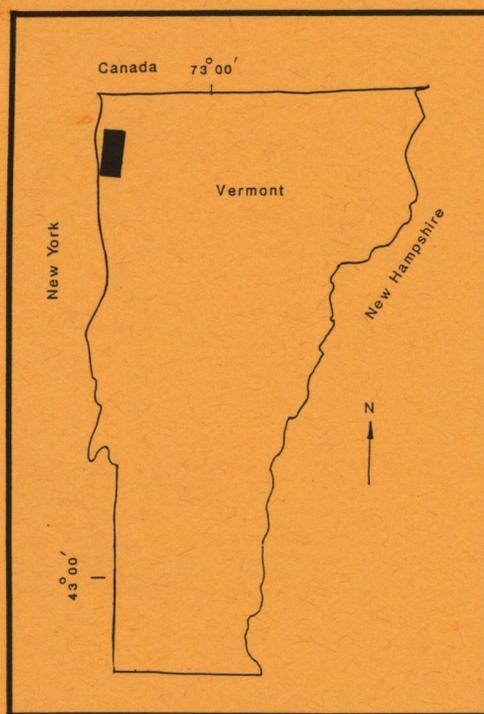


STRATIGRAPHY AND BEDROCK GEOLOGY OF PARTS OF THE ST. ALBANS AND GEORGIA QUADRANGLES, NORTHWESTERN VERMONT

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ABSTRACT

This study of the bedrock geology of a portion of the St. Albans and Georgia 7.5 minute Quadrangles, Vermont, has resulted in a new geologic map (1:24,000) for the region. The significant difference between this map and the existing State Geologic Map (Doll, et al., 1961) lies in the differentiation of facies within the Rugg Brook Dolomite, which was formerly mapped as a continuous belt of a homogenous lithology. The Rugg Brook is shown to consist of pods of breccia, representing discrete sediment gravity flow deposits within the shale matrix of undifferentiated Parker and Skeels Corners Slates. A more detailed map (1:6,000) shows the structure of a small synform within the Rugg Brook Dolomite on the eastern side of the study area.

Introduction

The study area is in the St. Albans Quadrangle and the northern part of the adjacent Georgia 7.5 minute Quadrangle. It is underlain by Cambrian rocks which record the evolution of the Cambro-Ordovician platform in the northern Appalachians. These rocks are part of an extensive belt of similar facies extending from Newfoundland to Alabama along what Rodgers (1968) recognized as the margin of the Lower Paleozoic platform in eastern North America following the opening of the Iapetus Ocean. These facies consist of carbonate and siliciclastic deposits characteristic of a shallow-water platform, bordered to the east by a basin which accumulated fine-grained sediments and debris flows shed off the platform. These basinal deposits are represented by discontinuous slate and breccia horizons.

This study completes a revision of the bedrock geology of northwestern Vermont begun by Mehrtens and Dorsey (1987) in the Highgate region to the north and Mehrtens and Borre (1989) to the south in Georgia Plains and Milton.

PREVIOUS WORK

Shaw (1958) extensively studied the geology of the St. Albans area and he developed a regional stratigraphy for the shale and breccia horizons in northwestern Vermont. He interpreted the Cambrian sequence as a north-south trending outcrop belt of eastwardly-dipping, laterally continuous strata, where breccia horizons (Rugg Brook, Mill River, and Rockledge Formations) separated discrete shale units (Parker, St. Albans, Skeels Corners, Morses Line Slates). Mehrtens and Dorsey (1987) remapped a portion of the St. Albans region and demonstrated that the rock units within the region record complex sedimentology at the platform/platform margin transition. Breccia horizons were interpreted as individual horizons of sediment gravity flows into a basin which was accumulating fine-grained pelitic sediment. In contrast to Shaw's earlier interpretation, the stratigraphy has been re-interpreted as a sequence where units were not time-stratigraphic horizons.

Similar conclusions have been reached by Mehrtens and Borre (1989), who mapped part of the Milton and Georgia Quadrangles. Their study area included rocks of the shallow water platform (Dunham Dolomite) in the south and west, with the platform to basin transition recognized in the Dunham, Monkton, and Winooski Formations in the south, passing northward into the Parker, Skeels Corners and Rugg Brook Formations. Mehrtens and Borre were able to recognize and map the distribution of lithofacies first described by Mehrtens and Dorsey (1987).

STRATIGRAPHY

Within the study area, rocks have been assigned to the Western Shelf and Eastern Basinal Sequences (terminology after Dorsey, et al., 1983). The Western Shelf Sequence includes carbonate and siliciclastic rocks of shallow water platform affinity. They outcrop in the north-south trending belt which comprises the western part of the study area. The Eastern Basinal Sequence consists of shale, sandstone, and breccia horizons. Horizons within the Eastern

Basinal Sequence contain trilobites, and the results of biostratigraphic studies are included in Shaw (1957 and 1958), Palmer (1970) and Palmer and James (1980). The general unfossiliferous nature of the Western Shelf Sequence has made biostratigraphic correlations between the two groups of rocks impossible. Existing correlations are based on physical relationships of intertonguing. A correlation chart for the Cambrian and Lowest Ordovician sequence in northwestern Vermont is presented in Figure 1. It is based on a summary of existing biostratigraphic data and also on observed physical stratigraphic relationships. The ages of individual units will be discussed later, but it should be pointed out that: (1) Palmer and James (1980) recognized the presence of an unconformity within the Parker Slate, which they termed the Hawke Bay Event, a period of non-deposition within the basin; (2) the Skeels Corners Slate is interbedded with, and often indistinguishable from the Parker Slate, and it may have a wide age range; (3) based on outcrop patterns throughout northwestern Vermont, the Rugg Brook Formation occurs at a variety of stratigraphic levels, from immediately overlying the Lower Cambrian Dunham Dolomite in the Milton region to interfingering with the Upper Cambrian Rockledge Formation in the Highgate region. This report does suggest, however, that there may be an internal stratigraphy to the units which reflects the importance of source area of the adjacent platform on the distribution of basinal deposits. It is not yet clear whether these have any time-stratigraphic significance. Figure 2 presents a correlation chart of the Cambrian through Upper Ordovician stratigraphy of western Vermont, including allochthonous and autochthonous strata.

