The Prospect Rock thrust: western limit of the Taconian accretionary prism in the northern Green Mountain anticlinorium, Vermont

Peter J. Thompson and Thelma B. Thompson

Abstract: This paper presents evidence for an early Taconian, west-directed fault in northern Vermont, the Prospect Rock thrust, which represents the trace of the contact between the Taconian oceanic accretionary prism (Dunnage Zone) and less allochthonous, continental margin rocks (Humber Zone). Mapping at 1 : 24 000 over the last decade has led to reassessment of units within the Camels Hump Group, resulting in newly defined lithotectonic packages: the Green Mountain slice and the Prospect Rock slice. Rocks in these slices may be of similar age, but those in the Green Mountain slice were originally deposited as more proximal sediments and remained on the Humber side of the subduction zone, whereas those in the Prospect Rock slice were transferred by underplating to the accretionary prism. Both slices contain ultramafics. Motion on the Prospect Rock thrust (D_1) preceded Taconian garnet-grade metamorphism and subsequent east-directed back-folding. However, D_1 structures were diachronous across the orogen. Late Taconian (D_2) structures record a change from east-verging back-folds in northern Vermont and southern Quebec to west-verging folds farther south. The Prospect Rock thrust does not correspond exactly to Cameron's line nor to the Baie Verte – Brompton line as originally defined. However, our understanding of the geometry of the Prospect Rock thrust demonstrates that the Dunnage Zone extends farther west than previously recognized and may also explain features farther to the east.

Résumé : Cet article présente des évidences pour une faille (Taconien précoce) de direction ouest dans le nord du Vermont, le chevauchement Prospect Rock, qui représente la trace du contact entre le prisme d'accrétion océanique taconien, (Zone du Dunnage) et les roches continentales de la bordure, moins allochtones (Zone de Humber). Une cartographie à l'échelle de 1 : 24 000 au cours de la dernière décennie a conduit à une réévaluation des unités du Groupe de Camels Hump, donnant des ensembles lithotectoniques nouvellement définis : la tranche de Green Mountain et la tranche de Prospect Rock. Les roches dans ces tranches peuvent avoir des âges similaires mais celles de la tranche de Green Mountain ont été déposés à l'origine en tant que sédiments plus proximaux et sont demeurés du côté Humber de la zone de subduction, alors que les roches dans la tranche de Prospect Rock ont été transférées par du sous-placage au prisme d'accrétion. Les deux tranches contiennent des ultramafiques. Du mouvement sur le chevauchement de Prospect Rock (D_1) a précédé le métamorphisme taconien, au faciès des grenats, et le subséquent plissement en retour, dirigé vers l'est. Toutefois, les structures D_1 étaient diachroniques durant tout l'orogenèse. Les structures (D_2) du Taconien tardif enregistrent un changement de plis en retour à déversement est dans le nord du Vermont et le sud du Québec à des plis à déversement ouest plus au sud. Le chevauchement de Prospect Rock ne correspond pas exactement à la ligne de Cameron ni à la ligne Baie Verte – Brompton telles que définies à l'origine. Toutefois, notre compréhension de la géométrie du chevauchement de Prospect Rock démontre que la Zone de Dunnage s'étend plus à l'ouest que reconnu antérieurement et peut aussi expliquer des reliefs situés plus à l'est.

[Traduit par la Rédaction]

Introduction

The purpose of this paper is to summarize the results and implications of recent mapping at a scale of 1 : 24 000 along the crest of the Green Mountain anticlinorium in northern Vermont. Starting in the 1970s, detailed mapping along the entire Green Mountain anticlinorium led to recognition of numerous faults, some predating the anticlinorium and others coeval or younger. Earlier mapping in the region, as summarized on the Centennial Geologic Map of Vermont (Doll et al. 1961), had not interpreted any contacts as faults. The map units were portrayed as an upwards topping sequence that became successively younger from the Camels Hump Group up into Ottauquechee, Stowe, and Moretown formations on the east and into Cheshire Quartzite and shelf carbonate rocks on the west. In a major departure from this view, Stanley and Ratcliffe (1985) proposed that a regionally important thrust fault within the Camels Hump Group had

Received 23 January 2002. Accepted 29 November 2002. Published on the NRC Research Press Web site at http://cjes.nrc.ca on 25 February 2003.

Paper handled by Associate Editor S. Hanmer.

P.J. Thompson.[1] James Hall, Earth Sciences Department, University of New Hampshire, Durham, NH, 03824, U.S.A.
T.B. Thompson. Dimond Library, University of New Hampshire, Durham, NH, 03824, U.S.A.

[1]Corresponding author (e-mail: pjt3@cisunix.unh.edu).

 doi: 10.1139/E02-109

transported rocks of an accretionary prism westward onto the Laurentian margin during the Taconian orogeny. Stanley and Ratcliffe designated the contact between the Hazens Notch and Underhill formations from Doll et al. (1961) as the base of the accretionary prism and referred to the rocks above the contact as the "Hazens Notch slice" (HNS in Fig. 1). The Hazens Notch – Underhill contact has been cited as a major boundary in numerous papers published since 1985 (e.g., Pinet and Tremblay 1995; Coish 1997; van Staal et al. 1998).

Our mapping shows that the Hazens Notch – Underhill contact follows a much more complicated pattern than that of Doll et al. (1961), due to repeated phases of folding and faulting. The contact itself is not marked by a fault in all places. We propose that the Hazens Notch slice ought to include some of the rocks formerly mapped as Underhill, and be renamed the Green Mountain slice (compare Figs. 1 and 2). Furthermore, we recognize a second regionally important fault, the Prospect Rock thrust, whereby rocks that correlate with Ottauquechee and Stowe formations lie in a thrust sheet above the Green Mountain slice (Fig. 2). We include the following units from Doll et al. (1961) in the overlying Prospect Rock slice: the Jay Peak and Foot Brook members of the Underhill Formation, the isolated area of Ottauquechee Formation south of Jay Peak, and some rocks formerly shown as Hazens Notch Formation.

In a concluding section, we will discuss what these slices may represent in the accretionary wedge model, relationships to Cameron's Line, the Baie Verte – Brompton Line and other regionally important faults, and possible applications of our model to structures east of these features. Leading up to that discussion we will present stratigraphic problems and criteria for the revised mapping, describe structures with emphasis on the geometry of the Prospect Rock thrust itself, and summarize evidence for relative timing of deformation and metamorphism in the northern Green Mountains.

Discussion of stratigraphy

Introduction

Recognition of the Prospect Rock thrust resulted from a fresh look at how map units had been defined in northern Vermont. Two stratigraphic problems confront the geologist who maps in the northern Green Mountains: little fossil control exists, and the differences among many map units are subtle and to a large extent reflect minor differences in sedimentary facies. Many formations contain lenses and layers nearly identical to lithologies present in other formations. Assignment of ambiguous rocks to particular units often involves recognition of their consistent association with other lithologies. A comparison between Fig. 3, based on mapping at 1 : 62 500 and Fig. 4*a*, based on more recent work at 1 : 24 000, demonstrates that applying more narrow criteria for defining units and no longer being constrained by an unfaulted stratigraphic model, has produced a very different map pattern. We reject as too simplistic the suggestion by Stanley et al. (1987) that green units (Underhill, Pinney Hollow, and Stowe formations) once formed a continuous depositional layer beneath the dominantly black units (Hazens Notch and Ottauquechee formations) and that map patterns between black and green units can all be explained structurally. Black slates in the Taconic allochthons, where fossil control is well established, are not consistently younger than green slates (Landing 2002). In northern Vermont, black layers and lenses do occur within green units, and vice versa. Alternating green and black rock units occur both above and below the Prospect Rock thrust (Fig. 4*b*). In rocks that have been subjected to intense tectonic imbrication, it may be impossible to distinguish between original depositional facies changes and tectonic mixing.

The relationships among units in the Camels Hump Group have been informally revised as mapping has progressed during the last few decades. Formal revision is beyond the scope of this paper and only the most pertinent changes are presented here, summarized in the following paragraphs. Doll et al. (1961) showed a fairly simple contact in northern Vermont between dominantly green Underhill Formation and dominantly black Hazens Notch Formation, based on mapping at 1 : 62 500 by numerous geologists (especially Albee 1957; Christman 1959; Christman and Secor 1961; Cady et al. 1962; Cady et al. 1963). Geologists mapping at 1 : 24 000 (e.g., O'Loughlin and Stanley 1986; Thompson and Thompson 1992; and Walsh 1992) found a much more complex pattern between green and black rocks from the Winooski River area south to Lincoln Mountain. Walsh (1992) informally introduced the Fayston formation as a new unit to include albitic silver-green rocks, regardless of whether they had previously been mapped as part of the Underhill or Hazens Notch formations. We have accepted this scheme in our more recent mapping (Thompson and Thompson 1998, 1999) and in the present paper.

