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Author: *Richard A. Gilman*

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Bedrock Geology of the Newfield 15' Quadrangle, Maine – New Hampshire

Richard A. Gilman
Department of Geosciences
State University College at Fredonia (SUNY)
Fredonia, New York 14063

INTRODUCTION

Geologic mapping of the Newfield quadrangle was initiated in 1965 as part of the regional bedrock mapping program of the Maine Geological Survey. Work was carried on intermittently between 1965 and 1971 concurrently with mapping adjacent quadrangles. A preliminary report (Gilman, 1978) was published in 1978. The present map and text have been revised to encompass the new interpretations resulting from work by Eusden et al. (1984) in New Hampshire. Traditional methods of pace and compass traverses, sample collecting, and petrographic examination were employed. In addition, preliminary geochemical work has been done on the Abbott Mountain pluton.

The relief is moderate, reaching a maximum of 700 feet on Sawyer Mountain in the northeast corner of the quadrangle. The region is hilly with thick glacial deposits filling the lowlands, commonly causing small lakes and ponds, many of which have had their levels raised by the construction of small dams at their outlets. The area is easily accessible by tar or gravel roads. Bedrock is generally well exposed at the higher elevations, but poorly exposed in the valleys.

The Newfield quadrangle (Plate 1) is underlain by igneous and metamorphic rocks of Paleozoic and Mesozoic age. Rocks of the Rindgemere Formation of Siluro-Devonian age have been metamorphosed and deformed under sillimanite-zone conditions, producing mica schists and magnetites, sulfide ("rusty") schists, and lime-silicate granulite. Sillimanite is ubiquitous, staurolite and andalusite are locally present, but kyanite is absent. The dip of the bedding/schistosity is gentle over much of the quadrangle with strikes trending north and northwest across the regional northeast structural grain of southern Maine. The sediments were metamorphosed, folded, and intruded by granitic rocks during and following the Acadian orogeny in Devonian time. A group of five post-tectonic alkalic stocks of Mesozoic age is aligned north-south through the center of the quadrangle.

DESCRIPTION OF THE METASEDIMENTARY ROCKS

All of the metasedimentary rocks of the quadrangle have been assigned to the lower and upper members of the Rindgemere Formation of the Shapleigh Group as defined by Hussey (1968, 1984).

Lower Member

The lower member consists of a variety of pelitic schists, rusty weathering sulfide-bearing schists, and lime-silicate granulite. Reddish-brown to gray, medium-grained muscovite-biotite-garnet-sillimanite schists and migmatites are the most abundant rock type; minor lithologic variations within this group could not be mapped separately due to their limited exposure. Sillimanite is present in the pelites throughout the quadrangle, but staurolite and andalusite have been found only along the eastern margin. All of the metasedimentary rocks show a conspicuous foliation that is generally parallel to compositional layering where the latter is present. In some cases the compositional layering is likely due to metamorphic differentiation, but in other instances, particularly in the non-migmatized schists, it consists of alternating sandy and pelitic units that are interpreted to be original bedding. It is in exposures of the latter that bedding and foliation are sometimes at oblique angles.

The habit of muscovite is distinctive. In the migmatites, large (2 to 4 cm) porphyroblasts of muscovite have developed across the schistosity. On the other hand, in the non-migmatitic schists, muscovite and sillimanite clots lie in the plane of the schistosity, imparting a distinctive lenticular appearance.

Migmatite and non-migmatitic varieties of pelite are found interlayered throughout the quadrangle.

Rusty weathering quartz-muscovite-feldspar schist has been mapped as a separate unit in the northeast corner of the quadrangle (west side of Sawyer Mountain) and in the south near

Mousam Lake. The weathered surface is characteristically yellow-brown or black due to oxidation of disseminated iron sulfide including pyrrhotite. The rock is commonly gray to white on fresh fracture, and the schistosity tends to be irregular. Only those areas having numerous adjacent exposures of rusty schist are shown on the map. Similar rusty rocks are occasionally found in isolated outcrops, but these have not been connected on the map; their locations are indicated on the map by an "R".

Lime-silicate granulite is found in numerous isolated exposures in the northwestern half of the quadrangle and to a lesser extent in the south-central portion. The rock is characterized by its alternating, gray-green, 1 to 10 mm layers, and granular texture. It is usually fine- to medium-grained and contains thin interbeds of gray, fine-grained, granular biotite-quartz-feldspar schist. In addition to quartz, plagioclase, and diopside, which constitute 90% of the rock, grossularite garnet and vesuvianite are occasionally abundant. Seldom is there more than a few meters of lime-silicate granulite exposed at any one outcrop. Lacking evidence to the contrary, it has been assumed that all of the granulite in the northern and western parts of the area lies in the same general stratigraphic interval of perhaps a few tens of meters. This zone may also include the less extensive exposures in the Mousam Lake region.

Upper Member

Schists that have been assigned to the upper member of the Rindgemere Formation are exposed near Acton and are characterized by well preserved cyclic and sometimes graded bedding. In addition, the contrast between the swirly, migmatitic character of the lower Rindgemere Formation and the nearly planar, "apparently simple" structure of the upper Rindgemere Formation is striking. Bedding thickness varies from a few centimeters to as much as 75 cm, but does not show such variation within a single exposure. The beds consist of micaceous quartzite and silvery-gray mica schist; the latter is frequently characterized by the presence of "andalumps" (A term coined by Peter Robinson), i.e., porphyroblasts of andalusite, in most cases pseudomorphed by muscovite, that cause a lumpy appearance to the schistosity. The pseudomorphs may be up to 9 cm long and while their long axes lie within the foliation, they are not aligned to produce a lineation. Lenses and pods of fine-grained garnet + quartz (coticule) also characterize this unit and have been used as an important criteria for stratigraphic correlation (Eusden et al., 1984).

Two additional areas within the quadrangle have exposures of bedded schist that possibly belong to the upper Rindgemere Formation; on Sawyer Mountain in the northeast corner and near North Alfred in the southeast corner. In the Sawyer Mountain area, and especially on Moody Mountain and Libby Mountain to the east (Buxton and Sebago Lake quadrangles; Gilman, 1970), 1 to 25 cm thick, graded, cyclically bedded schist and quartzite contain minor coticule lenses and are therefore considered as possible correlatives to the rock at Acton. The rock contains abundant sillimanite as well as occasional staurolite and andalusite. In the North Alfred area, a thin outcrop band of 2 to 5 cm thick interbedded quartzite and silvery gray mica schist is exposed at the base of the eastern slope of Fort Ridge. The rock is poorly to moderately bedded quartzite and schist that locally displays good grading. Bedding thickness varies from 6 to 45 cm and the micaceous layers are often characterized by 2 to 5 cm clots of sillimanite. Bedding is obscured as the rock becomes more migmatitic towards the top of the ridge. No coticule lenses have been observed from this location.

Rocks of the North Alfred and Sawyer Mountain areas are presented as possible correlatives with the upper Rindgemere Formation because of similar lithologic features, i.e., well preserved cyclic bedding, graded bedding, and, in the Sawyer Mountain area, the occurrence of garnet + quartz coticule. But the distances between both areas and Acton are so great and the intervening structure so incompletely understood that other stratigraphic interpretations may be equally possible. On the geologic map they are indicated as well-bedded schist within the Rindgemere Formation.