WESTERN SHELF SEQUENCE

Cheshire Quartzite (€ch)

The Cheshire Quartzite occurs in a series of klippen within the eastern portion of the study area, and also as outcrops on the eastern limb of the St. Albans Synclinorium on the eastern margin of the study area. The Cheshire is recognized by its distinct lithology of fine-grained arkosic sandstone with anastomosing shale partings.

The Lower Cambrian age of the Cheshire is based on occurrences of *Hyolithes* (Shaw, 1955).

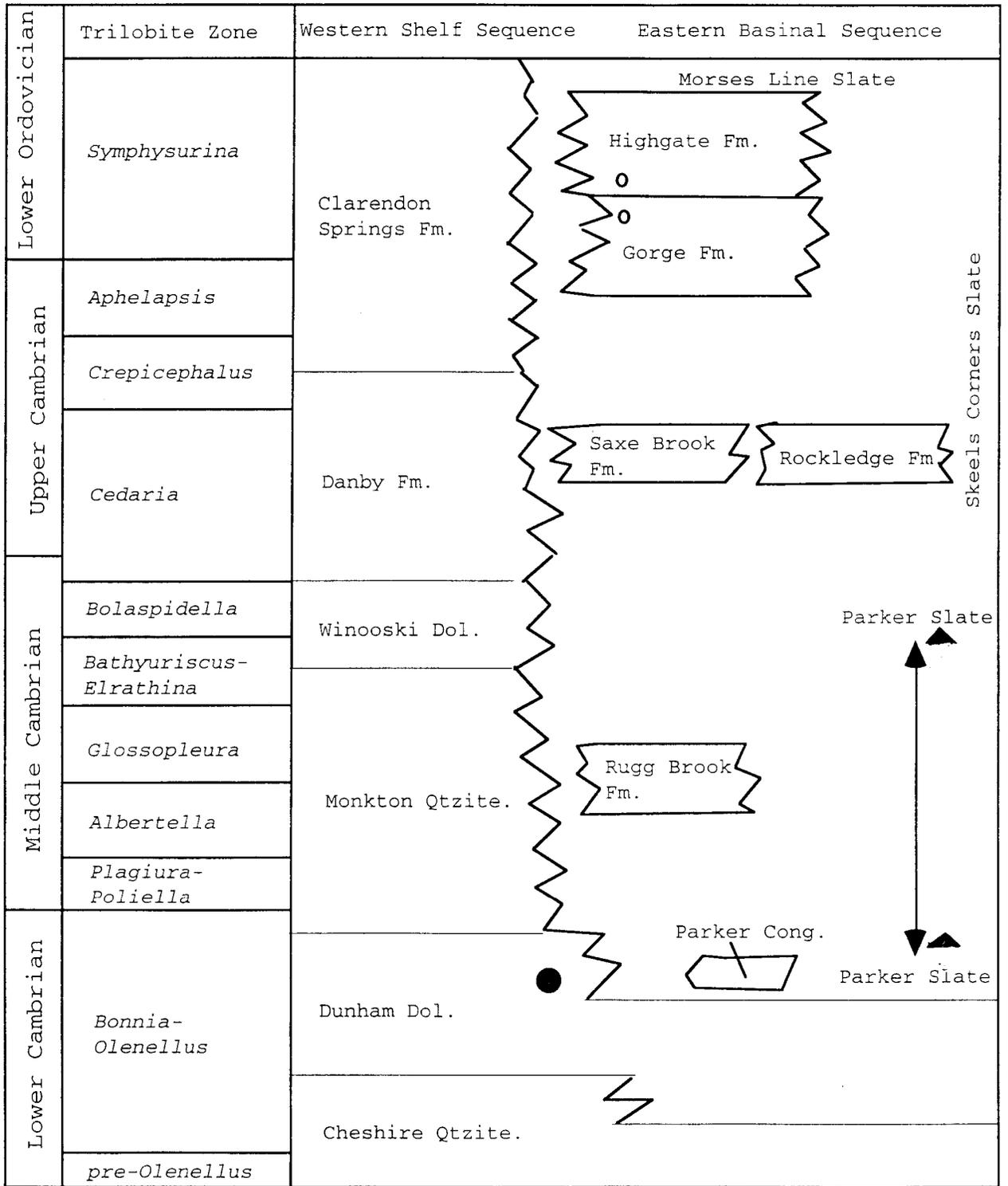


Figure 1

Figure 1 Caption. (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, triangles), Landing (1984, open circle), Mehlertens and Gregory (1983, closed circle), and physical stratigraphic relationships mapped by Dorsey, et al. (1983), Mehlertens and Dorsey (1987), Mehlertens and Borre (1989) and this report. Ages between all units on the platform are approximate because they are based on intertonguing relationships with basinal units. The Hawke Bay Event is illustrated by a vertical arrow spanning an interval of time in the Parker Slate. The Skeels Corners Slate has been dated as *Bolaspidella* zone in age but mapping relationships suggest that it has a much broader range.