The name Underhill Formation is herein restricted to the less albitic schists associated with metagraywackes and greenstones, mostly lying west of areas dominated by Hazens Notch Formation and Fayston formation, in the Underhill slice of Stanley and Ratcliffe (1985). The Underhill Formation and the associated Pinnacle Formation (Fig. 5) represent late Proterozoic to Early Cambrian rift- basin clastic deposits. Thin, discontinuous graphitic schist horizons containing quartzites and metamorphosed dolostone beds lie disconformably above the Underhill Formation. Middle Ordovician conodonts were recently recovered from these dolostones at two sites west of the Green Mountains and from one site within a window along the Winooski River (Thompson et al. 2002; solid triangles in Fig. 2). The conodonts are within the same age range as those previously reported at Melbourne, Quebec (M in Fig. 2) (Marquis and Nowlan 1991) and at West Bridgewater, Vermont, 40 km south of Fig. 2 (Ratcliffe et al. 1999). The Underhill Formation and the unnamed graphitic unit continue north into Quebec along the west side of the Monts Sutton anticlinorium and correlate directly to Mansville Complex units MN7 and MN8, respectively, (Fig. 5) (Colpron et al. 1994). This belt of graphitic rocks in the past has been variously assigned to the Hazens Notch Formation (Christman and Secor 1961, p. 42), carbonaceous member of the Underhill Formation (Doll et al. 1961), the White Brook Member of the Underhill Formation and Sweetsburg Formation (Dennis 1964), and the Sweetsburg Formation (Richford-Valcourt syncline of Osberg 1965).

Stratigraphy in the Green Mountain slice

Rocks below the Prospect Rock thrust are dominantly albitic

Fig. 1. Lithotectonic packages in northwestern Vermont and adjacent Quebec, after Stanley and Ratcliffe (1985), Slivitsky and St. Julien (1987), and Doll et al. (1961). Faults labeled on upper plate. Lithotectonic packages (legend boxes arranged from west to east): 1, Grenville basement; 2, Cambrian–Ordovician shelf; 3, Champlain slice; 4, Quebec allochthons; 5, Hinesburg (Oak Hill Group) and Underhill slices; 6, Hazens Notch slice; 7, Rowe slice; 8, ultramafics; 9, Moretown–Ascot arc-related rocks; 10, Late Ordovician flysch; 11, Silurian–Devonian rocks. BBL, Baie Verte-Brompton line; BMT, Belvidere Mountain thrust; BU, Burlington; CT, Champlain thrust; Ꞓufb, Underhill Formation, Foot Brook Member; Ꞓuj, Underhill Formation, Jay Peak Member; GMA, Green Mountain anticlinorium; HNS, Hazens Notch slice; HT, Hinesburg thrust; J, Jeffersonville; JP, Jay Peak; MSA, Monts Sutton anticlinorium; MT, Montpelier; R, Richmond; RS, Rowe slice; UT, Underhill thrust.

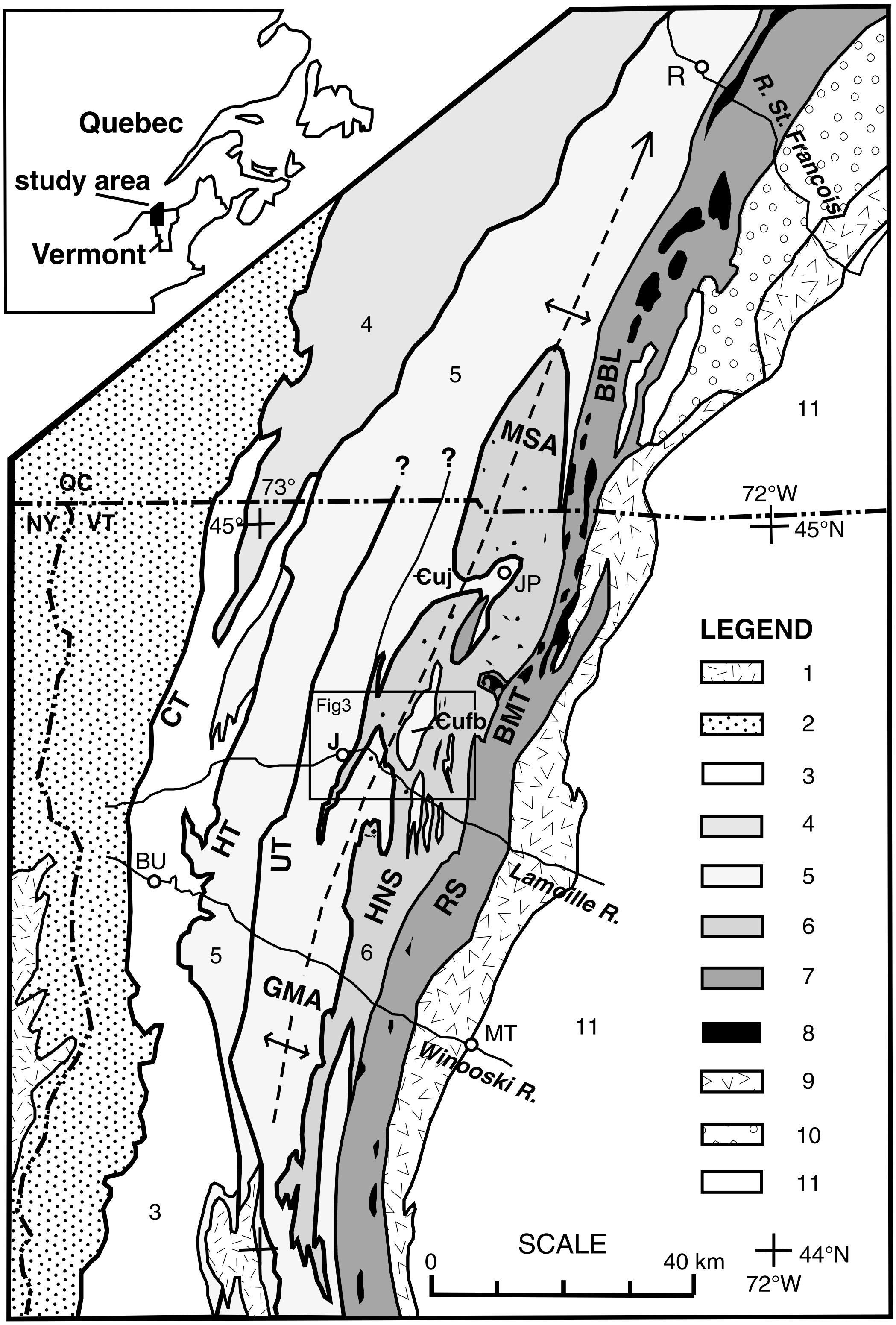
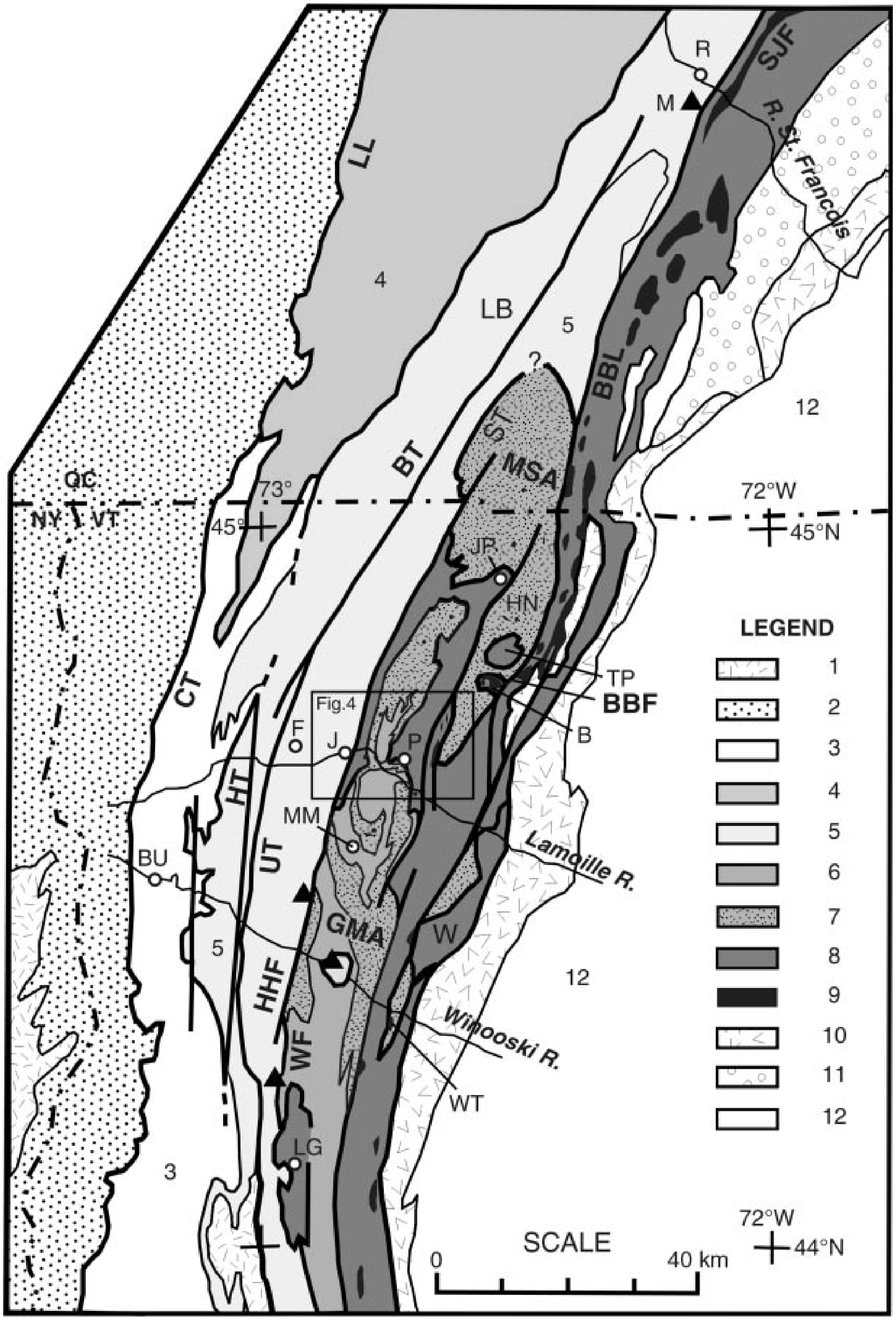


Fig. 2. Same area as Fig. 1 with lithotectonic packages presented in this paper. Geology after Thompson et al. (1999), Kim et al. (1999), Thompson and Thompson (1998), Colpron et al. (1994), Stanley et al. (1987), Slivitsky and St. Julien (1987), and Doll et al. (1961). Faults labeled on upper plate. Lithotectonic packages 1–5 same as for Fig. 1; 6, Green Mountain slice (Fayston and Pinney Hollow formations); 7, Green Mountain slice (Hazens Notch Formation and Sutton Schist); 8, Prospect Rock slice and related slices; 9, ultramafics; 10, Moretown–Ascot arc-related rocks; 11, Late Ordovician flysch; 12, Silurian–Devonian rocks. Abbreviations as in Fig. 1; also B, Belvidere Complex; BBF, Burgess Branch fault; BT, Brome thrust; F, Fletcher; HHF, Honey Hollow fault; HN, Hazens Notch; LB, Lac Brome; LG, Lincoln Gap; LL, Logan's line; M, Melbourne; MM, Mount Mansfield; P, Prospect Rock; SJF, St. Joseph fault; ST, Sutton thrust; TP, Tillotson Peak; W, Worcester Complex; WF Western Front fault zone; WT, Waterbury talc. Symbol: solid triangle, conodont localities.



