

STRATIGRAPHIC RELATIONSHIPS OF THE LOWER ORDOVICIAN CHIPMAN FORMATION IN WEST-CENTRAL VERMONT*

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ABSTRACT. The Chipman formation includes four members: the Burchards, characterized by limestone with dolomitic mottling; the Weybridge, composed of limestone with thin interbeds of sandy limestone; the Beldens, made up of interbedded limestone and massive dolomite; and the Bridport dolomite member, consisting of massive dolomitic beds, which in the Cornwall area interfinger with limestones of the Chipman formation. Nearly a century ago Augustus Wing correlated strata of the Weybridge and Beldens with those of the Bridport dolomite. This correlation has been recently reaffirmed by Marshall Kay, who also recognized the faunal affinity of the Weybridge member of the Chipman with late Beekmantown age. Recent mapping by the authors, particularly by Zen in the Sudbury-Brandon area, shows that the sequence of the Burchards, Weybridge, and Beldens members, though generally in about that order, is locally much varied; also the Weybridge is locally missing in western areas and the Burchards is missing in some areas to the east. The irregular distribution of the Burchards, characterized by localized fossils, suggests biostromal deposits. These deposits apparently formed offshore from the Bridport dolomite member, which was deposited in near-shore shallows that fringed the eastern Adirondack area.

INTRODUCTION

The Chipman formation of west-central Vermont is a rock unit in the uppermost part of the Lower Ordovician, of Beekmantown age, between the underlying Bascom formation and the overlying rocks of Middle Ordovician (Chazy) age. Its structural setting is the Middlebury synclinorium and adjacent areas to the west (fig. 1). Four principal types of rocks characterize the Chipman formation: buff-to-brown, sharply defined, and laterally persistent beds of massive dolomite; white to blue-gray limestone; gray limestone with thin interbeds of sandy limestone; and blue-gray limestone with irregular spots of dolomite that give weathered surfaces a mottled appearance. These lithofacies are interbedded in the type section of the Chipman formation at the north foot of Chipman Hill, 1.5 miles north of the village of Middlebury. The Chipman formation was first referred to as a group (Kay and Cady, 1947), but it is here reduced to the rank of a formation. More recent studies (Kay, 1950), which are to be discussed below, have shown the synchronous facies relationship of the Bridport dolomite of Cady (1945, p. 545-546) with the other lithofacies. The "Beldens formation", the "Weybridge member of the Beldens" (Cady, 1945, p. 548, 550-552), the "Burchards limestone" (Kay and Cady, 1947), and the Bridport dolomite are here redefined as members of the Chipman formation. The Weybridge and Burchards have not been mapped north of the Middlebury synclinorium, whereas the Beldens and Bridport are considered formations in northwestern Vermont (Kay, 1958, p. 79-80) that correlate in time with all or part of the Chipman formation.

The Burchards member of the Chipman formation is predominantly a blue-gray limestone with dolomitic mottling. It is missing from portions of the east limb of the Middlebury synclinorium. The Weybridge member, which is

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characterized by gray limestone with thin interbeds of sandy limestone, is locally absent in the west limb of the synclinorium. The Beldens member consists of interbedded white to blue-gray marble and limestone and buff-to-brown massive dolomite that crop out throughout the belt of the Chipman. The Bridport dolomite member consists largely of massive dolomite and is the western facies of the formation.