CORRELATION OF THE METASEDIMENTARY UNITS

All of the metasedimentary rocks of the Newfield quadrangle have been assigned to the Rindgemere Formation of the Shapleigh Group (Hussey, 1968, 1985) of Siluro-Devonian age. The formation takes its name from exposures in the Salmon Falls River near the former Rindgemere Station in East Rochester, New Hampshire (75 m upstream from the US Route 202 highway bridge). Hussey (1968) divided the formation into upper and lower parts, and in 1985 formalized these to the upper and lower members.

Exposures of the upper member have been traced from East Rochester, across the western side of the Berwick quadrangle and into the Newfield quadrangle in the vicinity of Acton (Gilman, 1986). It is on this basis that the well-bedded schist at Acton is correlated with the upper member. The remainder of the poorly-to-non-bedded, often migmatized metasedimentary rocks of the Newfield quadrangle have been assigned to the lower member following Hussey's work in the Berwick quadrangle (1968, 1985).

In older literature, the Rindgemere Formation was correlated with the Littleton Formation in New Hampshire (Hussey, 1968; Billings, 1956; Quinn, 1953). However, in recent years studies by Eusden et al. (1984, 1987) in New Hampshire have suggested that the stratigraphic sequence there resembles that of the Silurian section of central Maine as described by Moench and Boudette (1970) and traced southward by Hatch et al. (1983) in eastern New Hampshire.

Mapping by Gilman (1986) suggests that the well-bedded schist of the Acton area is correlative to Eusden's unit S2 which he correlates in part with the Perry Mountain Formation of the central Maine sequence (Eusden et al., 1984). The rocks in-

TABLE 1: STRATIGRAPHIC CORRELATION OF SILURIAN (?) METASEDIMENTARY ROCKS OF THE NEWFIELD QUADRANGLE WITH THOSE OF CENTRAL MAINE, SE NEW HAMPSHIRE, AND NORTHERN YORK COUNTY, MAINE.

York County	Newfield	SE N.H.	Central Maine
Rindgemere Fm. Upper member (in part)	Rindgemere Fm. Upper member	Unit S2	Perry Mtn. Fm. (in part)
			Sangerville Fm.
Lower member	Lower member	Unit S1	Rangeley Fm. (in part)

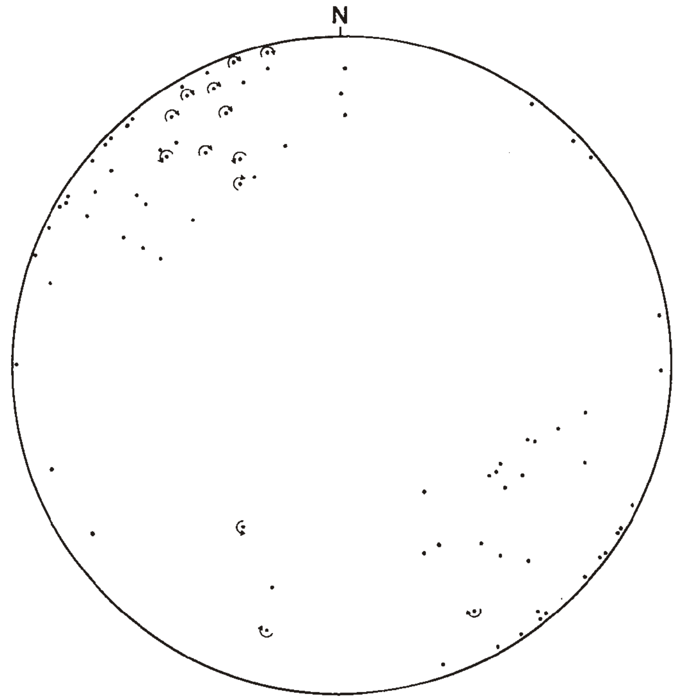

Figure 1. Equal area diagram (lower hemisphere) of minor fold axes and mineral lineations.

cluded with the lower member of the Rindgemere Formation are continuous from the southwestern part of the quadrangle into Eusden's unit S1, i.e., migmatized pelites that he suggests correlate in part to the Rangeley or possibly the Sangerville Formations of the central Maine sequence. If the latter is the case, the calc-silicate granulite of the Newfield quadrangle may be correlative with the Patch Mountain Member of the Sangerville Formation. Migmatites of the lower member of the Rindgemere Formation are continuous to the north and west where they were mapped as Littleton Formation in the Wolfeboro quadrangle (Quinn, 1953) and the Ossipee Lake quadrangle (Wilson, 1969). Studies by Eusden and others are currently underway in New Hampshire to reevaluate the stratigraphy of these rocks in light of revisions made farther north by Hatch et al. (1983).

Table 1 shows the proposed correlation of metasedimentary rocks of the Newfield quadrangle to those of the central Maine sequence and to Eusden's section at East Rochester, New Hampshire.

STRUCTURE OF THE METASEDIMENTARY ROCKS

Macroscopic Scale

On the quadrangle scale, the dominant structure of the metasedimentary rocks is the folded, gently dipping schistosity. Except as can be shown otherwise, the schistosity is assumed to be parallel to bedding. But at the same time it is inferred that in many cases the bedding has been transposed so that it is now "parallel" to axial surfaces of isoclinal folds. The only member of the lower Rindgemere Formation that shows conclusive bedding (other than the schist already mentioned) is the calc-silicate granulite. Bedding is commonly represented in this rock by 1 to 10 mm thick gray and green layers that are parallel to the schistosity in associated schist. The map shows the structural attitude of the schistosity for the non-bedded rocks and of bedding in the calc-silicate granulite and bedded schists. For the majority of the quadrangle, regional structures have been identified by interpolating between exposures of calc-silicate granulite using the attitude of adjacent schistose rocks as a guide. This results in the strong NW-SE pattern seen in the northern half of the quadrangle. Minor folds of schistosity for this region show consistent NW-SE trends with gentle plunges in both directions as do mineral lineations (Fig. 1).

The map pattern generated by this method is highly speculative for two reasons. First, the exposures of calc-silicate granulite are widely separated, thus making their connection uncertain. And second, the gentle dips of bedding and schistosity require that topography have a pronounced effect on the outcrop pattern. The result of these two factors is that while exposures of calc-silicate granulite are accurately indicated on the map, the map pattern generated by interpolating between them is open to alternative interpretations. Nevertheless, the existence of a strong NW-SE structural grain for the northern half of the quadrangle is evident. Furthermore, the predominance of southwesterly dips and the existence of small scale asymmetric folds with an easterly vergence suggest that the folding controlling the map pattern is one of west-over-east asymmetric folds having nearly horizontal, NW-SE trending hinge lines. (See cross section B-B).

The NW-SE structural trends continue into the southeast corner of the quadrangle, whereupon strike gradually swings N-S and dip steepens. In the Fort Ridge region where graded bedding is occasionally present in the schistose rocks, southwest-dipping beds are found both right-side-up and overturned, indicating tight-to-isoclinal folds with an easterly vergence as depicted in cross-section A-A'. Exposures of calc-silicate granulite are too few in the south to allow interpolation as was done in the northern half of the quadrangle, but it is inferred that a similar asymmetric fold style persists.

In the southwest corner of the quadrangle the schistosity dips at gentle angles in all directions, but with a slight southward preference. Minor fold axes are oriented NW-SE. The strike of bedding in the calc-silicate granulite between Great East Lake and Lovell Lake gradually shifts from NE-SW to N-S, while schistosity in the adjacent rocks shows varied orientations.