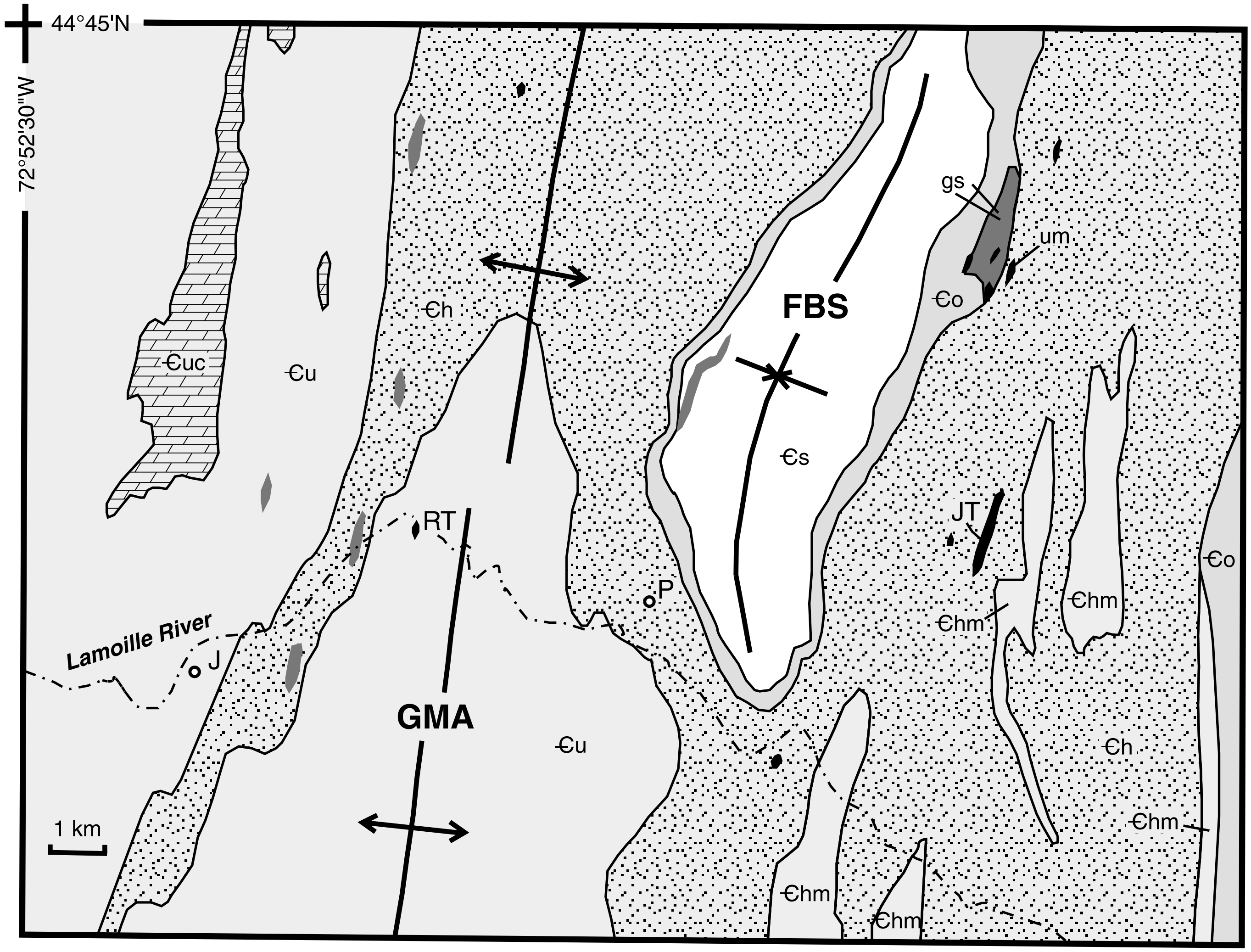
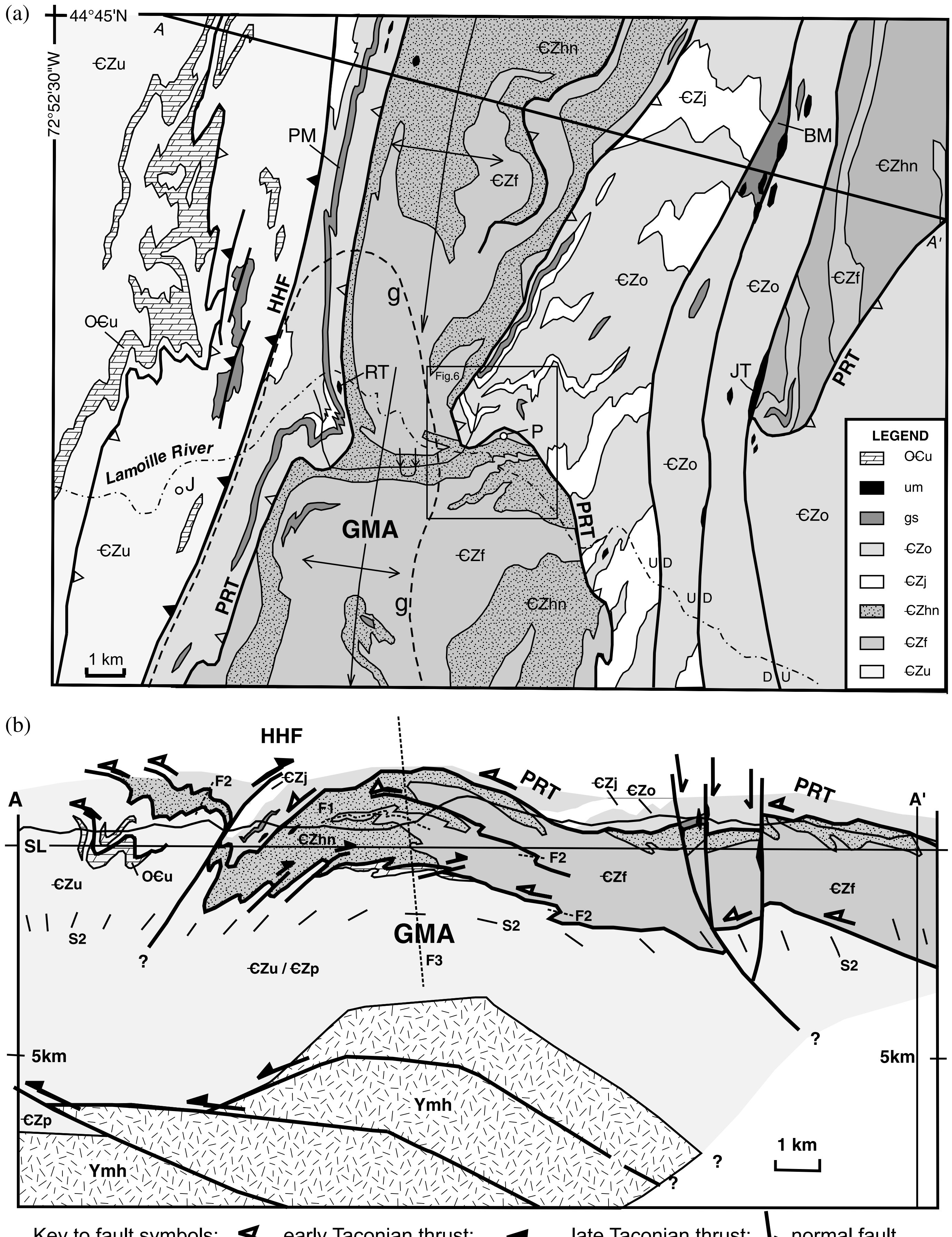


Fig. 3. Geologic map across the Green Mountain anticlinorium at the latitude of the Lamoille River, after Doll et al. (1961), Christman (1959), and Albee (1957). Rock units: Ꞓu, Underhill Formation.; Ꞓuc, Underhill Formation carbonaceous member with dolostones; Ꞓh, Hazens Notch Formation; Ꞓhm, Hazens Notch Formation, magnetite schist member; Ꞓo, Ottauquechee Formation; Ꞓs, Stowe Formation; gs, greenstones; um, ultramafics. FBS, Foot Brook syncline; GMA, Green Mountain anticlinorium; J, Jeffersonville; JT, Johnson talc mine; P, Prospect Rock; RT, Rousseau talc mine.

schists, subdivided into non-graphitic Fayston formation and graphitic Hazens Notch Formation, as described in the following text. In our view, they are metamorphosed rift clastics and slope-rise deposits ranging in age from Late Proterozoic to Cambrian, spanning the rift–drift transition. Faults occur between the two units in many places, as well as within each unit, but elsewhere they are in depositional contact. Therefore, we place both units in a single thrust slice, the Green Mountain slice, rather than using Stanley and Ratcliffe's (1985) term "Hazens Notch slice," which implies a slice containing only one formation.