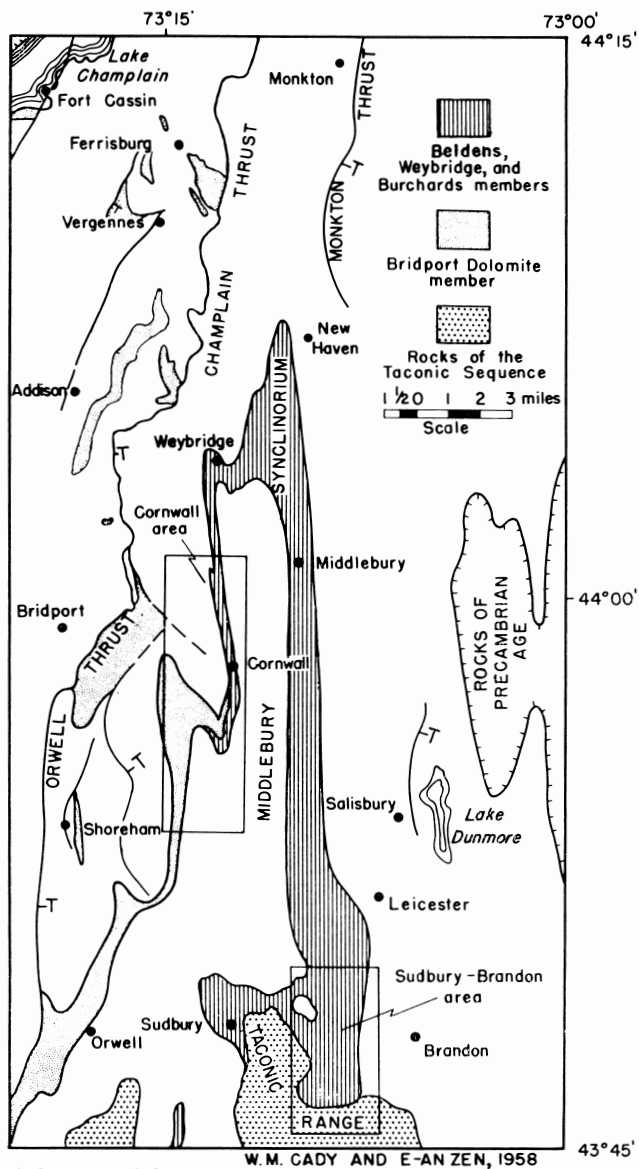


Fig. 1. Index map of the Middlebury synclinorium and vicinity, west-central Vermont, showing distribution of rocks of the Lower Ordovician Chipman formation.