Near Acton the well-bedded upper Rindgemere Formation forms the nose of a major fold with limbs that diverge southward. This is the nose of the Lebanon syncline as defined by Hussey (1968). It appears that this is an asymmetric structure with steep to vertical dips on the west limb, gentle dips on the east limb, and an axial surface that dips toward the west. Thus, in the Newfield quadrangle this structure seems to fit well with Hussey's original interpretation of the synclinal nature of the Lebanon "syncline". More recently however, Eusden et al. (1987) and Hussey (1985), based on excellent exposures along Route 16 north of East Rochester, New Hampshire, and on the apparent widespread dominance of inverted graded beds, have proposed that very large areas, perhaps involving much of the Newfield quadrangle, are underlain by the inverted limbs of large recumbent folds that have themselves been refolded. Within this context they have proposed that the Lebanon "syncline" is in fact a downward facing antiform in which the younger, upper Rindgemere Formation is exposed beneath the lower Rindgemere Formation (Fig. 2). This radically new interpretation warrants further field study. For the present I have represented the structure as a syncline on the grounds that this best fits the evidence from the Newfield quadrangle. An asymmetric, antiformal syncline with an axial plane that dips to the west as proposed by Eusden et al. (1987) would be expected to have a gently dipping west limb and a steep east limb; this is just the opposite from the inferred geometry for the exposures in the Acton area. Cross-section A-A' shows my

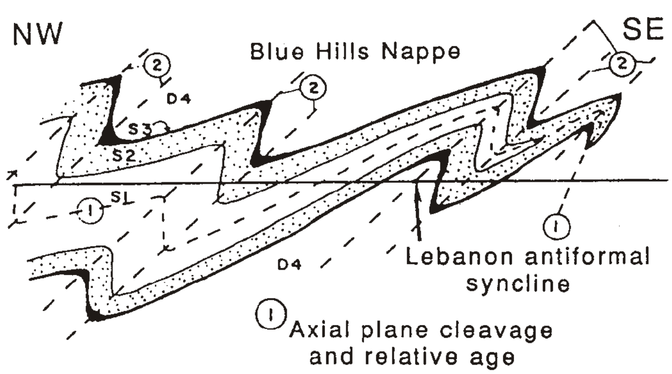

Figure 2. Blue Hills Nappe: schematic section showing location of the Lebanon "syncline". (after Eusden et al., 1987). S_1, S_2, S_3, D_4 refer to stratigraphic units (S_1 is the oldest). Proposed position of the Lebanon antiformal syncline is indicated.

interpretation of the general structural style along the southern margin of the quadrangle.

On a regional scale, the NW-SE structural trends of structures in the Newfield quadrangle continue into the Buxton, Wolfeboro, and Ossipee Lake quadrangles (Gilman, unpublished map; Quinn, 1953; Wilson, 1969; Hussey, 1985), whereupon the regional trends once again swing parallel to the NE-SW grain of southern Maine and New Hampshire. To the north, the northwest trends gradually swing to the northeast in the Kezar Falls quadrangle before being truncated at the contact of the Sebago batholith (Gilman, 1977). The cause of the deflection from the regional structural trend is not understood; it may be related to the emplacement of the Sebago batholith, or to some other late tectonic event (Lyons et al., 1982; Eusden et al., 1987).

Mesoscopic Scale

Only rarely are folds found in the metasedimentary rocks that can be measured in meters; these are found almost exclusively in the well-bedded schists. More commonly, a single outcrop will show only a schistosity that is parallel to discontinuous compositional layering (transposed bedding, metamorphic layering, etc.) in which numerous centimeter-scale folds are visible. Over most of the quadrangle, the dominant schistosity is parallel to compositional layering, both of which have been folded by the small scale crinkles. These folds provide most of the lineations indicated on the map, and the folded schistosity accounts for most of the dip-strike recordings.

In the three areas of well-bedded schist, and to a lesser extent in areas of calc-silicate granulite, bedding/schistosity relationships can be observed. In the Fort Ridge area, for example, the map shows the dominance of gentle, west-dipping schistosity on the top and west side, and moderate-to-steep, west-dipping bedding/schistosity on the east side. Exposures on the southern end of Fort Ridge suggest that the prominent schistosity is axial planar to tight-to-isoclinal folds of bedding, yet on the east side a steeply dipping bedding-plane schistosity is crossed by a gently dipping S_2 crenulation. Elsewhere, a variety of bedding/schistosity relationships can be found. For instance, along the Gully Oven Road (Berwick quadrangle) blocks of the upper Rindgemere Formation left from recent road construction contain folds in which the prominent schistosity, which in most other cases is nearly parallel to bedding, is at a high angle to bedding and is axial planar to mesoscopic folds. The schistosity does not appear to be a second generation structure since no evidence of an earlier bedding schistosity is observed (Fig. 3a); some exposures on Fort Ridge also show this relationship. However, at the south end of Mousam Lake (Gilman, 1986, stop 3), folds in the calc-silicate beds appear to be late structures; they are disharmonic, isoclinal, and recumbent with their axial surfaces parallel to a refolded schistosity in associated migmatites (Fig. 3b). In the Sawyer Mountain area, a steeply dipping bedding/schistosity is folded and crenulated by a gently dipping spaced cleavage (Fig. 3c). And finally, in an exposure near