The Fayston formation includes silver-green to gray schist with white to gray albite porphyroblasts, with or without magnetite and garnet, and discontinuous white quartzite beds and rare greenstone layers. Some garnet-bearing horizons are lustrous silver-green, without albite, much like the Pinney Hollow Formation. The Hazens Notch Formation includes rusty weathering, gray to black graphitic schist with white to black albites, with or without chlorite, garnet, and pyrite. It, too, contains discontinuous quartzites, ranging from white to black in color, and greenstones, but unlike the Fayston formation, it also contains serpentinized ultramafic and talc–carbonate bodies. These ultramafics occur only locally south of the Lamoille River, but become more common toward the north and east (Fig. 2).

On the basis of lithic similarity the Hazens Notch and Fayston formations correlate with Sutton Schist units SS4 and SS6, respectively (Fig. 5) (Colpron et al. 1994). The Hazens Notch Formation maps directly into SS4 across the international border. The Hazens Notch and Fayston formations together correlate in part with the Sutton Metamorphic Suite of Brodeur and Marquis (1995) and with Rickard's (1991) Sallys Pond and Mohawk Lake formations, although Rickard's units were not defined according to presence or absence of graphite. Overall, greenstones in the Green Mountain slice contain less titanium than rift metavolcanics in the Tibbit Hill Volcanics, Pinnacle Formation, and Underhill Formation (Coish 1997; Thompson and Thompson 1992). Colpron et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Ymh
5km
1 km
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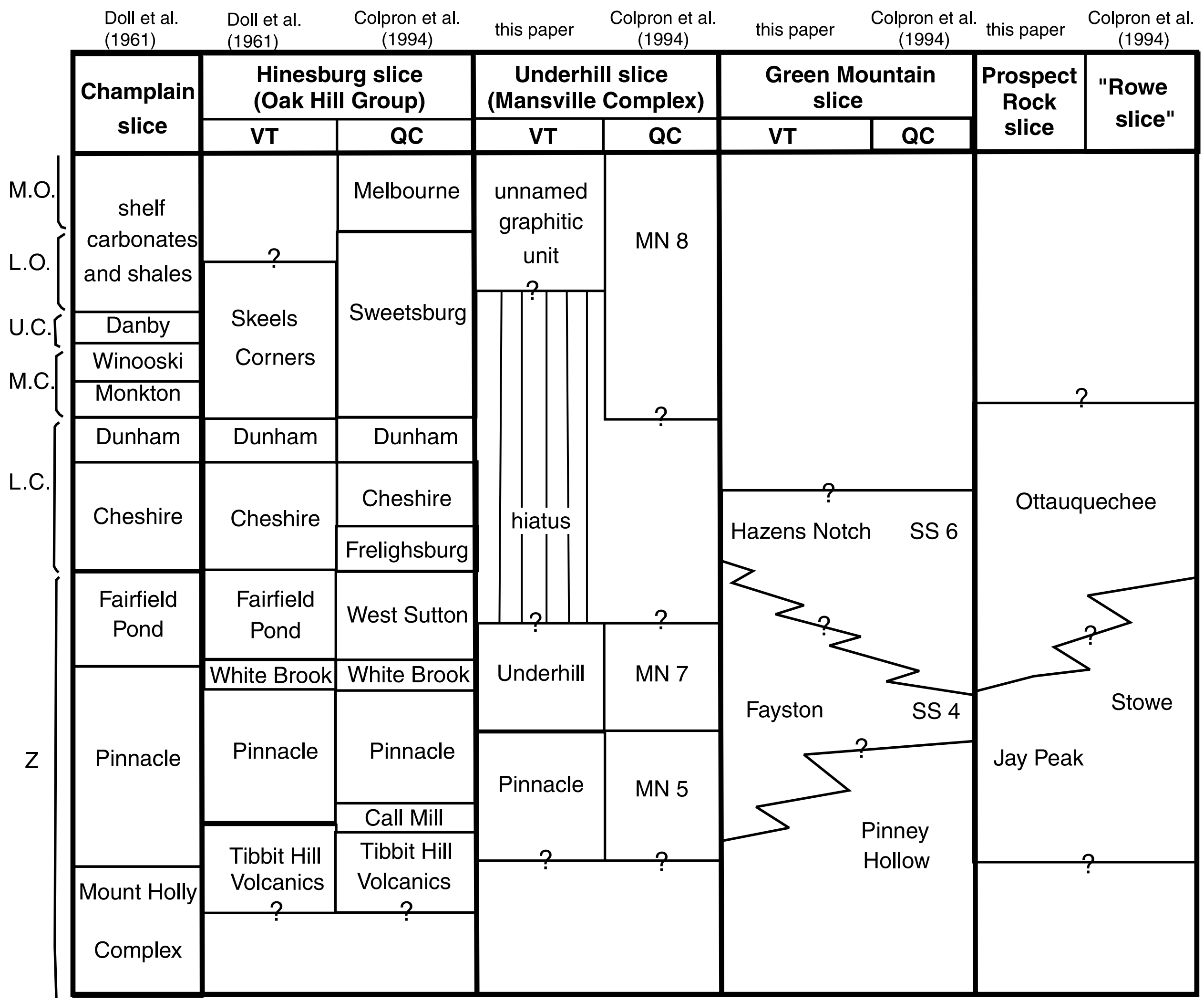
Key to fault symbols: early Taconian thrust; late Taconian thrust; normal fault

Fig. 4. (*a*) Same area as Fig. 3, adapted from Thompson et al. (1999) and Mock (1989). Rock units (legend not necessarily in stratigraphic order): OCu, unnamed graphitic schist with dolostones; um, ultramafics; gs, greenstones; ꞓZo, Ottauquechee Formation; ꞓZj, Jay Peak Formation; ꞓZhn, Hazens Notch Formation; ꞓZf, Fayston formation; ꞓZu, Underhill Formation. BM, Bowen Mountain greenstone; GMA, Green Mountain anticlinorium; HHF, Honey Hollow fault; J, Jeffersonville; JT, Johnson talc mine; P, Prospect Rock; PM, Peaked Mountain greenstone; PRT, Prospect Rock thrust; RT, Rousseau talc mine; g, garnet isograd. Structural Symbols: Open teeth, early Taconian thrust; solid teeth, late Taconian thrust; U/D, normal fault. (*b*) Cross-section A–A′, no vertical exaggeration. Rock units as in (*a*); also Ymh, Mount Holly Complex; ꞓZp, Pinnacle Formation. Abbreviations as in (*a*); also F_1 early Taconian folds; F_2 late Taconian folds; F_3 Acadian fold (axial traces shown as dashed lines); S_2 dominant foliation (short solid lines).

Fig. 5. Correlation chart for rock units in lithotectonic packages of northwestern Vermont and adjacent Quebec. Z, Late Proterozoic; L.C., M.C., and U.C, Lower, Middle, and Upper Cambrian, respectively; L.O. and M.O., Lower and Middle Ordovician, respectively.



al. (1994) found that greenstones in their Sutton Schist unit SS4 are depleted in light rare-earth elements compared with the Tibbit Hill Volcanics, and concluded that they were associated with late stages of Iapetan rifting.

Stratigraphy in the Prospect Rock slice

Turning now to rocks above the Green Mountain slice, rocks in the Prospect Rock slice are mostly non-albitic, fine-grained schists and phyllites. Whether the lack of albite is entirely due to differences in bulk composition or in part due to differences in metamorphic history is an important, as yet unresolved, question, discussed more fully in the section on metamorphism. Two units have been mapped in the Prospect Rock slice, the largely graphitic Ottauquechee Formation, and the gray-green Jay Peak Formation. Before describing the rocks in detail, it will be helpful to review the history of mapping in the Foot Brook area of the Hyde Park 15′ quadrangle.

Albee (1957), noting the similarity of rocks along Foot Brook (north and east of Prospect Rock, P in Figs. 3, 4*a*) to the Ottauquechee and Stowe formations, interpreted them as a synclinal outlier of those units surrounded by rocks of the Camels Hump Group. Doll et al. (1961) retained the synclinal structure but unfortunately assigned the two lithologies to units within the Camels Hump Group: the gray-green Stowe-like phyllites became Foot Brook Member of the Underhill Formation, and the black Ottauquechee-like phyllites became part of the Hazens Notch Formation. Identical black phyllite and quartzite 5–15 km farther north, however, were shown by Doll et al. (1961) as Ottauquechee Formation overlying the Stowe-like Jay Peak Member of the Underhill Formation (Fig. 1).