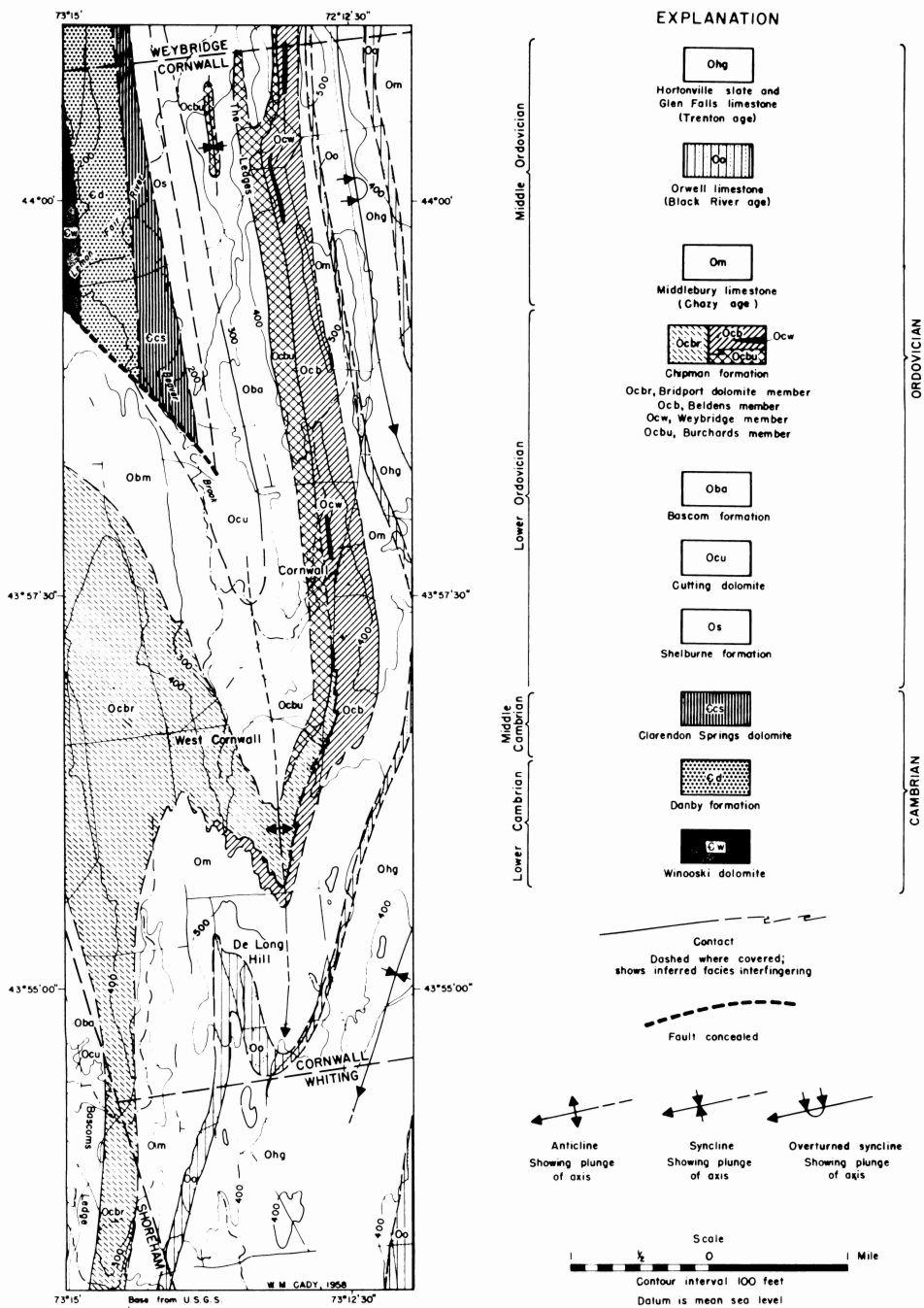


Fig. 2. Geologic map of the Cornwall area.

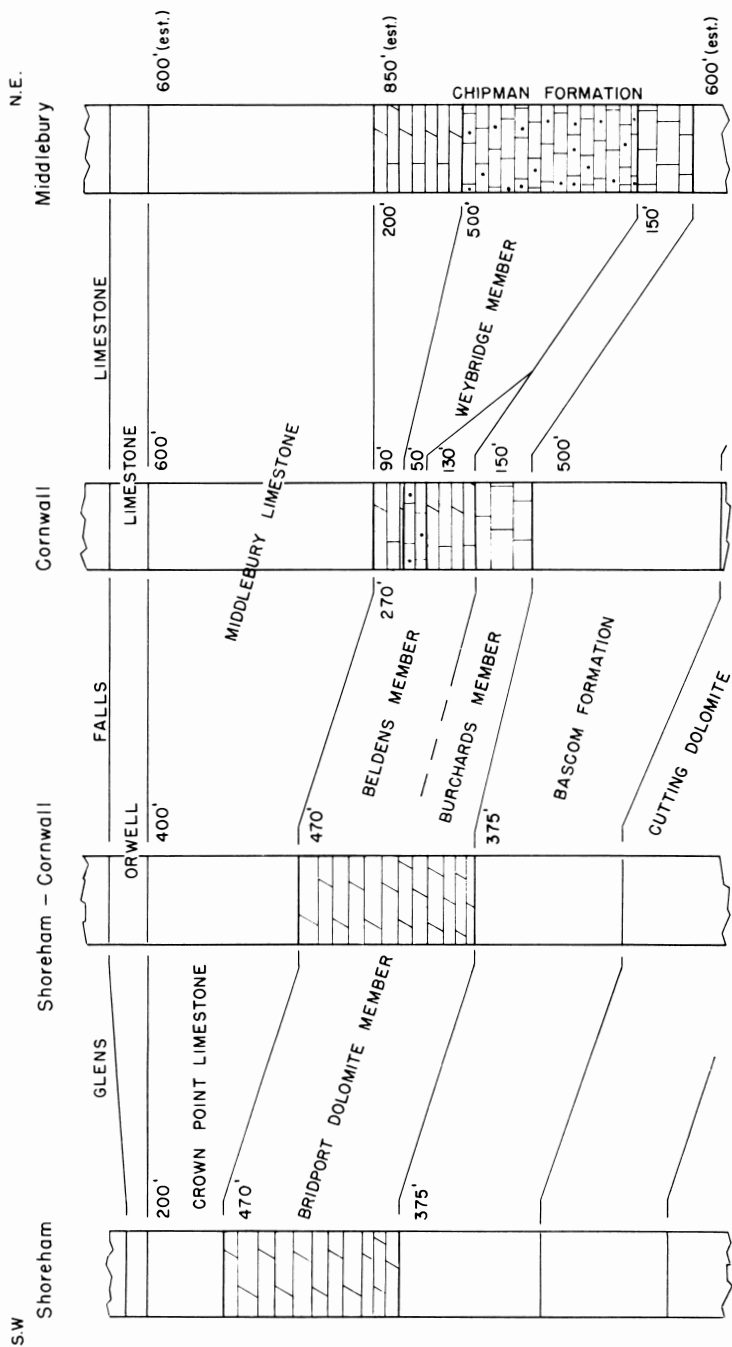
The Cornwall area, on the west limb of the Middlebury synclinorium (fig. 1), is most critical in showing the relationship of the Bridport dolomite member to the other members of the Chipman formation. Another critical area, which shows varied mutual relations of eastern lithofacies of the Chipman formation, is at the north foot of the Taconic Range between the villages of Sudbury and Brandon, on the east limb of the Middlebury synclinorium (fig. 1). The geologic maps (figs. 2 and 5) bring the mapping of these two critical areas up to date with the stratigraphic interpretations presented below, correcting earlier inferences (Cady, 1945, pl. 10) as to the areal distribution of the members of the Chipman formation, particularly of the Burchards and Beldens members.