Dunham Dolomite (Edu)

The Dunham Dolomite is a pink to buff-colored dolomite which outcrops in a north-south belt in the western portion of the study area, and also on the eastern part of the study area on the east limb of the St. Albans Synclinorium. The base of the unit is truncated by the Champlain Thrust, which has emplaced the sequence of Cambro-Ordovician rocks on Middle Ordovician shales. Lithofacies within the Dunham have not yet been recognized in this study area, however to the south, in Milton, Gregory (1982) identified four lithofacies: peritidal, channel, open shelf, and shelf margin.

The Dunham Dolomite is Lower Cambrian in age and collections of *Salterella conulata* Clark by Mehlertens and Gregory (1983) in the Milton region indicate that the unit is at least in part, *Olenellus* zone in age.

Undifferentiated Beekmantown and Chazy Groups (Obc)

The Highgate Springs Thrust has brought slivers of dolomite and limestone of the Ordovician Beekmantown and Chazy Groups to the surface, emplacing them against the Dunham Dolomite. Doll, et al. (1961) recognized the Beldens Member of the Chipman Formation as comprising the sliver of Beekmantown Group east of the Highgate Springs Thrust in northwestern Vermont. The Beldens Member is a buff-colored dolomite to bluish grey colored marble in composition. The overlying Chazy Group is undifferentiated in this portion of the study area but is composed of interbedded horizons of limestone and argillaceous limestone. In the field the two units can be distinguished because of the differences in bedding: the Beekmantown being characterized by its massive beds, and the Chazy by its fissile, thinly-bedded nature.

THE STRATIGRAPHY OF WESTERN VERMONT

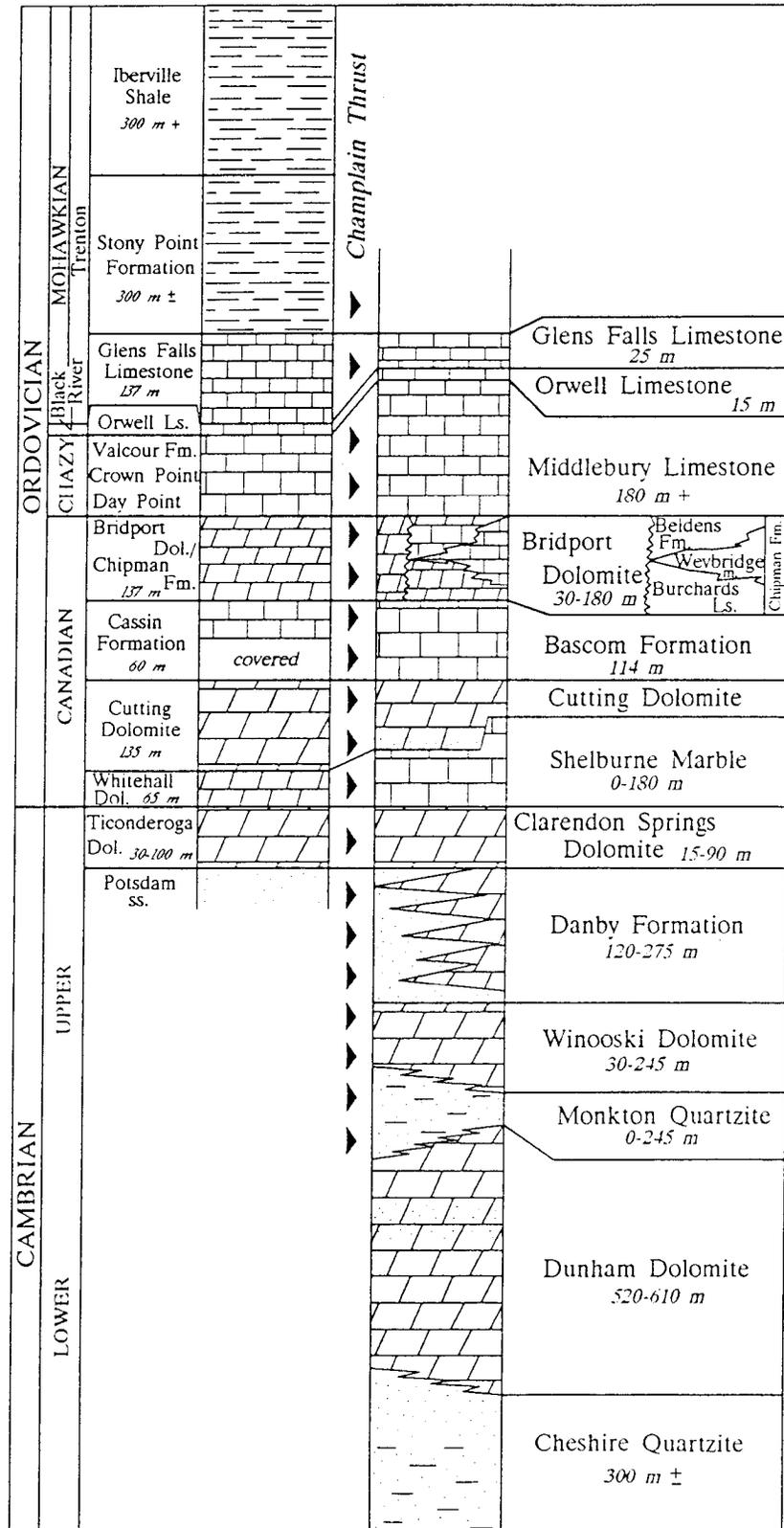


Figure 2

Ages of both units have been determined outside of the study area. The Beekmantown Group is Lower Ordovician (Canadian Series) in the southern Champlain Basin (Mazzullo and Friedman, 1975) and the Chazy Group is Chazy Series (Lower Middle Ordovician) in the northern Champlain Valley (Pitcher, 1964).

