U.S. DEPARTMENT OF THE INTERIOR
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Preliminary Bedrock Geologic Map of the Plymouth Quadrangle and eastern portion of the Killington Peak Quadrangle, Windsor and Rutland Counties, Vermont

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Open-File Report

OF 94-225-A Discussion and map
OF 94-225-B Six 35 mm color slides of map

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INTRODUCTION

Bedrock in the Plymouth quadrangle and eastern portion of the Killington Peak quadrangle consists largely of the Late Proterozoic to Devonian metasedimentary cover rocks immediately east of the Middle Proterozoic gneissic rocks of the Green Mountain massif. This section of rocks, referred to as the eastern cover sequence and Connecticut Valley sequence, has classically been considered to be a continuous, eastward-topping and eastward-dipping sequence. It defines the main stratigraphic framework of southern Vermont, east of the Green Mountain massif. This section contains from the base upwards, the Tyson, Hoosac, Pinney Hollow, Ottauquechee, Stowe, Mississquoi, Shaw Mountain, Northfield, and Waits River Formations of Doll and others (1961).

Recent geologic studies in the western part of the map (Ratcliffe, 1992; in press) have redefined the structural and stratigraphic relationships in the lower part of the section. Ongoing work in the Ludlow area (Ratcliffe, 1992, and Ratcliffe and Walsh, unpublished data) as well as the information presented here, has modified some of the relationships of units from the Pinney Hollow eastward.

Previous studies in the Plymouth area of particular note are the pioneering works of Elwyn Perry (1929) who mapped the Bridgewater and Plymouth Townships, and that of William Brace (1953) who mapped the Rutland 15-minute quadrangle and the western part of the Woodstock quadrangle. Chang and others (1965) remapped areas previously studied by Perry and Brace in the Woodstock 15 minute quadrangle.

Mapping of the area west of the Pinney Hollow Formation was conducted in 1990 and 1991 by Ratcliffe (in press) and results are summarized in USGS Bulletin 2060. This paper redefines the succession from the basal Tyson Formation up to the Pinney Hollow Formation and suggests that the Tyson and newly redefined Plymouth Formation are lateral facies equivalents, now juxtaposed by thrust faults. An age of Late Proterozoic to Early Cambrian is assigned to these rocks. A correlation of map units is included following the text portion of this report.

Remapping of the type sections of the Pinney Hollow and Ottauquechee Formations, begun in 1990 by Norman L. Hatch, Jr. and Ratcliffe in the central and eastern parts of the quadrangle, was completed by Walsh and Ratcliffe in 1993, and assisted by W. Lansing Taylor.

One of the basic conclusions derived from the present study is that many of the contacts between the major units in this area, previously considered to be depositional, are thrust faults. As a consequence, the stacking order of these units may be largely structural rather than stratigraphic. Important faults that cut the section are the Black River fault zone, the Pinney Hollow and Bald Mountain faults that bound the Ottauquechee Formation, the Raymond Hill fault on the east side of the Stowe Formation, and the Hale Hollow fault on the east side of the Whetstone Hill Member of the Moretown Formation.

Because the succession of Plymouth, Ottauquechee, and Stowe may be largely tectonic and because of the lack of fossils, the age assignments of rocks in this quadrangle are quite uncertain. On the Correlation of Map Units, the Pinney Hollow, Ottauquechee and Stowe are shown as overlapping in age and largely older than the Plymouth, Hoosac, and Tyson Formations. The carbonate rocks in Tyson and Plymouth Formations resemble dolostones near the base of the carbonate shelf sequence, and it seems reasonable that the carbonate rocks of the Plymouth may correlate with the cambrian Rutland Dolomite of the Vermont Valley Sequence as suggested by Thompson (1972). The Tyson Formation and feldspathic quartzites in the Plymouth may therefore correlate with the Lower Cambrian Cheshire Quartzite and older rocks on the western side of the Green Mountain massif. The succession from Tyson through Plymouth in the Plymouth area lacks mafic volcanic rocks, as do the sub-Cheshire, Cheshire, and all younger cover rocks of the Vermont Valley Sequence. However, abundant and widespread metabasalt occurs within the older parts of the Hoosac outside this area, and throughout the Pinney Hollow, Ottauquechee, and Stowe formations. The metadiabase dikes in the Green Mountain massif, in the Adirondacks, and the metabasalts in the Hoosac, Pinney Hollow, and Stowe Formations are generally thought to be Late Proterozoic to Cambrian continental rift and ocean floor basalts formed prior to the formation of the carbonate platform of Early Cambrian through Medial Ordovician age (Coish and others, 1985; 1986). Therefore we assign a probable age of Late Proterozoic through Cambrian to the Pinney Hollow Formation and Cambrian ages for the Ottauquechee and Stowe Formations. The upper range of ages is very uncertain, but based on the arguments above they probably do not extend into the Ordovician.

Rocks of the Mount Holly Complex experienced hornblende-granulite facies metamorphism during the Middle Proterozoic Grenville orogeny and extensive retrogression in later Paleozoic events. The regional metamorphic grade attained during the Paleozoic Taconic and Acadian orogenies ranges from biotite-grade in the west to garnet-grade in the east. In general, the higher grade rocks to the east have been strongly affected by Acadian metamorphism that occurred relatively late in the structural history. In the central and western parts of the area, in rocks older than the upper parts of the Moretown Formation, a well-developed foliation (S2) expressed by lepidoblastic and fine-grained muscovite, chlorite, and biotite formed synchronous with thrust faults and deformation. This period of metamorphism is believed to have occurred during the Taconic orogeny in the Medial and Late Ordovician. In the Pinney Hollow Formation, chlorite pseudomorphs after garnet are widespread and suggest that this early Paleozoic metamorphic event may have reached at least garnet-grade as far west as the Pinney Hollow Formation. Generally, rocks east of the Pinney Hollow Formation have abundant static-overgrowth porphyroblasts of biotite, hornblende, and garnet which postdate all foliations and are believed to be Acadian.

STRATIGRAPHY

Mount Holly Complex

Highly retrograded and deformed gneissic rocks of the Mount Holly Complex of Middle Proterozoic age occur on the map in the west, where they form the core of the Green

Mountain massif. Structural trends are east-west to northeasterly and the units are subvertical in many areas. The various units mapped (see description of map units) are typical of rocks in the Mount Holly Complex found to the west in the core of the massif, with one notable exception: At or near the contact with the cover rocks, and for a variable distance (as much as 2 km to the west), the gneisses are overprinted by an exceptionally well developed, retrogressive, and penetrative foliation of Taconic and/or Acadian age. Because the regional metamorphic grade here is only biotite grade, and because the deformation is so intense, relict Middle Proterozoic textures and hornblende granulite facies mineral assemblages are scarce. As a result, the gneisses at or near the eastern margin of the massif contain abundant muscovite, epidote, albite, chlorite or actinolite making mineralogic distinctions between basement and cover rocks difficult.

Nonetheless, the presence of conglomeratic rocks, locally along the basement-cover contact, suggests a profound unconformity at the base of the Tyson Formation. Where the basement-cover contact is faulted (for example, from a point south of Cherry Knoll to the southern border of the map), distinguishing the contact between retrograded and phyllonitized gneisses of the basement and phyllonites derived from cover rocks is difficult. The contacts may be seen in the numerous small, east-draining streams west of the Black River. Here a relict, subvertical east-west trending gneissosity can be discerned in the gneisses within 100 meters of the fault contact, but the gneissosity is progressively destroyed at or near the fault, where determination of the protolith of the mylonites in practically impossible.

Outliers of gneissic rocks belonging to the Mount Holly Complex reappear on Spruce Knoll north of West Bridgewater, on the steep cliffs east and southeast of Black Pond, and as far south as Mount Tom. These eastern occurrences underlie rocks of the Plymouth Formation, east of the Black River Fault zone.

Tyson Formation

As used here, the name Tyson applies to the sequence of rocks west of the Black River fault zone, and east of the rocks of the Mount Holly Complex of the Green Mountain massif. This follows in general the usage of Doll and others (1961), except that wider areas along the western margin of the map were previously assigned to the Tyson Formation; these rocks are now assigned to the Mount Holly Complex (Ratcliffe, in press).

Rocks of the Tyson Formation constitute a relatively continuous sequence from basal clastic rocks that rest unconformably on the Mount Holly Complex of the Green Mountain massif to phyllite, dolomite and quartzite. Basal conglomerates and associated quartz-rich gritty, feldspathic rocks are present above the unconformity, from a point 2 km south of Cherry Knoll, to the northern edge of the map. In the southern two-thirds of the map, the basal contact of the Tyson is a thrust fault that extends to the west side of Dry Hill in the Ludlow quadrangle (Ratcliffe, 1992).

A prominent black phyllite unit (Ꞓtbs), overlain by interbedded quartzite, beige to gray quartzose dolostone and dolomitic quartzite (Ꞓtdq), minor gray-green magnetite-chlorite phyllite (Ꞓts), and a fairly continuous vitreous quartzite (Ꞓtq), extends along the slopes west of the Black River valley. From Black Pond northward, the vitreous quartzite (Ꞓtq) passes upwards into white- to cream-, beige- and blue-gray weathering dolostone (Ꞓtd). This dolostone contains distinctive beds of gritty, cross-bedded quartzite and suspended, rounded grains of blue quartz as large as 2 mm in diameter. The presence of oolitic beds as well as cross beds suggests shallow water deposition. The dolostone is present as far south as Old Notch and its presence is conjectural south of that point. Sedimentary tops occur throughout the quartzite and dolostone units of the Tyson and indicate eastward topping continuously toward the Black River fault zone.

Hoosac Formation

The upper contact of the Tyson and the overlying rocks of the Hoosac Formation are locally very tightly controlled. This contact may be seen at Mission Chapel, in the narrow bridge of land between Woodward Reservoir and Black Pond, and in the old magnetite mine on the north side of route 100A at Plymouth Union. At these areas the contact is sharp with no evidence of interbedding. At Mission Chapel and Woodward Reservoir, mylonitic rocks are present at the contact. The overlying Hoosac Formation (ꞒZh) is either a greenish gray, white- or gray-albite spotted biotite granofels rich in magnetite, or a highly deformed biotite-rich schist having 0.5 cm- to 1 cm-thick stringers of quartz and feldspar. The latter variety is especially prominent from Woodward Reservoir south to Plymouth Union where it forms two belts surrounding a central inlier of gneiss (Ymg). The upper belt which is especially mylonitic, narrows to the north and widens to the south. South of Plymouth Union, a mylonitic pattern on the map distinguishes the highly sheared rocks which at this point are surrounded by less deformed biotite-rich albitic schists. The nature of the contacts of the Hoosac with gneisses east of Black Pond could not be determined, however they are quite possibly faults, based on the extensive mylonitization of both rocks.

Although this belt of rocks has been named Hoosac Formation, the bulk of the rocks are not typical of the type-locality Hoosac but are more like the albitic-biotite schists and feldspathic quartz schist of the Dalton Formation of Massachusetts (Ratcliffe and others, 1993). For example, very few zones have the characteristically abundant white-albite porphyroblasts common in green chlorite-quartz-albite or gray albite-biotite-quartz granofels of the Hoosac as mapped on Hoosac Mountain (Ratcliffe and others, 1993) or in the Mount Snow - Readsboro area (Ratcliffe, 1993) as ꞒZhgab and ꞒZhab, respectively. Although the schists mapped here as Hoosac are dark colored, they are largely non-rusty weathering and not as muscovitic as map unit ꞒZhrab of the Hoosac Formation mapped throughout the Hoosac elsewhere in southern Vermont (Ratcliffe and others, 1988; 1992; 1993; and Ratcliffe, 1993). The Hoosac Formation on a regional scale laterally replaces rocks of the Tyson Formation from south to north along the east flank of the Green Mountains (Ratcliffe, in press).

