THE CAMBRIAN PLATFORM AND PLATFORM MARGIN IN NORTHWESTERN VERMONT

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INTRODUCTION

The stratigraphy of northwestern Vermont is dominated by sedimentary rocks of the Cambro-Ordovician platform and basin sequence, which is part of an extensive belt of similar facies extending from Newfoundland to Alabama. These facies consist of carbonate and siliciclastic deposits characteristic of a shallow water platform, bordered to the east by a basinal sequence of shales and sedimentary breccias. Rodgers (1968) recognized this platform to basin transition as the margin of the Lower Paleozoic platform in eastern North America.

Cambro-Ordovician sediments were deposited on a passively subsiding shelf following late Precambrian rifting. These sediments accreted at a rate which kept pace with thermal subsidence as the shelf assumed the morphology of an accretionary rimmed platform during the Lower Cambrian. Examining the distribution of facies comprising the shallow water platform indicates that the interior regions were affected by tidal and wave processes whereas the shelf margin regions were subtidal and wave reworked (Gregory, 1982; Butler, 1986; Rahamanian, 1981; Myrow, 1983; Chisick and Friedman, 1982; Braun and Friedman, 1969). The adjacent deeper water basins accumulated talus, debris flows, and turbidites composed of detritus shed off the platform (Mehrtens and Dorsey, 1986; Mehrtens and Borre, 1987; Mehrtens and Hillman, in review).

The Cambro-Ordovician sequence in northwestern Vermont is unique in that the platform to basin sequence is intact and undissected by faults. Looking at the Cambro-Ordovician sequence throughout the Appalachians, only Pfeil and Read (1980) describe a platform to basin sequence, but it has been dismembered by faults and cannot provide information on the original geometric relations on the platform.

This field trip guide describes the facies and evolution of a portion of the Cambro-Ordovician carbonate platform in northern Vermont (Figure 1). The Cheshire Quartzite is the basal unit in the sequence (Figure 2),

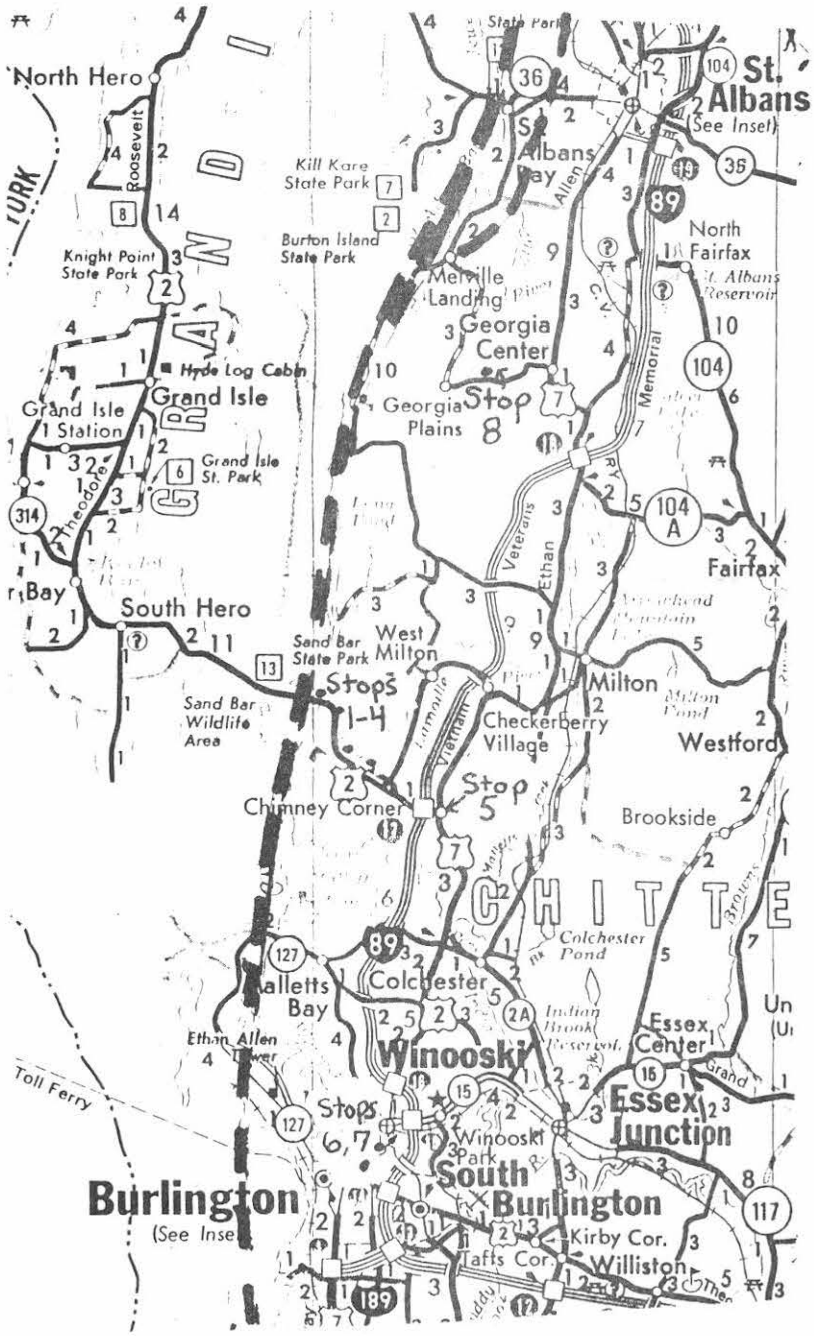


Figure 1. Locality map for stops 1-8. The trace of the Champlain Thrust is shown.