EASTERN BASINAL SEQUENCE

The rock units comprising the Eastern Basinal Sequence lie to the east of the Dunham Dolomite and consist of the Parker, and undifferentiated Parker and Skeels Corners Slates, the Rugg Brook Formation, the Rockledge Formation and the Morses Line Slate.

Parker Slate (Єp)

The Parker Slate is the oldest, lowermost shale unit of the basinal deposits. The Parker was described by Shaw (1958) as a gray-to-black micaceous slate containing horizons of limestone, dolomite, quartzite, and limestone "bioherms." In this study area, the Parker Slate occurs immediately overlying the Dunham Dolomite (Plate 1, Figure 1, localities C1 and D3), and as a discrete pod in the middle of the study area (Plate 1, Figure 1, localities D2 and D3). It is characterized by laminations of dolomitic siltstone and mica in a black shale matrix. With the exception of these two localities, most of the shale in the study area can not be distinguished as belonging to either the Parker or Skeels Corners Slates. Mehtens and Dorsey (1987) discussed the gradational nature of these two units in the Highgate region to the north.

Palmer (1970) and Palmer and James (1980) reviewed the trilobite collections from the Parker presented earlier by Shaw (1958) and determined that the lower Parker Slate is early Middle Cambrian in age while the upper Parker is late Middle Cambrian (Figure 1). The hiatus in deposition within the Parker Slate was termed the Hawke Bay Event by Palmer and James (1980). They suggested that it represents a major regressive event on the shallow water platform and a period of non-deposition in the adjacent basin during the Middle Cambrian.

Parker Conglomerate (€pc)

The Parker Conglomerate was recognized by Mehrtens and Dorsey (1987) in the Highgate region of northwestern Vermont. It is described as an arenaceous slate with clasts of dolomite and arenaceous dolomite. Clasts weather orange in color, and are generally well-rounded and poorly sorted. Within this study area, the Parker Conglomerate immediately overlies the Dunham Dolomite (Plate 1, Figure 1, location D6). Although its age has not been determined by biostratigraphic means, it is interpreted to represent Dunham detritus shed into the basin from the adjacent platform, and would therefore be Lower Cambrian in age. This interpretation agrees with that of Gregory (1982), who described the platform to basin transition in the Dunham. He recognized that clast composition within the Parker corresponds to lithologies found in the Dunham.

Undifferentiated Parker and Skeels Corners Slates (€-Op-sk)

The Skeels Corners Slate is in gradational contact with the Parker Slate; in most of the field area it is difficult to distinguish the units. The end members in composition are recognizable: the Parker is characterized by its micaceous silty shale composition, and the Skeels Corners by its black limonitic laminae of quartz silt and dolomite, giving the unit an orange pinstripe appearance. However, within many portions of the field area, both lithologies are interbedded in varying proportions.

Dorsey, et al. (1983) redefined the stratigraphy of the Skeels Corners Slate in the Milton region, recognizing that it overlies both the Lower Cambrian Dunham Dolomite and the Upper Cambrian-Lower Ordovician Clarendon Springs Dolomite. These physical stratigraphic relationships suggested a much broader age range than those proposed by Shaw (1958) and Palmer (1970), possibly spanning the Lower Cambrian to Lower Ordovician.

Rugg Brook Formation (€rb)

Shaw (1958) applied the name Rugg Brook Formation to the dolomite horizon that lay stratigraphically above the Parker and St. Albans Slates, and it was interpreted by him to represent the northern equivalent of the Winooski Dolomite. The Rugg Brook Formation was redefined by Mehrtens and Dorsey (1987) to describe

all dolomites, arenaceous dolomites, dolomitic breccias and quartzites lying below the Rockledge Conglomerate. They recognized five lithofacies in the Rugg Brook in the Highgate region: (1) recrystallized dolomite (€rdb), in part conglomeritic; (2) white, coarse-grained dolomitic quartzite (€rbq); (3) sand-rich matrix, dolomite clast conglomerate (€rbs); (4) shaley-silty matrix, dolomite clast conglomerate (€rbsh); and (5) sandstone clast, dolomite matrix conglomerate (€rbsc). This study recognizes a new facies within the Rugg Brook Formation: thin sandstone horizons with intercalated shale horizons, designated as €rbq2.

Within this study area, the distribution of facies of the Rugg Brook were mapped and shown to have a stratigraphic distribution similar to those described to the north (Mehrtens and Dorsey, 1987) and south (Mehrtens and Borre, 1989). That is, the Rugg Brook occurs as pods of conglomerate, dolomite and sandstone, surrounded by the fine-grained sediments of the undifferentiated Parker and Skeels Corners Slates. The recrystallized dolomite facies (€rbd) occurs immediately overlying the Dunham Dolomite, but otherwise there does not appear to be any internal stratigraphy to the unit. The Rugg Brook Formation, therefore, represents a mappable group of rocks and not a time-stratigraphic unit.