From the vicinity of Plymouth Notch south, black biotite schists of the Hoosac (ꞒZh) are shown in stratigraphic contact with the next overlying unit, the Plymouth Formation (Ꞓpfq). The contact relations, however, suggest that this contact may be a disconformity or local unconformity because the Plymouth Formation rests directly above the Mount Holly at Black Pond with no intervening Tyson or Hoosac rocks. The map relations among the Mount Holly, Hoosac Formation, and Plymouth Formation from Mount Tom north to Black Pond are not totally satisfactory as portrayed; quite probably there are unrecognized faults along the Plymouth-Hoosac contact from Plymouth Notch to Mount Tom.

The amphibolites and greenstones, that are present in the Hoosac Formation throughout southern Vermont (see Ratcliffe, 1994) are absent from the Hoosac, Tyson, and Plymouth Formations.

Plymouth Formation

The name Plymouth Formation has been proposed for a series of feldspathic and dolomitic quartzites, and dolostones and black phyllites that overlie the probable Middle Proterozoic gneisses in the hanging wall of the Black River fault zone (Ratcliffe, in press). The formation derives its name from exposures in and near the village of Plymouth, Vermont, where various members crop out. Rocks assigned to the Plymouth Formation were previously referred to as the Plymouth Member of the Hoosac Formation by Doll and others (1961) and by Chang and others (1965).

From a point on the small ridge above Mission Chapel, south to Mount Tom, and on Soltudus Mountain, a nearly continuous belt of very regularly layered, tectonized, gray and pinkish-gray feldspathic quartzites and possibly admixed mylonitic gneiss crop out. All contain the same distinctive pin-striped structure and strong tectonic lineation that plunges east, down the dip of the foliation. The foliation is parallel to a well developed transposition fabric. Some of the rocks in this belt appear to be microcline gneiss or other gneissic rocks that contain shredded pegmatites. These rocks are believed to be Middle Proterozoic and are not part of the Plymouth Formation as defined here.

Less microcline-rich rocks are clearly gray or tan quartzite or gray silty-textured phyllites having thin but transposed siliceous layers 0.1 to 0.5 cm thick (Ꞓpfq). These rocks are interpreted as metaquartzites and metasiltstones. The contact with the Middle Proterozoic rocks is difficult to map, but a sequence of dolomitic quartzites or thin bedded quartzite in the Plymouth Formation appear to mark the contact. Well bedded feldspathic quartzite and siliceous phyllite can be seen in the roadcut exposure north of Route 100A, east of Plymouth Union, and are well exposed in abandoned quarries at the 1600 foot altitude on the south slopes of hill 1796 at Plymouth Notch. On Soltudus Mountain, dark, laminated silty phyllites laterally replace the more feldspathic quartzites.The feldspathic quartzites and schists near the base of the Plymouth bear a striking resemblance to feldspathic rocks of the Dalton Formation of southern Vermont and Massachusetts, exposed on Hoosac Mountain (see Ratcliffe and others, 1993). In the Plymouth area dark-gray schistose quartzites and more massive vitreous quartzites (Ꞓpq) or dolomitic quartzite (Ꞓpfd) pass stratigraphically upward to the east into well-bedded, cream-weathered, light-gray dolostone breccia that contains irregular fragments of a darker gray dolostone (Ꞓpd). Associated with these lower beds are light-gray and black ribbon dolostone in layers 3 to 10 cm thick that pass into a distinctive intraformational edgewise-conglomerate in which the lighter-gray dolostone forms fragments in a darker-blue-gray matrix (Ꞓpdb). An interbedded zone of light-blue-gray fissile and white dolostone passes upward into massive medium-grained white dolostone (Ꞓpd). The dolostone unit exposed west of Plymouth is as much as 300 m thick. A similar section of dolostone is exposed in a small stream south of the road leading east from Moores Ponds starting about 600 m east of BM 1829. In this section, dark-gray dolostones and mottled dolostones (Ꞓpd) give way upward over a thickness of about 150 m to light-whitish-gray, cream-weathered dolostone (Ꞓpwd). Mottled blue-gray dolostone breccia and associated white dolostone and quartzite of the Plymouth Formation crop out to the south in the Ludlow quadrangle (Ratcliffe, 1992) in an abandoned quarry east of Lake Amherst.

The dolostone member of the Plymouth Formation, as described above, is distinct from the dolostone of the Tyson Formation as it contains abundant sedimentary breccias, intraformational conglomerate, and thin ribbony dolostone. The light-colored dolostone near the top of the member superficially resembles the light-colored white dolostone of the Tyson, but it lacks the coarse gritty beds and suspended quartz grains common in the dolostones of the Tyson. Numerous crossbeds and cut- and fill-structures indicate the section tops from the quartzite up into the dolostone.

The upper member of the Plymouth Formation is a black graphitic, siliceous phyllite (Ꞓpbs) that contains 1 to 3 cm thick layers of dark-gray ferruginous quartzite, dolomitic quartzite, and ribbony beds of dark blue-gray dolostone (Ꞓpbd). Glistening, black to dark-gray, vitreous quartzite (Ꞓpdq) in beds as much as 10 cm thick are present locally. Where the lower contact is exposed, for example, at the west foot of East Mountain, blue-gray dolostone of the dolostone member (Ꞓpd) passes through interbedding of black phyllite, upwards into the phyllite; the contact is gradational over a distance of approximately 10 meters. The absence of the white- and cream-colored dolostone (Ꞓpwd) at this point may be due to nondeposition or faulting. At other localities, for example east of Woodward Reservoir, black phyllite is in contact with white dolostone (Ꞓpwd) with no evidence of interbedding, although the phyllite does contain lenses of blue-gray dolostone. At West Bridgewater, at the base of Morgan Peak, on Wood Peak, and from Blueberry Hill south to Ludlow, lenses of light-gray to tan and yellow to tan feldspathic quartzite or vitreous quartzite (Ꞓpfqd) appear irregularly near the upper part of the member as do pods of dolostone (Ꞓpbd). These dolostones are in a different stratigraphic position from the main belt of dolostone and quartzite which makes up the middle member of the Plymouth Formation. The upper contact of the Plymouth Formation is placed at the first occurrence of light silvery-green magnetite-muscovite-quartz phyllites of the Pinney Hollow Formation. The contact is sharp and in many places expressed by strong development of a second generation, mylonitic foliation that transposes an earlier schistosity. Fold axes and lineations plunge down the dip of the foliation in a fashion identical to structures found in the thrust faults at the Tyson contact west of Woodward Reservoir and in the Black River fault zone. The contact therefore appears to be a fault. This interpretation is, however, not entirely defensible as pods of a very distinctive deep reddish-brown-weathered pyritic dolostone as much as 2 meters thick (Ꞓpfqd) occur at or near the Pinney Hollow contact at several localities north and south of

Blueberry Hill suggesting a stratigraphic contact. However, evidence of interbedding is not present and the map relations suggest low angle truncation of mapped units within the upper part of the Plymouth Formation.

Pinney Hollow Formation

Schists of the Pinney Hollow Formation occur in two outcrop belts, a western belt in the core of a refolded and faulted syncline on the high ground east of Woodward Reservoir, and in a fault slice between the Plymouth Formation below, and the Ottauquechee Formation above. These two belts of Pinney Hollow may have different contact relations with the underlying Plymouth Formation.

Remapping has confirmed the basic characteristics of the Pinney Hollow determined by the previous studies (Perry, 1929). The unit is primarily a lustrous ilmenite-chloritoid-chlorite-quartz-sericite phyllite characterized by abundant pods and stringers of milky-white quartz. Magnetite, garnet and less commonly biotite and albite (without chloritoid) are also present. Near the base is a very chloritoid-rich gritty appearing rock (ЄZphc) that contains abundant chloritoid (25 to 30%) in small rosettes, and abundant dark-gray, muscovite-chlorite-rich layers. These rocks resemble grits but contain little quartz and overall lack even quartz-rich layers. Beds as much as 2 meters thick are present. These beds are of unusual composition and may be Fe-Ti rich, Al_2O_3 enriched metasediment derived from a deeply weathered basaltic or other volcanic protolith. Greenstones, ankeritic greenstones, and less commonly amphibolite are distinctive and mappable units in the Pinney Hollow. One belt of chloritic, ankeritic greenstone (ЄZpha) extends nearly the entire length of the quadrangle. These greenstones are well bedded rocks which show sedimentary, interbedded contacts with the enclosing strata. They probably are altered volcaniclastic basaltic tuffaceous deposits and clearly are not lava flows. The ankeritic greenstones may pass along strike into more massive epidote amphibolite lacking the abundant ankerite and chlorite. These smaller lenses may be metabasalts. The greenstones serve as important internal marker units. From the north to the south, five or more belts of greenstone appear to traverse diagonally across the belt of the Pinney Hollow. Greenstones in the upper half of the formation are truncated against the contact with the overlying Ottauquechee Formation. In the northern part of the map, and in the upper third of the formation, a narrow but distinctive belt of black, carbonaceous phyllite (ЄZphb) occurs beneath an ankeritic greenstone. Rocks of the Pinney Hollow above this greenstone tend to be more biotitic (and less chloritic) and contain gray-green layers of albitic schist. Both the albitic-biotitic schists and the black carbonaceous schist resemble rocks in the Ottauquechee and these relations suggest an interlayering of Ottauquechee-like rocks in the upper third of the Pinney Hollow. These units appear to be cut out beneath the Ottauquechee to the south and are absent in the Pinney Hollow of the Ludlow area (Ratcliffe, 1992).

In the Ludlow area a fairly continuous belt of garnetiferous schist is located near the base of the Pinney Hollow Formation (ЄZphgt). This unit could not be mapped in the Plymouth area. In the western half of the Pinney Hollow, chlorite pseudomorphs after garnet are common, but large fresh poikiloblastic garnets occur throughout the eastern half of the belt and are im places associated with very coarse chlorite and chloritoid. Likewise magnetite, although widespread throughout the Pinney Hollow, becomes extremely abundant and coarse grained locally. In some areas, for example on the ridge 1 km east of Wood Peak, abundant magnetite occurs on joint surfaces. Magnetite is also particularly abundant along the eastern side of the formation south of Pinney Hollow Brook to the quadrangle boundary. The distribution of the very coarse-grained magnetite-garnet chloritoid schist is irregular and does not appear to be stratigraphically controlled. Garnets overgrow the foliation as do chloritoid and biotite where present.

The semicontinuous bedded greenstones and the rather distinctive upper part of the formation that contains black phyllite and more albitic and biotitic rocks argues against any structural repeat by large isoclinal folds within the belt. Therefore, although it is a fault slice, the section may be considered continuous from west to east. Channels and crossbeds are found locally in the volcaniclastic greenstones and indicate tops are to the east.