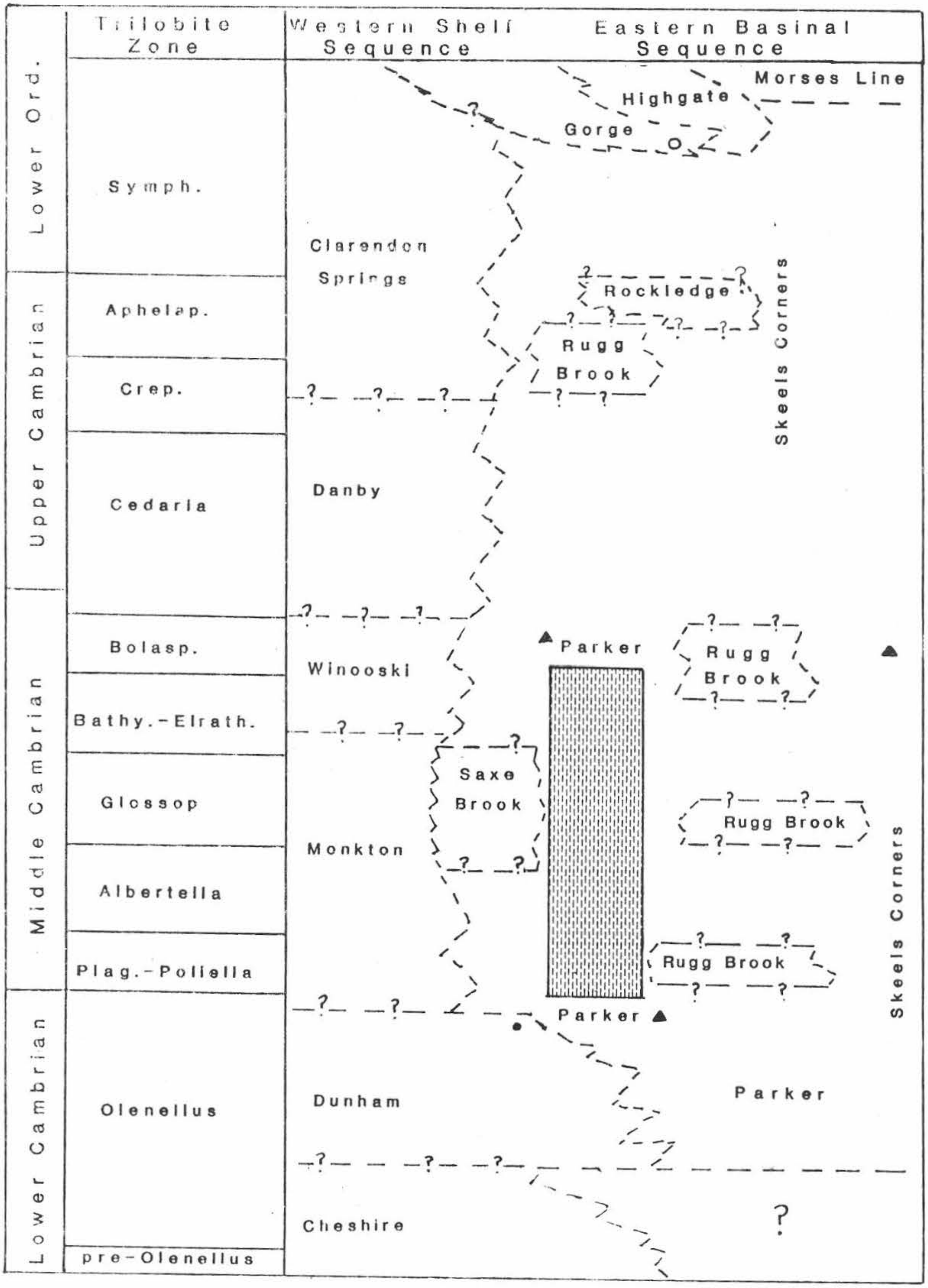

Trilobite Zone
Western Shelf Sequence
Eastern Basinal Sequence
Lower Ord.
Upper Cambrian
Middle Cambrian
Lower Cambrian
Symph.
Aphelap.
Crep.
Cedaria
Bolasp.
Bathy.-Elrath.
Glossop
Albertella
Plag.-Poliella
Olenellus
pre-Olenellus
Morses Line
Highgate
Gorge
Clarendon Springs
Rockledge
Rugg Brook
Skeels Corners
Danby
Parker
Winooski
Saxe Brook
Monkton
Dunham
Cheshire
?

Figure 2. (previous page) Correlation chart for the Cambro-Ordovician strata of northwestern Vermont. Chart is based on biostratigraphic data by Palmer (1970), Palmer and James (1980), Landing (1983), and Mehrtens and Gregory (1984), and physical stratigraphic relationships by Mehrtens and Dorsey (1986) and Mehrtens and Borre (1987). Age relationships on the platform are approximate because they are based on intertonguing relationships with the basinal units. The Hawke Bay event is illustrated with shaded bar within the Parker Slate. Pods of Rugg Brook Dolomite extend from post-Dunham to Rockledge time. The Skeels Corners Slate has been dated as Bolaspidella zone in age but mapping relationships suggest it has a much broader age range.

overlying Eocambrian rift-related sediments of the Pinnacle and Fairfield Pond Formations (Tauvers, 1982), and it will not be examined on this trip. The Cheshire is in gradational contact with the overlying Lower Cambrian Dunham Dolomite (Myrow, 1984), a carbonate unit which records sedimentation in peritidal, subtidal and platform margin environments (Gregory, 1982). The facies distribution and paleogeography of the Dunham Dolomite influenced the platform geometry and evolution in subsequent Cambrian deposits, consequently it will be examined in detail.

Overlying the Dunham Dolomite is the lower Middle Cambrian Monkton Quartzite, a mixed siliciclastic/carbonate unit which also records tidal flat to platform margin sedimentation (Rahmanian, 1981) . The Middle Cambrian Winooski Dolomite has not been studied in detail, but a review of sedimentary and biogenic structures suggests that it also records peritidal to platform margin environments of deposition. The Upper Cambrian Danby Quartzite overlies the Winooski and contains a diverse suite of sedimentary structures documenting tidal flat, shallow subtidal, and platform margin environments, with significant storm overprinting (Mehrtens and Butler, in review).

This field trip will look at each of these units and examine evidence for their interpretation as shallow water platform deposits. The trip will also examine one basinal unit, the Rockledge Formation (Upper Cambrian). The Rockledge Formation is a limestone-clast conglomerate unit with associated massive sandstones and laminated siltstones interpreted to represent high and low density turbidity currents (Mehrtens and Hillman, in review).