Although Shaw (1958) found no fauna in the Rugg Brook Formation in the St. Albans region, he assigned it a Middle Cambrian age on the basis of its stratigraphic position between the Parker and St. Albans Slates. The latter rock unit was reassigned to undifferentiated Parker and Skeels Corners Slates by Mehrrens and Dorsey (1987). The fact that its position immediately overlies the Dunham Dolomite, and contains Dunham clasts suggests that the base of the Rugg Brook Formation may be at least, in part, Lower Cambrian in age. Hadley (1991) identified clasts of red siltstone of the Monkton Quartzite within the €rbq facies, which suggests at least a lower Middle Cambrian age for some portions of the Rugg Brook. The overlying rock unit, the Rockledge Formation, has been dated by trilobites as early Upper Cambrian (Dresbachian) by Shaw (1957). This would provide an upper age limit on the Rugg Brook.

Rockledge Formation (€rlsh, €rls)

The Rockledge Formation is an easily recognizable unit in the study area due to its distinct limestone composition. There are only three outcrops of Rockledge in the study area (Plate 1, Figure 1,

localities F2, D2 to E2, and E6). Mehrtens and Dorsey (1987) noted that there are horizons of interbedded limestone (Rockledge Formation) and dolomite (Rugg Brook Formation) in the Highgate region to the north, suggesting that they may represent diagenetic facies of one another. In this field area, one exposure of Rockledge does occur at the top of the stratigraphic section (Plate 1, Figure 1, locality F2), while the other outcrops in the middle of the study area (Plate 1, Figure 1, localities D2 to E2 and E6) and is therefore stratigraphically equivalent to horizons of the Rugg Brook Formation.

The age of the Rockledge Formation was discussed by Mehrtens and Dorsey (1987). Based on their definition of the unit, the Rockledge spans an Upper Cambrian-Lower Ordovician interval, as a limestone horizon formerly included in the Corliss Conglomerate was included in the Rockledge. This conglomerate horizon yielded a Lower Ordovician fauna (Shaw, 1951), but it was considered part of the Rockledge because it was lithologically identical to other sediment gravity flow deposits in this unit.

The Rockledge occurs as two facies, a coarse-grained arenaceous dolomite matrix with limestone clasts and a shaly or silty matrix limestone clast conglomerate. The former facies is also associated with quartzite horizons. Hillman and Mehrtens (1988) described the sedimentology of the Rockledge Formation and found that it represents a series of sediment gravity flows which formed a debris apron adjacent to the carbonate platform.

Morses Line Slate (Oml)

The Morses Line Slate is recognized as a dense black non-calcareous slate with orange-colored silt laminae. It is distinguished from the underlying Parker and Skeels Corners Slates by being less calcareous. Because it is confined to the eastern half of this study area, it is strongly cleaved. The best exposures of this unit are associated with Cheshire klippe, such as on the flanks of Aldis Hill (Plate 1, Figure 1, locality F5). The contact between the Morses Line Slate and the underlying Cambrian units is interpreted as a high angle fault in the Aldis Hill area.

The age of the Morses Line Slate is not precisely known, however all accounts would place it as the youngest unit in the study area. The Morses Line Slate was recognized by Mehrtens and

Dorsey (1987) in the Highgate region to the north of this study area. They placed the base of the unit to include pods of micrite limestone (Erlm) within the underlying Rockledge Formation. Shaw (1958) evaluated the fauna collected from these limestone horizons in the Moses Line and found them to be Lower to Middle Ordovician in age. Earlier, Shaw (1951) felt the Moses Line was overlain by the Lower Ordovician Highgate Formation, which suggested to him that it was also Lower Ordovician in age.

SEDIMENTOLOGIC INTERPRETATION

Earlier workers (Shaw, 1958; Rodgers, 1968) recognized the north to south facies change from the Burlington area in the south northwards towards the Canadian border, however its significance as a record of a major paleogeographic feature was not apparent. Mehtens (1985) suggested that the facies changes seen in this area were the result of a pronounced change in the bathymetry which marked a platform to basin transition within the Cambrian platform. Mapping of the distribution of facies associated with the platform to basin transition marked the outline of an intra-shelf basin within the Cambrian platform which Mehtens and Dorsey (1987) termed the St. Albans Reentrant. The basin is bordered to the south by the shallow water platform deposits of the Dunham through Clarendon Springs Formations, and on the north by Gilman (equivalent to the lower Cheshire Quartzite), Dunham Dolomite and Saxe Brook Dolomites. The Highgate and Gorge Formations overlie the Saxe Brook, and these carbonate breccias and shales record the foundering of the northern rim of the Reentrant by Upper Cambrian time. Landing (1984) obtained a diverse fauna from both units which provides a precise age for the collapse of the northern rim: the Gorge is Trempleauian (Upper Cambrian) in age and the overlying Highgate spans the Upper Cambrian/Lower Ordovician boundary.

From the time of deposition of the Dunham Dolomite through the Lower Ordovician, shallow water sediments accreted on a platform and shed detritus into the adjacent basin. The ambient sediment accumulating in the basin was shale. A wide range of sediment gravity flow deposits occur within the shales, which are recognized as limestone and dolomite breccia units. Mehtens and Dorsey (1987) were the first to recognize that the laterally discontinuous outcrop pattern of the breccias reflected the geometry and distribution of the original sediment gravity flow deposits. Mehtens and Hillman (1988) discussed the criteria for

identifying turbidite and debris flow deposits within the Rockledge Formation and also obtained paleocurrent data on clast orientation which indicate a strong north-south paleoflow. Hadley (1991) described the sedimentary processes involved in the deposition of the Rugg Brook Formation. As part of a paleontologic study of the Cambro-Ordovician boundary, Landing (1984) suggested that the Highgate and Gorge Formations were also carbonate slope deposits. What is developing from these studies is a model for basinal sedimentation within the St. Albans Reentrant, specifically, the relationship of basinal sedimentation to sea level change. As we understand more clearly how similar or different the breccia deposits are throughout the basin, we can begin to address questions such as potential platform source(s), the continuity or periodicity of basinal sedimentation, and their relationship to sea level.