In mapping the Johnson 7.5′ quadrangle, which is the northwestern quarter of the Hyde Park quadrangle, Thompson and Thompson (1998) found that stratigraphic symmetry does not exist across Albee's (1957) Foot Brook syncline (compare Fig. 3 and Fig. 4*a*). Rather, the gray- green and black units are interlayered and (or) interfolded in a pattern truncated by faults (Fig. 4*a*). The western edge of the "syncline" is a fault, the Prospect Rock thrust, which has been folded. The eastern side is truncated by a steep, unfolded normal fault. East of the normal fault, rocks identical to the Ottauquechee Formation continue, passing south of the Johnson talc mine (JT in Fig. 4*a*) and thence east to the rocks originally mapped by Albee as Ottauquechee Formation (Fig. 3). Albee's Ottauquechee Formation continues southward 130 km to the type locality at Plymouth, Vermont. We see no distinction between what Albee mapped as fine-grained Hazens Notch Formation and the Ottauquechee Formation. Albee's magnetite schist member of the Hazens Notch Formation (Fig. 3) is similar to gray-green rocks at Jay Peak and in the Stowe Formation. The coarse albitic schists northeast of the Johnson talc mine are continuous with the type locality of the Hazens Notch Formation (HN in Fig. 2). By excluding fine-grained graphitic rocks from the Hazens Notch Formation, we have expanded the area underlain by the Ottauquechee Formation in northern Vermont. Osberg (1969) suggested that the Hazens Notch and Ottauquechee formations are one and the same. We agree that they were both deposited as slope-rise sediments in the same basin, but consider the Ottauquechee Formation to be a more distal facies that experienced a different tectonic history. Because the two can be distinguished as mappable units, we argue for retaining both names.

The Ottauquechee Formation consists of rusty-weathering, gray to black graphitic, quartzose phyllite and schist with local layers and lenses of non-graphitic, gray-green phyllite. Discontinuous quartzite beds are present, much like those in the Hazens Notch Formation, ranging from a few centimetres to almost 1 m thick. Layers of gray to green phyllitic granofels occur locally, and sparse detrital blue quartz pebbles may indicate a Laurentian source of sediment (Doolan et al. 1982; Stanley et al. 1987). Serpentinized ultramafic bodies and talc–carbonate schist are common within the Ottauquechee Formation and along its contacts with other units in the area of Fig. 4*a*.

Greenstones occur within the Ottauquechee Formation at several locations in the study area. Near Bowen Mountain (BM in Fig. 4*a*) a pale-green, actinolitic greenstone associated with talc schist has a rare-earth element (REE) pattern similar to that of mid-ocean ridge basalt (Kim et al. 2001). The Peaked Mountain greenstone (PM in Fig. 4*a*), a compositionally layered, 20 km-long body on the west side of the Green Mountain anticlinorium is an enigma. Over a third of its length, this greenstone appears to be concordant within graphitic phyllites; a quartzite bed is exposed parallel to it (Thompson 1975). However, toward both the north and south, the greenstone is also in contact with gray-green phyllite more typical of the Jay Peak Formation (described later in the text). The greenstone's REE pattern resembles that of enriched rift volcanics, yet ultramafic bodies occur less than 500 m away (e.g., the Rousseau talc mine, RT in Fig. 4*a*). The compositional layering suggests an origin as a water-laid tuff, perhaps from some distance away. Yet if that is the case, why is the greenstone found in different host rocks from place to place? A similar greenstone, which we interpret as the same layer, is exposed along the east side of the anticlinorium, north of Prospect Rock, and cut by the Prospect Rock thrust (Fig. 4*a*). North of the area of Fig. 4*a*, on the west side of the anticlinorium, the Peaked Mountain greenstone is also cut out by faults so that it does not reach the international border; greenstones within the Sutton Schist north of the border (SS1 of Colpron et al. 1994) should not be correlated with the Peaked Mountain greenstone.

The Ottauquechee Formation continues north along the east side of the Green Mountain slice into Quebec (Fig. 2). Brodeur and Marquis (1995) show it continuing north and northeast, in fault contact with the Sutton Schist, but not connecting directly to the Sweetsburg Formation as described by Osberg (1956). Many geologists (Stanley et al. 1987; Rickard 1991; Rose 1993; Doolan et al. 2001) have assumed a direct connection on the ground between Sweetsburg and Ottauquechee formations, a conclusion we think needs further investigation. The age of the Ottauquechee Formation is poorly constrained, and whether or not it was deposited directly on oceanic crust cannot be proven. It may have been deposited over a very long time, coeval in part with the Hazens Notch Formation, and possibly ranging upwards as distal equivalents to the Sweetsburg Formation (Fig. 5). The Ottauquechee Formation may correlate in part with lithically identical rocks in the Rosaire Group of Quebec.

The Jay Peak Formation (Cady et al. 1963; Jay Peak Member of the Underhill Formation, Doll et al. 1961) includes pearly gray-green to blue-black, muscovite– chlorite–quartz phyllite and schist, with or without magnetite, garnet, chloritoid, and albite; quartzose pale-green phyllite and schist; white quartzite; and rare greenstone. Except for the paucity of greenstones, it is very similar to the Stowe Formation. Cady et al. (1963) remarked that the Jay Peak Formation resembles the non-graphitic zones within the Hazens Notch Formation in the eastern parts of the Hyde Park quadrangle. We have reassigned those zones to the Jay Peak Formation, and the associated graphitic rocks to the Ottauquechee Formation. The Jay Peak and Ottauquechee formations both lack carbonates, except for a few lenses of coarse-grained, white calcite marble associated with greenstones and rare, thin dolomitic quartzites. We have arbitrarily chosen to include within the Ottauquechee Formation, rather than the Jay Peak Formation, rocks where black and green phyllite are interbedded and cannot be mapped out separately. Although the original depositional distribution of black and green sediments may have been patchy, foliated talcose surfaces and dismembered quartzites in many exposures indicate a tectonic mixing of lithologies. A similar situation prevails in rocks mapped as the Lowell Mountain member of the Stowe Formation, some 20 km to the east (Kim et al. 1999). Because of its close association with Ottauquechee Formation, we correlate Jay Peak Formation with the Stowe Formation rather than with the Underhill Formation. The Jay Peak and Ottauquechee formations may correlate with the lustrous, gray-green Mount Abraham Schist and black carbonaceous schist at Lincoln Gap (O'Loughlin and Stanley 1986), interpreted by them as a klippe along the crest of the anticlinorium 60 km south of the Lamoille River (Fig. 2). Rickard (1991) suggested that his albitic Bolton Glen Formation in the Monts Sutton, Quebec, might correlate with the Jay Peak Formation, but Colpron et al. (1994) have mapped those rocks as SS6, equivalent to our Fayston formation.

Discussion of structures

Introduction

Rocks in the northern Green Mountain anticlinorium have undergone at least three phases of deformation. Briefly, these phases reflect the following tectonic history, to be expanded upon in the final section. D_1 folds and thrusts developed over an extended time, first as the accretionary prism grew by underplating along an east-dipping subduction zone far from the Laurentian margin and eventually as this prism overrode the thicker clastic apron along the margin. As deeper thrusts encountered basement at the Laurentian margin, D_2 folds and thrusts developed at higher levels in the orogen and, in northern Vermont, splayed out into back- folds and back thrusts. D_3 folds deformed all the older structures as the Green Mountain anticlinorium developed in response to collision of the volcanic arc against the accretionary prism, and normal faults followed in a period of post-collisional relaxation. We will start our discussion with a detailed look at the Prospect Rock area and from there proceed to the larger picture.

Structures in the Prospect Rock area

The Prospect Rock thrust was initially identified by mapping truncations of units in both upper and lower plates near Prospect Rock (P in Figs. 2, 6), a prominent cliff overlooking the Lamoille River valley east of Jeffersonville, Vermont (Thompson 1998). Phyllites of the Ottauquechee and Jay Peak formations overlie the coarse, albitic schists of the Hazens Notch and Fayston formations, except in the overturned short limb of a D_2 fold west of Prospect Rock itself, where the albitic rocks lie on top of the phyllites. It is critical to understand the geometry of the folded Prospect Rock fault before observing its relationship to the Green Mountain anticlinorium. We have marked the axial traces of selected folds on Fig. 6. Note that some repetitions of map units may be due to facies changes or older, unrecognized, folded faults. Note also that S_2 foliation dips moderately southeast throughout Fig. 6 (compare stereonets A and B), curving around to strike more toward the southwest as it is deformed by the anticlinorium. The fault also dips generally east, except where it passes through fold hinges, and it dips more steeply southeast on the short D_2 limb than on the long limbs. Bedding and S_1 foliation are folded by D_2 deformation into northeast-verging folds on the long limbs, and southwest-verging folds on the short limb, all with fold axes plunging from 20 to 40°ESE. The map pattern of D_1 folds in the albitic rocks south of Prospect Rock is not much disturbed by the large D_2 fold because they are so nearly coaxial; the fault was at a higher angle to the D_2 fold axis so it is noticeably deformed.

Strongly lineated surfaces throughout the area of Figs. 4*a* and 6 are interpreted as stretching lineations parallel to the transport direction during D_1 and D_2 deformation. Quartz-vein rods and mineral lineations (quartz, mica, chlorite clots, magnetite, or albite) are obvious on all bedding and foliation surfaces, plunging more or less parallel to D_1 and D_2 fold axes (Fig. 6, stereonet C). Across the entire anticlinorium, these lineations trend roughly east–west. Distinguishing D_1 from D_2 folds is difficult at the latitude of the Lamoille River because they are nearly coaxial. A critical locality ~400 m east from Ithiel Falls (ITH in Fig. 6) in Hazens Notch Formation is one of the few places where all fold phases can be observed in one outcrop (Thompson et al. 1999). D_1 folds are tight to isoclinal, mostly in the form of disarticulated hooks with sheared-out limbs in quartzite beds and quartz veins. D_1 fold axes lie parallel to quartz lineations. The fold axes and associated lineations are deformed by overturned, moderately tight D_2 folds, which have a pervasive foliation (S_2) parallel to their axial planes. Confusing the geometry still further, open, nearly upright D_3 folds arch all older structures. A spaced cleavage lies parallel to D_3 axial planes (Fig. 6, stereonet D).