GEOLOGIC SETTING AND STRATIGRAPHY OF THE CAMBRO-ORDOVICIAN SEQUENCE

The Cambrian to Lower Ordovician stratigraphic sequence in western Vermont outcrops in a north-south trending belt, a region bordered on the east by the Greeen Mountain Anticlinorium, a belt of Precambrian rocks thought to represent the easternmost occurence of the north American craton in the Lower Paleozoic (Rodgers, 1968). The north-south trending outcrop belt consists of several major fold belts (St. Albans and Middlebury Synclinoria) and thrusts (Champlain, Hinesburg, Pinnacle, Highgate Springs). The north-western portion of the outcrop belt is well suited for sedimentologic studies because it lies within the Quebec Reentrant (Thomas, 1978), which kept deformation and metamorphism associated with the Taconic and Acadian Orogenies to a minimum. The most complete exposures of the Lower Paleozoic are contained within thrust sheets in this region. Stratigraphy within the thrust sheets is coherent, which enables us to reconstruct original geographic relationships on the Cambro-Ordovician platform.

The Cambro-Ordovician stratigraphic sequence (Figure 2) in northwestern Vermont was divided into two sequences by Dorsey and others (1983). The Western Shelf Sequence is composed of alternating siliciclastic (Cheshire, Monkton, Danby Formations) and carbonate (Dunham, Winooski and Clarendon Springs Formations) units of the platform.

The Eastern Basinal Sequence consists of units which are coeval with the platform sequence, but were deposited in deeper water adjacent to the platform. This Sequence consists of shale (Parker and Skeels Corners Slates) and conglomerates and breccias (Rugg Brook, Rockledge Formations). Unlike the Western Shelf Sequence, correlations are well developed in the Eastern Basinal Sequence, with a trilobite zonation developed by Shaw (1959) and Palmer (1970) and physical stratigraphic relationships (Mehrtens and Dorsey, 1986) and Mehrtens and Borre (1987).

SUMMARY OF THE DEPOSITIONAL ENVIRONMENTS OF THE WESTERN SHELF SEQUENCE

Pre-Cheshire Units

The Pinnacle and Fairfield Pond Formations underly the Cheshire Quartzite in central Vermont. The stratigraphy and structure of these units was studied by Tauvers (1982) and their depo-tectonic setting described by Dorsey and others (1983). The Pinnacle and Fairfield Pond Formations are interpreted as representing sediments which infilled grabens formed during Eocambrian rifting. Doolan and others (1982) have suggested that this rifting may have occured around 560mybp. The proposed topography of the rift basin resulted in deposition of coarse-grained clastics, possibly alluvial fan in origin, overlain by finer-grained siliciclastic sediments of the Fairfield Pond Formation in marignal marine basins (Tauvers, 1982). The contact of the Fairfield Pond Formation was shown by Tauvers to be conformable. These units will not be seen on this trip.

In northern Vermont, the Eocambrian syn-rift sediments of the pre-Cheshire Oak Hill Group also record deposition in a marginal marine setting (Dowling, et al, 1987). These units will also not be seen on this trip.

Cheshire Quartzite

Myrow (1983) completed a study of the Cheshire Quartzite in west-central Vermont. He recognized eight lithofacies within the Cheshire, five within the lower Cheshire and three from the upper Cheshire. The lower Cheshire is composed of: (1) fine-grained, mottled grey, argillaceous arkose with extensive bioturbation, thin white rippled beds and shale partings; (2) fine-grained, white subarkosic and fine-grained arkosic beds with ripple bedding, wavy and lenticular bedding, thick and thinly interlayered bedding, parallel laminations, cross stratification, and U-shaped vertical burrows; (3) fine-grained, white subarkosic beds with thin clay drapes and massive parallel laminated and low angle tabular cross stratification, lenticular beds, low angle trough cross stratification, rippled beds, reactivation surfaces and low angle erosional surfaces; (4) thin, lenticular, structureless sand bodies with erosional bases and flat upper surfaces; (5) tabular sand beds characterized by planar, non-erosive bases and reworked tops.

The upper Cheshire is composed of: (1) a pink to white, moderately sorted massive fine-grained arkosic to quartz arenite sandstone; (2) shale clast conglomerate composed of interbedded quartzite; (3) massive quartzite beds, lenticular in shape, with large scale erosional surfaces at their bases and trough cross stratification.

Interpretation:

These eight lithofacies can be interpreted to represent sediments deposited on a newly formed shelf, at least in part within wave base, and partially tidally influenced. The Cheshire Quartzite is thought to represent the marine shelf sand blanketing the underlying rift basin topography. Shelf sediments of the lower Cheshire exhibit periodic storm sedimentation, and are capped by the prograding strandline sediments of the upper Cheshire. These interpretations are based on: (1) the stratigraphic position of the Cheshire between the Eocambrian rift-related sediments and the overlying Dunham Dolomite; (2) the absence of any evidence of a supratidal environment; (3) a suite of sedimentary structures indicating wave working of the substrate, and the presence of tidal currents; and (4) bedforms indicative of episodic high energy events (storms?).

The Cheshire Quartzite will not be seen on this trip as the best exposures of this unit are in west-central Vermont. It is an important unit within the Cambro-Ordovician sequence, for its presence marks the transition from sedimentation associated with graben infilling to that of the newly formed shelf (rift-drift transition).

Dunham Dolomite

The Lower Cambrian Dunham Dolomite will be seen at Stops 1-3.

The lithofacies and depositional environments of the Dunham Dolomite were studied by Gregory (1982) and Mehrtens and Gregory (in review). These authors described the Dunham Dolomite as a 400 meter thick unit composed of four major lithofacies representing peritidal, channel, subtidal/open shelf, and platform margin environments. Both the lower and upper contacts with the Cheshire and Monkton Quartzites, respectively, are conformable.

The peritidal lithofacies of the Dunham is characterized by a bedding style termed "sedimentary boudinage", which describes the rhythmic interbedding of dolomite and dolomitic siltstone and subsequent differential compaction to produce beds which exhibit pods or boudins. This rhythmic interbedding is interpreted to be the result of deposition in a tidally-influenced regime, possibly a tidal flat. Bioturbation has disrupted the bedding, and early cementation lithified horizons enough to have formed intraclasts and local intraformational conglomerates. Cryptalgalaminites also occur in this facies.

The subtidal/open shelf lithofacies is characterized by shallowing-up cycles (SUC) 6 to 10 meters in thickness which have at their base massive, structureless beds of bioturbated dolomite passing up into rhythmically interbedded dolomite and silt-rich dolomite of the peritidal lithofacies. The bulk of the Dunham Dolomite is composed of these shallowing-up cycles, indicating that tidal flats prograded across the adjacent platform.