STRATIGRAPHIC DISTRIBUTION OF UNITS

Stratigraphic distribution of rock units shows a progressive eastward-younging sequence, with the oldest Lower Cambrian Dunham Dolomite forming the base of the sequence and Ordovician Moses Line Slate outcropping in the east. With few exceptions there does not appear to be an internal stratigraphy within this sequence. Two exceptions to this are the restriction of the Parker Slate and Parker Conglomerate to horizons immediately above the Dunham Dolomite, and the concentration of the dolomitic facies of the Rugg Brook Formation (€rdb) to horizons adjacent to the Dunham Dolomite. It is important to note that the stratigraphy of the eastern limb does not repeat the western limb; the east limb lacks the Parker Slate, Parker Conglomerate, or Rugg Brook Dolomite facies above the Dunham. As discussed later, this absence of stratigraphic repetition, combined with an absence of structural data indicating folding, suggests that the St. Albans Synclinorium is not well developed within the study area.

STRUCTURE

Rocks in the field area lie on the upper plate of the Champlain Thrust, which has emplaced Cambrian strata on Ordovician shales, and on the west limb of the St. Albans Synclinorium, which has folded these rocks into a broad synform. A second thrust, the Highgate Springs Thrust, has ramped up onto the Champlain, bringing slivers of younger Ordovician carbonates to the surface. Smaller,

imbricate thrusts of Ordovician carbonates lie along the Champlain Thrust (Plate 1, Figure 1, localities D4 and D5).

The north-south trending belt of carbonate deposits in the western half of the study area dips gently (3-12 degrees) and uniformly to the east, forming a homoclinal upright limb. With the eastward passage into younger shales and breccia horizons in the eastern part of the study area, deformation in the shales becomes more pronounced as dips steepen (35-50 degrees), resulting in the development of a synform. This deformation is associated with the emplacement of several small klippe complexes of the Cheshire Quartzite, emplaced into undifferentiated Parker and Skeels Corners Slate. In one example, the shale and associated Rugg Brook lithofacies have been folded into an overturned syncline as a result of emplacement of the adjacent klippe (Figure 3). Structural data taken from parasitic folds associated with the overturned syncline indicate that the fold axes align with the hinge axes for the larger, overturned syncline (Figure 4). The hinge axes are subhorizontal, and trend slightly to the northeast. Calculations of poles to cleavage indicate that the axial surface of the fold dips east 29 degrees.

The eastern boundary of the study area represents the eastern limb of the St. Albans Synclinorium, which, on the basis of three lines of evidence, is interpreted to be a condensed sequence of thrust slivers of the Dunham Dolomite and Cheshire Quartzite. First, the facies package on the eastern limb is distinctly different from the western limb, with several units (Parker Slate, Parker Conglomerate, Rugg Brook Formation, dolomite breccia) missing. Secondly, the Dunham and Cheshire units are anomalously thin. Thirdly, no westward-dipping horizons are found.

One high-angle Mesozoic normal fault trending northeast is present in the study area to the east of St. Albans and Aldis Hill (Plate 1, Figure 1, localities F5 to E1). Evidence for this fault is based on the sharp truncation of the east side of the klippe at Aldis Hill, and also on the topographic difference between the St. Albans Hill klippe and the higher unnamed hill of folded shales and breccias immediately to the east. This fault lies immediately to the north of a series of northeast-trending normal faults described by Stanley (1980) from an area south of this study area.