Both the upper and lower contacts of the main belt of Pinney Hollow in the type section, appear to be faults. The evidence for the lower fault contact with the Plymouth Formation is the more equivocal, however. On the west slopes of Morgan Peak, west of Mount Pleasant, on Wood Peak, and at a number of localities extending from Route 100A south to Blueberry Hill, the basal contact of the Pinney Hollow Formation can be closely located. In all instances the contacts are sharp with no evidence of interbedding of the green phyllite with the underlying rocks. A strong foliation and down dip quartz-rodding is present for 100 m on both sides of the contact. The schistosity is plicated and numerous second generation folds are present. The folds also have hingelines that plunge down-dip to the east. Despite what seems to be good structural evidence for a fault, pods and lenses of salmon- to reddish-brown weathering dolomitic quartzites, dolostone, and quartz-veined pyritized schists occur along the contact and in places within the Plymouth Formation. A thick belt of such rocks is present between Mount Pleasant and Wood Peak. The association of the ferruginous dolostone and dolomitic quartzites (Ꞓpfqd) with the contact suggests a stratigraphic marker in the Plymouth that is parallel to the contact. However, dolostone and quartzites occur throughout the Plymouth and the distribution of such rocks at the contact may only represent blocks of resistant, more brittle dolostone pods along the fault. The strong deformation associated with the contact, and the abundant quartz veining and sulphide mineralization suggest faulting and syntectonic mineralization. Based on these arguments, the base of the Pinney Hollow in the main belt is interpreted as a fault. The contact with the Plymouth Formation in the syncline at Plymouth, however is different. It is not marked by the presence of the sulphide mineralization, the carbonate and dolomitic quartzites, or the strong second generation shearing. Nonetheless, the contact is sharp and it is parallel to the regional foliation on the limbs of the structure. At the northern termination of the syncline, the early foliation within both rocks appears to be the axial surface of folds that produces the closure. Therefore, the contact against the Plymouth Formation here is either a stratigraphic contact (nonfaulted) or a pre-metamorphic fault. On the map, this contact is shown as a possible early pre-metamorphic fault. Evidence for or against this argument is not compelling, and further work is needed. If these rocks are in normal stratigraphic position above the Plymouth Formation, then some of the rocks shown as Pinney Hollow may be younger than the Plymouth. Alternately, there may be two belts of Pinney Hollow like rocks which are of different ages.

The upper contact of the Pinney Hollow is more clearly a fault. At or near the contact with the Ottauquechee, small pods and stringers of ankeritic greenstone, and feldspathic schists are disarticulated and strongly foliated. The same down dip lineations that are present along the lower contact are well displayed along the fault. In the northern part of the map, from the low hills, 0.5 km north of route 4, and for a distance of 3 km to the south, the pods and stringers of different kinds of rocks are abundant. One small pod of talc-carbonate rock occurs 1.2 km south of Route 4. In the vicinity of the crossing of Route 100A, and hills to the north, a late fault marked by a distinctive quartz-feldspar breccia locally marks the contact; this fault is clearly a different, younger generation structure than the contact to the north and to the south. In the southern part of the map from the area of the Calvin Coolidge State Park to the southern border of the map, the contact is sharp, highly foliated and marked by fine-grained phyllonite. Along this segment of the contact, ankeritic greenstones in the Pinney Hollow are successively truncated and different units of the Ottauquechee appear at the contact.

The Pinney Hollow at its type locality, therefore, appears to be fault bounded. Despite the faults, the observation from the western occurrences in the syncline at Plymouth and the interlayering of black schists like the Ottauquechee in the upper part of the Pinney Hollow suggests that the Pinney Hollow may have originally had stratigraphic continuity with the Ottauquechee, and possibly but less certainly, with the underlying Plymouth Formation.

Ottauquechee Formation

The name Ottauquechee Formation was applied first by Perry (1927, 1929) for typical exposures of black to dark-gray, carbonaceous phyllite and beds of massive, slate-gray quartzite in the Ottauquechee River valley of the Plymouth quadrangle. Perry (1929) noted the marked contrast of the dark phyllites of the Ottauquechee from the distinctly greenish rock above, named the Bethel Schist by Richardson (1924), and the Pinney Hollow below. The contact with Pinney Hollow rocks was described by Perry as sharp, whereas the contact with the overlying Bethel Schist, now referred to as the Stowe Formation after Cady (1956), was described as gradational over a distance of 200 to 300 feet. Although Perry noted that the Ottauquechee Formation was predominantly dark gray or black phyllite, he recognized that other beds more characteristic of units above the Ottauquechee, i.e. feldspathic biotite or chloritic-feldspathic rocks do occur, notably in the southern exposures in Plymouth Township in the present Plymouth and Ludlow quadrangles. Perry mapped the serpentinite and amphibolite within the Ottauquechee Formation as intrusive rocks. Chang and others (1965) accepted Perry's definition of the Ottauquechee, and noted the relative abundance of quartzites in the lower third of the Formation as well as greenstones that they regarded as mafic volcanics in the lower and middle parts of the formation. They assigned an age of Cambrian to the Ottauquechee Formation.

Our remapping shows the distribution of the thicker quartzites (Ꞓoqb and Ꞓoq), black phyllite (Ꞓob), and five feldspathic units; a gray-green schist characterized by distinctive cross-biotite (Ꞓog), a coticule-bearing schist (Ꞓogc) and a garnet-bearing schist (Ꞓogg) similar in composition to Ꞓog, a gneissic, gray, biotite albitic granofels and schist (Ꞓogp), and a green albitic schist (Ꞓoga). Amphibolite and greenstone units (Ꞓoa), and in fewer places serpentinite and talc-carbonate schist, are distributed throughout.

Examination of the map reveals that a belt of feldspathic units (Ꞓog, Ꞓogp, Ꞓogg, and Ꞓoga) associated with amphibolite and greenstone occurs in the central part of the Ottauquechee Formation from the northern edge of the map to a point 2 km south of Slack Hill. South of Slack Hill the units terminate in a series of complexly refolded isoclinal folds that have east to northeast plunging hingelines. The map relations suggest an infold in the center of the Ottauquechee. This structure is referred to here as the Slack Hill syncline. At the southern end of the map, and extending southward into the Ludlow quadrangle, the feldspathic units and associated greenstones and amphibolite lie near the upper contact of the Ottauquechee Formation. The feldspathic units we map are the same ones Perry (1929, p. 28) described as, "beds of light colored chlorite-mica schists and micaceous quartzites." Due to the narrowing of the Ottauquechee Formation from north to south, the feldspathic units are more abundant relative to the percentage of black phyllite and quartzite in the southern part of the Plymouth quadrangle and northern part of the Ludlow quadrangle. Perry (1929) recognized this change in lithology and attributed it to a north to south variation in the original sedimentation.

Primary topping information is very limited in the Ottauquechee Formation, despite the numerous occurrences of quartzite. The dark-gray vitreous quartzites (Ꞓoqb) near the lower contact are finely laminated on a mm scale, but do not contain cross beds, channels or obvious graded bedding. The tan variety of quartzite (Ꞓoq) locally is channeled and a single determination near the western border of the large amphibolite just north of Pinney Hollow suggests tops are to the east toward the amphibolite. Limited data there suggest that the feldspathic units and amphibolites in the central part of the Ottauquechee may be stratigraphically above some of the black phyllite.

In the northern part of the map and west of the Slack Hill syncline, as many as four zones rich in quartzite occur. In the southern part of the map, south of the termination of the fold, quartzites are rare except near the borders of the southern belt of feldspathic schist and amphibolite. The distribution of the quartzites suggests the possibility of repetition by folding in the northern part of the map.

We conclude that the Ottauquechee Formation at the type locality has experienced intrafolial folding which may have produced a tripling of the section in the north and a doubling near the southern border of the map. Fold structures of this kind are absent from the underlying units to the west suggesting either an earlier deformation in the Ottauquechee or decoupling from the lower rocks.

Amphibolites and greenstones within the Ottauquechee Formation are thickest and most abundant near or in the Slack Hill syncline. Amphibolites are locally very coarse-grained, almost gneissic, i.e. hornblende-plagioclase amphibolite or gabbroic to pyroxenitic appearing rocks. Near the borders of the amphibolite and greenstone bodies the mafic rocks are finer grained, and in places are interbedded with feldspathic schist and granofels layers. Exposed contacts suggest interlayering with surrounding metasedimentary rocks.

The contact between the Ottauquechee and Stowe Formations is herein named the Bald Mountain fault for exposures just west of the summit of Bald Mountain in Bridgewater. A sharp break in slope defines the contact and is easily visible from the Ottauquechee River valley to the north, and from Pinney Hollow to the south. Earlier authors characterized the contact as either a transition zone of interlayered black and green rocks 200 to 300 feet wide (Perry, 1929), or an abrupt upward change from black phyllite to pale-green schist (Chang and others, 1965). Keith (1932) was the first to state that the Ottauquechee was terminated at the top by a fault. Our mapping demonstrates that there are interlayered black and gray-green rocks throughout the Ottauquechee, and that the gray-green feldspathic schists (Ꞓog and Ꞓogg) are present as mappable layers within the black phyllite right up to the contact with the overlying Stowe schists. The contacts between the gray-green schists and the black phyllite are both sharp and gradational and by intercalation. The gray-green schists are lithologically similar to rocks in the overlying Stowe Formation (especially Ꞓogg and Ꞓsgt), but because of the interlayering and intercalation with the black phyllite we believe that they represent original layering within the Ottauquechee.

Ultramafic Rocks

Five bodies of ultramafic rock are shown on the map: one large body west of Plymouth Five Corners; three small bodies south of Five Corners; and one small body along the Pinney Hollow fault in West Bridgewater. The ultramafic rocks crop out in, or at the base of, the Ottauquechee Formation. Perry (1929) reported two small occurrences of talc/serpentinite rock on the slopes north of the Ottauquechee River, approximately 1 km east of the lower contact of the Ottauquechee Formation — these deposits were not located in this study.

The Five Corners ultramafic body contains both massive, brecciated, dark-green to black serpentinite and chrysotile asbestiform serpentinite, talc-carbonate schist, green to light-green actinolite gneiss, and light-gray to salt and pepper colored, plagioclase-tourmaline-garnet-sphene-biotite-clinozoisite-quartz gneiss. Additionally, ten meters downstream of a small adit to an abandoned mine, a lens of gray cross-biotite schist is bounded on both the east and west sides by serpentinite. The contact between the large ultramafic at Plymouth Five Corners is not exposed. The mapping demonstrates that the ultramafic body is surrounded largely by the Ottauquechee black phyllite (Ꞓob). West of the ultramafic, however, the black phyllite is interlayered with gray quartz-rich cross-biotite schist (similar to Ꞓog) on a scale too small to show on the map. These relationships are visible in stream exposures located between an abandoned mine and a small man-made pond approximately 400 m northwest of Five Corners, and on the hillside just west of an abandoned quarry approximately 300 m west-southwest of Five Corners. This body of ultramafic rock is somewhat smaller than previous studies report (Perry, 1929; Chang and others, 1965), but extensive lumbering in the area southwest of Five Corners makes location of outcrops difficult at present.

A small (<5 m^2), isolated outcrop of talc-carbonate schist and massive serpentinite is exposed on the Blueberry Hill jeep trail approximately 2.2 km south of Five Corners.

Ottauquechee black phyllite (Єob) bounds the ultramafic body to the east and west. The contact is not exposed.

The third ultramafic body is exposed on an unnamed hill 2.1 km south of Five Corners, and contains massive serpentinite and lesser amounts of talc-carbonate schist. The ultramafic is apparently enclosed entirely within a large greenstone body. Close to the ultramafic the greenstone body consists of medium-grained, poorly foliated amphibolite, while farther away the body consists of fine-grained amphibolitic greenstone and fine-grained biotite-chlorite-carbonate-plagioclase schist. The large greenstone body itself is surrounded largely by gray feldspathic cross-biotite schist and paragneiss (Єog) and, to a lesser extent, black phyllite.

A fourth ultramafic body consisting of talc-carbonate schist is exposed on the west side of a jeep trail, approximately 70 m south of an abandoned prospect pit and 0.9 km south of Five Corners. The talc-carbonate schist is in contact with fine-grained greenstone, and again appears to be entirely contained within the greenstone body. The greenstone body is in contact with gray feldspathic cross-biotite schist to the east and carbonate-bearing schists (Єoc) to the west.

The fifth ultramafic body consists of talc-carbonate schist and is exposed at an elevation of 1470 feet in an unnamed stream northeast of Morgan Peak. The talc-carbonate schist is in sharp contact with the Ottauquechee black phyllite above and the Pinney Hollow silvery green schist below along the Pinney Hollow fault. The fault is characterized by phyllonitic and mylonitic fabric, and the talc-carbonate schist is interpreted as a fault sliver.