The third lithofacies, the channel deposits, are interbedded with both the peritidal and subtidal/open shelf lithofacies. Channels are best exposed in outcrops that trend parallel to strike so they are not exposed at the Route 2 outcrop but they are found in the Georgia and St. Albans localities. A typical channel is several meters wide and 0.5 meters deep, with a lenticular shape and a downcutting base. Channel sediments contain trough cross bedded quartz sand and both intraformational and exotic clasts.

Rocks characteristic of the platform margin lithofacies exhibit horizons of polymictic breccias within a quartz sand-rich dolomite matrix. These deposits are interpreted as talus deposits and debris flows accumulating off the edge of the Dunham platform. In the Milton, Georgia and St. Albans regions the Dunham breccias grade conformably into clast-rich horizons of the Parker Slate. Analysis of the distribution of the platform margin breccias is important in developing a model for the geometry of the Lower Cambrian carbonate platform, since these deposits very accurately place the position of the platform-to-basin transition. The Dunham Dolomite passes eastward, down dip into the Parker Slate and this facies change marks the passage into the shale basin and deeper water sediments of the Iapetus Ocean (seen for example at Arrowhead Mountain). Platform margin breccias also pass northward into a basin which Mehrtens and Dorsey (1986) proposed represents a foundered graben within the shelf. The distribution of platform margin facies defined the platform-to-basin transition and led to the definition of a horseshoe-shaped intrashelf basin, termed the St. Albans Reentrant (Mehrtens and Dorsey, 1986). We see the configuration of the St. Albans Reentrant maintained throughout the remainder of the Cambrian.

<u>Montkton Quartzite</u>

The Monkton has been dated as lower Middle Cambrian in age by Palmer and James (1980) and its lithofacies were first described by Rahmanian (1981). Seven lithofacies were recognized in the 300 meter thick Monkton. Shallowing-up cycles are characterized by repetitive packages of: (1) basal subtidal sand shoals and channels overlain by, (2) interbedded sand, silt, and carbonate intertidal flat sediments, capped by (3) carbonate muds of the high intertidal and supratidal flat. These cycles are interpreted to represent prograding tidal flat deposits. Two siliciclastic lithofacies were recognized: (1) sand bars and tidal channels and (2) mixed rippled sands with mud drapes of the intertidal. These supra-, inter-, and shallow subtidal sediments exposed in the Burlington and Winooski areas pass downdip to the east and north into subtidal oolitic dolomites and platform margin breccias exposed along Route 2 and the Milton region.

The high degree of similarity between the environments of deposition and facies distribution of the Dunham Dolomite and Monkton Quartzite suggests that the morphology of the platform established in the Lower Cambrian was maintained into the Middle Cambrian. Although composition of the platform sediments changed from dominantly carbonate (Dunham) to mixed siliciclastic and carbonate (Monkton), the environments of deposition in which these sediments were deposited remained the same.

In the Burlington and Winooski areas the shallow water platform sediments of the Monkton Quartzite are gradationally overlain by the Winooski Dolomite. In the Milton and Georgia areas the Monkton platform margin facies pass into the Rugg Brook Conglomerate and undifferentiated Parker and Skeels Corners Slates (Mehrtens and Borre, 1987) basinal deposits.

Winooski Dolomite

The environments of deposition and lithofacies of the Middle Cambrian Winooski Dolomite have not been studied in the detail of the other units, but initial studies indicate that it is approximately 300 meters thick and composed of the following lithofacies: (1) interbedded rippled fine--grained sand and silt with minor clay; (2) dolomite with planar cryptalgalaminite structures; (3) dolomite with LLH stromatolites; (4) dolomite with disseminated quartz sand; (5) quartz arenite beds with a dolomite matrix, and (6) polymictic breccia beds with a matrix of dolomite and quartz-rich dolomite.

Lithofacies 1 through 5 are arranged in a vertical stratigraphic sequence in Whitcomb's Quarry in Winooski. Lithofacies (1) and (2) are interbedded with the underlying Monkton Quartzite and are interpreted to represent peritidal deposits. Lithofacies (3), (4), and (5) overlie facies (1) and (2) and they make up the bulk of the Winooski stratigraphic sequence seen along the Winooski River (Stop 6). Due to an absence of any diagnostic sedimentary structures and a position overlying lithofacies (1) and (2) these lithofacies are interpreted as shallow subtidal in origin. Lithofacies (4), (5) and (6) are recognized as composing the uppermost horizons of the Winooski Dolomite, and are interpreted as representing subtidal and platform margin deposits.

As also seen in the Dunham and Monkton, the Winooski exhibits significant north-south facies changes parallel to depositional strike. In the Burlington and Winooski region the Winooski is gradationally overlain by the platform deposits of the Danby Quartzite while along Route 2 and in the Milton area the Winooski is overlain by the basinal deposits of the Rugg Brook Conglomerate (Mehrtens and Borre, 1987). Thus, the platform geometry first observed in the Dunham Dolomite was maintained into the Middle Cambrian.

Danby Quartzite

The Danby Quartzite (Upper Cambrian) is a 35-80 meter thick mixed siliciclastic/carbonate unit. The Danby is composed of a basal un-named sand-rich unit and the upper Wallingford Member. Significant variations in sand--carbonate ratios occur from southern to northern Vermont; the Danby is thinner in northwestern Vermont and more carbonate-rich while to the south it is thicker and dominantly sandstone in composition. Four lithofacies have been recognized by Butler (1986): (1) intertidal to shallow subtidal; (2) subtidal, (3) open shelf sand shoals and (4) platform margin. The inter- to shallow subtidal facies is characterized by interbedded sandy dolomites, sandstone and shales with mudcracks, vertical burrows, wave and current ripples, cryptalgalaminites, and oncolites. The subtidal sediments are composed of thick-bedded sandy dolomites, and pure dolomite with herringbone cross stratification, oncolites, pinch and swell bedding, upbundling of ripples, and LLH stromatolites. These features will be seen at Stop 7 along the Winooski River. The open shelf facies is characterized by thick-bedded, coarse-grained dolomitic sandstones and sandstones with large scale tabular cross stratification interpreted as sand shoals.

Platform margin facies include polymictic breccias in a dolomite matrix and ball and pillow sands and shales.

The Danby Formation is characterized by complex facies mosaicing and compositional heterogeneity. Butler (1986) proposed that storms on the platform were a major factor influencing the distribution of sand.