scale 1:6,000

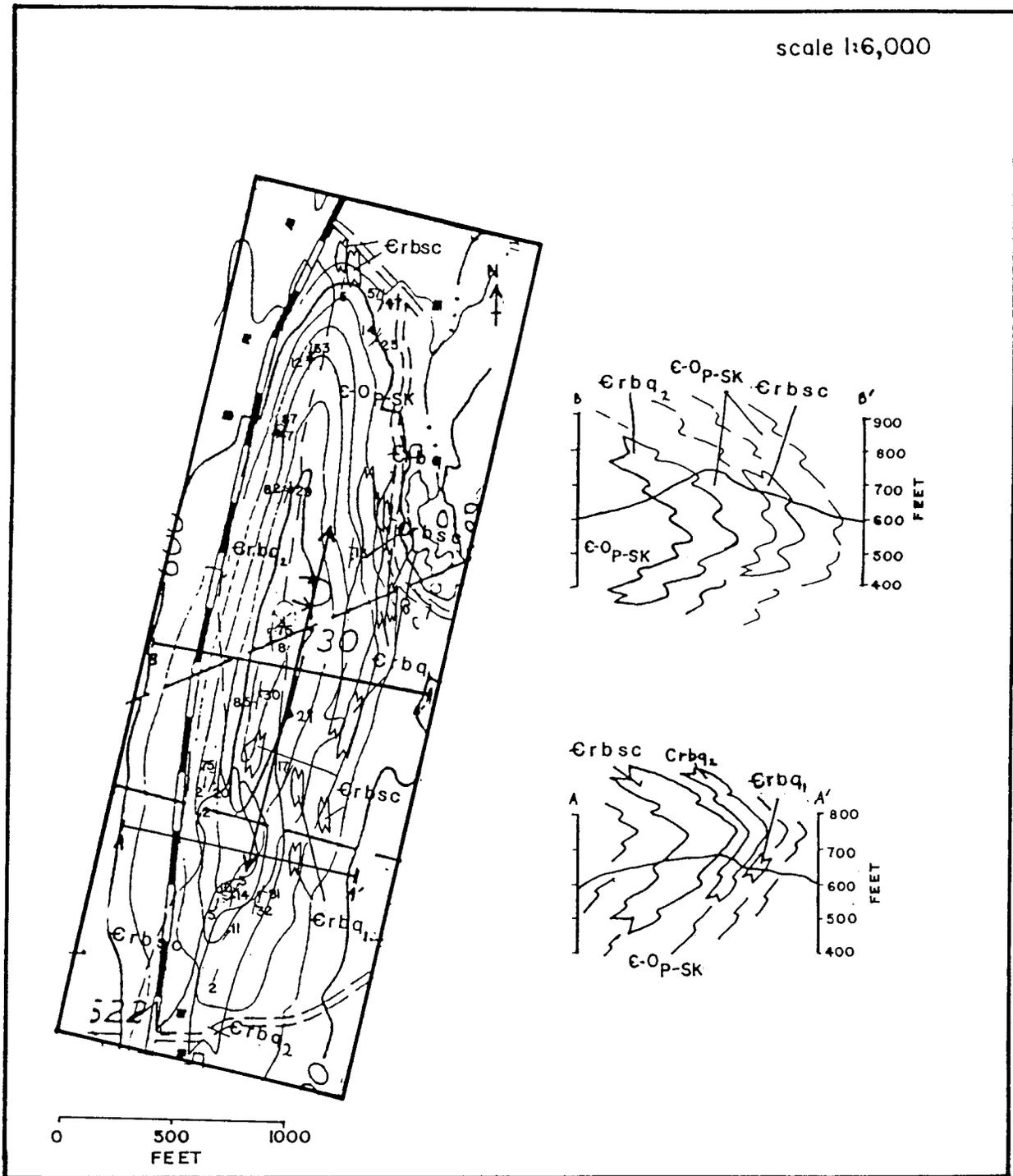


Figure 3. Detail of map area at 1:6,000 showing the detail of the small, overturned fold.

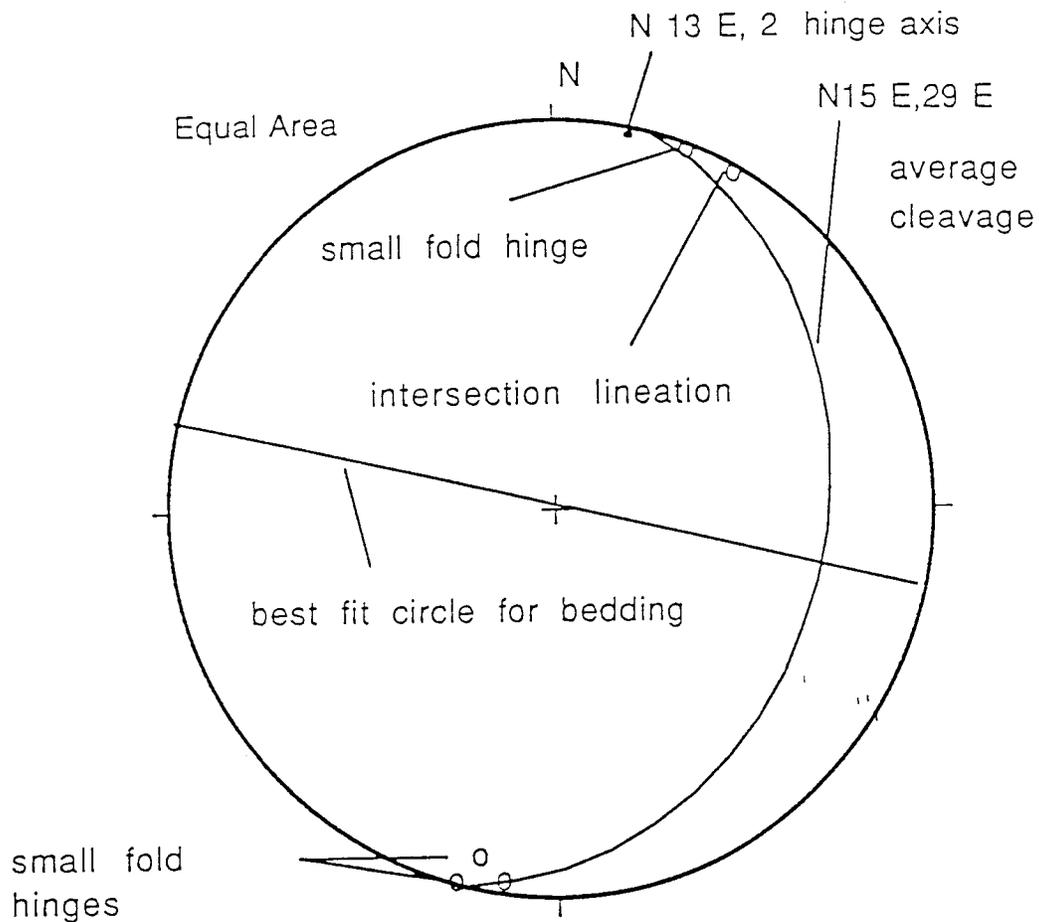


Figure 4. Lower hemisphere equal area projection of data from the St. Albans area, Vermont. Synoptic diagram illustrating the average cleavage, major fold hinge axis, small fold hinges, and bedding/cleavage intersection lineation. Plane of the projection is horizontal with north marked by "N".