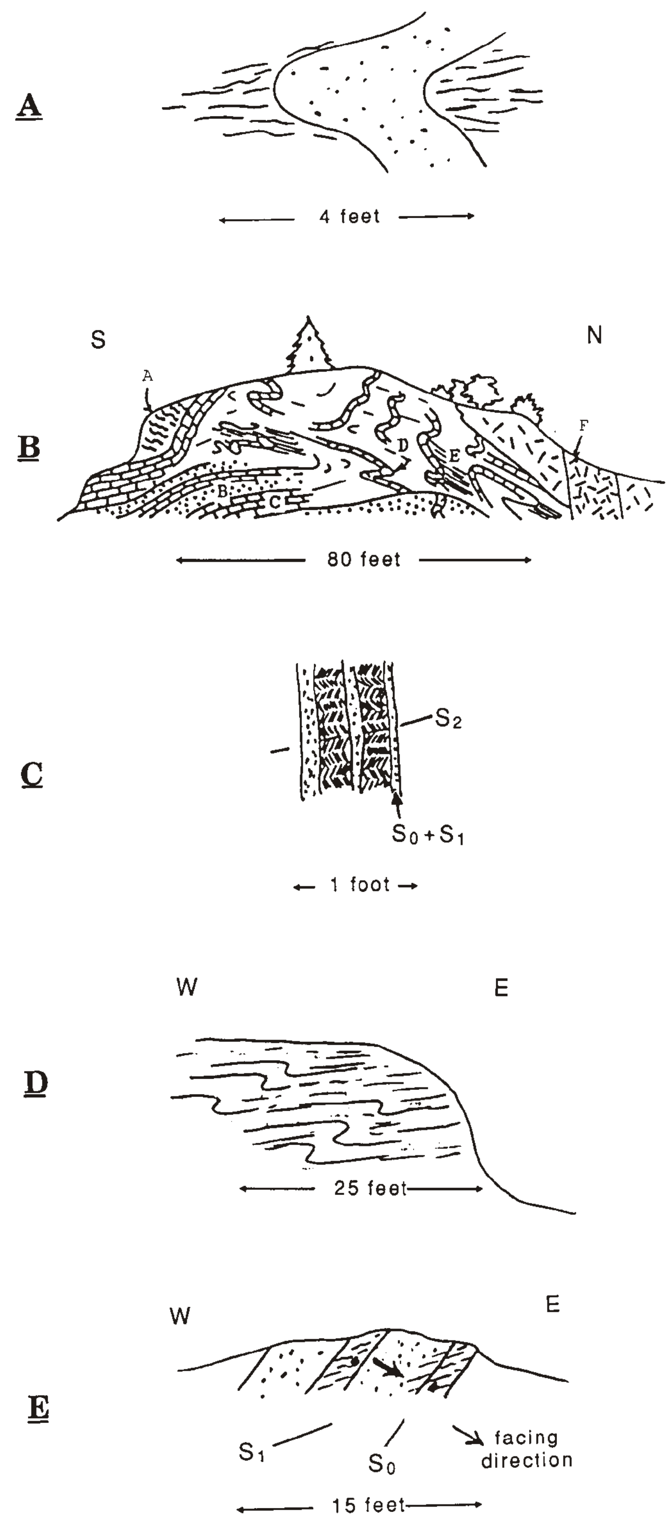

Figure 3. Sketches of fold styles: (a) F_1 fold hinge with axial plan schistosity S_1; Gully Oven Road, Berwick quadrangle. (b) F_2 folds, south end of Mousam Lake; migmatite at A has a folded schistosity that is parallel to the axial surface of minor folds in the calc-silicate at d and e. (c) S_2 crenulation cleavage crossing bedding (S_0) and schistosity S_1, Sawyer Mountain area. (d) F_2 folds near South Acton. (e) S_1 crossing S_0 indicating overturned west limb of a syncline, near Acton.

South Acton (Gilman, 1986, stop 4) schists of the upper Rindgemere Formation with a layer-parallel schistosity have been refolded producing open, asymmetic folds with axial surfaces dipping moderately to the west, but without the development of a new cleavage (Fig. 3d). There is a suggestion at this exposure (from poorly defined cross-bedding) that these late folds have refolded earlier isoclinal folds having an axial plane schistosity.

Summarizing these structural features, at least two episodes of schistosity development are indicated, both of which are axial-planar to their respective generation of folds. In nearly all cases of migmatitic rocks the schistosity is gently dipping and parallel to transposed(?) compositional layering; only where bedding is clearly preserved are steep dips observed.

Additional studies are needed to fully understand the complex relationships between the various generations of schistosity development and folding. Both Lyons et al. (1982) and Eusden et al. (1987) have attempted to synthesize the regional structural data into appropriate generations of folds and schistosities. Lacking a reliable stratigraphic marker with which to trace the present geometry of bedding, fold generations are recognized on the basis of the regional geometry of the schistosity and on bedding/schistosity relationships at fold hinges. Throughout the quadrangle, the schistosity is clearly folded thus producing F_2 folds, assuming that earlier F_1 folds were cogenerated with the schistosity. Hinges of F_2 folds display a folded schistosity in contrast to F_1 hinges in which the schistosity is axial planar to the folds with no evidence of an earlier, deformed schistosity. F_2 folds are abundant in migmatites and non-bedded schists and produce the NW-SE structural trends over much of the quadrangle. F_1 fold hinges have been observed only in well-bedded schist of the upper Rindgemere Formation near Gully Oven (Berwick quadrangle) southwest of Acton. Other exposures of bedding and schistosity that I interpret to show S_1 intersecting S_0, and therefore part of an F_1 fold, are found along strike in the vicinity of Acton. Exposures along and near the Acton-South Acton road indicate a vertical to steep west-dipping (but east facing) bedding, crossed by a gentle (20°) west dipping schistosity (Fig. 3e). These exposures suggest that the Lebanon "syncline" may be an F_1 fold rather than an F_2 fold as proposed by Eusden et al. (1987). Complicating the picture, however, is an exposure at South Acton (Gilman, 1986, stop 6) in which well-bedded upper Rindgemere Formation with a bedding-plane schistosity is crossed by a crenulation cleavage (S_2) that dips 40° to the west; thus suggesting an F_2 fold. It may be that in certain lithologies and structural environments S_2 has completely obliterated S_1, thus raising the possibility that the principal schistosity seen throughout the quadrangle is not all of the same generation. Exposures of well-bedded schist on the east side of Fort Ridge which involve a steeply dipping, folded, bedding-plane schistosity, thus belong to an F_2 fold system; this is also the case on Sawyer Mountain.

A final folding phase, F_3, has been proposed by Eusden et al. (1987) to account for the deflection of regional trends of the schistosity from NE to NW as is found in much of the Newfield quadrangle. This deflection in regional trend has been attributed to the emplacement of the Sebago and Effingham plutons by Lyons et al. (1982).

Joints and Dikes

Data from the Kezar Falls and Newfield quadrangles show that the preferred strikes of steep-to-vertical joints are E-W, N 15°-30° E, and N 40°-60° W (114 measurements). Preferred strikes for post metamorphic basic dikes are N 20°-30° E and N 80°-90° E (61 measurements). The E-W and N 15°-30° E directions are reflected in both joints and dikes, whereas the N 40°-60° W joint trend is not represented by abundant dikes. McHone and Trygstad (1982) studied sixty dikes in southern Maine, finding a strong preferred orientation around N 30° E with a secondary maximum near N 60° E.

IGNEOUS ROCKS

Igneous rocks of the quadrangle are correlated with the New Hampshire plutonic series and the White Mountain plutonic-volcanic series of Billings (1956) in New Hampshire. Rocks of the New Hampshire series consist of light gray binary granite and pegmatite, and gray, foliated granodiorite to quartz diorite. The White Mountain pluton-volcanic series rocks consist of discordant stocks of alkaline syenite and granite.

New Hampshire Plutonic Series

Light gray binary granite is found in three small unnamed plutons as well as in the northwest corner of the quadrangle where extensive exposures near Province Lake are part of the Effingham pluton that extends into New Hampshire as far as the Ossipee Mountains (Billings, 1956). The rock is generally medium-grained, nonfoliated, and carries muscovite and biotite, both of which are visible in hand specimen.

Modal compositions average 30% quartz, 45% K-feldspar, 15% plagioclase, 3% muscovite, 4% biotite, and 3% accessories. The granite commonly grades into pegmatite and is thought to be related to the pegmatite that is abundant throughout the metasedimentary rocks of the quadrangle. The Effingham pluton was mapped as “Concord Granite” by Quinn (1953) and Wilson (1969), and was dated at 325 Ma by Hayward and Gaudette (1984) and Aleinikoff et al. (1985).

Fine-grained, gray, foliated granodiorite to quartz diorite occurs in a large, elongate body in the center of the quadrangle, and in three small stocks; two near Acton and one near North Shapleigh. The rock is characterized by its uniform fine-grained texture and a pervasive but faint foliation caused by the alignment of biotite grains. The average composition of the rock is 35% quartz, 50% plagioclase (An_{25-30}), 10% orthoclase, and 5% biotite. The same rock has been mapped in the Kezar Falls area to the north (Gilman, 1977) and in the Ossipee Lake quadrangle in New Hampshire where Wilson (1969) mapped it as trondhjemite of the New Hampshire plutonic series. Xenoliths of mica schist are sometimes found within the rock, and it is commonly cut by pegmatite.

Pegmatite is ubiquitous throughout the quadrangle except within the mesozoic stocks. In addition to quartz and feldspar, mica, garnet, and tourmaline are common, and beryl is occasionally present. The texture is sometimes porphyritic with 9 to 15 cm feldspars set in a medium-grained host. The widespread extent of the pegmatite adds to the difficulties encountered in attempting to map the metasedimentary units.

White Mountain Plutonic-Volcanic Series

Rocks correlative with the White Mountain plutonic-volcanic series of New Hampshire (Billings, 1956) occur as a group of small stocks aligned north-south through the center of the quadrangle (Gilman, 1983). All are discordant and post-tectonic. Two of the stocks have associated volcanic(?) breccias.