The distribution of facies of the Danby is identical to that of the underlying units: platform margin facies are found in the Milton region, bordering the St. Albans Reentrant, while shallower water platform sediments occur to the south.

Rockledge and Rugg Brook Formations

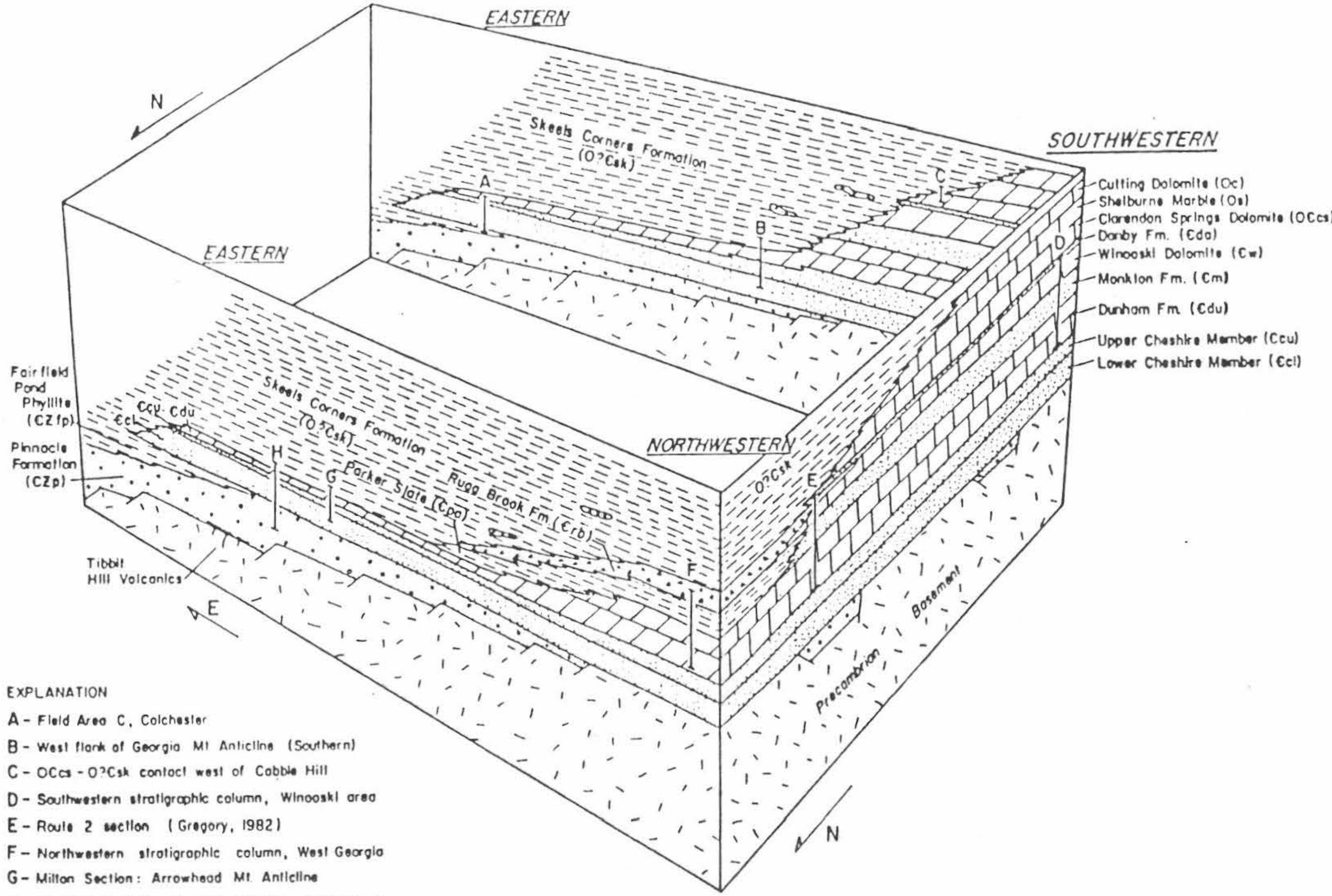
Bedrock mapping by Mehrtens and Dorsey (1986) and Mehrtens and Borre (1987) documented the distribution of these units in northwestern Vermont. Previous workers had, on the basis of map patterns and dolomite lithology, interpreted the Rugg Brook to be a lateral equivalent of the Middle Cambrian Winooski Dolomite. Mehrtens and her coworkers documented, however, that the Rugg Brook is not a time-stratigraphic unit and it occurs at several horizons interbedded with the Parker and Skeels Corners Slates (Figure 2). The Rugg Brook was recognized as consisting of four lithofacies: dolomite with sparse dolomite clasts, dolomitic sandstone, sandy matrix dolomite clast conglomerate, and shaley-matrix dolomite clast conglomerate. All of these lithofacies are interpreted to represent various types of sediment gravity flows accumulating basinward of the shallow-water platform.

The distribution of the Rockledge Formation was also studied by Mehrtens and her coworkers. Previously thought to be confined to a narrow time-stratigraphic horizon (Shaw, 1958), Mehrtens was able to document its occurence at several stratigraphic horizons. The Rockledge is an easily recognizable deposit of limestone clast conglomerates within undifferentiated Parker and Skeels Corners Slates. It is also interbedded with the Rugg Brook Formation. Mehrtens and Hillman (in review) described four lithofacies within the Rockledge, including: limestone clast conglomerate, massive sandstone, laminated and rippled siltstone, and structureless micrite. These lithofacies are all interpreted to represent sediment gravity flows formed along a slope apron adjacent to the platform. Because the clasts of the Rockledge are not dolomitized they have been valuable in describing the pre-dolomitization composition of the shallow water platform sediments from which they were derived. Five dominant clast compositions were recognized. These include: pelsparites, algal boundstone, oomicrites, calcareous sandstone and micrite, indicating that the Upper Cambrian shelf was characterized by agitated, shallow water conditions.