Previous workers in the Plymouth quadrangle (Perry, 1929; and Chang and others, 1965) interpreted the ultramafics as metamorphosed intrusive rocks. Recent interpretations for the origin of similar ultramafics in Vermont regard most of the rocks as fault slivers of oceanic crust (Stanley and others, 1984; Stanley and Ratcliffe, 1985). None of the ultramafic rocks in the Plymouth area exhibit cross-cutting relationships indicative of an intrusive origin. Interpretations regarding the large Five Corners body and the Blueberry Hill jeep trail body may be equivocal because the contacts are not exposed. The two bodies, however, are located along strike of each other and appear to mark a zone where rocks of the Slack Hill syncline are offset, suggesting the presence of an unrecognized fault. The remaining two bodies crop out in a greenstone within the Slack Hill syncline belt. No faults have been recognized between the greenstone and the ultramafic rocks, and we know of no means for incorporating the ultramafics entirely within the greenstone by faulting. Indeed, the greenstone and amphibolite units (Єoa) themselves contain a very heterogeneous assemblage of non-bedded, coarse-grained areas of massive hornblende amphibolite resembling metagabbro or metapyroxenite, ankeritic greenstone, as well as feldspathic well-layered amphibolite. These may have formed as a chaotic, volcanic, igneous breccia from a block-faulted basaltic substrate. We believe that these two ultramafic bodies, and in part some of their surrounding greenstone and amphibolite, may be olistoliths. These ultramafics are also closely associated with the Ottauquechee carbonate-bearing schist unit (Єoc). The carbonate-bearing schist unit was first described by Chang and others (1965) as a calcareous black phyllite with bands and beds of marble up to one foot across, although it was not shown on their map. The heterogeneity, presence of discontinuous pods, and elevated level of chromium suggests that this unit may be an olistostrome associated with the nearby ultramafic rocks. The immediate Five Corners area where the Єoc unit is exposed is known for producing historically significant (but economically insignificant) quantities of gold. The presence of gold and chromium micas suggests that the Ꞓoc rocks also underwent metasomatic and/or hydrothermal alteration.

Stowe Formation

The two major units in the Stowe Formation are a garnetiferous schist (Ꞓsgt) and silvery-green schist (Ꞓs). The contacts between the two units are gradational by intercalation and are also marked by a progressive increase in the size and number of garnet and biotite porphyroblasts from Ꞓs to Ꞓsgt. Were it not for the presence of the conspicuous garnet and biotite porphyroblasts, it would be difficult at best to separate the Stowe Formation into the two major map units. The distribution of the two units appears to be the result of folding with the axial surfaces of the folds trending north-south parallel to the schistosity; were the distribution the result of a facies change it would be unlikely that the change would still be preserved parallel to the schistosity everywhere. Both Ꞓs and Ꞓsgt contain small greenstone and amphibolite bodies. Where the units in the Stowe are mapped to the contacts with the bounding formations, both upper and lower plate truncations are evident.

Whetstone Hill Member of the Moretown Formation

The name Whetstone Hill Member of the Moretown Formation applies to a collection of rocks that map as a virtually continuous unit from the Plymouth area south to the type locality of Thompson (1950) on Whetstone Hill in the Andover quadrangle. The two main units in the Whetstone Hill Member are a gray biotite-garnet phyllite (Omwhg) and a black graphitic phyllite (Omwhb). The contact between the two units is gradational, and beds of each are not uncommon in the other. In the northern part of the Plymouth quadrangle a volcanic conglomerate (Omwhv) up to 150 m thick crops out within the Whetstone Hill Member. The conglomerate is matrix supported and contains generally rounded rock-fragment clasts (≤ 15 cm long and 5 cm thick) that are elongate parallel to the lineation. The fragments are light-colored and consist of fine-grained to cryptocrystalline quartz and feldspar containing larger quartz and feldspar porphyroclasts (phenocrysts?), and lesser biotite, muscovite, and garnet. The fragments contain no evidence of tectonic grain-size reduction, suggesting that the fine-grained nature of the clasts is primary. The matrix consists of garnet-chlorite-biotite-plagioclase-quartz granofels and biotite-plagioclase-quartz granofels to paragneiss. The conglomeratic rocks are interlayered with lesser non-conglomeratic garnet-chlorite-biotite-plagioclase-quartz granofels and schists, that are in places well-bedded in layers up to 15 cm thick, and are interpreted as volcaniclastic sediments and bedded tuffs. The contacts with the bounding gray phyllite (Omwhg) and black phyllite (Omwhb) are gradational over short distances of less than 5 m. Stanley and Ratcliffe (1985) suggested that some volcanogenic rocks in the Moretown Formation may have been derived from an eastern island-arc source. The volcanic and volcaniclastic rocks of Omwhv may represent such arc-related deposits, perhaps even exhalative rocks produced from the same or similar source that created the intrusive rocks of the Barnard Gneiss.

According to Doll and others (1961) and Chang and others (1965) the Whetstone Hill

Member occupied the axial portion of the Moretown in this area. This map shows that the Whetstone Hill Member does not occupy an axial position in the Moretown Formation. Rather, rocks originally mapped as a continuous belt of Moretown on the west side of the Whetstone Hill are absent south of the Ottauquechee River. Here the Stowe Formation is in contact with the Whetstone Hill along the Raymond Hill Fault, and Moretown rocks are found as slivers along the fault. In the Plymouth quadrangle the upper (eastern) contact of the Whetstone Hill is in fault contact with Moretown rocks along the Hale Hollow Fault, but in the southern part of the quadrangle the units are, in places, interlayered. Whetstone Hill and Moretown rocks are also interlayered in the 7.5 minute Ludlow and Andover quadrangles to the south (Ratcliffe and Walsh; and Ratcliffe, unpublished data).

Barnard Gneiss

The name Barnard Gneiss is applied to a collection of rocks previously called the Barnard Volcanic Member of the Moretown or Mississquoi Formation (Chang and others, 1965; and Doll and others, 1961). These authors interpreted the Barnard as volcanics because the Barnard rocks were interlayered with Moretown rocks, contact relations were everywhere concordant, and the coarse-grained nature of the Barnard was a product of metamorphic recrystallization. Our mapping here and in the Ludlow quadrangle (Ratcliffe and Walsh, unpublished data), suggests an intrusive origin for the majority of these rocks, thus the name Barnard Gneiss is resurrected from Richardson (1924) who originally named the rocks and interpreted them as an acid igneous intrusion. Furthermore, the presence of preserved fine-grained primary textures in rocks with a similar metamorphic and structural history (Whetstone Hill volcanic rocks, Omwhv) suggests that the coarse-grained textures in the Barnard are not the result of metamorphic recrystallization. Here, the Barnard Gneiss is not considered to be a member of the Moretown Formation, however, the Barnard does intrude the Moretown. Near the eastern boundary of the Moretown, laminated granofels (Oml) and garnet schist (Omgt) are intruded by coarse tonalitic to trondhjemitic gneiss and amphibolite. Dikes and sills of Barnard rocks are found up to 600 m west of the main Moretown - Barnard contact, and screens of Moretown are found up to 100 m east of the same contact within the main mass of Barnard. A roadcut in the Moretown Formation (Oml) located approximately 0.5 km west of downtown Bridgewater on U.S. Route 4 contains dikes of Sbm and Sbd and clearly illustrates the cross-cutting relationships.

The age of the Barnard Gneisss in the Plymouth area is best approximated by the concordant U-Pb zircon age of 418 ± 1 Ma obtained from a fine-grained felsic layer (or sill) near the top of the unit in Bridgewater (Aleinikoff and Karabinos, 1990). These authors interpret the Lower Silurian age as a crystallization age for the rock, rather than a metamorphic age (lower intercept age) because Acadian metamorphism here is younger than 418 Ma, probably 375 to 385 Ma based on $^{40}Ar/^{39}Ar$ ages (Laird and others, 1984; and Sutter and others, 1985). We therefore accept a possible upper age limit of 418 Ma for the Barnard. The lower age limit is highly uncertain and may range downward into the Middle Ordovician.

STRUCTURE

At least six generations of foliations are present in the rocks of the Plymouth and eastern Killington Peak quadrangles. The oldest recognized structure is the gneissic layering in the Middle Proterozoic Mount Holly Complex. The steeply dipping to vertical gneissosity generally trends east-west, and is parallel to the axial surfaces of Middle Proterozoic folds. A bed-parallel foliation (S1) is present in all the Late Proterozoic to Cambrian rocks. The second generation foliation (S2) in the cover rocks is a penetrative north-striking east-dipping schistosity characterized by an east-to-southeast trending lineation with sub-parallel isoclinal reclined fold hinges (F2), and is present in all rocks older than the Whetstone Hill Member of the Moretown Formation. The third generation foliation (S3) in the cover rocks increases in intensity from west to east, and is present in all rocks. Generally east of the Bald Mountain fault, S3 is a penetrative north-striking east-dipping schistosity characterized by a northeast-to-east trending lineation with sub-parallel tight to isoclinal, upright to reclined fold hinges (F3). Generally west of the Bald Mountain fault, the S3 foliation varies from a north-striking, steeply east- and west-dipping crenulation cleavage to penetrative fault-related foliation. Fold hinges in the west have generally shallow plunges to both the north and south. The S2 and the S3 schistosities are the most penetrative foliations in the area, and both are spatialy associated with thrust faults. Figure 1 shows a generalized structural-domain map that summarizes the structural relationships in the area based upon the characteristics of the S2 and S3 foliations. A still younger crenulation cleavage (S4) cuts all older foliations, and is more common to the east. Generally, the S4 cleavage is northeast-striking and west-dipping, however, northwest-striking and east-dipping to north-striking and steeply east- and west-dipping orientations are also present in places. In places, the S4 cleavage forms conjugate sets. To the west, the S4 cleavage occurs as spaced kink bands in places. In the east, Acadian-aged porphyroblasts of biotite and hornblende create a north-trending shallow plunging mineral lineation which is parallel to the intersection of S4 and earlier foliations, and is sub-parallel to open to tight F4 fold hinges. The youngest foliation is a rare, weakly to poorly developed spaced cleavage with associated broad to open folds which deform all earlier foliations.

Structures in the Whetstone Hill Member of the Moretown Formation

In places in the Plymouth quadrangle, the Whetstone Hill contains well-preserved bedding that is deformed by a single penetrative foliation (S3), but contains no definitive relict foliation (S2). There are places, however, where bedding is transposed by a penetrative foliation and in such cases it is difficult to determine whether the foliation is a single (S3) or composite (S2-S3) fabric. To the south the Whetstone Hill locally contains what appears to be a relict foliation (S2) where it is interlayered with the Moretown rocks. Based on these observations and the apparent structural disparity between the Whetstone Hill and older rocks, we suggest that much of the Whetstone Hill Member may be younger than the Moretown on which it lies or that most, but not all, of it was deposited in an area that escaped D2 deformation. Such an interpretation would require that the Whetstone Hill rest unconformably on the Moretown or be separated from it by a fault. Lithic similarities and a similar structural history of the Whetstone Hill Member and Northfield Formation suggest a possible correlation between the two units, although they are not currently in the same structural position.

Structures in the Barnard Gneiss

The Barnard intrusive rocks lack the S2 fabric found in the Moretown Formation and cut across the earlier structures in the Moretown. The Barnard rocks, however, do contain the S3 schistosity found in all rocks suggesting that they intruded the Moretown subsequent to D2 deformation. These findings are consistent with a post-Taconian and pre-Acadian nearly concordant age of 418±1 Ma described earlier for a sample from Bridgewater (Aleinikoff and Karabinos, 1990). Although their sample site is in the 7.5 minute Woodstock South quadrangle 0.7 km east of the boundary of the Plymouth quadrangle, and therefore has not been mapped in this study, the rock closely resembles a felsic gneiss from the layered Barnard unit Sbm.