CORNWALL AREA

The Beldens, Burchards, and Weybridge members of the Chipman formation are exposed in the northeastern part of the Cornwall area, and the Bridport dolomite member crops out in the southwestern part (fig. 2). Covering the northern part of the Bridport member are extensive surficial deposits that have made it impossible to prove correlation of the Bridport with the other members by walking out the units. Stratigraphic correlation is satisfactorily shown, however, by comparison of the sequences of formations in which the several members of the Chipman are contained. All units of the Chipman formation overlie the Bascom formation and underlie the Middlebury limestone.

The Chipman formation is exposed in a belt of discontinuous outcrops of rock of Beekmantown age that extends from about a mile south of the village of Cornwall north through The Ledges and into the town of Weybridge. The Chipman is in a section that, at the latitude of The Ledges, includes three Cambrian formations—the Winooski dolomite, the Danby formation, and the Clarendon Springs dolomite—as well as Ordovician formations of Beekmantown, Chazy, Black River, and Trenton age. The distribution and relationships of the stratigraphic units in this section are about as described and mapped by Cady (1945, p. 532-545, pl. 10), though their terminology is partly changed. The Shelburne is now referred to as a formation rather than a marble unit because it contains dolomite beds in addition to calcite marble, and also because limestone instead of marble occurs where the rock is unmetamorphosed, as in the Cornwall area. The “Crown Point limestone” becomes the Burchards member of the Chipman formation; and the Orwell limestone, like similar rocks that succeed those of Chazy age along Lake Champlain, is now assumed to be of Black River age rather than Trenton (Cady, 1945, p. 556; Kay, 1958, p. 91-92).

The Burchards member of the Chipman formation contains undetermined species of *Maclurites* and of a partly coiled cephalopod, *Eccyliomphalus*, such as occurs in upper strata of Beekmantown age. The *Maclurites* in particular are fairly abundant and can be seen in most outcrops. The Weybridge member, near the town line between Cornwall and Weybridge, contains the brachiopod genera *Diparelasma*, *Orthambonites*, and *Syntrophopsis* and the trilobites *Goniurus* and *Isoteloides*, forms which are diagnostic of rocks of late Beekmantown age (Kay, 1958, p. 79). The Beldens member, about a mile southeast of



W. M. CADY, 1958

Fig. 3. Columnar sections showing stratigraphic relationships of the members of the Chipman formation and associated rocks between the villages of Shoreham and Middlebury.