PLATFORM GEOMETRY

Figure 3, taken from Dorsey and others (1983) summarizes the geometry of the Cambrian platform in northwestern Vermont. Several important features are shown on this diagram, constructed from a view looking southeast. The St. Albans Reentrant, the shale basin lying along depositional strike in the shelf, is shown. Note also the north-to-south, and west-to-east facies changes present within every Cambrian platform deposit. The shallow water facies are present in the south, and they pass northward and eastward into subtidal and platform margin deposits, and ultimately into the shale basin. The diagram also shows the localization of the platform margin from Dunham through Danby time. This is important because it indicates that the platform was up-building throughout the Cambrian. Platform facies did not build out into the basin, nor did the platform founder to produce significant onlap of shales. What could have caused the localization of the platform margin? If the St. Albans Reentrant is indeed a graben within the shelf which foundered as a result of movement of an underlying Eocambrian rift-related lystric fault, then these localized deposits accumulated along the fault scarp. Sedimentation on the platform itself was able to keep pace with thermal subsidence on the young, hot, recently-rifted margin, and the sediment built vertically, with an abrupt pinchout into the adjacent basin. The timing of initial movement of the graben which formed the St. Albans Reentrant is thought to be late-to--post-Dunham time, based on the fact that the Dunham Dolomite is the only shelf unit which continues across what becomes the shale bsin. Following deposition of the Dunham, the facies on the northern rim of the Reentrant are different than those to the south (Mehrtens and Dorsey, 1986).

Figure 3. (following page) Block diagram from Dorsey, et al (1983) illustrating the proposed paleogeography of the southern margin of the St. Albans Reentrant. Diagram shows the platform deposits pinching out to the east into the marginal Iapetus Ocean, and to the north into the St. Albans Reentrant; the latter platform margin is characterized by thick conglomerate and breccia deposits. The field trip will be viewing sections D (Winooski River) and E (Route 2).



EXPLANATION

A - Field Area C, Colchester

B - West flank of Georgia Mt Anticline (Southern)

C - OCcs - O?Csk contact west of Cobble Hill

D - Southwestern stratigraphic column, Winooski area

E - Route 2 section (Gregory, 1982)

F - Northwestern stratigraphic column, West Georgia

G - Milton Section: Arrowhead Mt. Anticline

H - West flank of Georgia Mt Anticline (Northern)

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FIELD TRIP ITINERARY

Several stops require parking on the shoulders of roads, and space is often at a premium. Please try to condense into as few cars as possible. Visits to private farms (Stop 8) require permission.

Assembly point: Sand Bar State Park on Route 2, Vermont

Mileage

1.6 Stop 1- Abandonned quarry on the north side of Rt. 2.

Park on the southwest (right) shoulder, cross Rt 2, and ascend overgrown driveway into quarry. The Champlain Trust floors the quarry as the Dunham Dolomite is emplaced on the Middle Ordovician Stony Point Shale. The Dunham Dolomite exposed here is the basal facies of the Dunham, characterized by the rhythmic interbedding of dolomite (white) and silty dolomite (pink). This bedding style is interpreted to be the result of alternating sedimentation in a tidal flat setting, producing "ribbon bedding". Look for: undisturbed horizons of the dolomite and silt-rich dolomite, horizons of intraclasts, burrows, and cryptalgalaminites. Note that many of the clasts show rips and tears in their margins, others are bent. Many clasts are cored by calcite. Greiner (1982) recorded occurences of gypsum in this facies in sub-surface cores.

Return to cars and continue east on Route 2.

2.4 Stop 2 Shallowing-up cycles in the Dunham

This roadcut on the left (north shoulder) exposes 3 shallowing-up cycles within the Dunham. They are recognizable in the large roadcut because of the characteristic pink and white ribbon bedding of the peritidal caps of the SUC's. One SUC can be studied in detail on the northwest corner of the roadcut. The SUC (Figure 4) is composed of a basal subtidal dolomite overlain by the ribbon bedding of the peritidal cap. The cycles in the Dunham are similar to "muddy shallowing-up cycles" of James (1983) and they consist of 6-10 meters of bioturbated, sandy dolomite passing up into ribbon-bedded dolomite and silt-rich dolomte and local intra-formational conglomerate. What is the origin of the sand within the Dunham subtidal muds? SEM work led Gregory (1982) to suggest that frosting micro-textures on quartz grains recorded an eolian history to the sediment. However, channels within the Dunham are sand-filled, and provide a mechanism for the transport of sand across the platform. This is similar to the tidal channels of Shark Bay, western Australia, where channels are infilled with a mixture of carbonate mud and quartz sand from eroded Pleistocene bedrock.

Return to cars and continue driving east on Route 2.

3.1 Stop 3- Dunham subtidal and platform margin facies.

Pull off about 100 yards beyond the speed limit sign on this long roadcut. At the base of this outcrop (west end) there are good exposures of the subtidal facies of the Dunham with the character istic mottled texture, thought to be produced by burrowing. Burrow mottles are irregular in shape, 1 to 8 cm in diameter, and lack sand. The segregation of siliciclastic material is one property that implies bioturbation produced this mottled texture. Between the white burrows the red matrix is very clay and sand-rich, and Stone and Dennis (1964) attribute this color variation to differing concentrations of trace metals. Specimens of Salterella conulata (Mehrtens and Gregory, 1983) were found in this facies. The platform margin facies is exposed on the east end of the same outcrop. This facies is composed of chaotically-bedded, laterally discontinuous horizons of breccia in a sand-rich dolomite matrix. Clast composition is highly variable, and includes chert pebbles, sandstones, sandy-dolostones, and dolomitic