The Prospect Rock slice across the anticlinorium

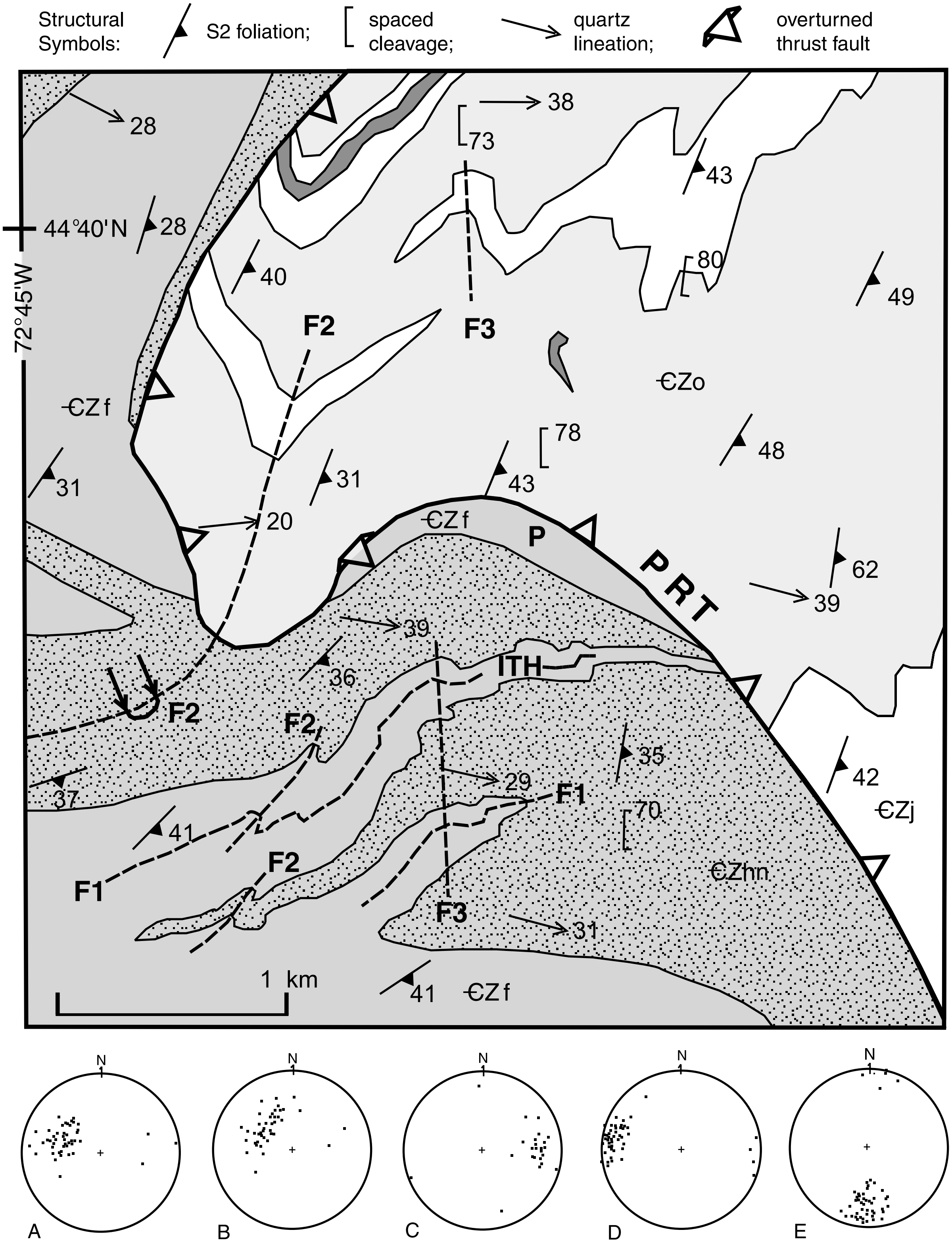
As seen on Fig. 6, the axial trace of the D_2 fold curves more to the west toward the left edge, and continues west across the anticlinorium (Fig. 4*a*), cored by the overturned synform of Hazens Notch Formation. Because of their orientations, D_1 and D_2 folds are difficult to show in an east–west cross-section, so the early fold closures on Fig. 4*b* are somewhat schematic. The relationships south of the Rousseau talc mine (RT in Fig. 4*a*) on the west side of the anticlinorium are less well exposed, but equally convincing in that the Ottauquechee Formation dips south underneath the Hazens Notch Formation in the short limb of the large D_2 fold. Otherwise, in this area, the dips are all to the west, and D_1 and D_2 fold axes plunge west.

From the Lamoille River valley on the west side of the anticlinorium (Fig. 2), the Prospect Rock fault continues south until it truncates against a major back thrust, the Honey Hollow fault. From the Lamoille River, it continues north to the place where it bridges the anticlinorium in the Trout River valley. From there it heads south to Prospect Rock. Note that the folded map pattern results from both D_2 and D_3 folds. In the Trout River valley, the upper plate of the fault is entirely made up of the Jay Peak Formation in a D_2 synform opening to the north, comparable in scale to the one at the Lamoille River. As the Prospect Rock fault continues south along the east side of the anticlinorium from Prospect Rock, it is offset by a normal fault, and then cut by another normal fault, such that it does not reappear south of the Winooski River anywhere on Fig. 2. East of the Johnson talc mine, a folded fault that seems to be comparable to the Prospect Rock fault brings Ottauquechee Formation onto Hazens Notch Formation. This fault is cut by the Burgess Branch fault farther north, a steep normal fault east of the Belvidere Complex (Kim et al. 1999).

The Green Mountain slice (D_1)

The fault that placed the Green Mountain slice onto the Underhill slice is also truncated by the Honey Hollow fault. It is exposed about 10 km south of the Winooski River,

Fig. 6. Geologic map of the Prospect Rock area on the east limb of the Green Mountain anticlinorium. Rock units and abbreviations as in Fig. 4. ITH, Ithiel Falls. Structural Symbols: Dashed line, representative axial traces of folds. Equal area nets show structural data from area of Fig. 6. (A) Poles to S_2 (pervasive foliation) from upper plate of Prospect Rock thrust. (B) Poles to S_2 from lower plate of Prospect Rock thrust. (C) Quartz lineations from both plates. (D) Poles to S_3 (Acadian spaced cleavage). (E) F_3 fold axes.



where Stanley and Wright (1997) referred to it as the "Western Front fault zone" (WF on Fig. 2) and potentially the root zone for Taconic allochthons. Far to the north in Quebec, the Green Mountain slice reappears on the west side of the Honey Hollow fault, where the Sutton thrust (ST in Fig. 2) places Sutton Schist westward onto Underhill equivalents (Colpron et al. 1994). The fate of the Sutton thrust to the north is unknown. It may follow the Bolton Glen Formation, with its associated small ultramafic bodies (Rickard 1991), east across the anticlinorium and truncate against the St. Joseph fault. Whether rocks of the Green Mountain slice in the Monts Sutton lie above the Underhill Formation (and equivalent Bonsecours Formation north along the anticlinorium) or plunge north beneath them is a critical unanswered question.

Late Taconian back thrusting (D_2)

Early Taconian, west-directed thrusts (D_1) have been described from southern Vermont (Ratcliffe et al. 1997) through central Vermont north of Mt. Abraham (Walsh 1992) and northern Vermont into Quebec (Colpron et al. 1994). However, east-directed back thrusts and associated folds that deform the older structures in Quebec and northern Vermont have not been recognized south of the area we mapped along the Winooski River (Thompson and Thompson 1992). Thus, the area of Fig. 2 apparently spans a significant transport direction reversal as recorded by late Taconian structures. Pinet et al. (1996) suggest that back thrusts may have occurred in southern Vermont, but at a higher structural level above the present-day erosional surface. Osberg's (1965) sections across the northern end of the Monts Sutton anticlinorium elegantly portray the east- verging folds, refolded by upright anticlinorial folds, which are so characteristic of southern Quebec and northern Vermont. Rose (1993) concluded from detailed mapping across the Monts Sutton anticlinorium northeast of Lac Brome, Quebec (LB in Fig. 2) that west-verging isoclinal folds and thrust faults, rooted to the east, are deformed by back-folds. Rose's mapping also defined a major east-directed fault, the Stukely Sud fault zone, along the west side of the anticlinorium in a position similar to that of the Honey Hollow fault in Vermont. Colpron et al. (1994), mapping in the western Monts Sutton directly north of the international border, also documented northwest-directed early thrusts, locally decorated by ultramafics and deformed by southeast-directed back thrusts. Tremblay and Pinet (1994) reported a similar sequence of structures in the Notre-Dame Mountain anticlinorium 100 km farther north. Both Rose (1993) and Colpron et al. (1994) suggested that west-directed imbrication of basement slices at depth may have been responsible for the back thrusting at higher structural levels.