Cornwall village, contains several undetermined orthoconic cephalopods but for the most part is barren of fossils.

The Bridport member of the Chipman formation appears at the extreme south end of the rock belt of Beekmantown age that passes through Cornwall village. A tongue of dolomite, which lacks interbeds of limestone such as characterize the Beldens, extends northward between the Burchards and Beldens members of the Chipman formation but pinches out about three-fourths of a mile south of the village. This relationship indicates that the Bridport interfingers laterally with the Beldens and Burchards members. This type of transition is inferred in an extensive area that is covered by surficial deposits, in the directions of De Long Hill and West Cornwall.

The principal exposures of the Bridport member in the Cornwall area are at Bascoms Ledge, which is in the vicinity of the eastern boundary of the town of Shoreham. The Bridport at Bascoms Ledge is in a section above the Cutting dolomite and Bascom formation (Cady, 1945, p. 541-545) of Beekmantown age and beneath the Middlebury limestone (Cady, 1945, p. 552-554), which is of Chazy age. The distribution and terminology of the stratigraphic units in the section near Bascoms Ledge, as shown in figure 2, are in part a revision of the former interpretation of Cady (1945, pl. 10).

The Cutting and Bascom formations and the Bridport dolomite member are as previously mapped (Cady, 1945) at Bascoms Ledge, but the Middlebury limestone is expanded westward and downward stratigraphically to the top of the Bridport and includes rocks that had been interpreted as "Crown Point limestone" and "Beldens formation". The Orwell limestone on the summit of De Long Hill, northeast of Bascoms Ledge, was misidentified as the Beldens during previous mapping. Also, the contacts between units in a covered area south of the summit of De Long Hill were incorrectly shown as solid rather than dashed lines. The inferred pattern of the Orwell limestone and of the overlying rocks of Trenton age (Glens Falls limestone and Hortonville slate) has been modified in this area.

The stratigraphic relationships of the members of the Chipman formation within, and also southwest and northeast of the Cornwall area, are shown in the columnar sections (fig. 3). The Cornwall section is a little north of the village of Cornwall and the Shoreham-Cornwall section is in the vicinity of Bascoms Ledge. The Shoreham and Middlebury sections are near the villages of Shoreham and Middlebury (fig. 1). Sections south of the Cornwall area on the west limb of the Middlebury synclinorium are like that in the vicinity of Bascoms Ledge.

The first, and apparently the correct, interpretation of the stratigraphic relationships of the Beldens and Burchards members to the Bridport member was arrived at nearly a century ago by Augustus Wing (Dana, 1877, p. 341-345), in the Cornwall area. One of the purposes of the present paper is to call attention to Wing's conclusions in further support of the inclusion of the Bridport as a member in the Chipman formation and of the time-stratigraphic unity of the various lithofacies of the Chipman. Figure 4 shows the correspondence between Wing's stratigraphic terminology and that used here.

		BASCOMS LEDGE AND VICINITY		CORNWALL VILLAGE TO THE LEDGES				
		CADY, 1945, 1960	WING, 1877	CADY, 1945, 1960	WING, 1877	BRAINERD, 1891		
MIDDLE ORDOVICIAN	BLACK RIVER	Hortonville slate	8. Hudson River slates	Hortonville slate	8. Hudson River slates	[Not discussed]		
		Glens Falls limestone	7. Sparry limestone	Glens Falls limestone	7. Sparry limestone			
	Orwell limestone	Orwell limestone						
	CHAZY	Middlebury limestone		Middlebury limestone				
LOWER ORDOVICIAN	BEEKMANTOWN	Bridport dolomite member of the Chipman formation	6. <i>Rhynchonella</i> beds	Beldens member	6. <i>Rhynchonella</i> beds	"Chazy C"		
				Weybridge mem.			5c. Coarse limestone	"Chazy B"
		Bascom formation	Zone 4	5b. Conglomerate	Bascom formation	Zone 4	5b. Conglomerate	"Chazy A"
			Zone 3	5a. Trilobite beds		Zone 3	5a. Trilobite beds	[Not discussed]
			Zone 2	4. <i>Ophileta</i> beds		Zone 2	4. <i>Ophileta</i> beds	
			Zone 1			Zone 1		
		Cutting dolomite		Cutting dolomite				
		Shelburne formation	3. Subcrystalline limestone	Shelburne formation				
Clarendon Springs dolomite	2. Upper Potsdam	Clarendon Springs dolomite			[Not discussed]			
Danby formation	1. Potsdam	Danby formation						
	[Not exposed]		Winooski dolomite					

Fig. 4. Stratigraphic terminology.