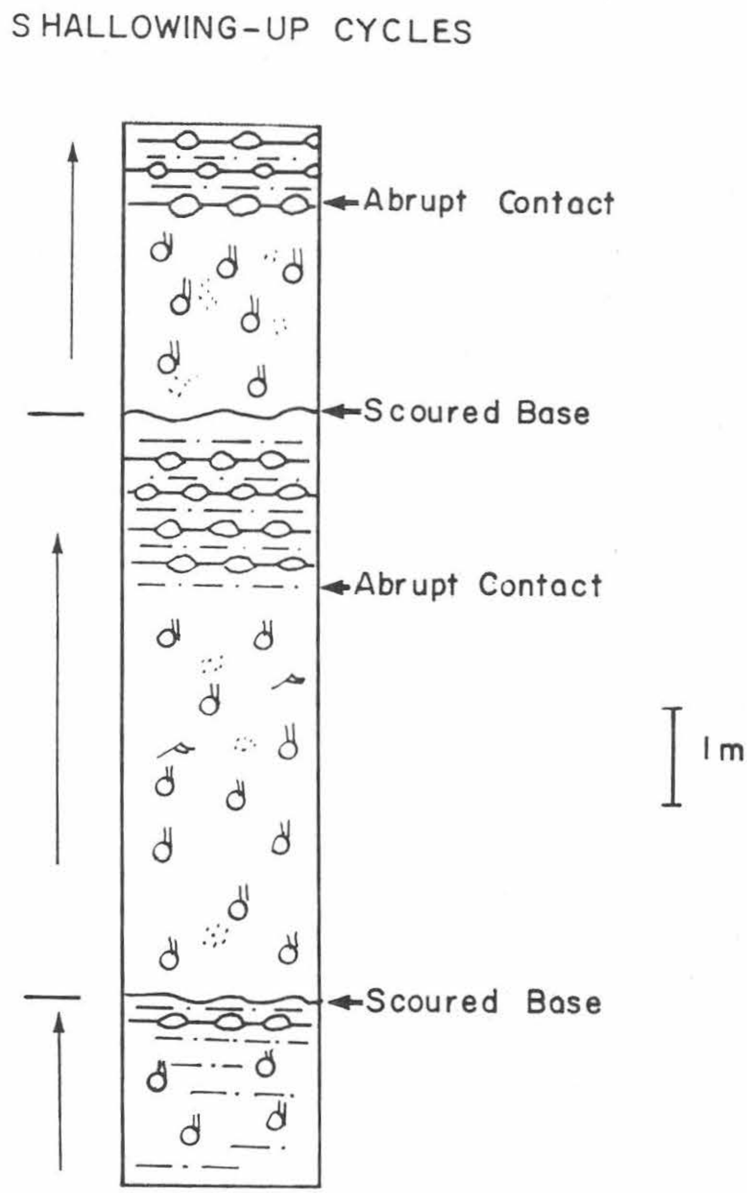

Figure 4. Shallowing-up-cycles in the Dunham Dolomite.

sandstones. Breccia beds are structureless and very poorly sorted. Graded beds of sandstone are also present.

Return to cars and continue east on Route 2.

3.8 <u>Stop 4</u>- Monkton Quartzite, subtidal and shelf edge facies

This roadcut exhibits the subtidal and shelf edge facies of the Monkton, as evidenced by the overall thickness of the individual beds, increasing amounts of shale between sandstone beds, presence of relict oolites in some dolomite horizons, and occurences of large scale tabular cross stratification. Many of these beds probably represent shelf edge sand shoals. Note characteristics of the Monkton here for comparison to the shallower-water deposits seen at Stop 6.

Walk east 0.3 miles to the small knoll beyond the road sign. Here the polymictic breccia of the platform margin facies is exposed. The clasts are floating in a matrix of sandy dolomite and are interbedded with cross-bedded sandstones. Clast composition includes dolomite, sandstone and dolomitic sandstones. Beds are structureless and poorly sorted. These breccias are interpreted to represent talus deposits formed at the edge of the platform. These breccias can be traced to the north, where they form a rim around the St. Albans Reentrant. Mehrtens and Borre (1987) have documented that the Monkton passes laterally into the Rugg Brook Conglomerate within the basin.

Return to cars and continue east on Route 2.

4.7 T-intersection with Routes 2 and 7 at Chimney Corners.
Turn left.

4.8 Pull off into commuter parking lot.

<u>Stop 5</u>- Winooski platform margin facies

Walk from the parking lot back to, and across the intersection, to the outcrop on the southwest side. This is an exposure of recyrstallized dolomite, cross-bedded, and in places oolitic, of the upper most Winooski. Cross the road to the low-lying outcrop on the east side of Route 7. Note the variable clast composition and abundance of sand in the dolomite matrix in this Winooski platform margin breccia. These outcrops of Winooski at Chimney Corners and the adjacent I-89 exit ramps are the northernmost outcrops of Winooski Dolomite in northwestern Vermont. Immediately to the north on I-89 and Route 7 are exposures of the Rugg Brook Dolomite, a breccia deposit within the St. Albans Reentrant.

Return to cars and head south to Burlington.

5.1 Southbound entrance ramp on I-89. Outcrops of the Monkton Quartzite occur as roadcuts all along I-89.

11.1 First outcrop of Winooski Dolomite on the median of I-89

11.3 Exit off I-89, southbound onto Routes 2 and 7.

12.5 Intersection in Winooski with Routes 2, 7 and 15. Continue straight ahead on Routes 2 and 7.

12.7 Bridge over the Winooski River (Stop 6 is below us).
Bear right at the "Y".

12.9 Park in the small pull-off on the right, or if there are many cars, across the street in store parking lots.

Stop 6- Salmon Hole- tidal flat facies of the Monkton, Winooski and Danby Formations.

Descend the pathway down to the broad bedding planes of the Monkton in the south bank of the river. This beautiful outcrop of Monkton is in danger of being destroyed by dam construction. Examine the multitude of rippled surfaces, and note the multiple paleoflow directions. Examine these rippled beds in cross section and note that they are composed of rippled dolomite, silty dolomite, and fine-grained sandstone with shale drapes, a typical tidal bedding style. Examining bedding planes again, look for both vertical and horizontal burrows. Mudcracks can also be found. The thick, structureless buff-colored dolomite bed near the top of the Monkton is interpreted to be supratidal in origin (carbonate mud washed up onto the tidal flat during a storm?). This implies that the section of Monkton just examined would be the upper portion of a shallowing-up cycle, which characterize the Monkton Quartzite. From having seen the subtidal and platform margin facies of the Monkton at Stop 4 you can now compare the features seen at the two outcrops. The tidal flat facies seen here and at other localities around the Burlington and Winooski areas were prograding northward towards the platform margin in the Milton region. The Monkton/Winooski contact is under water here but can be examined at Whitcomb's Quarry at the I-89 interchange. It is gradational over about 10 meters, with progressively decreasing amounts of sand up section into the Winooski.

Return to cars. Turn around to head back across the river.

13.4 Drive across the river to the entrance to the Winooski Mill shopping mall. Drive to the back parking lot adjacent to the river. Carefully descend to the river bank on the upstream side of the building.

<u>Stop 7</u> - Danby Quartzite and Winooski Dolomite

You are now on the bedding planes of the shallow subtidal facies of the Danby Quartzite (Figure 5), which is a dolomitic sandstone at this exposure. There are many exposures of sedimentary structures at this outcrop,including hummocky cross stratifi cation, complexly-woven ripple bundles, bedding planes with interference ripples, and graded beds. Biogenic structures include small LLH stromatolites and oncolites. Most of these features suggest that the sediments of the Danby were frequently reworked by storm action, resuspending and reworking the substrate, and rapidly depositing sediment during post-storm surge ebb flow.