The Bald Mountain Fault

The Bald Mountain fault is a significant structural boundary in the Plymouth area. West of the fault the S2 schistosity is characterized by a down dip, east-to-south-east trending lineation (L2) with sub-parallel isoclinal reclined fold hinges (F2). Within the Ottauquechee Formation, the younger S3 foliation varies from a crenulation cleavage with associated tight to open, upright, north-to-northeast plunging folds to a penetrative fault-related schistosity. Where S3 is a penetrative schistosity anywhere west of the fault, S2 and S3 become a sub-parallel composite foliation. In the lower plate exposures on Bald Mountain (and elsewhere along the fault) the S2 schistosity is progressively transposed by the S3 foliation as the fault is approached. The fault itself is characterized by a planar phyllonitic to mylonitic fabric parallel to the S3 foliation. East of the fault, the foliation is a composite S2-S3 schistosity. Where S2 and S3 are a composite fabric, the older schistosity is transposed into the S3 orientation on the limbs of F3 folds, and a relict S2 schistosity is often preserved in the hinges of such folds. The east-to-southeast trending L2 lineation is preserved in places east of the fault, but more prominent are a north-east trending lineation sub-parallel to F3 fold hinges and a north-trending lineation sub-parallel to F4 fold hinges. The Bald Mountain fault, therefore, appears to represent a structural boundary between dominantly Taconian structures to the west and dominantly Acadian structures to the east.

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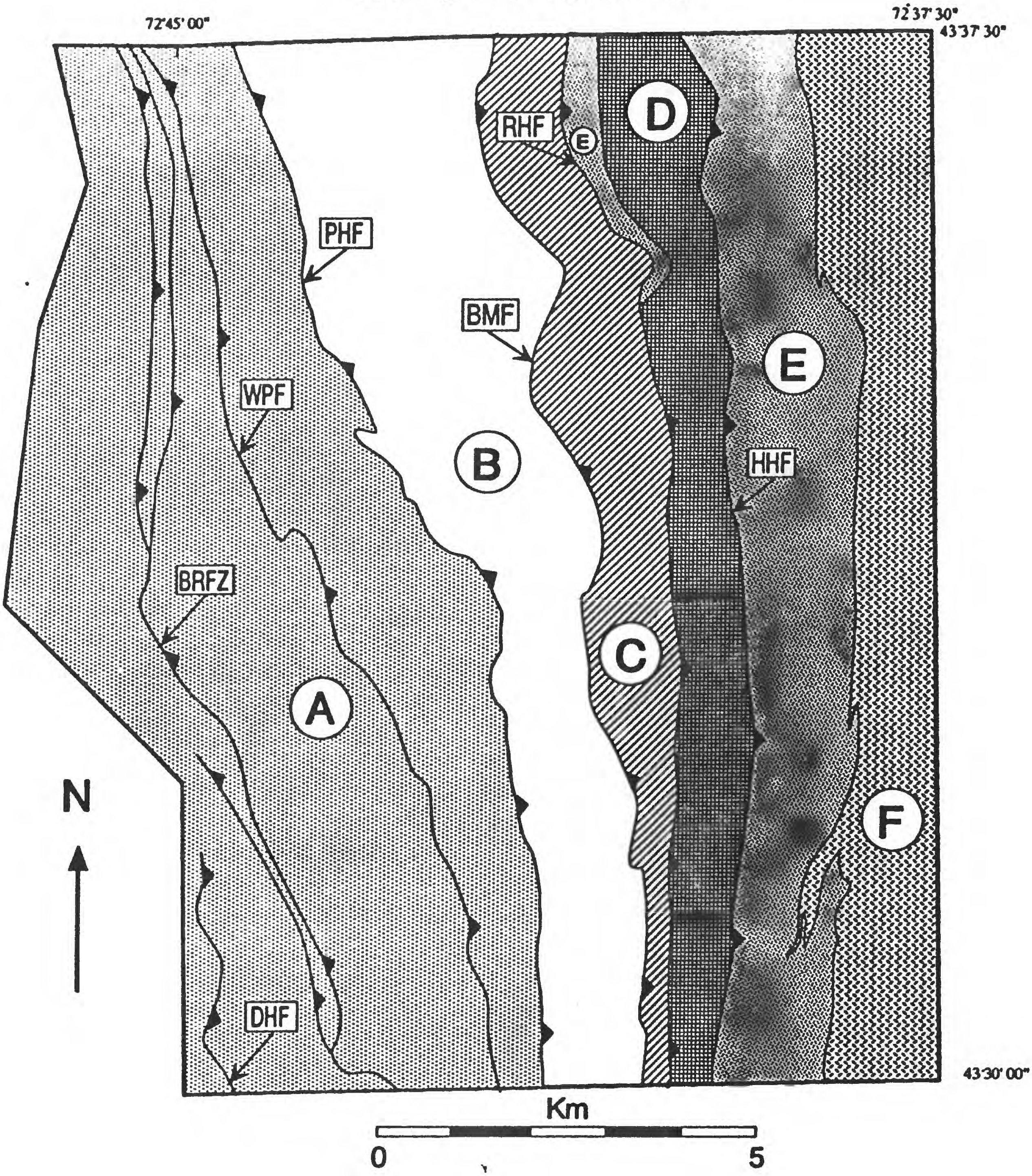
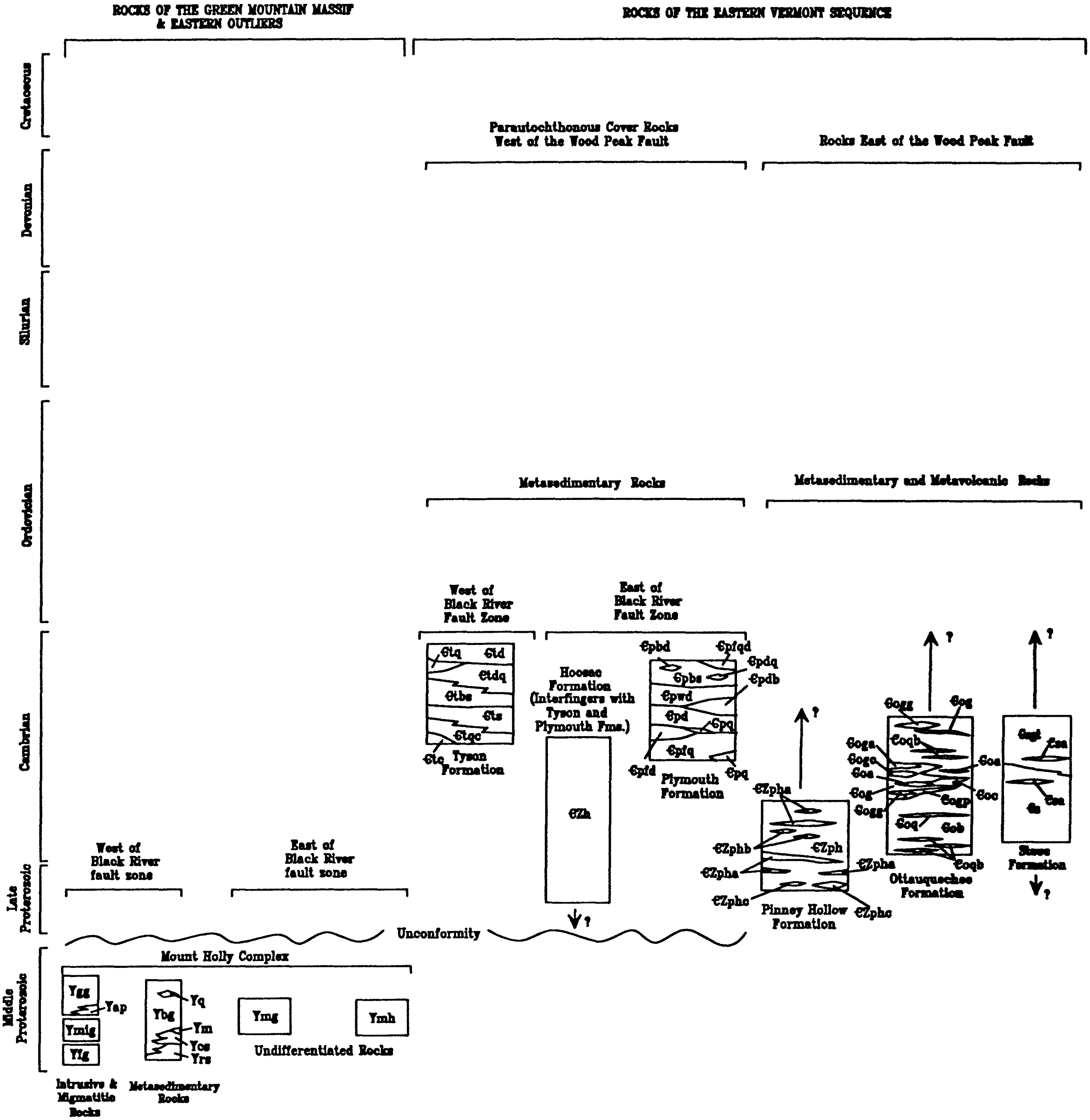


Figure 1. Generalized structural-domain map of the Plymouth quadrangle and eastern portion of the Killington Peak quadrangle. Domains defined on the relationship of the principal foliations S2 and S3 to older and younger structural features. Domain A — Principal foliation is S2, younger cleavages are generally spaced but in places S3 is penetrative. Domain B — Principal foliation is S2 to a composite S2-S3 fabric where S3 is a pervasive fault-related foliation, especially to the south. Domain C — Principal foliation is a composite S2-S3 fabric. Domain D — Principal foliation is S3. Where bedding is observed the oldest fabric that deforms it is S3, and there is no definitive evidence of an older S2 fabric. Domain E — Principal foliation is a composite S2-S3 where S2 is recognized as a relict fabric. Domain F — Principal foliation is S3, no evidence of any older foliation. DHF = Dry Hill fault, BRFZ = Black River fault zone, WPF = Wood Peak fault, BMF = Bald Mountain fault, RHF = Raymond Hill fault, and HHF = Hale Hollow fault.