Wing (Dana, 1877, p. 341-342, 343-345) referred to both the Bridport and the Beldens as unit 6, the "*Rhynchonella* beds", and left no doubt that the two are to be correlated. Beneath the Beldens in the section near and north of Cornwall Village is the Burchards, a limestone that Wing referred to as unit 5c (Dana, 1877, p. 344). He mentioned the local occurrence of this unit in The Ledges north of Cornwall. Recent mapping shows that the Burchards is a lithofacies that is extensive enough to be mapped as a member of the Chipman formation north and south of the village of Cornwall. Also in the section near and north of Cornwall village is the Weybridge member (Cady, 1945, p. 550-551), which was referred to by Wing (Dana, 1877, p. 344) as the "striped stratum" in the "*Rhynchonella* beds". Wing also mentioned the "striped stratum" in the "*Rhynchonella* beds" at Bascoms Ledge (p. 343). There the "*Rhynchonella* beds" are now known as the Bridport dolomite member of the Chipman formation.

Brainerd (1891, p. 299) assigned a Chazy age to Zone 4 of the Bascom formation ("Califerous D4") and to the whole sequence now known as the Burchards and Beldens members of the Chipman formation, in The Ledges north of Cornwall village. This incorrectly made these units younger than Bascom Zone 4 and Bridport (Beekmantown) of the section at Bascoms Ledge. The assignment of a Chazy age was predicated chiefly on the occurrence of coiled gastropods and cephalopods in the Burchards that in their poor state of

preservation resemble the gastropod *Maclurites magnus* of the type strata of middle Chazy age. Cady (1945, p. 548) recognized Zone 4 of the Bascom in The Ledges in Cornwall but followed Brainerd in correlating Wing's unit 5c (the Burchards) with the Crown Point limestone of middle Chazy age, and Wing's "*Rhynchonella* beds" (the Beldens) with strata of late Chazy age. The Beldens was mistakenly extrapolated into the section east of and stratigraphically above the Bridport southwest of De Long Hill (Cady, 1945, pl. 10). The rock above the Bridport here is actually the Middlebury limestone, which is of Chazy age but contains a few dolomitic zones that had suggested the "Beldens formation".

Kay and Cady (1947) "proposed that the 'Crown Point' formation east of the Champlain thrust in west-central Vermont be designated the Burchards limestone, named from a stream that enters the Lemon Fair River three miles west of the type locality in the belt of outcrop between Cornwall village and The Ledges." This seemed advisable because of the structural separation from the typical Crown Point limestone along Lake Champlain. Later Kay (1950; 1958, p. 79) recognized fauna in the Weybridge supporting late Beekmantown age, as well as the stratigraphic correlation of the Weybridge and the Beldens with the Bridport. Rock of Chazy age in the vicinity of Shoreham village is structurally isolated from the Middlebury limestone and is lithically and faunally like the typical Crown Point limestone; it is here continued as the Crown Point (fig. 3).