During low water levels the entire Danby can be walked out from its contact with the Winooski on this side (upstream) of the bridge. The contact is gradational and is characterized by increasing amounts of quartz sand in dolomite until it becomes a dolomitic sandstone. The Winooski Dolomite does not exhibit many features but thin wisps of carbonaceous material with sand grains concentrated along the laminae are interpreted to be cryptalgalaminites.

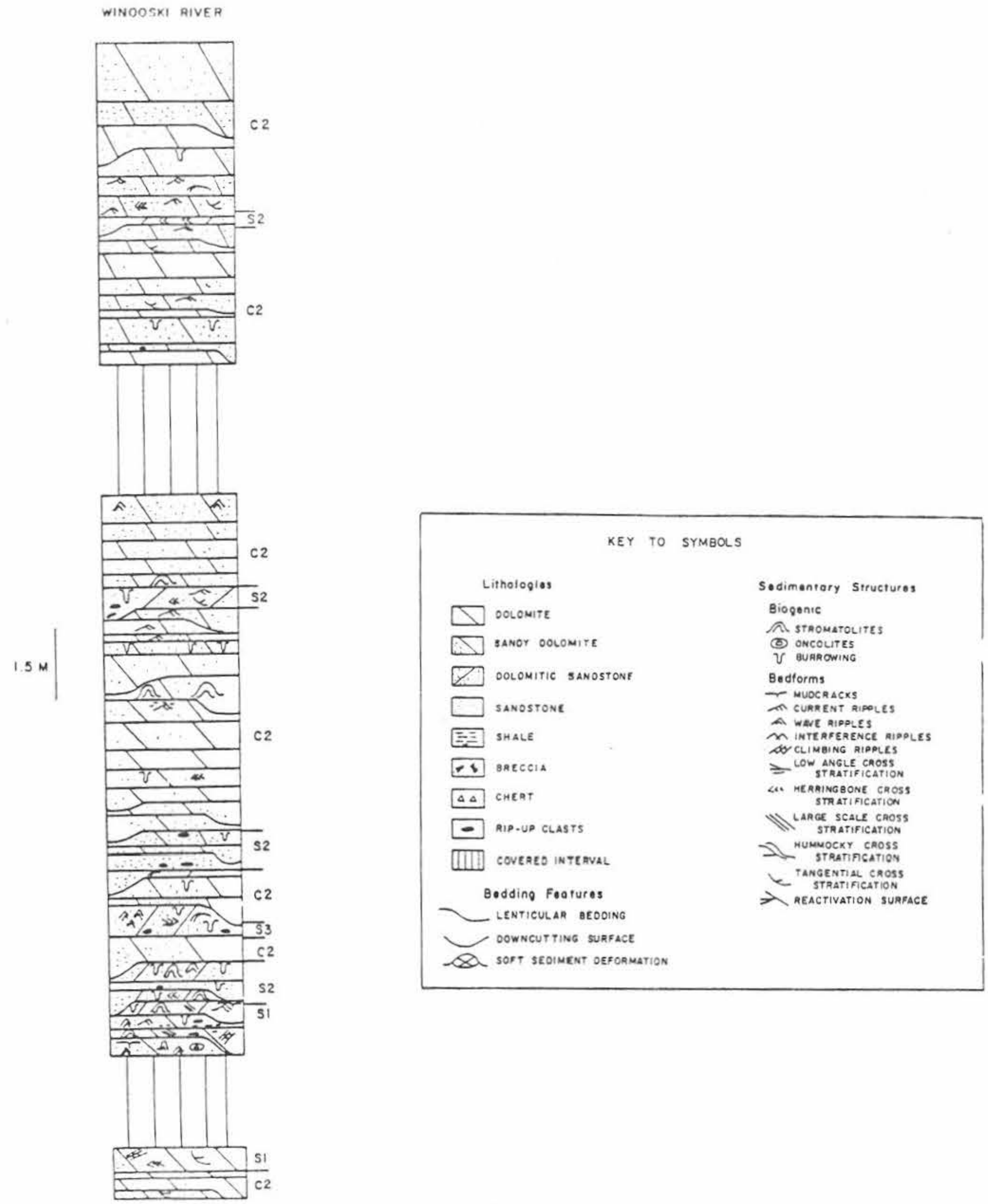

Figure 5. Measured stratigraphic section of the Danby Formation along the Winooski River.

Return to cars and exit shopping mall to Route 7.

14.8 Ascend Route 7 to I-89, passing Whitcomb's Quarry.

29.6 Head north on I-89, passing (at 23.3 miles) an exposure of Rugg Brook Conglomerate and at 25.1 and 25.7 miles, exposures of folded Skeels Corners Slate.

Exit 18 Georgia Center/Fairfax.

32.3 Head north on Route 7 to Georgia Center
Left at Center Market towards Georgian Plains (west).

32.8 Go straight at Y in road. Knoll to your right (north) is Rockledge Conglomerate.

33.2 Knoll of Rockledge on the right. Pull off onto shoulder.

You must ask permission to visit this outcrop.

Stop 8- Rockledge Conglomerate

In the field immediately to the north of the road are scattered outcrops of the Rockledge Conglomerate limestone clast facies. Examine exposures of the conglomerate and the poor sorting and angularity of clasts, and the sandy limestone matrix. Pods of the conglomerate, interpreted as individual flows of high density turbidity currents, are surrounded by the laminated siltstones of the Skeels Corners Slate.

Time permiting, it is possible to continue west along this road and examine several facies of the Rugg Brook Formation.

34.2 Small ridges 100 yards to the north are composed of massive dolomitic sandstone facies of the Rugg Brook Formation.

Skeels Corners Slate occurs across the street to the west.

Turn right at the stop sign and head north

35.1 In the fields behind the yellow farm house are exposures of various facies of the Rugg Brook, primarily the massive dolomite with scattered clasts and dolomitic sandstones.

Continue north

35.6 Turn Right

37.5 Intersection with Route 7. Turn right (south)

41.1 Intersection with I-89. Head southbound

49.9 Route 2 Champlain Islands exit ramp off I-89. Head west (right).

53.8 Return to Sand Bar State Park and meeting place for start of trip.