Randall Mountain Stock. Randall Mountain is located in the north-central part of the quadrangle between the villages of South Parsonsfield and East Parsonsfield. The one square mile area is easily accessible on both sides by blacktop and gravel roads. There is approximately 600 feet of relief, the summit of Randall Mountain standing at 1118 feet above sea level.

The area is completely forested except for bald ledges at the summit of Randall Mountain. Nevertheless, there are good exposures on the steep south and southeast slopes and on the ridge crests. The north facing slopes are gentle and outcrops are scarce. A man-made pond now occupies the former marsh on the southwest side of the mountain.

The stock consists of (1) fine-to medium-grained, gray-to-brown syenites and (2) gray, fragmental, trachyte prophyry.

Brown-to-greenish gray syenite is the most abundant rock type. Hornblende and/or biotite are visible in hand specimen while aegirine-augite was recognized in thin section only. The rocks vary from a porphyritic phase carrying up to 30% 2.0 to 4.0 mm long phenocrysts (dominantly orthoclase microperthite) set in a fine-grained groundmass, to an equigranular, medium-grained phase with orthoclase grains averaging 3.0 to 5.0 mm with a maximum length of 10.0 mm. This textural variation does not appear to be mappable and the change from one type to another is gradual. Mafic minerals are conspicuous, but never amount to more than 5% of the rock. Sphene is the principal accessory mineral; nepheline and sodalite were observed in a few thin sections. Igneous lamination or other primary structures were not found in place, however, loose blocks on the ridge northeast of the summit show a well developed parallel arrangement of feldspar crystals. Several varieties of the syenite may be seen in a traverse up the south side of the mountain; the syenite at the summit is an equigranular medium-grained variety.

Light gray porphyries, some of which carry xenoliths, occur both as dikes cutting the syenite and as inclusions within the syenite. They show only minor differences in thin section and are indistinguishable in hand specimen. Where exposures are limited, it is not always possible to determine which of the two types is present.

The map shows one large area of trachyte porphyry that is interpreted to be a xenolith within the syenite. Other instances of smaller, more completely exposed inclusions of porphyry support this interpretation. In hand specimen these rocks consist of othoclase phenocrysts (2.0 to 4.0 mm long) and rock fragments (commonly trachyte) enclosed in a gray, aphanitic groundmass. Primary flow structures were observed only in thin section. The rock fragments, though not always present, are usually sub-angular and range in size from 1 to 15 cm, the smaller being the most common. Inclusions and/or phenocrysts constitute 20% to 40% of the rock.

Dikes of fragmental trachyte porphyry are similar to the rocks just described, the major difference being the tendency for the groundmass to be allotriomorphic-granular rather than trachytic. Rock fragments include trachyte and syenite.

The contact of the syenite with the country rock is exposed on the west side of Randall Mountain in a zone approximately thirty meters wide consisting of angular blocks of schist enclosed in pinkish, quartz-bearing syenite. The contact dips steeply to the northwest. Elsewhere the contact is not exposed, but the limits of the body are well delineated by exposures of the surrounding country rock. The contact is discordant to the surrounding rock structure which shows no deflection from the regional pattern as the margin of the stock is approached.

Abbott Mountain Stock. Abbott Mountain lies just east of the village of North Shapleigh. The summit is 1,077 feet above sea level, approximately 600 feet above the surrounding elevations. Exposures are excellent along the ridges and remain good along the steeper slopes. The lower slopes and surrounding areas are generally covered by thick glacial deposits. Fresh samples are frequently difficult to obtain due to the rounded, weathered nature of the exposures; bald outcrops are often covered with thin sheets of crumbled rock. The entire area is forested, but trees are sparse along the ridges. The area is accessible by dirt road on the north side and by discontinued roads on the south and west sides, and through the center.

The stock consists predominately of brown-to-gray, coarse-grained syenite in the interior with fine-grained diorite dikes at the margins. Subdivisions of the coarse syenite are possible by thin section study but were not recognized in the field. The syenites are cut by late stage aplitic dikes.

The coarse-grained syenite has been subdivided into three types on the basis of microscopic study. The most widespread type contains fayalite and aegirine-augite as the characteristic minor constituents. A second variety is similar to this but in addition contains minor amounts of quartz. The third variety, the "leucocratic syenite" lacks both mafic minerals and quartz.

Fayalite syenite carries from 90% to 95% euhedral to subhedral, randomly arranged feldspar laths averaging 5.0 mm in length with maximum of 10.0 mm. The feldspar is dominantly orthoclase or microcline microperthite with patches and veins of albite distributed either uniformly throughout the grain or restricted to grain margins. Pyroxene constitutes from 2% to 7% of the rock and usually occurs in 0.5 to 2.5 mm, euhedral-to-subhedral grains commonly with hornblende alteration. The pyroxene is darker green than common augite, suggesting aegirine-augite, but pleochroism is faint or nonexistent. Fayalite (sign (-), 2V approximately 40°) constitutes up to 3% of the rock and is found as 0.5 to 2.0 mm equant, anhedral grains that are partially altered along fractures to red iddingsite and yellowish serpentine. In some grains the original olivine has been completely replaced. Biotite, apatite, zircon, and opaques complete the assemblage. This variety occurs in the east, south, and west parts of the area, including Abbott Mountain where there are abundant exposures.

Quartz syenite is characterized by minor interstitial quartz, otherwise it is similar to the fayalite syenite. Orthoclase and microcline microperthite constitute 85% to 95% of the rock occurring as subhedral grains averaging 4.0 to 8.0 mm in length. Grains of medium green, non-pleochroic aegirine-augite are usually subhedral and average 1.0 mm in diameter. Some grains have been totally altered to secondary minerals. Quartz varies in amounts from a trace to 8% and occurs as anhedral, interstitial grains. Relatively large (up to 0.5 mm) euhedral zircons are also characteristic of this variety. Biotite, apatite, and opaques complete the assemblage. This variety has been found only in the contact zone of the stock and appears to form a continuous shell between the country rock and syenite of the interior.

The leucocratic syenite contains feldspar as the only essential mineral with mafic and accessory minerals never constituting more than one or two percent of the rock. Feldspar consists of euhedral to subhedral grains averaging 4.0 to 8.0 mm long. Both orthoclase-microperthite and antiperthite are present in various ratios, but antiperthite is frequently the more abundant. The orthoclase is commonly clear in the center of grains and perthitic at the margins. Microcline twinning is occasionally present. The antiperthite consists of albite showing extremely thin twin lamellae and patches of orthoclase. The albite twin lamellae are commonly tapered producing an unusual "splintery" appearance. Accessory minerals are hornblende, zircon, and opaques. This type is found in the north central part of the stock, but its boundaries and contact relations are not well known. One sample from the inferred margin carries small amounts of aegirine-augite and fayalite, suggesting that it is gradational into the fayalite syenite.

Fine-grained (0.1 to 1.0 mm) diorite consists of approximately equal amounts of weakly zoned, intermediate plagioclase (An_{35-50}) and mafic grains arranged in an intergranular texture. Augite constitutes about 35% of the rock and usually occurs as subhedral interstitial grains, but occasionally is found in larger poikilitic grains. Biotite occurs in small, red-brown irregular plates and amounts to 5 to 20 percent of the rock. Brown hornblende is occasionally associated with augite. Accessories are apatite and opaques. This rock type has been found in several localities at the margin of the stock where it occurs as brown-weathering dikes that cut the country rock. Xenoliths of the diorite have been found enclosed in the border phase of the syenite.

