding - inclined, vertical
Note: S1 foliation is always parallel to beddingand is not shown by separate symbol.

20 — Bedding with known topping direction - inclined, vertical.

20 — Overturned bedding.

20 — S2 foliation - inclined, vertical.

20 — S3 foliation - inclined, vertical.

20 — Joint - inclined, vertical.

20 — Shear fabric - inclined, vertical.

20 — Lineation

Outcrops without structural data.

Symbols representing inclined fabrics are annotated with dip angles.

?— Contact

?— High-angle fault

?— Thrust fault

All linear features are solid where approximately placed, dashed where inferred, dotted where concealed, and queried where uncertain.

Bedrock Geology of the Bar Mills Quadrangle, Maine

Bedrock geologic mapping by
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Digital cartography by:
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Cartographic design and editing by:
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1995
First color printing: February, 2004

Quadrangle Location

SCALE 1 : 24,000

1 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 0 1 KILOMETER

CONTOUR INTERVAL 10 FEET

TRUE NORTH

SOURCES OF INFORMATION

Bedrock mapping by Robert G. Marvinney completed during the 1994 field season.

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

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