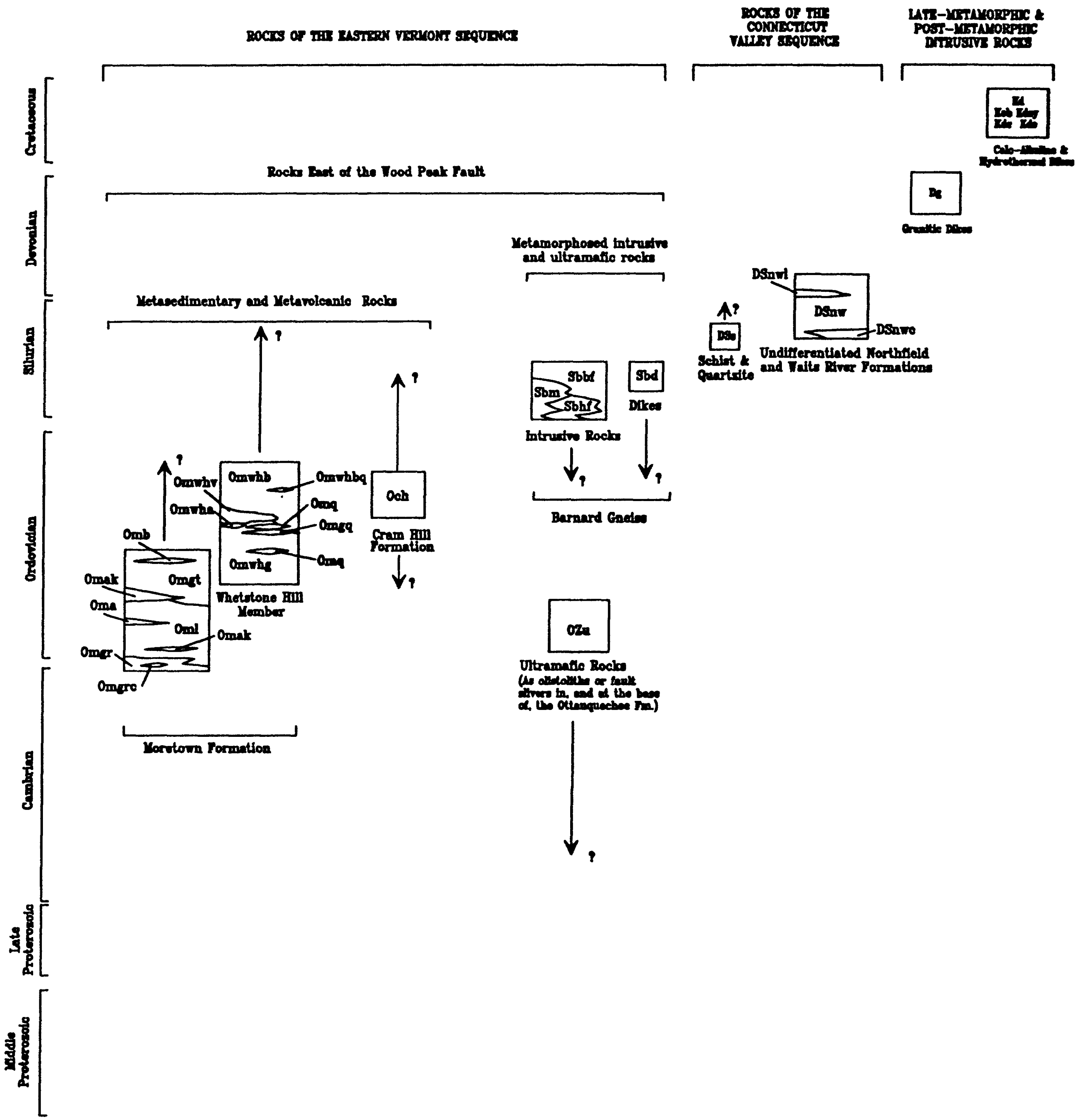
Correlation of Map Units
Plymouth Quadrangle and Eastern Portion of the Killington Peak Quadrangle, Vermont
(Vertical arrows indicate probable age range, queried where uncertain)



Correlation of Map Units

Plymouth Quadrangle and Eastern Portion of the Killington Peak Quadrangle, Vermont

(Vertical arrows indicate probable age range, queried where uncertain)



Description of Map Units
(Major minerals listed in order of increasing abundance)

LATE-METAMORPHIC AND POST-METAMORPHIC INTRUSIVE ROCKS

Kd — Lamprophyre and diabase dikes (Cretaceous) -- Aphanitic, dark-gray to black lamprophyre and medium- to coarse-grained dark-gray to black diabase or lamprophyre. Dikes range in thickness from 0.5 to 2.0 m and may contain phenocrysts of biotite, amphibole, pyroxene, and olivine. May contain amygdules filled with dolomite or calcite. Dikes are unfoliated but may be highly jointed.

Keb — Epidosite breccia dike (Cretaceous) -- Fine- to coarse-grained, rusty weathering, pitted, pistachio-green epidosite breccia. The dike possesses a weak, sub-vertical flow foliation and contains fragments of country rock up to 10 cm. Contains fine-grained, granular, rusty and gray-colored sulphides. The dike is 0.5 m thick and cuts the Ottauquechee carbonate-bearing schists, Ꞓoc, 0.9 km south of Plymouth Five Corners.

Kds — Sausseritized lamprophyre dike (Cretaceous) -- Aphanitic, light-tan to buff, sausseritized lamprophyre dike. Dike is 1.0 m thick and cuts the Barnard mixed gneiss, Sbm, 3.2 km northeast of Reading Pond. Dike is unfoliated but highly jointed.

Kdsy — Syenitic dike (Cretaceous) -- Aphanitic to fine-grained, tan-weathering, light-gray syenitic dike. Dikes are 1.5 m thick and contain phenocrysts of plagioclase and biotite. Dikes are located in Hale Hollow approximately 1.5 km south of Toplift Cemetery. Dikes are unfoliated but may be highly jointed, and in places cut an older set of joints.

Kdo — Ouachitic breccia dike (Cretaceous) -- Dark-green, pitted, coarse-grained dike located 0.6 km northeast of downtown Plymouth on the west slopes of East Mountain.

Dg — Granodiorite (Devonian) -- Non-foliated to weakly-foliated, medium- to coarse-grained biotite-muscovite granodiorite. Occurs as unfoliated dikes and a lenticular intrusive body 100 by 700 m

ROCKS OF THE CONNECTICUT VALLEY SEQUENCE

Undifferentiated Northfield and Waits River Formations

DSnw — Gray phyllite (Silurian-Devonian) -- Silvery-gray to dark-gray, highly crenulated, quartz-muscovite phyllite to schist with abundant 2 to 5 mm garnet porphyroblasts and less abundant 2 to 5 mm cross-biotite porphyroblasts. May contain graded beds 2 to 10 cm thick with gray quartz-rich bases grading into phyllitic tops.

DSnwc — Quartzite and conglomerate (Silurian-Devonian) -- Light-gray to gray quartz-pebble conglomerate to quartzite. May contain quartz pebbles up to 1.5 cm. The unit crops out on the west slopes of Ohio Hill between the Barnard mixed gneiss, Sbm, and DSnw, however, the contacts with the adjacent units are unexposed. Bedding is approximately 5 to 15 cm thick.

DSnwl — Siliceous limestone (Silurian-Devonian) -- Rusty weathering, gray siliceous limestone. Occurs as a single outcrop in DSnw. The thickness of the bedding exceeds 0.5 m, but is not accurately known as both contacts with DSnw are not exposed.

Undifferentiated schist and quartzite

DSs — Schist and quartzite (Silurian?-Devonian?) -- Interlayered gray muscovite-quartz schist, green ankeritic quartz-chlorite schist, and rusty-pitted, gray ankeritic quartzite. Layering is generally gradational and ranges in thickness from 5 to 20 cm. The unit crops out locally on the east slopes of Mount Tom between Sbbf and DSnw. Contacts with adjacent units are sharp (<1 m), but not clearly exposed. Unit interpreted as clastic and volcaniclastic sediments deposited unconformably atop Barnard Gneiss and stratigraphically below DSnw.

ROCKS OF THE EASTERN VERMONT SEQUENCE

Rocks East of the Wood Peak Fault

Barnard Gneiss

Sbd — Hornblende metadiorite dike (Silurian) -- Medium-grained, white and black, epidote-plagioclase-quartz-hornblende metadiorite. Dike is 0.5 m wide with a 5 cm wide chill margin, and cuts Oml in a roadcut on Route 4 approximately 0.5 km west of downtown Bridgewater on the south side of Hudson Hill. The dike cuts a relict schistosity (S2) but contains a foliation (S3) and a late cleavage (S4).

Sbbf — Biotite metatrondhjemite gneiss (Silurian) -- Coarse-grained, light-gray biotite-muscovite-quartz-plagioclase gneiss. Contains accessory hornblende, garnet, and magnetite. May be massive, poorly foliated, and well-lineated to moderately-layered, -foliated, and well-lineated. Contacts with Sbhf are gradational by change in mafic mineral content. Contacts with Sbm are generally sharp and interlayered. May contain rare, green, hornblende-chlorite schist segregations.

Sbhf — Hornblende metatrondhjemite gneiss (Silurian) -- Coarse-grained, light-gray hornblende-muscovite-quartz-plagioclase gneiss. Contains accessory biotite, garnet, and magnetite. May be massive and poorly foliated but well-lineated to moderately-layered, -foliated, and well-lineated. Contacts with Sbbf are gradational by change in mafic mineral content. Contacts with Sbm are generally sharp and interlayered. May contain green, hornblende-chlorite schist segregations.

Sbm — Layered metatrondhjemite, amphibolite, and mafic schist (Silurian) -- Interlayered biotite and hornblende metatrondhjemite, garnet-hornblende-plagioclase amphibolite, and ankerite-hornblende-chlorite schist. Layering is generally concordant and locally discordant, and ranges in thickness from 5 cm to 1 m. Sbbf and Sbm intrude Oml as dikes and sills that are discordant with a relict schistosity (S2) and roughly concordant with the dominant schistosity (S3) in the Moretown. No S2 foliation is recognized in the Barnard rocks.

Cram Hill Formation

Och — Rusty schist (Ordovician?) -- Light-gray to gray, slightly rusty weathering, gritty, quartz-rich, biotite-muscovite-quartz schist with small (<1 mm) garnet porphyroblasts, and gray to dark-gray or black, rusty weathering, carbonaceous, biotite-muscovite-quartz schist. Mapped only on the east side of the Barnard Gneiss, along the border of the adjacent Woodstock South quadrangle, approximately 1.5 km north of downtown Bridgewater.

Whetstone Hill Member of the Moretown Formation

Omwhb — Black phyllite (Ordovician?) -- Dark-gray to black, rusty weathering, graphitic quartz-muscovite phyllite to slate. May contain 1 to 3 mm cross-biotite porphyroblasts. Contains interlayered quartzite (Omwhbq). Intercalated with Omwhg.

Omwhbq — Quartzite (Ordovician?) -- Dark blue-gray to black, non-vitreous, gritty quartzite in beds up to 1 m thick. May contain 1 to 3 mm biotite porphyroblasts. Interlayered with Omwhb.

Omwhg — Biotite-garnet phyllite (Ordovician?) -- Light- to dark-gray quartz-muscovite phyllite to schist with 1 to 3 mm cross-biotite porphyroblasts and 1 to 3 mm garnet porphyroblasts that give the foliation surface a bumpy texture. Bed-parallel carbonaceous partings are common. May contain graded beds 2 to 10 cm thick with gray quartz-rich bases grading into phyllitic tops. May contain disarticulated, rusty weathering, siliceous dolostone beds <10 cm thick, and rare ironstone (Fe on map) and coticule (C on map) horizons.

Omgq — Garnet-quartz granofels (Ordovician?) -- Gray, slabby, chlorite-muscovite-biotite-quartz granofels to garnetiferous quartzite with abundant small (<3 mm) garnet porphyroblasts.

Omq — Feldspathic quartzite (Ordovician?) -- Light-gray to tan, in places rusty weathering, chlorite-muscovite-plagioclase-quartz quartzite to quartzose schist. may contain pyrite, chalcopyrite, or magnetite.

Omwhv — Volcanic conglomerate (Ordovician?) -- Light-gray to gray, matrix of garnet-chlorite-biotite-plagioclase-quartz granofels to biotite-plagioclase-quartz granofels and paragneiss with coticule (C on map) that contain segregations and clasts of light-colored, fine-grained to cryptocrystalline quartz and feldspar containing larger quartz and feldspar porphyroclasts, and lesser biotite, muscovite, and garnet. The conglomerate is matrix supported and the clasts are generally rounded, lens-shaped, <5 cm long and 2 cm thick, but in places, up to 15 cm long and 5 cm thick, and elongate parallel to the lineation. The fragments contain no evidence of tectonic grain-size reduction, suggesting that the fine-grained nature of the clasts is primary. May contain amphibole-rich horizons, gray feldspathic quartzite, garnet-quartz granofels horizons similar to Omgq, small (<2 mm) blue quartz grains,and garnet-chlorite-biotite-plagioclase-quartz granofels and schists that are in places well-bedded in layers up to 15 cm thick. Interpreted as volcaniclastic sediments and bedded tuffs.

Omwha — Amphibolite and greenstone (Ordovician?) -- Light- to dark-green, fine- to medium-grained, well-foliated to weakly-foliated ankerite-quartz-chlorite-amphibole-plagioclase amphibolite to biotite-quartz-epidote-amphibole-plagioclase amphibolite, and ankerite-hornblende-quartz-plagioclase-chlorite greenstone that is, in places, well-bedded in layers up to 10 cm thick.