SUDBURY-BRANDON AREA

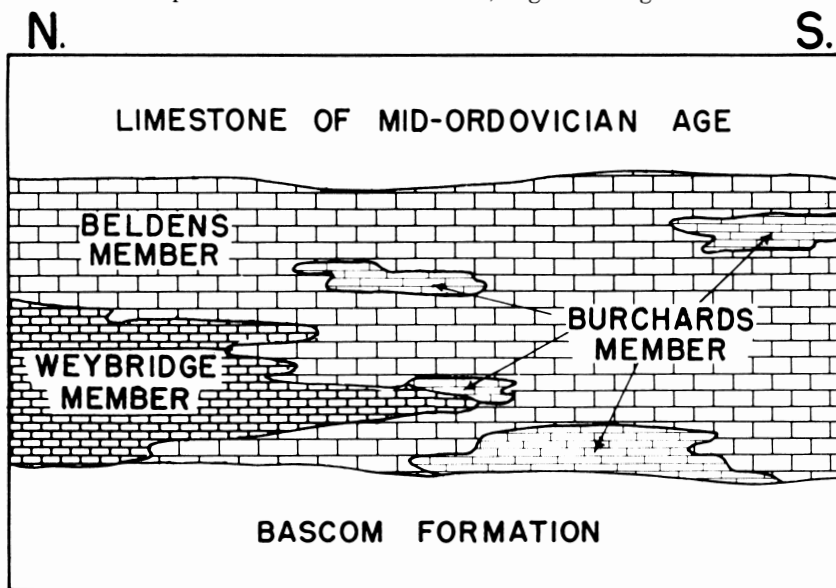
The geologic map of the Sudbury-Brandon area (fig. 5) includes most of the stratigraphic units that are in the section near and north of Cornwall village, as well as various rocks of the Taconic Range, which are shown as a single unit. The map shows several changes from previous mapping (Cady, 1945, pl. 10), notably discontinuous distribution of the Burchards ("Crown Point") member of the Chipman formation. The Chipman formation is underlain by the Bascom formation and overlain by Middle Ordovician limestone in the towns of Sudbury and Brandon much as it is in Cornwall. The rocks of the Taconic Range appear to overlie the Bascom and Chipman formations; their relationships are complex and are the subject of a continuing study by Zen.

The Bascom formation crops out three-fourths of a mile south-southwest of Arnold School and west of a secondary road, near the northeastern corner of the Sudbury-Brandon area. There the beds dip west in the east limb of the Middlebury synclinorium, and drag-fold relationships indicate that the tops of beds are to the west. The Weybridge member of the Chipman formation crops out about 500 feet west of the Bascom; 500 feet farther west near the Rutland Railroad, and at the eastern edge of the Brandon Swamp the Beldens member crops out. The Bascom and Chipman reappear, from beneath Long Swamp, at Halls Island one and one-half miles to the south. The unit directly above the Bascom at Halls Island is the Beldens member of the Chipman instead of the Weybridge member. Some of the limestone beds in the Beldens show dolomitic mottling such as is characteristic of the Burchards member.

Seager Hill, which is one and one-half miles south of Halls Island, is underlain by black slates that form part of the Taconic Range in the southern

A little south of Willow Brook School the Weybridge member strikes northwest and dips southwest, but north of Stiles Mountain it swings to an east strike and a gentle south dip and conforms to the trend of the contact between the Burchards member and the rocks of the Taconic Range. Crossbedding indicates that the section is right side up. To the south of the Weybridge, and apparently stratigraphically above it, are rocks of another area of the Beldens as well as of the east-trending belt of the Burchards.

The areal distribution and structural and stratigraphic relations of the Beldens, Burchards, and Weybridge (outlined above) indicate that these members are lithofacies in the Chipman formation. The sequence of these units varies; southwest of Arnold School the Weybridge member is at or near the bottom of the formation; at Halls Island and northwest of Seager Hill either the Beldens or the Burchards is at the bottom, and they are succeeded to the west and upward stratigraphically by the Weybridge; north of Stiles Mountain the Weybridge is succeeded by both Burchards and Beldens lithofacies. The time-stratigraphic position of the latter two is above that of the Beldens and Burchards at Halls Island and northwest of Seager Hill. The gradational contacts between units make it improbable that such repetition is produced by faulting. A schematic restoration of the Chipman formation, which interprets these relationships in a north-oriented section, is given in figure 6.



E - AN ZEN, 1958

Fig. 6. Restored section of the Chipman formation approximately along the town line between Sudbury and Brandon.