Aplite dikes consist of stubby, euhedral to subhedral phenocrysts of orthoclase (1.0 to 2.0 mm) embedded in a fine-grained (0.2 mm) groundmass of quartz and feldspar. Tiny grains of riebeckite are scattered throughout the rock. Biotite is present in small amounts.

Field observation and petrographic study demonstrate a consistent pattern in the distribution of the major rock types of the stock. The diorite is always found at the margin as dikes cutting the country rock. It appears that these are isolated intrusions along fractures at the margin of the stock rather than a continuous body such as a ring dike. The quartz-bearing phase of the syenite has been found at several locations, always at the margins of the stock. Since it occurs as massive, coarse-grained rock, it appears that it forms a marginal phase several tens of meters wide around the entire body except where it seems to have been cut out by younger phases along the northern side. The fayalite syenite constitutes the main body of the stock on the west, south, and east sides. The leucocratic syenite is found in the north central part of the stock. The distinctive microfeatures of this phase were not recognized in the field, thus sampling was not specifically planned to determine its extent. The one sample that appears to be near the margin of this phase is from the ridge northwest of Abbott Mountain. This sample has a mineral assemblage intermediate between the leucocratic syenite and the fayalite syenite, thus the contact has been drawn through this location; elsewhere it has been drawn separating known exposures of the two rock types based on microscopic study. No crosscutting relationships between the three varieties of syenite have been observed.

The attitude of the contact with the country rock is well displayed on several ridges. On Abbott Mountain the contact can be followed up the southeast side nearly to the summit. The outcrop pattern indicates that the contact dips to the southeast. Similarly, the contact can be followed at several localities around the margin of the stock; on the north side the contact dips northward at about thirty degrees, but on Sugarloaf Mountain the contact is nearly vertical. The overall shape of the contact is domal. The stock is discordant as is best shown along the northeastern margin where the schistosity strikes uniformly northwest with a westerly dip. There has been no deflection in the orientation of the schistosity as a result of the intrusion.

Foland and Faul (1977) obtained a K/Ar date of 221 8 Ma for the fayalite syenite. Earlier work by Christopher (1969) using apatite fission tracks obtained an age of 119 Ma; this is now interpreted as an unroofing date rather than a crystallization age (Foland and Faul, 1977).

Chemical analyses of eight samples from the Abbott Mountain stock are given in Table 2. It is evident that the three varieties are very similar chemically. However, the leucocratic syenite is considerably lower in CaO and MgO, and is slightly higher in Na_2O. The quartz-bearing syenite at the margin of the stock is not reflected in bulk chemical differences from the other syenites. There is as much SiO_2 variation, for example, between the two samples of leucocratic syenite as there is between the leucocratic syenite and the quartz-bearing syenite. Thus no significant SiO_2 contamination from the country rock is apparent. However, norm calculations (Table 3) show a considerable quartz enrichment in the border phase. Normative feldspar compositions are nearly constant throughout the body; only a slight increase in albite toward the leucocratic syenite and an accompanying decrease in orthoclase and anorthite is indicated. Considering the minor elements, only the leucocratic syenite shows any appreciable difference in that Rb, Zr, and Nb are higher, and Sr and Ba are lower. In summary, the quartz syenite and fayalite syenites are indistinguishable on the basis of bulk chemistry, but the leucocratic syenite is slightly different in both major and minor element abundances.

TABLE 2. WHOLE ROCK CHEMICAL ANALYSES: ABBOTT MOUNTAIN

	Diorite		Quartz Syenite		Fayalite Syenite		Leucocratic Syenite	
Sample	23	56	16	40	15	31	24	26
Major-minor (wt. %)								
SiO_2	51.6	48.7	63.2	61.7	60.0	61.6	63.7	61.7
Al_2O_3	13.4	13.5	16.9	16.8	17.0	17.1	17.8	17.9
CaO	7.86	7.76	1.11	2.01	2.08	1.78	0.09	0.08
MgO	7.37	7.13	0.36	0.45	0.52	0.37	0.08	0.09
Na_2O	2.96	2.17	5.17	5.77	6.32	6.02	7.11	7.48
K_2O	0.43	0.29	6.40	5.13	5.13	6.04	5.40	5.00
Fe total*	13.1	14.2	4.59	5.92	4.62	6.11	4.45	5.64
MnO	0.22	0.26	0.16	0.19	0.16	0.21	0.13	0.07
TiO_2	2.44	4.45	0.43	0.52	0.55	0.48	0.28	0.53
P_2O_5	0.42	1.13	0.08	0.21	0.23	0.28	0.05	0.03
LOI	0.23	0.38	0.85	0.70	1.47	0.23	1.08	10.8
Total	100.2	99.98	100.0	99.6	99.1	100.3	100.3	99.7
Trace elements (ppm)								
Cr	250	240	20	20	20	10	20	10
Rb	40	20	220	170	130	120	230	230
Sr	430	980	80	270	440	40	10	10
Y	10	30	40	40	30	40	20	20
Zr	130	470	1010	330	230	140	420	540
Nb	40	140	90	80	60	60	100	250
Ba	240	360	290	980	2170	390	60	90

XRF analyses by X-RAY ASSAY LAB. LTD., Don Mills, Ontario
*Total Iron as Fe_2O_3

Symmes Pond Stock. The Symmes Pond stock lies just east of Symmes Pond. Its margins are poorly defined, but neighboring outcrops of schist and granite limit the size to approximately that shown on the map. A breccia zone can be observed on the south side of Hall Road where it crosses the southwest side of the stock. The stock consists of green-brown, coarse-grained syenite containing xenoliths of the foliated granodiorite country rock. The syenite contains small amounts of sulfides including molybdenite and has been the site of minor

TABLE 3. CIPW NORMS: ABBOTT MOUNTAIN

Sample	Diorite 23	Diorite 56	Quartz Syenite 16	Quartz Syenite 40	Fayalite Syenite 15	Fayalite Syenite 31	Leucocratic Syenite 24	Leucocratic Syenite 26
Quartz	2.71	6.36	3.54	4.90	1.28	1.01	1.48	--
Orthoclase	2.54	1.71	37.82	30.30	30.32	35.7	31.9	29.5
Albite	25.05	18.36	48.32	48.8	53.31	50.9	60.1	60.9
Anorthite	22.01	26.24	1.58	4.8	3.9	1.18	0.12	0.2
Corundum	--	--	--	--	0.37	--	0.22	0.11
Hypersthene	26.8	28.09	--	--	1.29	--	0.24	--
Magnetite	2.26	2.45	4.05	5.25	3.73	4.64	4.15	4.53
Ilmenite	4.63	8.62	0.82	0.99	1.04	0.91	0.53	1.0
Hematite	--	--	0.16	0.19	0.40	0.04	--	0.5
Apatite	0.97	2.62	0.19	0.49	0.53	0.65	0.12	0.07
Diopside	11.68	3.99	1.9	2.42	--	1.99	--	--
Wollastonite	--	--	0.38	0.29	--	1.11	--	--
Nepheline	--	--	--	--	--	--	--	0.2
Olivine	--	--	--	--	--	--	--	0.1

Note: Calculations used $Fe_2O_3/FeO = 2$

prospecting in past years. In thin section, the rock consists of 95% microperthite and about equal amounts of fayalite and clinopyroxene. The petrographic and mineralogical character of this syenite is similar to the fayalite syenite of the Abbott Mountain stock. Dikes of tan trachyte cut the country on the hill northeast of the stock.