Along the Winooski River, quartz rods parallel to D_1 disarticulated hooks trend east–west, as they do farther north, but D_2 folds are nearly coaxial with D_3 folds (Thompson and Thompson 1992). The gradual shift in orientation of D_2 fold axes from approximately north–south at the Winooski River to nearly east–west from Mt. Mansfield north may be related to a swirl in transport direction during late stages of the Taconian orogeny, from west-directed at deeper levels in the south to east-directed at higher structural levels in the north. The east-directed deformation may have increased in intensity northward, drawing what are east-verging folds in the Winooski valley more and more into parallelism with the transport direction. Detailed documentation of this shift in the D_2 fabric will be published in a later paper. Pinet et al. (1996) suggested that D_2 (their D_3) lineations and fold axes are colinear in the core of the Monts Notre-Dame anticlinorium because of reorientation of fold axes in the more ductile levels of thrust sheets, compared with still higher, less-deformed structural levels, where D_2 lineations and fold axes are almost orthogonal. A comparable structurally higher, lower strain level is not seen in the northern Green Mountain anticlinorium, perhaps because it has been eroded away.

The D_2-age Honey Hollow back thrust (HHF in Fig. 2) is not exposed as a single fault in the field, but is inferred from a zone of east-directed folds with sheared-out limbs, shear zones with papery schistose fabric subparallel to D_2 axial planes, and truncations of contacts, especially in the footwall (Doolan et al. 1995). The trends of D_2 fold axes change orientation gradually across the fault zone. Mock (1989) noted albite porphyroblasts with helicitic inclusion trails recording west-over-east sense of motion in an albitic facies of the Underhill Formation 5 km west of the Honey Hollow fault. Most of his D_2 fold axes plunge toward the south. The Honey Hollow fault places the Underhill Formation onto previously faulted rocks of the Prospect Rock and Green Mountain slices (Fig. 4*b*). Potentially the same geometry could be achieved by back-folding alone. Or, a segment of the Western Front fault zone may have been rotated and reactivated with the opposite sense of slip. A similar relationship between faults occurs farther west, where the west-directed Underhill thrust merges with or is offset by the southern extension of the east-directed Brome thrust (Fig. 2) (Schoonmaker 1997).

Observing kinematic indicators in thin section may help document transport directions on faults in the northern Green Mountains. The only detailed study to date (Lamon 2001) describes albite porphyroblasts from three locations near the Prospect Rock thrust. The albites enclose deformed S_1 inclusion trains, and the S_2 fabric is deformed around them, indicating that they grew after D_1 but before or during D_2 deformation. Albites from all three sites indicate west-over-east rotation associated with shear parallel to S_2 foliation during back thrusting. The strain is heterogeneous, with highly strained zones that contain elongated feldspars and shear bands. From a series of samples taken from outcrops east of and structurally below the Rousseau talc deposit (Fig. 4*a*), Lamon documented increased strain west toward the Prospect Rock thrust itself. However, unlike Lamon, who attributes this shear to primary emplacement, we interpret this gradient as a result of local reactivation along the fault during D_2 deformation. Significantly, the other two locations studied by Lamon, approaching the fault near Prospect Rock itself, did not show increased strain toward the fault.

D_3 structures

The overall trend of the northern Green Mountain anticlinorium is approximately N15°E, although individual en echelon segments trend closer to due north. Stanley (1999), based on study of unpublished seismic traverses, suggested that the anticlinorium may have been initially produced by late Taconian ramp structures involving basement along the Champlain thrust, much like the basement imbrications shown by Rose (1993) and Colpron et al. (1994) and like the basal thrust ramps proposed for southern New England (Stanley and Ratcliffe 1985). During the Acadian orogeny, tightening of the anticlinorium produced D_3 structures. In the Prospect Rock area, F_3 folds are typically open, upright folds that deform S_2 foliation. Axial planes dip steeply and strike within about ten degrees either side of due north (Fig. 6, stereonet D). Spaced cleavage (S_3) parallel to axial planes is especially well developed in phyllites, where it may even become the dominant foliation in the rock. Fold axes of minor folds, crinkle lineations and intersection lineations formed by S_3 on S_2 foliation plunge generally south at the latitude of the Lamoille River (Fig. 6, stereonet E). Along the length of the anticlinorium plunge varies from gently north to gently south. F_3 folds *may* plunge quite steeply, if the surface being folded had a steep dip prior to being folded. This is especially true directly east of Prospect Rock, where bedding and S_1 foliations dip moderately to steeply south, almost at right angles to D_3 folds and faults.

Timing of metamorphism and deformation

Albee (1968) suggested that rocks in the northern Green Mountains had experienced two distinct metamorphic events. $^{40}Ar/^{39}Ar$ analysis on amphiboles and micas by Lanphere and Albee (1974) and Laird et al. (1984) confirmed the presence of both Taconian and Acadian ages. The core of an amphibole from near Fletcher (F in Fig. 2) gave a total fusion age of 439 Ma, but results from step-wise heating indicate an older age. However, the spectrum did not maintain a plateau, and the data have been reinterpreted from as old as 463 Ma (Laird et al. 1993) to as young as 452 Ma, but still Taconian. Metamorphism in the Underhill slice at 452 Ma is compatible with Taconian D_1 deformation, which folded rocks containing conodonts that are ~462 Ma old (Thompson et al. 2002). M_1 in the Belvidere Complex happened much earlier (505 Ma, Laird et al. 1984), and structures in the complex are truncated at the contact with the Hazens Notch Formation (Doolan et al. 1982).

East of the Brome thrust all metamorphic rocks reached at least biotite grade before experiencing retrogression, presumably during the Acadian. Farther east, garnet appears along the crest of the anticlinorium in an elongate zone (Laird et al. 1984), which closes north of the Lamoille River (Fig. 4*a*). The garnet isograd crosses the Prospect Rock thrust, suggesting that it postdates the last motion on the thrust. The isograd coincides with the Honey Hollow fault from the Lamoille River south to about halfway to the Winooski River, where it gradually migrates westward into the hanging wall. Conodonts collected from garnet-grade rocks east of the isograd (Fig. 2) have a color alteration index of 7.5–8 (Thompson et al. 2002). The isograd continues to migrate westward across the Underhill thrust to the Precambrian rocks of the Lincoln massif (Tauvers 1982). We attribute this garnet isograd map pattern to the emplacement of the hotter rocks of the Green Mountain slice westward onto the Underhill slice, producing a narrow "metamorphic overhang" zone, which was later cut by the Honey Hollow fault. Rocks in the Underhill slice, exposed in the Winooski River window in the core of the anticlinorium, also contain garnet and conodonts with a high color alteration index. The present elongate zone of garnet-grade metamorphism, centered on the Green Mountain anticlinorium, resulted from the rise of the anticlinorium, without which the garnet- bearing rocks would have remained buried beneath higher levels.

South of Mt. Mansfield (MM in Fig. 2), dark green chlorite has partially replaced garnet. Still farther south, beyond the Winooski River, garnets are completely replaced by chlorite in many samples. This chloritization has been attributed to a lower grade Acadian overprint on garnet-grade Taconian metamorphism (Thompson and Thompson 1992; Walsh 1992), but chloritization of Acadian garnets cannot be ruled out. Some garnets from the Fayston formation on Mt. Mansfield have cores with rutile inclusions and clear rims. They are nearly euhedral and appear to predate S_2, which wraps around them. Electron microprobe study of one such garnet shows an Fe/Mn ratio that increases from core to rim (almandine increases from 50 to 55%; spessartine decreases from 35 to 30%), but with a spike of manganese at the core/rim boundary. This pattern is much like that reported by Karabinos (2002) in garnets from southeastern Vermont. He attributed the manganese spike to partial resorption of garnet by prograde reactions as the host rock moved from higher to lower pressure regimes. The garnet rims in southeastern Vermont are clearly Acadian, but a similar mechanism during the Taconian might explain the zoned garnets from Mt. Mansfield.

A period of decompression may also explain the abundant albite porphyroblasts in the Green Mountain slice. Based on textures observed in thin section, the albites grew before and as S_2 foliation developed, to become sheared in late stages of D_2 deformation. Garnet now enclosed by albite may have started growing at the same time as the manganese-rich garnet cores, and the large albites may be contemporaneous with the rims. Jamieson and O'Beirne-Ryan (1991) attributed albite growth in the Fleur de Lys Supergroup of Newfoundland to nearly isothermal decompression. There, albite grew at the expense of matrix phyllosilicates and, in some assemblages, garnet. However, applying this argument to albites in Vermont must take into account that many other metamorphic reactions could potentially produce albite, some prograde, some retrograde. Small changes in bulk composition could also account for presence or absence of albite. Such changes might be a more likely way to account for local albitic zones within the Underhill Formation west of Fletcher (Mock 1989) or to account for non-albitic facies within the Fayston formation on Camels Hump and Mt. Mansfield, which otherwise look identical to the Jay Peak Formation (Thompson and Thompson 1992, 1999). Local absence of albite in otherwise albitic schist could also result from destruction of porphyroblasts in a high-strain zone.

In southern Quebec, garnet occurs in only a few isolated areas in the Monts Sutton (Rickard 1991; Colpron et al. 1994). Regional (peak) metamorphism in Quebec, as in Vermont, is associated with the earliest west-directed deformation (D_{1-2} composite foliation of Tremblay and Pinet 1994). Castonguay et al. (2001) attribute retrogression in the Monts Notre-Dame anticlinorium to conditions during the back- folding (their D_3, our D_2), which they date as Silurian, based on results from $^{40}Ar/^{39}Ar$ step-wise heating of amphiboles and micas. Further work is needed to clarify the timing of retrogression in northern Vermont.