The lithofacies of the Burchards member differs from that of the Beldens only in the numerous dolomitic spots that give the rock a mottled appearance. Close inspection of these spots reveals that they are remains of fossils. The spots are commonly so crowded together that they are actually in contact. It is

suggested here that the difference between the Burchards and the Beldens is primarily ecologic; the irregular distribution of the Burchards in the Sudbury-Brandon area suggests biostromes.

Small cystoid or crinoid stems have been found in the Weybridge and Beldens members of the Chipman formation, and sections of fossil shells are shown in the Burchards member by dolomitic mottling. The mineralogy of the Burchards limestone, particularly its relation to fossil preservation, is discussed by Zen (1959). Though specific identifications of fossils that might be useful in correlation have not been attempted, the lithofacies of the various units are so distinctive that correlation with the section near Cornwall is clear.

DISTRIBUTION OF FACIES AND PALEOGEOGRAPHY

The Chipman formation is a complex of limestone and dolomite facies; strata of massive dolomite, which are interbedded with limestone in the Beldens member, extend westward into similar dolomite that characterizes most of the Bridport member (fig. 3). The massive dolomite, as already indicated, forms sharply defined and laterally persistent buff-weathered beds as opposed to the mottled and irregularly distributed dolomite produced by alteration of fossil shells in otherwise nondolomitic limestone. Such westward increase in proportion of dolomite relative to limestone is generally characteristic of rocks of Beekmantown age not only in western Vermont but in other areas of the Appalachian region (Cady, 1945, p. 540).

The Burchards member of the Chipman formation, which shows the dolomitic mottling, is irregularly distributed east of the zone of transition into the Bridport member. The Burchards is predominantly beneath the Beldens member in the section near and north of Cornwall village, but in the Sudbury-Brandon area some of it, as already pointed out, also occurs above the Beldens. The Burchards appears to be continuous laterally in the Cornwall section but not in the Sudbury-Brandon section. These relationships plus the fossil content suggest that the Burchards is an irregular biostromal zone that formed east of and offshore from the massive Bridport dolomite member, which was deposited simultaneously in near-shore shallows.

The Chipman formation thickens eastward (Cady, 1945, p. 551) from the postulated biostromes, and in this direction nondolomitic limestone becomes more abundant in both the Beldens and Weybridge members. The sandy limestone of the Weybridge member thickens from 0 at the meridian of Shoreham to a maximum of 500 feet at the eastern limits of its exposure in the east limb of the Middlebury synclinorium (Cady, 1945, p. 551); it grades westward into the Burchards and the lower part of the Beldens and in some places persists even into the Bridport member.

The Beldens and local facies like that of the Burchards are found in other areas to the north and south of west-central Vermont. The Beldens is mapped in northwestern Vermont and adjacent Quebec as a formation (Kay, 1958, p. 68, 72, 76), and the authors have recognized it as far south as Berlin, New York. The Bridport, on the other hand, seems restricted to west-central Vermont and to nearby parts of New York that border the eastern Adirondack Mountains.

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REFERENCES

- Brainerd, Ezra, 1891, The Chazy formation in the Champlain Valley: *Geol. Soc. America Bull.*, v. 2, p. 293-300.
- Cady, W. M., 1945, Stratigraphy and structure of west-central Vermont. *Geol. Soc. America Bull.*, v. 56, p. 515-587.
- Dana, J. D., 1877, An account of the discoveries in Vermont geology of the Rev. Augustus Wing: *Am. Jour. Sci.*, 3d ser. v. 13, p. 332-347, 405-419.
- Kay, Marshall, 1950, Ordovician Canadian-Chazyan relations in Vermont [abst.]: *Geol. Soc. America Bull.*, v. 61, p. 1476.
- 1958, Ordovician Highgate Springs sequence of Vermont and Quebec and Ordovician classification: *Am. Jour. Sci.*, v. 256, p. 65-96.
- Kay, Marshall, and Cady, W. M., 1947, Ordovician Chazyan classification in Vermont: *Science*, v. 105, p. 601.
- Zen, E-an, 1959, Carbonate mineralogy of the Lower Ordovician Burchards limestone in west-central Vermont: *Am. Jour. Sci.*, v. 257, p. 668-672.