Picket Mountain Stock. The Picket Mountain stock lies just south and west of the village of Newfield. Outcrops are limited to ridges on Picket, Knox, and Zekes Mountains and in the Little Ossipee River at Newfield. The contact can be found within a few meters on the west slope of the small hill east of Picket Mountain where the granite is in contact with pegmatite and foliated granodiorite.

The stock consists of homogeneous gray-brown, medium-grained equigranular to subporphyritic granite. The mafic minerals are biotite and hornblende. K-feldspar, sometimes present as phenocrysts, dominates over chalky-weathering plagioclase. Quartz is visible in all samples.

Thin section study shows that the rock is comprised of about 25% quartz, 50% microperthite, 20% plagioclase, and 5% mafics.

Acton Stock. The Acton stock is a small body located on the east side of Grant Road approximately midway between Acton and South Acton. Part of the area is an apple orchard and therefore is easily accessible. A few exposures are found in the orchard itself, but most large exposures are in the surrounding woods. The shape of the stock is not well known because of the lack of outcrops on the south and east sides.

Two rock units are present: (1) medium-grained, gray-weathering quartz diorite and (2) dark gray porphyritic and fragmental andesite. The contact between the two units is not exposed but, based on the absence of quartz diorite fragments in the fragmental andesite, it is tentatively concluded that the quartz diorite is the younger.

The medium- to coarse-grained, gray quartz diorite constitutes most of the body. Igneous lamination is evident in a few exposures. The rock consists of approximately 80% plagioclase (An_{50}), 15% pyroxene, and 5% opaques, apatite, and quartz. Both orthopyroxene and clinopyroxene are subhedral, average 1.0 mm diameter, and are partially altered to fibrous amphibole and biotite. Interstitial quartz is present in minor amounts. Several exposures of a fine-grained border phase can be found along the west margin where it is sometimes the host of a breccia containing fragments of hornfelsed schist. Small dikes of tan aplite cut the medium-grained quartz diorite.

Dark gray, prophyritic and fragmental andesite constitutes the northern part of the body, but the contact with the country rock has not been found. The rock is massive and has abundant phenocrysts of light gray weathering plagioclase and small, angular fragments of dark, aphanitic rocks that show up best on a weathered surface. The rock consists of 20% plagioclase phenocrysts set in a microcrystalline groundmass of plagioclase, biotite, and opaques.

SUMMARY

The metasedimentary rocks of the Newfield quadrangle reflect a history of thick accumulation of presumably marine shales during Silurian-Devonian time. Interbedded with these shales were thin zones of cyclically bedded siltstone and shale and one or more layers of impure limestone. Some of the shale was deposited under reducing conditions leading to the development of the sulfidic “rusty” schists upon metamorphism.

The Acadian orogeny of Early Devonian time brought the emplacement of granodiorite of the New Hampshire plutonic series. At the same time, the metasedimentary rocks underwent regional metamorphism of sillimanite grade and accompanying polyphase deformation. The significance of the NW-SE structural grain within the quadrangle is not yet well understood. Both east and west of the Newfield quadrangle the general structural grain is NE-SW, parallel to the regional trends for southern Maine and New Hampshire. Binary granites (Concord-type) of the New Hampshire plutonic series do not show a metamorphic foliation as does the granodiorite, indicating their post-tectonic character. Recent age determination of the New Hampshire plutonic series by Lyons and Livingston (1977), Hayward and Gaudette (1984), and Aleinikoff et al. (1985) support this conclusion.

Igneous activity of Mesozoic age is represented by five stocks of alkaline syenite and granite similar to those of the White Mountain plutonic-volcanic series of New Hampshire.

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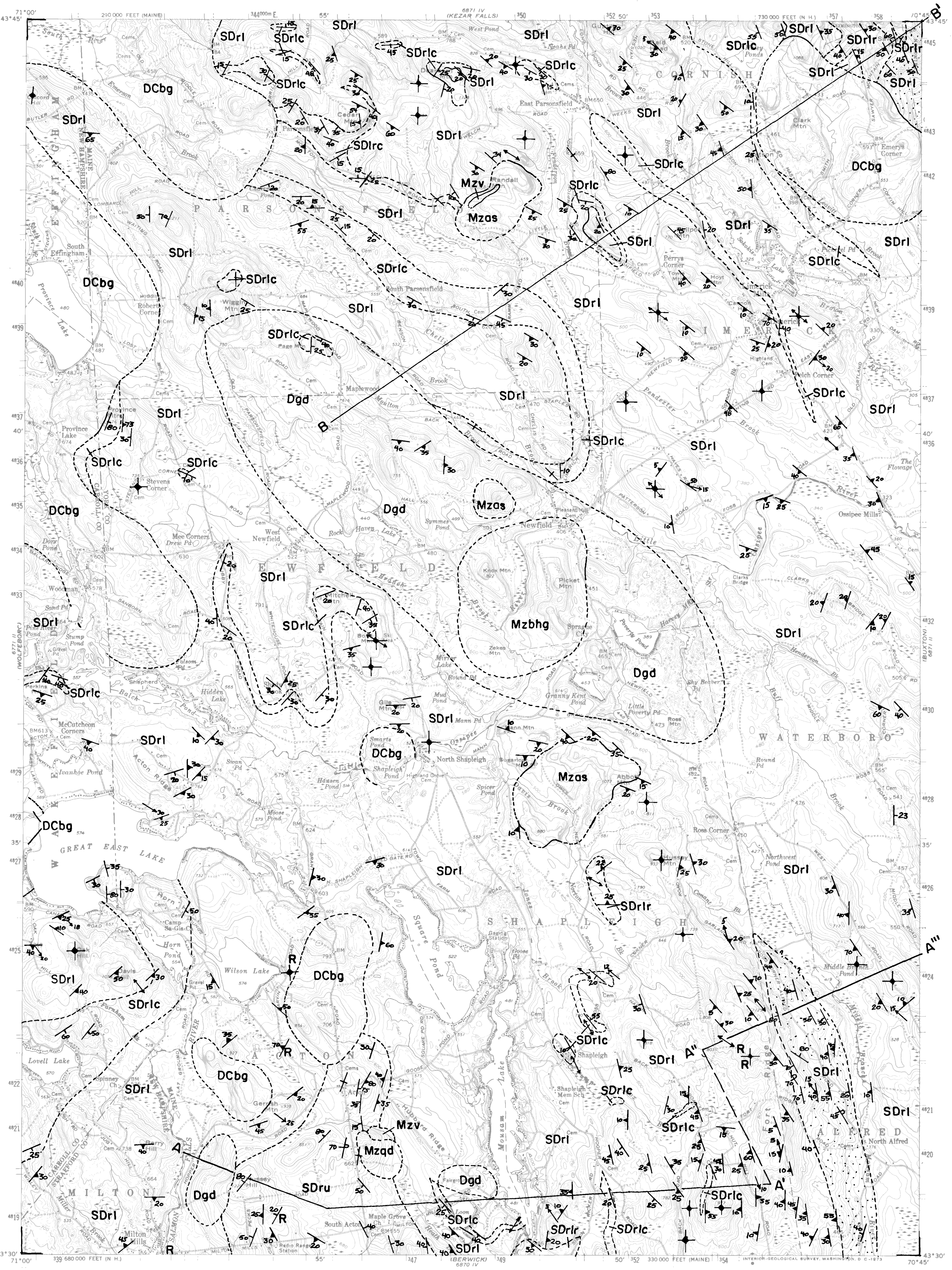
EXPLANATION