Regional context of structures in the northern Green Mountains

Accretionary prism model

We propose that the Prospect Rock thrust represents the sole of the Taconian accretionary prism. Some time after east-directed (present coordinates) subduction of oceanic crust was initiated in the basin that had formed along the Laurentian margin, distal sediments derived from Laurentia began to accrete against the upper plate. A prism of material, the Stowe and Ottauquechee formations in the Prospect Rock slice, grew toward the west by underplating. Some fragments of pelitic material, oceanic crust, and (or) ultramafic material were dragged down along the subduction zone farther than others and experienced higher pressure metamorphism, presumably still far away from the Laurentian margin. For example, the Belvidere Complex preserves the oldest Taconian $^{40}Ar/^{39}Ar$ age of 505 Ma (~9 kbar pressure; 1 kbar = 100 MPa), the Worcester Complex experienced ~7 kbar at 470 Ma, and the Tillotson Peak Complex underwent blueschist metamorphism (12–14 kbar) at 468 Ma (Laird et al. 1984; Kim et al. 2001). The wedge above the subduction zone continued to grow, incorporating more proximal sediments as well as slivers of mafic and ultramafic rocks and eventually began to ride up over the thicker continental crust. In our view, the surface between the prism and the underlying autochthonous rocks became the Prospect Rock thrust. Rocks that eventually became the Green Mountain slice moved down along the subduction zone, perhaps incorporating ultramafic material along faults internal to the slice.

As thicker, more buoyant Laurentian crust neared the subduction zone, the rate of subduction slowed and material began to be ejected. Blocks such as the Tillotson Peak Complex moved a significant distance, perhaps aided by ductile deformation of weak serpentinized ultramafics along their boundaries, as proposed for exhumation of eclogites in the Himalayas (Guillot et al. 2000). Because the prism had grown westward since the steep descent of such blocks, they now followed a different, more gently dipping path as they moved up along the active subduction zone. The Green Mountain slice must also have moved westward relative to the overlying Prospect Rock slice to account for our postulated decompression origin for its abundant albite porphyroblasts; the amount of displacement may not have been very great to accomplish the textural contrast between slices. All the events described so far resulted in structures described in this paper as D_1. Clearly the absolute age of D_1 covers a long span of time and varies from place to place. D_2 structures resulted when still deeper slices moved, such as the Champlain thrust slice. These may have involved Grenville basement, in some cases taking advantage of ancient normal faults at rift-basin margins. As these slices rode up over the carbonate bank edge, the material above them splayed out in both directions, continuing west to form west-verging D_2 folds and faults in western Vermont, but forming east- verging D_2 folds and back thrusts above and east of the ramp position.

Defining significant lines within a “cryptic suture”

Lines on various maps presented in the literature have attempted to portray the Taconian suture in the New England – Quebec Appalachians. Locating a single line on the ground between continental and oceanic domains is impossible, given the complex geological history of collisional orogens. Such contacts must be, in detail, “cryptic sutures” (Dewey and Bird 1970). However, rather than being a futile exercise, the process of defining significant lines within the suture zone aids visualizing three-dimensional surfaces within a regional tectonic framework. This final section of our paper will attempt to place our work in such a regional context.

Cameron’s line was originally described as the contact between miogeosynclinal and eugeosynclinal rocks in western Connecticut (Cameron 1951). Merguerian (1983) refined this definition in the context of plate tectonics as a ductile fault between the North American carbonate shelf to transitional rocks and a Taconian accretionary prism containing deeper water facies. Ultramafics are found only structurally above the surface represented by this line. Cameron’s line correlates directly to the Whitcomb Summit thrust, the contact between the Hoosac Formation and the overlying Rowe Formation of Massachusetts (Stanley and Ratcliffe 1985). Some of the Hoosac Formation rests conformably on basement, whereas some is allochthonous, but here too ultramafics are confined to the Rowe Formation, east of the thrust. A similar situation can be traced into southern Vermont between the Hoosac Formation and units correlative with the Rowe Formation, namely the Pinney Hollow, Ottauquechee, and Stowe formations. However, continuing north into central Vermont, the Rowe equivalents cover a much wider zone (Doll et al. 1961), which contains several faults internally, some of them Acadian (Ratcliffe et al. 1997; Walsh and Falta 2001). Beyond about 43°40′N, more “transitional rocks” are preserved in the section, and applying Merguerian’s (1983) criteria for Cameron’s line becomes more difficult. The eastern limit of carbonates lies along the Wood Peak thrust, which places Pinney Hollow Formation onto an autochthonous sequence that includes the Middle Ordovician conodonts at West Bridgewater and is equated with Cameron’s line by Ratcliffe et al. (1999). The western limit of ultramafics at the same latitude lies along the eastern, faulted contact of the Pinney Hollow Formation below Ottauquechee Formation. This line continues north to about 44°15′N (Fig. 2), where the Pinney Hollow Formation pinches out. From there the western limit of ultramafics becomes the folded and faulted contact of the Hazens Notch Formation with the Fayston formation. The eastern limit of carbonates, meanwhile, stays on the west side of the anticlinorium following the Western Front fault zone, the Honey Hollow back thrust, and the Sutton thrust.

Stanley and Ratcliffe (1985) suggested that the northern extension of Cameron’s line might follow the Ottauquechee – Hazens Notch contact to connect with the Baie Verte – Brompton Line (BBL). Stanley et al. (1984) mapped this contact in northernmost Vermont as a tectonized zone, with the Belvidere Mountain thrust (BMT in Fig. 1) along its western margin. However, Kim et al. (1999) showed that the fault along the east side of the Hazens Notch Formation and the Belvidere Complex is, in part, a late, normal fault (the

Burgess Branch fault). The fault moved down to the east and thus its relationship to the BBL is much like the St. Joseph normal fault east of the Monts Notre-Dame anticlinorium in Quebec (Pinet and Tremblay 1995). Their recognition that the suture is a more gently dipping surface than the Burgess Branch and St. Joseph faults has regional implications for the Prospect Rock thrust that will be discussed in our final section.

Williams and St. Julien (1982) described the BBL as a steeply dipping, narrow zone of ophiolites along the "interface" between continental (Humber Zone) and oceanic (Dunnage Zone) realms in Canada. Rock units believed to have been derived by erosion from Laurentia, such as the Sutton Schist, Caldwell Formation, and Ottauquechee Formation, were included in the Humber Zone. It is noteworthy that, defined in this way, small ultramafic bodies lie west of the BBL. Thus it differs significantly from Cameron's line in southern New England. Williams and St. Julien pointed out that where ophiolites are absent, the BBL would separate complexly deformed metamorphosed clastic rocks to the west from less deformed mélanges and volcanics. Except for the Belvidere Complex, a possible ophiolite remnant (Doolan et al. 1982), ultramafics in the "serpentine belt" of Vermont are mostly small, sheared talc and (or) serpentine bodies, more like those west of the BBL in Quebec. Mafic rocks in the northern Vermont serpentine belt show REE patterns that suggest trans-arc volcanics and boninite, as well as mid-ocean ridge basalt (Kim et al. 1999, 2001). The Vermont ultramafic bodies may also have originated in a wide range of tectonic settings, but their geochemistry has yet to be systematically explored.

Brodeur and Marquis (1995) mapped near Orford, Quebec, north along strike from the work of Stanley et al. (1984). They also concluded that the lenticular map pattern of fault-bounded, mixed-provenance lithologies in a black phyllitic matrix, suggested an accretionary prism. Brodeur and Marquis argued that all the rocks between the Sutton Schist and Quebec ophiolites, including the Ottauquechee Formation, should be considered as part of the Dunnage Zone. Even though some of the rocks were derived from Laurentia, they ended up above the subduction zone. We endorse this approach to defining the suture, and conclude that the Prospect Rock thrust represents a similar boundary in northern Vermont. It does not correspond to Cameron's line as applied by Ratcliffe et al. (1999) to the Wood Peak thrust, nor does it correspond to the BBL as defined by Williams and St. Julien (1982).

Some implications of our interpretation

The Prospect Rock thrust dips relatively gently across the region (Fig. 4*b*). By extending this geometry eastward, the lower plate of the Prospect Rock thrust ought to be at depth below the areas shown as Ottauquechee and Stowe by Doll et al. (1961), and albitic rocks might be exposed at the surface by virtue of Acadian anticlines or normal faults. Near Thetford Mines, Quebec, Taconian metamorphic ages of about 462 Ma are preserved in the Bécancour and Carineault antiforms (about 75 km northeast of Richmond, Fig. 1), which expose rocks in a fault slice beneath the Dunnage Zone (Castonguay et al. 2001). In Vermont, reconnaissance work has identified two fault-bounded albitic areas that occur within rocks formerly mapped as Stowe (Doll et al. 1961): one at the Winooski River east of the Waterbury talc mine (WT in Fig. 2) and the other 7 km north along the west side of the Worcester Complex, east of the Barnes Hill talc body. A third area of albitic rocks was mapped in the Ottauquechee Formation east of Rochester (Walsh and Falta 2001), where rocks typical of Ottauquechee and Stowe formations, along with ultramafics and greenstones, lie in fault contact above Hazens Notch- like rocks. These areas warrant further exploration.

Acknowledgments

We thank Vermont State Geologist, L. Becker, for continued support through State map contracts with the Vermont Geological Survey. Our work benefited from debate on the outcrop and over maps with numerous geologists, especially J. Kim, M. Gale, B. Doolan, R. Stanley, G. Walsh, J. Laird, W. Bothner, S. Castonguay, A. Tremblay, and R. Coish. We thank Cornell College students S. Wolfe, K. Haiar, and J. Bries for field assistance. J. Fournelle provided help in probe analyses at the University of Wisconsin, Madison. The paper greatly benefited from formal reviews by N. Ratcliffe, J. Kim, and S. Hanmer. M. Gale and W. Bothner also made helpful suggestions for improving the manuscript. Our colleagues may agree or not with the ideas presented, and we accept responsibility for errors or misinterpretations.

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