Moretown Formation

Omgt — Garnetiferous schist (Ordovician) -- Gray, in places rusty-weathering, plagioclase-biotite-muscovite-quartz schist with euhedral 3 to 7 mm garnet porphyroblasts. All contacts with Oml and Omgr are gradational, and generally marked by a decrease in size and abundance of garnet porphyroblasts into the adjacent units. In places the schist is well laminated and resembles a garnetiferous version of Oml.

Omb — Black phyllite (Ordovician) -- Dark-gray to black, rusty weathering, graphitic biotite-quartz-muscovite phyllite. May contain black and pink layered, well-rodded coticule (C on map) and ironstone (Fe on map).

Omak — Ankeritic greenstone (Ordovician) -- Green to dark-green, rusty-pitted epidote-amphibole-plagioclase-chlorite greenstone. May contain black to dark-green amphibole porphyroblasts up to 1 cm long. All contacts with Oml, Omgr, and Omgt are generally sharp but in places are gradational by intercalation over a distance of 1 m.

Oml — Laminated pin stripe schist (Ordovician) -- Light-gray to pale-green, laminated muscovite-chlorite-biotite-plagioclase-quartz schist to granofels. Quartzo-feldspathic layers 2 to 5 mm thick are laminated by <1 mm thick micaceous partings, typically with biotite and chlorite streaks on the foliation, which give the rock a pin stripe appearance. Oml is intercalated with Omgr in the southern part of the quadrangle.

Oma — Amphibolite (Ordovician) -- Fine-grained, dark-green to black, epidote-laminated chlorite-amphibole-plagioclase amphibolite. Interlayered with Oml and Omgr.

Omgr — Green phyllite and phyllitic quartzite (Ordovician) -- Green to silvery-green plagioclase-biotite-muscovite-chlorite-quartz phyllite with interlayered pale green phyllitic quartzite to slabby quartzite. Omgr differs from Oml in that it does not contain the spaced laminations, and foliation surfaces in Omgr contain significantly less biotite. Phyllite and quartzite layers are generally 1 to 10 cm thick. The unit crops out in the southern part of the quadrangle where it is intercalated with Oml. Omgr-like rocks crop out elsewhere in the quadrangle within Oml on a scale too small to map. Unit interpreted as a more quartz-rich facies of Oml.

Omgrc — Conglomerate (Ordovician) -- Gray-green muscovite-chlorite-plagioclase-quartz quartz-pebble conglomerate. Subrounded quartz pebbles predominate and do not exceed 1 cm. Occurs as massive layers within Omgr and generally nearby Omak.

Ultramafic Rocks

OZu — Ultramafics (Late Proterozoic to Ordovician) -- Small ultramafic bodies consist of undifferentiated serpentinite and talc-carbonate schist; in addition, the Plymouth Five Corners ultramafic contains both massive, brecciated, dark-green to black serpentinite and chrysotile asbestiform serpentinite, green to light-green actinolite gneiss, and light-gray to salt-and-pepper colored, plagioclase-tourmaline-garnet-sphene-biotite-clinozoisite-quartz gneiss.

Stowe Formation

Ꞓsgt	Garnetiferous schist (Cambrian) -- Silvery-green to gray-green plagioclase-biotite-chlorite-quartz-muscovite schist characterized by large (≤1.5 cm) garnet porphyroblasts. Contains rare, large (≤2 cm) chloritoid (Cd on map) porphyroblasts on the south slopes of Raymond Hill. The contact with Ꞓs is gradational, marked by a decrease in size and abundance of garnet porphyroblasts into Ꞓs.
Ꞓs	Silvery-green schist (Cambrian) -- Fine-grained, silvery-green plagioclase-biotite-chlorite-quartz-muscovite schist to phyllite with abundant quartz-vein segregations, may contain porphyroblasts of magnetite. Rare, 1 m thick, white quartzite (Q on map) crops out on Blueberry Ledges.
Ꞓsa	Amphibolite and greenstone (Cambrian) -- Green to dark-green epidote-amphibole-plagioclase-chlorite greenstone to plagioclase-hornblende amphibolite. Weathered surfaces of Ꞓsa may have a rusty pitted texture due to the weathering of carbonate minerals. May contain porphyroblasts of dark green to black amphibole needles up to 1.5 cm long. Ꞓsa is in contact with both Ꞓs and Ꞓsgt; contacts may be sharp or gradational. Unit interpreted as volcanic and vocaniclastic rocks.

Ottauquechee Formation

Ꞓob	Black phyllite (Cambrian) -- Gray to black, rusty weathering, graphitic biotite-chlorite-muscovite-quartz phyllite and schist. May contain thin quartz-laminations and -vein segregations, and 0.5 to 1 cm pyrite molds. Rare 2 to 3 mm biotite and garnet porphyroblasts.
Ꞓoqb	Black quartzite (Cambrian) -- Dark blue-gray to black, vitreous, laminated quartzite containing irregular white quartz-laminations and cross-cutting veins of white quartz. Forms prominent ridges in less resistant Ꞓob. Ranges in thickness from a few cm to 5 m.
Ꞓoq	Tan quartzite (Cambrian) -- Tan, vitreous to sandy quartzite and rusty-laminated sandy quartzose schist having 1 to 2 cm thick beds. May be calcareous in places.
Ꞓoc	Carbonate-bearing schists (Cambrian) -- A heterogeneous assemblage of rocks consisting of: Gray muscovite-chlorite-quartz-carbonate schist containing

porphyroblasts of carbonate and porphyroblasts of biotite and albite; rusty weathering, silvery light-gray to pale-green quartz-muscovite schist to micaceous quartzite pyrite and chalcopyrite; discontinuous pods of tan weathering, blue-gray to black calcareous quartzite with emerald green chromium-mica partings; white to emerald-green, rusty weathering, mariposite/fuchsite-ankerite/dolomite quartzite, chromium-mica occurs as emerald-green micaceous partings parallel to the dominant foliation, may contain granular, interstitial (<1 mm) pyrite and chalcopyrite; fine-grained greenstone; blue-black quartz-muscovite-chlorite phyllite; and rare, discontinuous, brecciated black dolomite pods <30 cm long and 5 cm thick.

Ꞓog — Gray-green feldspathic cross-biotite schist (Cambrian) -- Light-gray to gray-green, in places rusty-weathering, chlorite-muscovite-plagioclase-quartz schist with 2 to 5 mm cross-biotite porphyroblasts. Ꞓog may contain quartz-vein segregations and thin, black phyllite laminations. Ꞓog contains, and in places is subdivided into, coarse, gneissic, gray biotite albitic granofels and schist (Ꞓogp), green schist with albite porphyroblasts (Ꞓoga), garnet-porphyroblast schist (Ꞓogg), and coticule-bearing schist (Ꞓogc) (C on map).

Ꞓoa — Greenstone and amphibolite (Cambrian) -- Green to dark green epidote-amphibole-plagioclase-chlorite greenstone to gneissic plagioclase-hornblende amphibolite and massive hornblende amphibolite resembling metapyroxenite. Weathered surfaces of Ꞓoa may have a rusty pitted texture due to the weathering of carbonate minerals. May contain porphyroblasts of dark green to black amphibole needles up to 1.5 cm long. Thin, epidote-laminations (<1 mm) and -knots (<1 cm) along the foliation are common. Ꞓoa is in contact with both Ꞓob and Ꞓog-type rocks; contacts commonly are gradational near the borders of the larger bodies. The heterogeneous distribution of the coarse, gneissic metapyroxenite and laminated facies suggest that some of the larger masses may contain mafic olistolith blocks set in feldspathic volcaniclastic detritus.

Pinney Hollow Formation

ꞒZph — Silvery-green schist (Late Proterozoic? to Cambrian) -- Light-green, lustrous, ilmenite-chloritoid-chlorite-quartz-sericite phyllite and quartz-knotted phyllite and fine-grained schist. Magnetite, garnet, and less commonly biotite and albite (without chloritoid) are also present.

ꞒZpha — Amphibolite and greenstone (Late Proterozoic? to Cambrian) -- Dark-green hornblende-epidote amphibolite or lighter-green ankerite-albite-hornblende-chlorite muscovite greenstone, varies from well-bedded to massive, units have interbedded and gradational contacts with enclosing strata. Ankeritic greenstones pass along strike into zones rich in dark-green amphibolite and epidote amphibolite. Interpreted as altered mafic volcaniclastic deposits.

Ꞓzphb — Black schist (Late Proterozoic? to Cambrian) -- Dark-gray to black, sulphidic, finely-foliated, carbonaceous schist spatially associated with amphibolite and greenstone in the upper third of the Pinney Hollow.

Ꞓzphc — Chloritoid-quartz granofels (Late Proterozoic? to Cambrian) -- Dark-gray to steel-blue-gray, massive, chloritoid-quartz granofels to coarse schist.

Parautochthonous Cover Rocks West of the Wood Peak Fault

Tyson Formation

Ꞓtd — Dolostone (Cambrian) -- White- to beige-weathering, massive, well-jointed dolostone, commonly contains suspended, well-rounded, quartz grains as much as 2 mm in diameter, and beds of gray feldspathic and pebbly grit, locally cross-bedded and channelled.

Ꞓtq — Quartzite (Cambrian) -- Gray to tan, massive, highly jointed, vitreous quartzite.

Ꞓtdq — Quartzose dolostone and dolomitic quartzite (Cambrian) -- Interbedded beige, pinkish-gray and light-gray weathering quartzose dolostone and dolomitic quartzite, locally deeply weathered, contains discontinuous beds of vitreous quartzite as much as 5 m thick.

Ꞓtbs — Carbonaceous phyllite (Cambrian) -- Very fine-grained, highly foliated, dark-gray, carbonaceous, lustrous, quartz phyllite containing abundant pyrite; locally contains pods of beige- to orange-gray weathering dolostone as much as 1 m thick.

Ꞓts — Phyllite (Cambrian) -- Gray to greenish-gray magnetite-chlorite-muscovite-quartz phyllite and greenish-gray gritty phyllite.

Ꞓtqc — Phyllitic quartzite (Cambrian) -- Quartzose, phyllitic quartzite and gritty quartzite; laterally replaces Ꞓtc.

Ꞓtc — Conglomerate (Cambrian) -- Conglomerate to white-weathering feldspathic quartzite or gritty quartz schist; locally contains beds of gneiss-cobble or quartz-cobble conglomerate.

Plymouth Formation

Єpfqd	Dolomitic quartzite and dolostone (Cambrian) -- Ferruginous, dolomitic quartzite and dolostone marked by abundant siderite, pyrite, and knots of vein quartz. Unit may be, in part, brecciated and mineralized fault breccia, derived from blocks of more brittle dolostone localized along the Wood Peak fault.
Єpdq	Dolomitic quartzite and carbonaceous dolostone (Cambrian) -- Dark-gray, laminated, thinly bedded, dolomitic quartzite and carbonaceous dolostone in layers 1 to 2 cm thick. Contains pods and thin beds up to 1 m thick of blue-gray dolostone, or mottled, gray and blue-gray dolostone, interbedded within Єpbs.
Єpbd	Dark blue-gray dolostone (Cambrian) -- Dark blue-gray, fine-grained to very fine-grained, dolostone. Occurs as small, isolated pods 1 to 2 m thick and thin beds 1 to 3 cm thick throughout Єpbs or as large masses as much as 10 m or more thick.
Єpbs	Phyllite (Cambrian) -- Dark-gray to sooty-gray-weathering, thinly layered, carbonaceous biotite-muscovite-quartz phyllite to fine-grained schist that contains thin beds of blue-gray quartzite, dolomitic quartzite, and blue-gray ribbon dolostone all in layers 1-5 cm thick. Contains lenses of thinly bedded blue-gray dolostone near base.
Єpwd	Dolostone (Cambrian) -- Light-gray, whitish-gray to pinkish gray, medium-grained, massive dolostone.
Єpdb	Dolomite breccia and conglomerate (Cambrian) -- Blue-gray, mottled, dolomite sedimentary breccia and intraformational conglomerate with disrupted tabular beds of blue-gray or light-gray beds of irregular soft-sediment breccia.
Єpd	Dolostone and dolostone conglomerate (Cambrian) -- Predominantly a medium- to dark-gray, thin-bedded dolostone containing thin zones of intraformational conglomerate as much as 10 cm thick, like Єpbd, but too small to map.
Єpq	Vitreous quartzite (Cambrian) -- Light-tan and blue-gray to gray, vitreous and feldspathic quartzite, occurs as beds within Єpfq at the base of the Plymouth Formation, and closely resembles quartzites in the Dalton Formation of Massachusetts and found in the base of the Hoosac Formation in the Mount Snow area of Vermont (Ratcliffe, 1994).