INTRUSIVE AND VOLCANIC ROCKS

Mzas	Mzbhg
Mzqd	Mzv

Alkalic rocks of the White Mountain plutonic-volcanic series

MESOZOIC

- Mzas — Medium- to coarse-grained gray-green syenite
- Mzbhg — Medium- to coarse-grained light gray biotite-horneblende granite
- Mzqd — Medium-grained gray quartz diorite
- Mzv — Medium- to dark gray porphyry and breccia

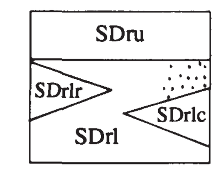
Dgd	DCbg

Granitic rocks of the New Hampshire plutonic series

DEVONIAN TO CARBONIFEROUS

- Dgd — Fine- to medium-grained light gray foliated granodiorite and quartz diorite
- DCbg — Medium-grained light gray binary granite and associated pegmatite

STRATIFIED ROCKS



Rindgemere Formation

SILURIAN TO DEVONIAN

- SDru — Upper member: cyclic, well-bedded schist and quartzite; bedding thickness varies from 3 to 75 cm; frequently graded; may contain quartz and garnet lenses ("coticule") and muscovite pseudomorphs after andalusite.
- SDrl — Lower member: Predominantly poorly bedded red-brown to gray, garnet-mica schist and migmatite ± sillimanite, staurolite and andalusite; stippled areas represent schist with cyclic bedding
  - SDrlr — Rusty weathering, light gray quartz-muscovite-feldspar sulfidic schist. "R" indicates isolated exposure of rusty schist.
  - SDrlc — Thin bedded green-gray lime-silicate gneiss with interbedded fine-grained, gray, biotite-quartz-plagioclase schist

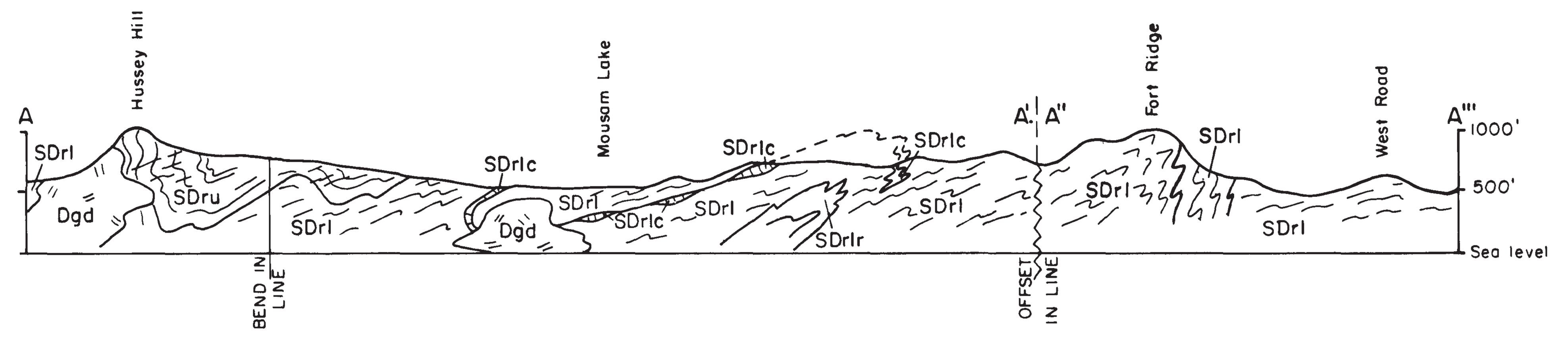
SYMBOLS

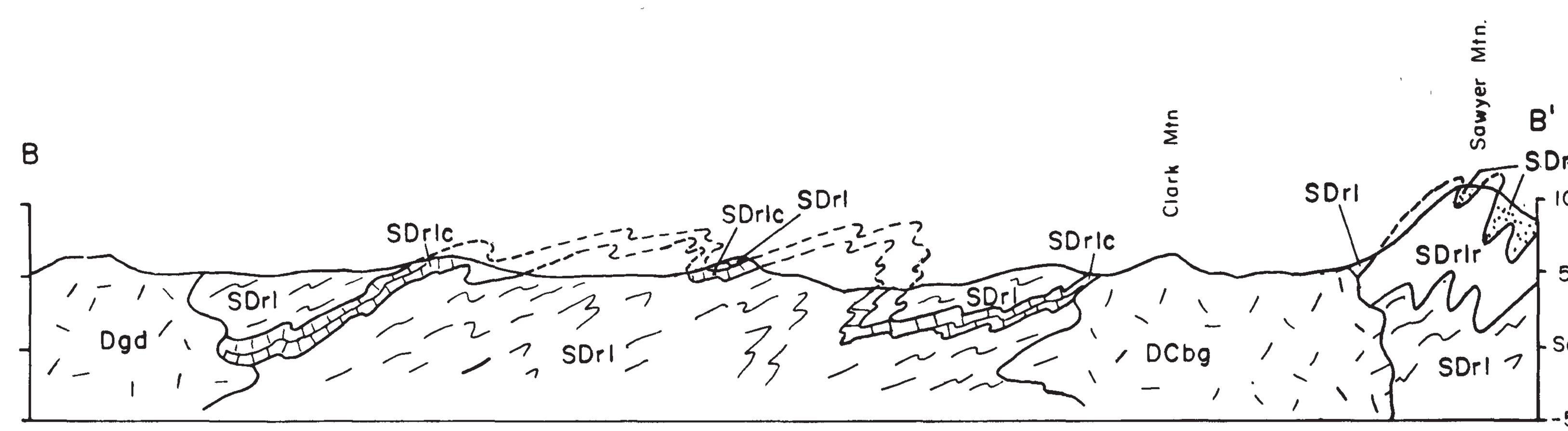
Geologic contact. Dashed when approximate or inferred.

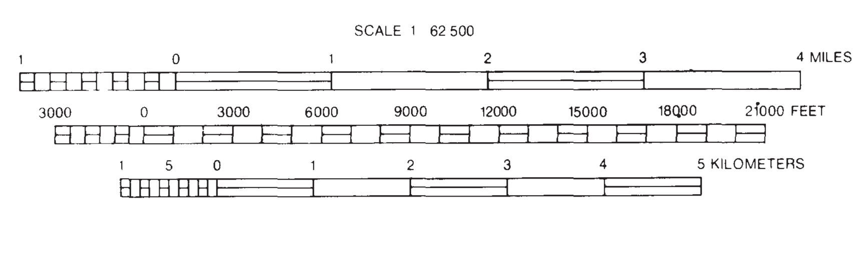
Bedding (inclined, horizontal, overturned, and vertical). Overturning determined from graded bedding.

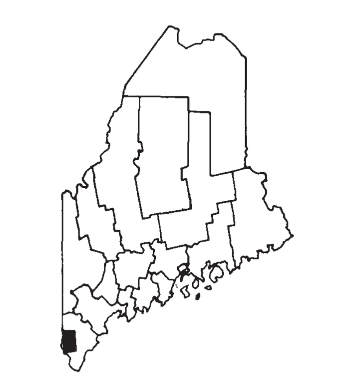
Schistosity (inclined, horizontal, and vertical).

Trend and plunge of lineation; horizontal lineation









Quadrangle Location

RECONNAISSANCE
BEDROCK GEOLOGY
OF THE
NEWFIELD QUADRANGLE, MAINE
BY
RICHARD A. GILMAN
1991

Maine Geological Survey
DEPARTMENT OF CONSERVATION
Augusta, Maine 04333

Walter A. Anderson, State Geologist

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PLATE 1