REGIONAL SYNTHESIS AND SUMMARY

With the conclusion of this study, the entire St. Albans Reentrant has been mapped at a scale of 1:24,000 and, in selected areas, at 1:12,000 or 1:6,000. This has provided much information regarding the distribution of units within the basin and confirmed details of the platform-to-basin transition. More importantly, completion of this map permits the recognition of any trends in lithofacies distribution from the south of the basin to the north. Several trends have been noted: (1) The Parker Conglomerate lithofacies (Cpc) stratigraphically overlies the Dunham Dolomite in this study area as well as the Milton and Highgate regions. (2) The large exposure of the recrystallized, partially conglomeritic Rugg Brook Formation (Crbd) is confined to the Milton region. This facies thins to the north through this study area and occurs as isolated pods to the north in the Highgate region. (3) Similarly, thick exposures of the massively-bedded, coarse-grained sandstone lithofacies of the Rugg Brook Formation (Crbq) are more abundant in the south, in the Milton region, are less common in this study area, and also occur as isolated pods in the Highgate region. This lithofacies seems to be associated with proximity to the southern platform margin and a possible Monkton Quartzite source.

Internal stratigraphy appears to be lacking within the carbonate lithofacies of the Rugg Brook Formation, an observation noted earlier by Merhtens and Dorsey (1987). Detailed work in progress on the petrography of the sandstone and quartzite units within the Rugg Brook by Hadley (1991) revealed that the platform source for this unit was, at least in part, the Monkton Quartzite.

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PLATE 1

MEHRTENS and HADLEY

FIGURE 1

73°07'30"

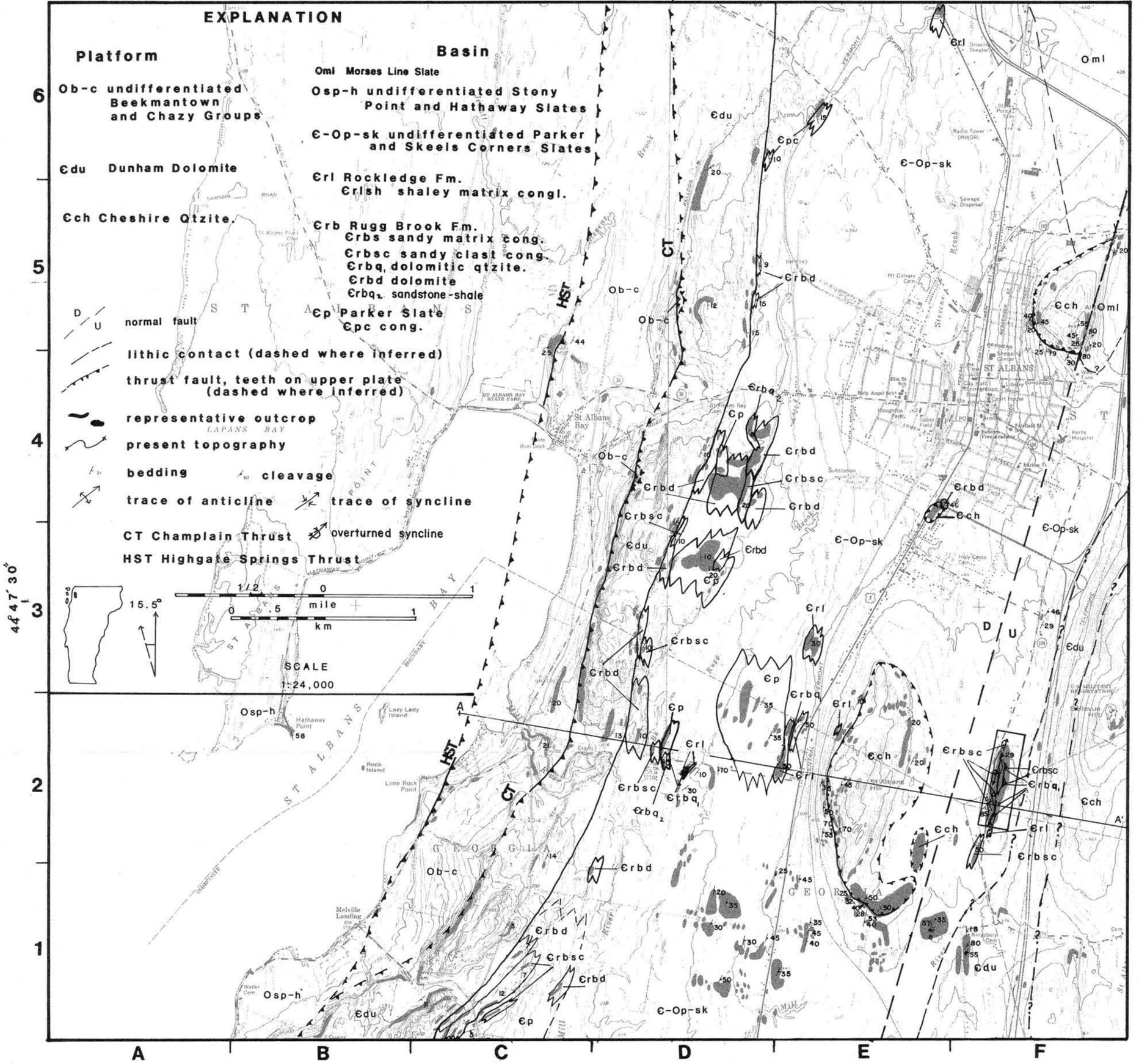


PLATE 2

FIGURE 1

CROSS SECTION