Ꞓpfd Dolomitic quartzite and ferruginous dolomite (Cambrian) -- Reddish brown to dark gray-brown, deeply weathered, dolomitic quartzite or ferruginous dolomite. Passes laterally or vertically into gray to blue-gray vitreous quartzite (Ꞓpq). Unit interpreted as iron-rich terra rosa developed on disconformity at or near the base of the carbonate section in the Plymouth Formation.

Ꞓpfq Pinstriped quartzite (Cambrian) -- Tannish-gray to medium-gray, well-foliated, feldspathic biotite-muscovite-quartzite and schistose quartzite. Contains a distinctive tectonic-pinstriped structure 0.5 to 1 cm thick. Unit may be, in part, derived from gneiss of the Mount Holly complex by mylonitization, feldspathic quartzite beds closely resemble units near the base of the Dalton Formation of northern Massachusetts and southern Vermont (see Ratcliffe and others, 1993).

Hoosac Formation

ꞒZh Schist (Late Proterozoic? to Cambrian) -- Dark-gray to black, quartz-feldspar knotted schist and phyllonitic schist, and dark-gray to greenish-gray, white-albite spotted, biotite-albite-quartz granofels and schist. Units mapped on Soltudus Mountain are highly deformed and tectonically laminated rocks that may, in part, be mylonitized Mount Holly Complex. Hoosac interfingers with either the Tyson Formation to the south of the quadrangle or with the Plymouth Formation in this quadrangle.

ROCKS OF THE GREEN MOUNTAIN MASSIF AND EASTERN OUTLIERS

Mount Holly Complex

Undifferentiated Rocks

Ymh Undifferentiated gneiss (Middle Proterozoic) -- Dark- to medium-gray, biotite-quartz-plagioclase gneiss and mylonitic gneiss; exposed on Spruce Hill.

Ymg Mixed gneiss (Middle Proterozoic) -- Heterogeneous mixture of biotite-muscovite-microcline-quartz gneiss, biotite-quartz-plagioclase gneiss, and possible granitic gneiss; all highly foliated and mylonitic. Exposed east of Black Pond.

Intrusive and Migmatitic Rocks

Ygg Biotite granite gneiss (Middle Proterozoic) -- Light pinkish-gray, coarse-grained gneissic granite and granodiorite containing phenocrysts of plagioclase mantled by microcline and brown pleochroic biotite.

Yap — Aplite (Middle Proterozoic) -- White, fine-grained plagioclase- or microcline-rich aplite and gneissic aplite especially well-developed near amphibolites or calc-silicate rocks where it pervasively intrudes them; may in part be a metasomatic reaction product of Ygg and other units.

Ymig — Migmatite gneiss (Middle Proterozoic) -- coarse-grained, pinkish-gray, epidote-biotite-plagioclase-quartz-microcline gneiss; massive in outcrop but well-foliated and marked by distinct clots, stringers, and lenses of microcline-rich granite, 1 to 2 cm thick. Interpreted as a metamorphosed and anatectic rock produced by partial melting of a felsic volcanic or intrusive rock.

Yfg — Felsic magnetite gneiss (Middle Proterozoic) -- Pinkish gray-green to white, fine-grained, finely foliated, granular magnetite-plagioclase-microcline-quartz gneiss, locally containing actinolite.

Metasedimentary Rocks

Ybg — Biotite-quartz-plagioclase gneiss (Middle Proterozoic) -- heterogeneous assemblage of biotite- and quartz-rich plagioclase gneisses; commonly dark- to medium-gray, biotite-rich, well-foliated gneiss or schistose gneiss that weathers dull gray. Contains layers of epidote- and quartz-rich gneiss or metaquartzite, amphibolite, and hornblende-biotite-quartz-plagioclase gneiss. Unit contains mappable belts of Ycs and Yq.

Yq — Quartzite (Middle Proterozoic) -- White, vitreous garnet-muscovite quartzite or chlorite-muscovite quartzite.

Ycs — Calc-silicate rocks (Middle Proterozoic) -- Consists of one or more of the following rock types intimately interlayered: light-green coarse-grained diopside rock; dark-gray to black, coarse-grained, knotted, hornblende-diopside rock; and white, vitreous diopside quartzite. May contain interlayered marble, Ym.

Ym — Marble (Middle Proterozoic) -- Tremolite-phlogopite-calcite marble, greenish talc-calcite marble, and calcite marble; all interlayered with Ycs.

Yrs — Rusty aluminous schist (Middle Proterozoic) -- Commonly a lustrous to rusty-brown-weathering, steel-gray to light-yellowish-gray schist, or quartz schist; contains chlorite pseudomorphs after garnet, muscovite, chloritized biotite and/or plagioclase.

Explanation of Map Symbols

Contact accurately located

Contact approximately located

Contact concealed by water

Thrust fault or shear zone accurately located and parallel to regional S3 foliation, interpreted Acadian age, teeth on upper plate

Thrust fault or shear zone approximately located and parallel to regional S3 foliation, interpreted Acadian age, teeth on upper plate, queried where uncertain

Thrust fault or shear zone accurately located and parallel to regional S2 foliation, interpreted Taconian age, teeth on upper plate

Thrust fault or shear zone approximately located and parallel to regional S2 foliation, interpreted Taconian age, teeth on upper plate, queried where uncertain

Pre-metamorphic conjectural thrust fault accurately located, interpreted Taconian age, teeth on upper plate

Pre-metamorphic conjectural thrust fault approximately located, interpreted Taconian age, teeth on upper plate

Shear zone in Proterozoic rocks parallel to regional S2 foliation, interpreted Taconian age

Strike and dip of inclined dikes

Strike and dip of vertical dikes

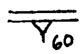
Strike and dip of inclined right-side up bedding

Strike and dip of inclined overturned bedding

Strike and dip of inclined bedding, tops uncertain

Strike and dip of vertical bedding, tops uncertain

Average strike and dip of compositional layering in the Barnard Gneiss (red)

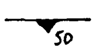


Strike and dip of inclined gneissic layering of Proterozoic age

Strike and dip of vertical gneissic layering of Proterozoic age

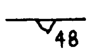
Strike and dip of inclined schistosity parallel to compositional layering

Strike and dip of vertical schistosity parallel to compositional layering

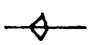


Strike and dip of inclined schistosity in Late Proterozoic through Ordovician rocks and of penetrative retrogressive foliation imposed on Middle Proterozoic rocks, probably Late Ordovician (Taconian, S2)

Strike and dip of vertical schistosity in Late Proterozoic through Ordovician rocks and of penetrative retrogressive foliation imposed on Middle Proterozoic rocks, probably Late Ordovician (Taconian, S2)

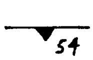


Strike and dip of inclined dominant schistosity in Late Proterozoic through Ordovician rocks, may represent a composite foliation of at least two or more foliations or a single foliation without any recognizable older foliations



Strike and dip of vertical dominant schistosity in Late Proterozoic through Ordovician rocks, may represent a composite foliation of at least two or more foliations or a single foliation without any recognizable older foliations

Generalized strike and dip of highly plicated schistosity or gneissosity, may be annotated with S2 where known

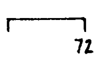


Strike and dip of inclined schistosity in Cambrian through Ordovician rocks that transposes an older S2 schistosity, or in Ordovician through Devonian rocks where no S2 is recognized, probably Devonian (Acadian, S3) (red)

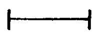
Strike and dip of vertical schistosity in Cambrian through Ordovician rocks that transposes an older S2 schistosity, or in Ordovician through Devonian rocks where no S2 is recognized, probably Devonian (Acadian, S3) (red)

Strike and dip of inclined crenulation cleavage in Proterozoic through Ordovician rocks that cuts an older S2 schistosity, or in Ordovician through Devonian rocks where no S2 is recognized, probably Devonian (Acadian, S3) (red)

Strike and dip of vertical crenulation cleavage in Proterozoic through Ordovician rocks that cuts an older S2 schistosity, or in Ordovician through Devonian rocks where no S2 is recognized, probably Devonian (Acadian, S3) (red)

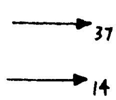


Strike and dip of inclined spaced to crenulation cleavage in Late Proterozoic through Devonian rocks that cuts older foliations, intersection with older foliations is parallel to a north-trending shallow plunging mineral lineation, probably Devonian (Acadian, S4) (red)

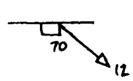


Strike and dip of vertical spaced to crenulation cleavage in Late Proterozoic through Devonian rocks that cuts older foliations, intersection with older foliations is parallel to a north-trending shallow plunging mineral lineation, probably Devonian (Acadian, S4) (red)

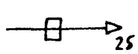
Strike and dip of inclined spaced to crenulation cleavage in Ordovician through Devonian rocks that cuts older foliations, probably Devonian (Acadian, S5) (red)



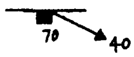
Trend and plunge of mineral lineations comprised of chlorite (CH), biotite (BI), and hornblende (HB), and grain cluster lineations such as quartz rods, may be combined with foliation symbols, where combined with S2 the lineation is believed to be Taconian, where combined with the dominant schistosity symbol the age is uncertain, where shown in red the lineation is believed to be Acadian



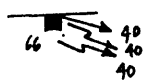
Strike and dip of inclined axial surface of minor fold of Middle Proterozoic age, arrow shows trend and plunge of hinge line of fold

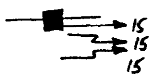


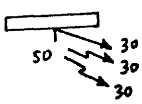
Strike and dip of vertical axial surface of minor fold of Middle Proterozoic age, arrow shows trend and plunge of hinge line of fold

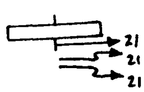

Strike and dip of inclined axial surface of minor F2 fold, arrow shows trend and plunge of hinge line of fold

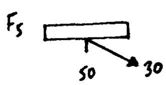

Strike and dip of vertical axial surface of minor F2 fold, arrow shows trend and plunge of hinge line of fold

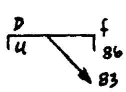

Strike and dip of inclined axial surface of minor F3 fold, arrow shows trend and plunge of hinge line of fold, may also show rotation sense (red)

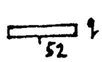

Strike and dip of vertical axial surface of minor F3 fold, arrow shows trend and plunge of hinge line of fold, may also show rotation sense (red)


Strike and dip of inclined axial surface of minor F4 fold, arrow shows trend and plunge of hinge line of fold, may also show rotation sense (red)


Strike and dip of vertical axial surface of minor F4 fold, arrow shows trend and plunge of hinge line of fold, may also show rotation sense (red)


Strike and dip of inclined axial surface of minor F5 fold, arrow shows trend and plunge of hinge line of fold (red)


Strike and dip of outcrop-scale brittle fault or fracture, arrow shows trend and plunge of slickenlines where present, vertical relative motion indicated by U=up and D=down


Strike and dip of inclined quartz vein


Strike and dip of vertical quartz vein


Approximate location of abandoned mine shaft, mine adit, prospect pit, or quarry